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Appendix D

Course material for AEE Plovdiv Energy Efficiency Courses

Course in Energy Efficiency and Management
1997
Association of the Energy Engineers, Bulgaria, Plovdiv

Goal:
Training of energy managers as part of the American Association of Energy Engineers' program.

Topics:
Theoretical and practical aspects of energy efficiency.
Practical training in using modern monitoring equipment for energy analysis.

Materials:
Full set of proceedings, charts, tables, and materials used and distributed during the lectures.
Workbook (guidelines) of energy management (in English)

Duration:
10 school days, 6 academic hours a day (1 academic hour ~ 45 min.)

Price:
10,000 leva

Necessary qualifications:
Graduate technical degree

Time and place:
The course will be held in an academic hall and laboratory of the Institute of Food Industry, Plovdiv; every day from 9:30 am - 4:30 pm.

First course will start:	May 1997
Second course will start:	October 1997
Third course will start:	December 1997

Academic Program/Lectures
1. Energy and Ecology: Dr. Stefan Dichev (2 hours)
2. Technical and economic aspects of the energy technologies: Dr. G. Raichev (2 hours)
3. Energy audit: E. Genchev (2 hours)
4. Economic analysis of projects for energy efficiency improvements already identified through energy analysis: M. Ruslanov (2 hours)
5. Types of contracts for energy services: T. Georgiev (2 hours)
6. Improvement of the energy efficiency of burning systems: Dr. G. Vulchev (2 hours)
7. Steam and condensing systems:
8. Insulation for hot and cold conditions:
9. Heating and ventilation systems:

10. Air-conditioning systems:
11. Energy efficiency of refrigerators and thermal-pump systems:
12. Optimization of the efficiency of the heat-exchange equipment:
13. Systems for air condensation (?)
14. Energy efficiency improvement of hydraulic systems for starting and operation of machines and equipment:
15. Energy efficiency improvement of electrogenerators and transformers:
16. Energy efficiency improvement of lighting installations:
17. The role of automatic systems for energy efficiency improvement:
18. Integrated systems for energy management:
19. Practical training:

The program was prepared by:

B. Petkov, Dr. St. Dichev, Dr. Ivan Dragotinov

Course Staff:

Cource manager: B. Petkov tel. (32) 455 505
Academic supervisor: Dr. Stefan Dichev tel. (32) 437 841
Coordinator: Dr. Emanuilov tel. (32) 44 181-250

Note:

For more information, please contact the above peolpe.
There will be other modular courses (specific topics and areas) organized in the future.

Energy Management as a profession:

Energy manager is a specialist who has the knowledge of how to optimize energy consumption. He must be able to identify problems related to the effective energy use, find efficient technical solutions and implement them successfully. In order to accomplish professionalism, the energy manger needs to have a broad engineering knowledge, as well as skills for good economic analysis of alternative technical solutions.
If energy efficiency and management is of interest to you, we would like to invite you to participate in this course for energy efficiency and management. Space is limited.

The Association of Energy Engineers (AEE) is a professional non-profit organization with a mission to unite engineers, architects, and other specialists working in the area of energy efficiency and management. The organization has more than 10,000 members and chapters in more than 71 countries.

(Follow history of the Bulgarian chapter, available literature and resources, and invitation for professional improvement and development of those who are interested in energy efficiency. Do you need the details of this section?)

ПРОФЕСИЯТА ЕНЕРГИЕН МЕНИДЖЪР

Енергийният мениджър е специалист, въоръжен със знания как да оптимизира енергийните разходи Той трябва да може да идентифицира проблемите свързани с ефективното използване на енергията, да намира рационални технически решения и успешно да ги внедрява За постигане на висок професионализъм енергийният мениджър трябва да има широки инженерни познания, но така също и добре да преценява икономическата изгода на различните технически решения

Ако енергийната ефективност и мениджмънт, представлява интерес за Вас, най-любезно Ви каним да участвате в първия курс по енергийна ефективност и маниджмънт Местата са ограничени, побързайте!

Association of Energy Engineers (Асоцияция на енергийните инженери) е професионална организация с нестопанска цел, сдружение на инженери, архитекти и други специалисти, работещи в областта на енергийната ефективност и мениджмънт Организацията има над 10 000 члена и клонове в повече от 71 страни

През 1995 година В България бяха регистрирани два клона - първо в град Пловдив, а след няколко месеца и в град София Членовете на Българските клонове участват в Проекти за енергийна ефективност, спонсорирани от международни институции Разпространяват информация за свои продукти и услуги в регионални и международни издания

В Пловдивския клон на Association of Energy Engineers разплага с богата гама от съвременно измервателно оборудване за изготвяне на енергийни анализи и баланси, с информация в областта на енергийната ефективност за сродни консултантски фирми, оборудване, международни прояви, контакти с международни фондове, финансиращи проекти в областта на енергийната ефективност

Разполагаме с Internet връзка с клоновете на организацията в цял свят
В Пловдивския офис на асоциацията има богата справочна литература на английски език в областта на енергийната ефективност.

Асоциацията е отворена за всички, които желаят да работят за повишаването на енергийната ефективност и с удоволствие ще подпомагаме успешното Ви професионално развитие В енергийния мениджмънт и услуги в енергийната област (одит, анализи и др) Това ще Ви помогне да намерите място на конкурентния пазар зо консултански и инженерингови услуги в областта на енергийната ефективност

aee®
Association of Energy Engineers

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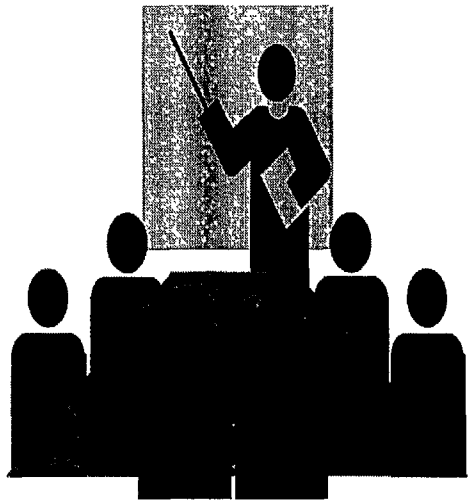
Ел. поща: ipetkov@mbox.digsys.bg

КУРС ПО ЕНЕРГИЙНА ЕФЕКТИВНОСТ И МЕНИДЖМЪНТ

1997



Асоциация на Енергийните Инженери,
България, Пловдив

А. ЦЕЛ НА КУРСА:

- Обучение и подготовка на енергийни мениджъри по програма на Американската Асоциация на Енергийните Инженери

Б. ПРЕДМЕТ НА КУРСА.

-
- Теоретични и практически аспекти на енергийната ефективност
- Практическо запознаване със съвременна измервателна апаратура за енергиен анализ

В. МАТЕРИАЛИ ЗА КУРСИСТА:

- Пълен сборник от анотация на лекциите, помощни таблици, графики и проспекти
- Наръчник по енергиен мениджмънт (на английски език)

Г. ПРОДЪЛЖИТЕЛНОСТ НА КУРСА:

- 10 учебни дни по 6 академични часа

-
Г. ЦЕНА НА КУРСА:

-
- 10 000 лева за курсист

-
Д. НЕОБХОДИМА КВАЛИФИКАЦИЯ :

- Висше техническо образование на кандидатите

Е. ВРЕМЕ И МЯСТО НА ПРОВЕЖДАНЕ:

- Курсът ще се проведе в учебна зала и лаборатории на територията на Висшия институт по хранителна и вкусова промишленост, град Пловдив съвместно с деканата по СДК, при дневен график от 9 30 до 16 30
  Първо издание на курса - Май 1997
  Второ издание на курса - Октомври 1997
  Трето издание на курса - Декември 1997

Ж. УЧЕБНА ПРОГРАМА:

1. Енергетика и екология, проф д т н Ст Дичев, 2 часа
2. Технико-икономически аспекти на енергийните технологии, доц Г Раичков, 2 часа
3 Енергиен одит, ас Е. Генчев, 2 часа
4 Икономическа оценка на проекти за подобряване на енергийната ефективност, идентифицирани в енергиен анализ, М Русалов, 2 часа
5 Видове договори за енергийни услуги, адв Т. Георгиев, 2 часа
6. Подобряване на енергийната ефективност на горивни системи, доц д-р Г Вълчев, 4 часа
7 Парни и кондензни системи, доц. д-р А Емануилов, 2 часа
8 Топло и студо изолации, доц д-р А Емануилов, 2 часа
9 Отоплителни и вентилационни системи, доц. д-р М Минчев, 4 часа
10. Системи за климатизиране на въздуха, гл ас Н Ангелов, 3 часа
11. Енергийна ефективност на хладилни и термопомпени инсталации, проф д т н Ст Дичев, 4 часа
12. Оптимизиране ефективността на топлообменни апарати, доц. д-р Г Раичков, 2 часа
13 Системи за сгъстяване на въздух, доц д-р М Ангелов, 3 часа
14. Подобряване на енергийната ефективност на хидравлични системи за задвижване и управление на машини и съоръжения, доц д-р Т Николов, 2 часа
15 Подобряване на енергийната ефективност на електродвигатели и трансформатори, гл ас д-р Г Динков, гл. ас. Л Костадинова, 5 часа
16 Подобряване енергийната ефективност на осветителни инсталации, д-р Н Груев/инж Г. Вангелов, 2 часа
17 Ролята на системите за автоматично управление при подобряване енергийната ефективност, доц д-р Ив Драготинов, 4 часа
18 Интегрирани системи за енергиен мениджмънт, ас Е Генчев, 3 часа
19 Практически занятия
   По тема 3, асп. Ламбрев, 1 час
   По тема 6, доц Г. Вълчев, 3 часа
   По тема 10, гл ас. Н Ангелов, 3 часа
   По тема 14, гл ас. Г Динков, Л Костадинова, 3 часа
   По тема 18, аг. Е Генчев, 2 часа

Съставители на програмата

1. инж Б Петков, Председател на АЕИБП
2 проф д т н. Ст Дичев, член на АЕИБП
3 доц д-р Ив Драготинов, член на АЕИБП

Ръководство на курса:

1. Мениджър на курса: инж Б Петков, MBA, CEM - АЕИБП тел. (032) 455 505
2 Научен ръководител на курса
проф д т н Ст Дичев - АЕИБП, тел (032) 437 841
3 Отговорник на курса. доц д-р Емануилов - ВИХВП, тел (032) 44 181 - 250

Забележка:

1 За повече информация и заявки за участие в курса, ползувайте и телефоните посочени за ръководство на курса

2 В бъдеще ще бъдат организирани модулни курсове (по отделни направления и области)

POWER ENGINEERING AND ECOLOGY

Prof. Stefan Ditchev, PhD

Summary

Power engineering is a basis for normal functioning of modern industry, but at the same time it is necessary to preserve nature in order to secure normal life conditions on our planet. In this aspect every power engineering technology should be evaluated not only from technical and economical point of view, but also from ecological.

The lecture covers the following topics:

1. Distribution of the energy sources for electricity generation in Bulgaria.

	Nuclear Power Stations	Thermo-Electric Power Stations with Local Coal	Thermo-Electric Power Stations with Imported Coal	Hydro-Electric Power Station
Installed Capacity	38 %	25 %	17 %	20 %
Electricity Produced in 1994	45 %	41 %	9 %	5 %

2. Emissions of harmful substances (dust, SO_2, NO_x, CO_2) in the atmosphere from recent and future power generation in Bulgaria. For instance, the emissions of CO_2 from the total electric power generation in Bulgaria in 1990 were 19.2 x 10^6 tons, while in 1994 they were 16.6 x 10^6 tons. The CO_2 emissions per 1 kW electricity generation with 0.33 system efficiency ratio for different kinds of fuels are: 1.14 kg CO_2/kWh for coal; 0.96 kg CO_2/kWh for oil; 0.58 kg CO_2/kWh for natural gas; 0 kg CO_2/kWh for hydro-, nuclear and solar energy.

3. Tendencies in the development of energy generation in Bulgaria , as priority will be given to the development of energy sources that do not emit

harmful gases as SO_2, NO_x and CO_2 (i. e . water, nuclear reactions, winds and tides, geothermal sources and solar radiation).

4. Environmental pollution that results from energy production and consumption an the global warming (greenhouse effect).

Special attention is paid to the negative effects of some working fluids (halogenated refrigerants) of certain power- consuming and/or power-generating systems such as refrigeration, air- conditioning and heat- pump equipment on the ozone layer. There are two basic measures for the ecological effect of certain refrigerant:

- Global Warming Potential (GWP);
- Ozone Depletion Potential (ODP);

Supplements:

N 1 - Diagram exhibiting the relative parts of the different energy generation technologies and capacities in Bulgaria.

N 2 - Tables and diagrams of the emissions of harmful substances (dust, SO_2, NO_x, CO_2) in the atmosphere from the energy generating capacities.

N 3 - Table of the values of the Ozone Depletion Potential and Global Warming Potential.

TECHNOLOGICAL AND ECONOMICAL ASPECTS OF ENERGY TECHNOLOGIES

Assoc. Prof. Georgi Raitchkov, PhD

The quantity of the energy used by man and society is a criteria for their standard of living. The increasing energy consumption that leads to increasing energy production leads to serious technological, economical, ecological, social and geopolitical problems.

The efficiency of the modern energy technologies is the basic technological and economical problem.

ENERGY TECHNOLOGY

Every set of energy conversion, energy transfer and concomitant secondary processes and technological systems that makes it possible to utilize the energy of a certain energy source. An example: Structure diagrams of energy technology for electricity generation from organic fuel-figures 1.1 and 1.2.

QUALITY OF THE DIFFERENT KINDS OF ENERGY

The quality of certain kind of energy is determined by the degree of its transformation in mechanical or electrical energy when the necessary conditions exist. The mechanical and electrical energy are of high quality. The quality of heat depends on the temperatures of the hot and the cold sources. The degree of transformation of the heat into mechanical work in the Carnot cycle is given in figure 1.3.

EFFICIENCY OF THE ENERGY CONVERSION PROCESSES AND TECHNOLOGIES

Every process of energy conversion, transition and transfer lead to energy losses. These losses depend on the type of the energy conversion process and on the process conditions. Increasing of the technical level of the systems and improving the process organization are the human factors that lead to improving the energy efficiency.

CONSUMERS play a significant part in increasing the overall efficiency of the energy technologies. The losses in all steps of energy conversion and energy transfer for a given activity are pointed out on figure 1.4. The most important CONCLUSIONS are: The energy that is used is only a small part of the primary energy of the source and that makes necessary to fulfill the following tasks:

1. Proper assessment of the perspectives, yields, processing and transportation;
2. Choosing an efficient energy conversion and transfer systems and technologies;
3. Optimal parameters of the consumers.

SOME POSSIBILITIES FOR INCREASING THE UTILIZATION EFFICIENCY OF THE HEAT SOURCES.

The following energy technologies for heat supply are analyzed and compared: direct fuel combustion; heat supply from a steam- power station; heat supply with a heat- pump; combined system of heat supply (figure 1.5).

CONCLUSION: Every system has its relative priorities and disadvantages and the choice of a certain system should be made according to the specific conditions and requirements.

ECONOMIC EFFICIENCY OF THE NATIONAL ENERGETIC COMPLEX OF BULGARIA - current state; tendencies and perspectives.

Lecture No 3

Energy Audit Definition

An energy audit is a report to management that identifies a plan of action to reduce energy cost.

An energy audit is the second step in a total energy management program:

1. The company's top management must make a commitment to reduce energy costs for a program to succeed.

2. Experts work together with company staff carry out an energy audit to analyze energy usage and costs, to identify ideas for energy saving projects, to analyze the costs and benefits of these ideas, and to develop an action plan to reduce costs.

3. Financing is arranged and the action are implemented to achieve improvements.

4. The company adopts a continuous energy management system, monitoring energy usage and costs, conducting follow-up energy audits, identifying and implementing additional improvements.

Energy Audit Objectives

1. Provide management with better information concerning energy use and energy costs.

2. Develop an improved energy management system.

3. Identify energy conservation opportunities (ESCo)

4. Achieve real savings during the audit.

5. Develop action plan for implementation.

6. Win management commitment for implementation

Energy Audit Meeting The Objectives

1. Provide management with better information on:

- Energy use
- Energy costs
- Energy as a function of production
- Energy as a function of other factors
- Waste of energy (losses, leaks)
- Efficiency of key equipment
- Equipment reliability & energy loss impact
- Energy cost of equipment operations and downtime
- Model of the plant energy characteristics
  - Baseline of plant energy performance
  - Simulation of process design

Energy Audit Meeting The Objectives

2. Develop an improved energy management system

Energy department in the broader organizational structure
- relationship to production department
- relationship to maintenance department

Organization of the energy department itself
Allocation of responsibility for energy efficiency
Setting up energy teams
Management report designs and reporting methods
Role of computerization
Metering and other instrumentation needs
Feedback system for motivation

Energy Audit Meeting The Objectives

3. Identify energy conservation opportunities (ECOs)

By interviewing plant staff

directors
managers
process engineers
shift supervisors
equipment operators

maintenance mechanics and electricians
janitors

By inspecting facilities
during normal working hours
during nights and weekends

By testing and measurement, using
existing plant instruments
portable energy monitoring instruments
additional fixed instruments

By analyzing data

By experience

By research

Energy Audit Meeting The Objectives

4. Implement operations & maintenance ECOs as they are identified to achieve real energy savings during the audit

combustion excess air adjustment

combustion burner adjustments

electric motor loads

filter maintenance

cleaning and lubrication

speed reduction

repairing leaks

help institute changes to energy management and reporting systems

form energy efficiency teams

Energy Audit Meeting The Objectives

5. Develop action plan for implementation

Rank ECOs and select projects based on:

economic performance

funding available

other constrains

Identify financing

internal sources, such as energy budget

loans from banks and other external sources

third party investors

Develop implementation schedule

ranking of projects

scheduling of projects based on ranking, funding availability and technical factors

Energy Audit Meeting The Objectives

6. Win management commitment for implementation

Making contacts

Good communication

Effective written report

Effective oral report

Doing your homework

Negotiation and persuasion

Energy Audit Reports

1. Executive summery

Brief introduction

Key findings on energy use and efficiency

Documentation of energy savings achieved during the audit

Action plan

2. Introduction

Description of plant and scope of audit

Description of audit activities

3. Energy data analysis

Historical energy database

Historical energy graphical analysis

Energy intensity

Equipment database

Energy balance

Energy costs

Reliability analysis

Plant energy model

Energy Audit Reports

4. Energy management action plan

Introduction

Listing of ECOs

Financing plan

Implementation schedule

5. Details of recommendation, description of each ECO

Name and number of ECO, location affected

Findings on existing conditions

Description of recommended action

Analysis of ECOs costs and benefits (inventory level, not full feasibility study)

- expected energy efficiency results
- estimate of costs
- cost-benefit analysis

Risk and other possible effects

Schedule for implementation

Technical data on equipment required

Ranking of ECOs based on economical criteria

Action plan

Energy Audit Scope

The scope of an energy audit I determined by the customer's willingness to pay for the information.

Lower limit
.....

Upper limit
.....

Scope can be defined across two dimensions, giving six possible levels of cost:

Level of detail of analysis

Walk-through audit
Mini-audit
Maxi-audit

Extent of plant covered

Focused audit
Comprehensive audit

Energy Audit Quality

The main factors which determine the quality of an energy audit are:

1. experience and expertise of the energy audit team

2. scope of audit

3. instrumentation available

4. degree of support and cooperation from the company being audited

The quality of an energy audit is shown by:

1. cost reduction

2. energy savings identified

3. number of ECOs identified

4. degree of detail in ECO recommendations

5. actual energy saved during the audit

6. clear, logical presentation of information in useful format

Energy Audit Data Collection

1. Source of data

.....

2. Design data selected for collection

.....

3. Historical data periods

Long-term data

.....

Short-term data

.....

4. Historical data selected for collection

Production for all products

Energy consumption....

Energy generation....

Submetered energy consumption

Measures of reliability

Instrument reading data....

Energy Audit Database Development

Databases and data analysis can help identify ECOs

Depending on the scope, various databases, tables or graphs may be developed for energy-related information, such as:

Historical long-term trend data

Historical short-term data, scatter diagrams

Reliability data

Plant and progress design data

Equipment inventory and design specs

Energy balance for:

- Peak steam demand
- Steam consumption
- Fuel usage
- Peak electrical demand
- Electrical energy consumption

Process modeling and simulation

Statistical regression models

Energy Audit Data Analysis

Results Desired	Database(s)	Analysis Required
.....	.....	.....

Lecture No 4

Energy efficiency project finance

Minko Russalov, MBA

1. Understanding project finance

The project financing related to energy efficiency is similar to any other capital decision and evaluation process. The key to successfully evaluating the financing decisions are to:

- understand the cost of capital
- understand the cashflows of projects
- understand the basic evaluation techniques to determine project viability
- understand the types of resources available to fund the project

Although project finance provides the tools and means for evaluating he economic viability of a project, it is important to recognize that all of the financial analysis is founded on the accuracy of the savings estimates generated by the energy efficiency engineers and the associated baseline cost analysis coordinated with the entities management, accounting and finance group.

Cost of Capital

Capital represents the funds used to finance an organization assets and operations. In a market economy capital can be generated from a variety of sources including both short and long term debt, equity. The cost to acquire these funds is referred to as the cost of capital. In financing a project the most common resource of capital will be the cost of debt. The cost of capital represents the minimum return required to ensure the creation of wealth to the organization. From an analysis perspective, the cost of capital should be used as the discount factor when evaluating the net present value of a project.

Project Cash Flows

A project cash flow analysis is critical in evaluating the viability of the project. Developing the cash flow analysis is more of an art than an exact science. In any energy savings project the analysis should result in a table such as the following:

Year	Program Cost	Energy Savings	Operation& Maintanace.	Net Savings

			Savings	
1997	(xxx,xxx.xx)	xx,xxx	xx,xxx	xx,xxx
1998	0	xx,xxx	xx,xxx	xx,xxx
1999	0	xx,xxx	xx,xxx	xx,xxx

The program cost represents the cost of the energy efficiency project. The energy savings is the amount of savings anticipated as a result of implementing the project. These numbers include direct savings such as reduced energy bills. The O&M figures are estimates of reduced costs associated with operating and maintaining the equipment. These generally include reduced repair costs and potentially reduced labor costs and increased productivity.
In calculating the cash flow estimates the energy savings will include an energy price escalation factor. This variable is typically included as an increase in the estimated cost of energy in the future. Be wary of these escalation factors since the higher the escalation the higher the anticipated savings. In the current situation in Bulgaria you have to account for inflation and a decrease in energy subsidies so that escalation factors is correctly estimated.

The cash flow analysis serves as the input for the financial evaluation such as the net present value analysis below. Overall, the cash flow analysis is very subjective. It is recommended that as part of any analysis, a range of potential savings should be estimated. These estimates should be altered by calculating a variety of scenarios. As a rule of thumb it is important to evaluate the probability of the projections from those that may be considered a best case scenario to those that are the most conservative scenario.

2. Evaluation of Project Viability

In evaluating an energy efficiency investment the project should be evaluated to determine if it will provide an adequate return on the investment while at the same time meet existing and future cash flow requirements. There are a variety of measures to analyze a project with the most common being the Simple Payback Period, Net Present Value, and Internal Rate of Return. On a typical project analysis all three methods are recommended to be used since they provide different financial measures about the project.

The Simple Payback is a measure of the expected number of years required to recover the original investment in the project. This method should be used in conjunction with the others. It is limiting in that it ignores the time value of money. It provides an indication of the project's risk and liquidity since it outlines how long the capital is at risk. The longer the payback period the riskier the project.

The net present value is found by discounting all cash flows (positive and negative) at the projects cost of capital and then summing those cash flows. The project is viable if the NPV is positive. This is generally considered the best evaluation tool since it

utilizes the time value of money and provides a measure in current dollars of the estimated economic value of the project. The effectiveness of the evaluation is driven by a thorough understanding of the discount factor being used and the accuracy of savings estimates.

The internal rate of return (IRR) is defined as the discount rate which forces the present value of the project's future cash inflows to equal the present value of the project's outflows. The accuracy of the IRR calculation can be tested by using IRR as the discount rate used in NPV calculation. If the IRR is accurate the NPV will equal zero. When evaluating projects with leases IRR calculations typically are not applicable since leases typically result in all positive cash flows.

The valuation methods described, are designed to provide a background of the most common techniques used in evaluating the economic viability of many different types of projects. In practice, care must be taken to understand the mechanics of the valuation since it is easy to manipulate any set of numbers to make a project look good when in reality it may not be.

Financing Resources
As part of the evaluation process, a key consideration will be the financing options. There are a variety of methods of financing an energy savings projects:

Commercial bank borrowing - extremely difficult in Bulgaria
Own funds - restricted availability
Endowments
Fund Raising - foreign aid agencies
Leasing and vendor financing - limited availability
Shared savings contracting - energy end users are not familiar with it so very suspicious.

With financing decisions there is no one correct and best method of financing. Each decision should be evaluated based on the econonomics of the energy efficiency project. Considerations should be given to the cash flow expectations.

INCREASING THE ENERGY EFFICIENCY OF THE COMBUSTION SYSTEMS

Assoc. Prof. G. Valtchev, PhD

OPTIMIZATION OF THE AIR FLOWRATE

In combustion systems usually organic fuels are used, and they can be solids, liquids or gases. Their chemical energy is transformed to heat due to reactions between oxygen and the burning substances- carbon, hydrogen and sulphur for solid and liquid fuels, hydrocarbons (C_nH_m), hydrogen sulphide and carbon oxide for gaseous fuels.

During complete oxidation of carbon to carbon dioxide 35 615 *kJ/kg* heat is released, and during incomplete oxidation to carbon monoxide 10 080 *kJ/kg* heat is released. During oxidation of hydrogen 142 124 *kJ/kg* heat is released if the water that is formed is in liquid state, and 118 666 *kJ/kg* heat is released if steam is formed. During burning of 1 kg sulphur 9050 *kJ/kg* heat is released. Very important for the complete oxidation is the amount of air that carries the oxygen that is necessary for the process. The theoretical quantity of oxygen (and air) is determined by the stoichiometry of the combustion process. In practice for complete combustion more air is fed into the system, and this quantity is determined by the excess air coefficient.

The real quality of air influences the heat losses from incomplete combustion as well as the losses from the flue gases. The presence of products of incomplete combustion in the flue gases causes heat losses which are 12 600 kJ/m^3 for carbon monoxide, 11 190 kJ/m^3 for hydrogen and 3 570 kJ/m^3 for methane. If an excess of air is available, then losses from incomplete oxidation diminish, but the heat losses with the flue gases increase. That is why an optimum value should be found. The air flow is controlled either with valves and depends on the quantity of the fuel that is fed to the burning chamber, or with variation in the rotation speed of the motor of the fan.

FLUE GASES TEMPERATURE CONTROL

Combustion temperature- influences significantly the formation of nitrogen oxides. High temperature favors their formation. It is necessary to comply with the regulations for release of hazardous substances in the atmosphere.

Temperature of the flue gases- The prescriptive temperature when burning solid fuels lies in the interval 110-180 °C; and when burning fuel oil and natural gas, the values are given in table 1.

Table 1.

Fuel	Temperature of the flue gas, °C
Fuel oil with high sulphur content (S>2.0 %)	150 -160
Fuel oil with normal sulphur content (0.5<S<2.0 %)	130 - 140
Fuel oil with low sulphur content (S<0.5 %)	110 - 120
Natural gas	110 - 120

The lower temperatures of the flue gases refer to energy systems that use low sulphur content fuel, while the higher temperatures refer to energy systems with lower capacities and higher sulphur content. The decrease of the flue gas temperature requires bigger capital investments due to the increased heat exchange surface. Due to temperature decrease the dew point temperature may be reached, and that may cause the condensed water to react with the sulphur trioxide and form sulphuric acids. This leads to corrosion of the metal surfaces. The increase of the flue gas temperature decreases the system's efficiency, but also decreases the required capital investments. Contamination of the heat transfer surface impedes the heat exchange and thus increases the flue gas temperature. The temperature of the flue gases should be determined by a technical and economical analysis. Fig. 1 reveals the interval of the optimum flue gas temperature.

COMBUSTION SYSTEM EFFICIENCY

An energy balance have to be done for every combustion system. This balance is based on the law of conservation of energy. According to this law the sum of the incoming energy in the combustion systems in the form of heat equals the outgoing. The outgoing energy is divided in two parts- one of them is that helps to achieve the purpose of the process and the other is that diverts from that purpose. The results of this balance help in carrying out a profound technical and economical analysis.

The energy balance helps to determine the quality of heat transferred from the combustion products to the heat transfer surface. If the heat flow calculations are performed for the design of a new combustion system, they are called "design calculations", and if their goal is to examine an existing

system, they are called " examination calculations". An examination energy balance is performed when it is necessary to determine the temperatures and the velocities of the flue gases in the ducts and those of the working fluid (steam, water or air) for regimes that differ from the design regimes. This balance is always done when a transition to another kind of fuel or either a reconstruction of the combustion chamber or of the heat transfer surface is done, and afterwards the necessary heat transfer surface is determined. The examination calculations are performed in the same scheme as the design ones until the fuel consumption and the efficiency of the system are computed. When the heat transfer surface is determined, an iterative method is used, as the temperatures of the air entering the combustion chamber and of the flue gases are assigned.

WAYS FOR INCREASING THE EFFICIENCY

Research on combustion system efficiency reveals that the flue gases give best opportunities for its improvement. Systems with contact economizers exist, and their purpose is to utilize the flue gas heat for warming of water. They can be very useful for boilers that use natural gas. The temperature of the water can reach 63 °C. The diagram of flue gas heat utilization system for KM12 boilers, installed in Plovdiv is shown on figure 2. It is designed by a team lead by Prof. D.Sc. N. Kolev. Not only a high level of heat utilization , but also small hydraulic resistance and decrease of hazardous gas emissions are achieved.

An additional water spraying device can be mounted to the installation for water cooling. The cooling if done with air that increases its temperature and moisture content before entering the combustion chamber. Figure 3 reveals the real efficiency of the KM12 boiler according to the gas consumption without heat utilization and water spraying (curve 1); with heat utilization but without spraying (curve 2). The curves illustrating the efficiency as a function of the fuel consumption when the installation works with heat utilization and water spraying, and for air temperatures equal to 35°C, 40°C and 45°C after spraying are listed.

For energy efficiency improvement of heating installations the low temperature boilers produced by VIESSMANN - Germany can be used. The company offers oil- and gas- boilers with multi-layer corrosion- resistant heat transfer surfaces ranging from 70 to 1 750 kW. They use the latent heat of condensation of steam from the flue gases. Their efficiency reaches as high as 96 %.

AUTOMATIC COMBUSTION CONTROL

In modern combustion systems the control of the combustion is performed by a computer. The existing software uses the stoichiometry of the process to compute the minimum amount of oxygen and air for complete oxidation of the combustible elements. The air flow is controlled according to the fuel consumption. The quality of oxygen and carbon monoxide in the flue gases is monitored and the air flow is regulated. Figure 3 lists the data received from computations performed for the KM12 boiler, and figure 4 reveals the relationship between the volume of the flue gases and the energy consumption.

The water boilers use computer control units for automatic regulation as a function of the ambient temperature, with daily and weekly programs, produced by VIESSMANN.

BLOWING THROUGH THE BOILERS

During warming of water on the surfaces of the heat exchangers a hard film that consists of crystals of calcium, magnesium and silicon salts is formed, and it is called "scale". It is a bad thermal conductor and the thickness of the scale in the different parts of the heat exchanger is different and that may lead to superheating and accidents. The scale decreases the efficiency of the heat transfer surfaces. From fig. 5 it can be seen that 1 mm of scale increases the energy consumption by 8 %. In order to prevent scaling, different methods of water treatment exist-thermal (destillation), chemical, mechanical and water softening . Blowing of the boiler aims to remove the sediments from the lowest parts of the boiler and to preserve the constant salt content of the water in the boiler, which impedes the scale forming, foaming and removing the salts by the steam.

The scale formation can be prevented with the use of the substance called "HYDRO-X", produced by "HYDRO-X S/A". It is used for water treatment for industrial installations and has four basic characteristics:

1. Softens water and regulates the total salts content and the alkalinity;
2. Continuously cleans the scale;
3. Prevents corrosion;
4. Impedes foaming and facilitates clean steam production for food treatment.

Magnetic water treatment is also used in industry. A device called "ABROT-91" is offered by a Bulgarian company called ECOTECHNIKA Ltd. The magnetic field influences the crystal structure of the scale forming. As a result the scale structure becomes loose instead of hard and falls down from the heat exchange surfaces in the form of slime that is removed from the system with the blowing. Fig. 6 reveals the iron content in industrial condensate before and after magnetic treatment with the "ABROT-91" device.

INFLUENCE OF THE EXPLOITATION AND MAINTENANCE ON THE ENERGY EFFICIENCY

The proper exploitation of the combustion systems influence significantly the energy efficiency. Pollution of the heat exchange surfaces is one of the reasons for diminishing the efficiency. It can be both on the flue gas side and on the working fluid side, and it increases the flue gas temperatures due to the insufficient heat transfer. If this increase is 12 °C, it leads to an increase in flue gas losses by 1 %. The normal exploitation of the combustion systems requires a recurrent cleaning of the heat transfer surfaces, blowing through the boilers, continuous control both on the process of combustion and on the working fluid. If a transition from one to another fuel is made or a repair is done, an energy balance of the equipment should be done.

For corrosion prevention the norms for exploitation are to be followed, and the quality of the water should be continuously monitored.

APPENDIX:

Fig. 1. Choosing the optimum flue gas temperature.

Fig. 2. Simplified diagram of the flue gas heat utilization unit for KM12 boilers.

Fig. 3. Computational data of the KM12 boiler.

Fig. 4. Relation between the volume of the flue gases and the energy consumption of the boiler.

Fig. 5. Relation between the scale thickness and energy consumption.

HEAT AND COLD INSULATION

Assoc. Prof. Angel Emanuilov, PhD

Insulating the pipelines and the industrial equipment is an important step that leads to energy savings.

Definitions and Concepts

Insulating the pipelines and the apparatuses helps in achieving one or all of the following goals: decreasing the heat losses (or the heat flows); creating safe conditions and technological parameters for carrying out of the processes.

Insulating materials are considered to be all materials that have thermal conductivity less than 0.2 W/(mK). these materials can be natural or synthetic.

The most widely used insulating materials are glass wool, slag wool, penopolyurethane, foam concrete etc., and in refrigeration expanded polystyrene, foam concrete, penopolyurethane and foam plastic are used.

The requirements that the insulating materials have to fulfill are very diverse and differ for heat insulation and cold insulation.

For heat insulation the most important are: low thermal conductivity, high combustion temperature, strength, low price, etc. For cold insulation in addition to the listed above the materials should have low vapor and water permeability, which is achieved with a specific pore structure that consists of closed pores.

The construction of the insulation is done on the spot over the apparatuses and the pipelines, and together with the walls of the cold rooms. The modern development leads to industrial manufacture of the insulating elements- insulating panels, shell structures, etc. Some insulation materials like penopolyurethane are placed in the prepared wall cavity, together with a foaming agent and a curing agent. The plastic foams up and fills the cavity, where the curing agent hardens it.

Special attention is paid to the reliability and the durability of the insulating material.

Assessment of the Thermal Losses and Flows

The Thermal losses and flows are determined with the Heat Transfer equations or measurements. The most often used conditions are:

- specified thermal losses;
- specified or accepted surface temperature;
- specified temperature difference of the fluid on both ends of the pipes;
- quantity of the condensate in the steam line;
- location of the pipes- indoor or outdoor, on the ground or underground;
- influence of the heat conducting elements in the construction;
- specification of surface temperatures that prevent water condensation.

The proper assessment of the thermal losses and flows directly concerns the energy consumption.

Methods for Decreasing the Energy Losses

Priority is given to the optimal design and proper calculations of the thickness of the insulation layer according to the working conditions.

It is rather more rational to determine the thickness of the insulation of every element or section of a branched pipe system than to adopt an equal insulation, which is often used in practice.

The applying of multi layer insulation gives very good results.

When it is necessary, a vapor and water insulation should be included.

A special attention should be paid to the decreasing of the thermal bridges to a minimum when designing the insulation.

If it is possible, not only the equipment and the pipes but all accessible elements of the pipeline should be insulated

Influence of the Exploitation and Maintenance on the Energy Efficiency

The periodical energy audit of the equipment is very important, and steps should be taken to decrease the thermal losses.

The insulation should be monitored and repaired. Practice reveals that greater part of the materials remain their quality for not more than 25-30 years. This is very important for refrigeration equipment insulation.

For longer and effective insulation performance it is necessary:

- Prevention of mechanical damages;
- Regular inspection and repair of the layer that covers the insulation;
- Prevention of damping and moisture leaks.

The faster detection of damages in the insulation and their repair leads to minimizing the losses and directly effects the energy efficiency.

Note: Several schemes of insulation materials as well as some constructions are included in the lecture.

Lecture No 9

Assoc. Prof. M. Minchev, PhD

7. Heating and Ventilation Systems.

Real assessment on basic factors having direct relation on energy efficiency has an important significance in heating and ventilation systems design.

1. Design Standards.

The calculating parameters selecting have a relationship to the overall energy efficiency in heating and ventilation systems, which impact on the capital and operation expenses.

2. Enhanced Energy Losses.

The energy losses are unavoidable for heat transmission systems, but the strategy in this area must be oriented to their restriction through total expense minimisation.

3. Insufficient Systems Control.

These type of energy expenses in insufficient control systems are frequently measurable with all remaining losses. These require a special attention on the problem, which is actually the main care of the most leading companies in this area (USA, Germany, France, Denmark e.c.), as well and Bulgarian's.

7.1. Standards for Design of Heating and Ventilation Installations (Networks).

The designing standards give an account of environmental specific features (climate), building up of constructional fund, the rational creation of heating and ventilation installations and maintenance of an economically efficient indoor microclimate.

1. Environment (fig.).

◆ Calculation parameters for heating and ventilation systems - relation with capital costs, operating expenses and energy efficiency.

◆ Calculation fuel consumption for a heating season.

2. Building envelope.

◆ Thermal resistance.

◆ outdoor air infiltration

◆ Building envelope humidity mode.

3. Microclimate.

◆ Human self-regulation mechanism.

◆ Indoor heat supply mechanism - convective and radiant.

7.2. Heating Systems.

1. Heating systems feature - efficiency, capital investments, energy losses, control equipment and harmful emissions.

◆ Individual heating.

◆ Central heating.

◆ District heating.

2. Main sources of energy losses.

◆ Inefficient process control in the heating plant and boiler houses.

◆ Heat - transmission network losses.

◆ Heat exchanger and distribution losses.

◆ Consumers' Losses.

7.3. Strategies for energy saving in the heating and ventilation systems.

1. Thermal resistance reduction of building envelope.

◆ Ceiling insulation.

◆ Cavities and air cushion insulation.

◆ External insulation.

◆ Reflectors assembly behind radiators.

◆ Seasonal preparation and maintenance.

2. Infiltration air restriction.

3. Maintenance of an economically efficient microclimate.

◆ 1 °C more costs 6 % more or 1 °C less saves 6 % of expenses (fig.1).

◆ Variable temperature mode - nights and holidays cycles.

4. No motivation to consumer, as regards energy saving.

◆ No energy metering and allocation to consumer.

◆ No motivation (legislative basis) to follow a common interest (or no total energy responsibility).

◆ Unstable national energy resources price policy.

5. Heat exchange station losses restriction.

◆ Imperfect control systems.

◆ Operating problems with executive mechanisms (regulating valves).

6. Losses restriction in supply systems for domestic (technological) hot water.

◆ Pipeline insulation.

◆ Building (where not available) a recirculating pump line.

7. Operating and maintenance discipline.

◆ Pipeline rehabilitation and equipment maintenance.

◆ Loses restriction from systems draining.

8. Losses restriction in ventilation systems.

◆ Fresh air limitation (cold seasons).

◆ Flow rate limitation in the systems.

◆ Heat losses decrease in the air duct.

◆ Heat utilisation of outlet air.

7.4. Renewable and secondary energy sources. Combined systems for heating and hot water supply.

1. Renewable energy sources.

◆ Geothermal water.

- low mineralized ($C_m < 10$ mg/l).

- high mineralized ($C_m \geq 10$ mg/l).

◆ Solar energy.

- Characteristics.

- Passive systems.

- Active systems.

- Combined systems (uses two or more energy sources).

2. Secondary energy sources.

◆ Secondary steam.

◆ condensates and high-potential streams.

◆ Outlet (waste) gases.

3. Energy storage systems.

◆ Nature.

◆ Regenerative and recuperative storage systems.

◆ Water storage systems.

◆ Storage systems with filling (rock-bed-type storage systems).

7.5. Main equipment selection.

1. Basic rules in pumps selection. Hydraulic regime.

2. Heat exchangers optimal selections.

3. Basic rules for selecting ventillators. Operating coordination of consecutively and parallelly connected ventillators. Noise level, sources and restriction approaches.

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This programme is composed by
Assoc. Proff. M.Minchev, PhD.

AIR CONDITIONING SYSTEMS

Assoc. Prof. Nikola Angelov

The purposes for installing and operating an Air Conditioning (AC) System are providing and maintaining prescribed air parameters, which are not influenced by the outdoor air temperature or the working conditions in the room. These systems require significant capital investment and operating costs. The energy efficiency of the AC system depends on the design concepts as well as on the proper functioning of the automatic control system and on the proper exploitation.

1. Air Conditioning parameters

Properly chosen parameters for design calculations are the basic factors that determine the energy efficiency of the AC System.

1.1 Outdoor air parameters- analyzing the influence of the outside air conditions the energy costs. Climate data for long term assessments;

1.2 Indoor Air Quality (Appendix 1)- prescriptive temperatures; Analysis of the micro climate parameters and the preciseness of the automatic controls on the energy expenditures; Hygienic and technological requirements for indoor air quality;

1.3 Prescriptive for the outside air flow.

2. Energy Assessment of the AC System

2.1 Assessment based on thermodynamic and energy balance;

2.2 Solutions for increasing the energy efficiency of the AC System (Appendix 2);

- Optimal volumetric planning;
- Removing or correcting existing sources of indoor pollutants;
- Providing adequate and effective work of the AC System; its components and the heating and cooling systems;
- Heat utilization in the AC System.

3. Energy optimization of the automatic control systems of the AC.

3.1 Automatic Control Systems of the AC;

3.2 Automatic devices and controls (Appendix 3);

3.3 Optimization of the automatic controls based on the optimal regimes.

4. Influence of the exploitation of the AC System on its energy efficiency

4.1 Exploitation discipline.

4.2 Technical measures for increasing the energy efficiency during the exploitation of the AC System.

4.3 Testing the AC System in exploitation.

APPENDIX:

N 1 - Air parameters for comfort and technological AC.

N 2 - Design and technical solutions for increasing the energy efficiency of the AC System.

N 3 - Schemes of AC System's automatic controls.

ENERGY EFFICIENCY IN REFRIGERATION AND HEAT- PUMP INSTALLATIONS

Prof. Stefan Ditchev, PhD

Summary

Refrigeration is widely used in modern industry- in agriculture and food processing, refrigerated transport, petroleum and chemical industries, medicine and construction.

Refrigeration equipment is energy consuming, as it is based on the second law of thermodynamics.

Several refrigeration systems exist according to the power that is used to carry out the cycle:

- Vapor compression cycles- use mechanical power;
- Heat - using cycles- absorption, steam- jet;
- Stream (vortex) cycles - use the power of streams and vortexes;
- Thermoelectric cycles- use electric power

The vapor compression cycles and the heat- using cycles are most often used in modern refrigeration.

This lecture emphasizes on the energy efficiency in refrigeration machines and installations, based on the vapor compression cycles.

The refrigeration cycles can be used both for chilling and heating. When the refrigeration equipment is used for heating or for simultaneous heating and chilling, it is called a heat- pump, and the installation that utilizes that heat (or both heat and cold), it is called a heat- pump installation.

A. Refrigeration machines and installations

The lecture covers the fundamentals and the most widely used schemes of vapor compression machines and installations (Appendix 1). The sources and the reasons for energy losses are pointed out for these schemes, and the ways for decreasing these losses are revealed. The ways for decreasing the energy losses are elucidated both on design and maintenance stages (Table 1).

B. Heat- pump systems

In this lecture the heat- pump is examined as a step- up heat transformer that gives opportunities for better low- potential heat recovery. The energy deficiency that exists all over the world is the most important reason that draws our attention to the usage of heat- pump installations as an energy-saving source of heating or heating and cooling.

In Appendix 2 a simplified line diagram of a heat- pump system is given, as well as the theoretical heat- pump cycle , the coefficient of performance (COP) and a simplified diagram of a heat- pump to be used with different low potential heat sources.

The practical applications of the heat- pump are revealed, as well as some of the latest trends in their development, and the different sources of low potential heat are evaluated.

Appendix:

N 1 - Line diagrams of refrigeration machines and installations and the influence of their arrangement on their energy efficiency.

N 2 - Functional diagram of heat- pump installation that can use different sources of low potential heat.

ENERGY LOSSES IN REFRIGERATION MACHINES AND INSTALLATIONS

N	Name of Object / Element	Abbreviation of the Element	Source and reasons for energy losses	Ways of decreasing the energy losses	Notes
1	2	3	4	5	6
1.	Compressor	Êì	♦Energy losses due to compression;	- Decreasing the compression ratio, σ	The energy lo in the compre depend on its
			♦ Energy losses due to friction	- Securing normal lubrication of the work pairs of the compressor	
			♦Volumetric losses that lead to energy losses:		
			- losses due to the clearance;	- proper compressor choice;	
			- losses due to throttling in the valves;	- proper compressor choice;	
			- losses due to heat exchange in the cylinder;	- proper choice and cooling of the compressor;	
			- losses due to valve leakage	- maintaining the operating state of the compressor	
2.	Condenser	Êí	♦Way of cooling:		The type of the condenser determines the energy costs as as the condensi temperature an pressure
			- water cooling	- using water with lower temperature;	
			- air cooling	- choosing the right type of the condenser unit;	
			- evaporative cooling	- proper circulation regime of cooling water or air;	
			- cooling with boiling refrigerant	- proper choice of refrigerant and its evaporating temperature	
			♦State of the heat-exchange surface (greater heat resistance):		
			- pollution on the side of the cooling fluid;	- cleaning the outer surface from corrosion, fouling, duckweed dust, etc. .;	
			- pollution on the side of the refrigerant;	- cleaning the inner surface from corrosion, lubricant film, etc.;	
			- existence of temperature difference in the condenser.	- decreasing the temperature difference to its optimum limits.	
3.	Evaporator and/or cooling device	È (ÎÑ)	♦Pollution of the heat- exchange surface and increase in the heat and hydraulic resistance:		Frost forming i disaster for air cooling device it should be prevented effectively in o to decrease pow consumption
			- on the side of the refrigerant or the cooling liquid;	- cleaning the surface from corrosion, lubricant film, etc.;	
			- on the side of the cooled fluid (when a liquid is cooled)	- cleaning the surface from corrosion and other pollutants when cooling liquids.;	
			- on the side of the cooled fluid (when air is cooled)	- defrosting when cooling air	

1	2	3	4	5	6
			♦ Existence of temperature difference in the evaporator or the cooling device.	- decreasing the temperature difference to its optimum limits.	
4.	Expansion valve	ĐÎ (ĐÂ) (ÒĐÂ)	♦Throttles the liquid refrigerant. Throttling is internally irreversible process that depends on the kind of the refrigerant.	- subcooling of the liquid refrigerant before throttling in water- cooled heat exchanger or internal heat exchanger.	The degree of subcooling sh match the irreversible lo during throttlin
5.	Refrigeration Machines	from fig.1.1. to fig . 1.4	♦Working conditions and working range:		The specific e
			- uneven heat loads	- regulating the refrigeration capacity of the compressor and use of accumulators of cold	consumption depends on th work paramet and the refrig
			- temperature range between t_0 and $t_è$	- decreasing the temperature range	
			- compression ratio, σ	- compression ratio $\sigma<8$	
			- high discharge pressure	- should be kept lower	
6.	Refrigeration Installations	from fig.2.1. to fig . 2.5	♦Working conditions:		The chosen s of cooling and the prope exploitation influence stro the energy consumption
			- presence of air in the system;	- removing of the air from the system;	
			- presence of lubricant oil film in the heat exchange units;	- draining the lubricating oil from the different units and removing the oil film from the inner surface of the evaporator with refrigerant vapors	
			- Pollution of the heat exchangers' surfaces (increased heat and hydraulic resistance);	- cleaning of the heat exchange surfaces	
			♦Cooling system:		
			- presence of temperature difference only in the evaporator;	- decreasing of the temperature difference	
			- presence of two temperature differences in the evaporator and in the cooling devices with indirect cooling	- decreasing of both temperature differences	

OPTIMIZING THE EFFICIENCY OF HEAT EXCHANGERS

Assoc. Prof. Georgi Raitchkov, PhD

I. POSSIBLE PROBLEMS OF OPTIMIZATION:

1. Searching for an optimum construction of a determined type of heat exchanger
2. Searching for an optimum work regime of a given heat exchanger.
3. Choice of the optimum dimensions from a series of heat exchangers of one and the same type.
4. Optimization of a system of one or several heat exchangers and the connecting elements.

II. COMPARISON OF HEAT EXCHANGERS:

1. Efficiency;
2. Energy coefficient;
3. Efficiency of unit's mass and volume utilization;
4. Efficiency of utilization of the heat source.

III. POSSIBLE TECHNICAL SOLUTIONS AND RECOMMENDATIONS for INCREASING THE HEAT EXCHANGERS' EFFICIENCY

1. Design aspects of heat exchange intensity:
- Pollution of the heat exchange surface. Recommendations to the designer and the maintenance personnel;
- Unevenness of the velocity field. Reasons. Recommendations for removal or decreasing of the unevenness;
- Shadow areas with inert fluids. Ways for removing them.

2. Hydro-dynamic aspects of the intensity of heat transfer.
- Optimum fluid velocities;
- Creating a turbulent flow and decreasing the thickness of the boundary layer. Vibrations, rotations, increasing the roughness of the heat exchange surface;
- Thin layer flow. Thin layer apparatuses;
- Flat passage flow. Plate apparatuses.

3. Thermophysical aspects of the heat exchange intensity and the efficiency of the heat exchanger
- Movement of the fluid flows. Parallel flow, counter flow, mixed flow, cross flow;
- Organization of the temperature regime. Optimum temperature difference;

- Heat recovery of the heated fluid. Optimum recovery coefficient;
- Putting fins on the heat exchange surface. Optimal fins. Recommendations for the choice of the form, dimensions and the material of the fins. economic efficiency of finned water and air cooling devices.

IV. MODERN HIGHLY EFFECTIVE HEAT EXCHANGERS:

1. Pipe Apparatuses;
2. Plate apparatuses;
3. Compact apparatuses;
4. Heat exchange systems.

AIR COMPRESSION CYCLES

Assoc. Prof. Miltcho Angelov

1. Technological requirements for compressed air.

The design calculations, construction and exploitation of the compressors are made with considering the real air properties. The air properties determine the dimensions and the construction of the main units and details of the compressor. The requirements for work with highly inflammable gases, toxic gases, chemically active gases (that react with oils) , as well as the work temperature should be taken into consideration. The ambient pressure and the air filtration also influence the energy efficiency.

2. Energy efficiency of the compressed air systems.

The energy efficiency of the compressed air systems is mainly determined by the compressor parameters that should be maintained at constant levels according to the technological requirements. According to the values of these parameters the type of the compressor is determined. A diagram that helps to determine the appropriate compressor type (reciprocating, centrifugal, screw, rotary) according to the application is given.

The power and the specific energy consumption for compression are the main parameters for air compression system's efficiency. Two diagrams that help to compare the specific energy consumption as a function of the pressure and the specific energy consumption as a function of the flow- rate are given.

3. Energy efficiency of the systems for automatic control of the compressed air installations.

Modern compression units are equipped with automatic control systems that maintain the necessary regime with low energy consumption. Two diagrams of automatic pressure- and flow control are given, and a comparison of their efficiency is made.

4. Influence of the exploitation an maintenance on the energy efficiency.

The compressor regulation is made in order to assure the necessary parameters according to the consumers' demands for pressure and flow-rate.

4.1 *Regulating the turbo compressors and the axial compressors*

It can be performed in one of the following ways

4.1.1 Throttling on the discharge line of the compressor. A diagram is given that elucidates this type of regulation and the optimum regime choice.

4.1.2 Throttling on the suction line. A diagram reveals both the type of regulation and the choice of an optimum regime ,avoiding dangerously low pressures in the suction line.

4.1.3 Use of flow directing unit. It changes the energy of the flow through its rotation and facilitates maintaining the necessary parameters.

4.1.4 Rotating the diffuser blades. This changes the compressor characteristics.

4.1.5 Changing the rotation speed. This is simple and cheap, but requires a variable speed drive. A diagram on this method is given.

4.2 *Reciprocating compressors regulation*

4.2.1 Regulation through variation of the rotation speed. Requires a variable speed drive or a steam (gas) turbine.

4.2.2 Throttling on the suction line- The lower suction pressure decreases the volume of the gas that enters the chambers.

4.2.3 Acting on the suction valve- a diagram is given that elucidates the method.

4.2.4 Regulating through the clearance variation. An indicator diagram is given for the different work conditions.

4.3 *Analysis of the compressor performance with its indicator diagram.*

Several types of indicator diagrams are included, and comparison between their efficiencies is made with their help. Indicator diagrams can be used for early diagnostics of the system (valves performance, leaks), and thus the energy efficiency in every moment can be monitored.

INCREASING THE ENERGY EFFICIENCY OF HYDRAULIC SYSTEMS FOR MACHINE DRIVES AND CONTROL UNITS

Assoc. Prof. Todor Nikolov

Due to a number of advantages hydraulic drives are modern devices for mechanization and automation of the technological processes in industry. They are widely used in construction, machine- building, transport, etc. That is why the problem of their energy efficiency is a part of the energy balance of every country.

It is known that the hydraulic systems have efficiency of approximately 50- 70 %, which is a significantly better performance that this of the similar pneumatic systems. But compared with the mechanical and electric systems, their efficiency is much lower. This gives opportunities to apply a number of general and specific steps for increasing the energy efficiency of the hydraulic systems during their design and exploitation.

In general, the energy that a system consumes equals the sum of the work performed and its energy losses. So the most important problem in the search for more efficient system performance is the application of new, more energy- efficient technologies, with reduced force- and velocity regimes, with lower energy consumption, which is possible in some of the non-hydraulic drive systems. In most cases it is more possible to decrease the energy losses than to change the system as a whole.

The total efficiency of the hydraulic systems is influenced by a lot of factors, some of which are: pressure losses (hydraulic resistance); flow- rate losses (the quality of the liquid discharged from the pump that is not used in the hydraulic drives i. e. the internal and external leaks, etc.).

Here are some of the prescriptive which realization will increase the efficiency of the hydraulic systems:

1. When designing a hydraulic system that consists of a single hydraulic drive, the optimum case is when its velocity is controlled by a three-way flow controller. In this case the pressure in the system adapts to the external force that is applied to the drive.

2. If the system consists of more drives, then:

- volumetric instead of throttle control of the drive's velocity should be preferred;
- a pump that allows flow control is to be used;

- a hydraulic accumulator should be attached to systems without flow control pump and uneven Q-t diagram;

- usage of self- relief (of power N and flow- rate Q) pumps when the drives are inert during a significant part of the total cycle, i.e. when Q is equal to 0 and the value of the pressure P is not equal to 0 for applying the power regime of the system;

- The parameters of the systems should be appropriately chosen. They are: flow- rate, pressure, temperature, dimensions of the pipes and elements, oil's viscosity, etc.;

- The elements should possess appropriate functional characteristics (small hydraulic resistance);

- reliable seals for the movable and steady joints are to be used;

- bending of the pipes should be made in order to decrease their hydraulic resistance.

IMPROVING THE ENERGY EFFICIENCY OF LIGHTING SYSTEMS

Dr. Nikola Gruev

The low power consumption is a major requirement in industry. With its 10% of the total electricity consumption artificial lighting is among the greatest consumers in modern economy.

The design and exploitation of lighting instalations give a lot of opportunities for energy savings without violating the norms for adequate lighting.

- Steps can be taken to diminish the complexity of visional work and thus decreasing the required light parameters (superseding visional information with another kind of information; simplifying the information through its coding with color, symbol, form, etc.; optimization of the vision angle; creating an appropriate color and brightness contrast between the object and the background; optimization of the viewing duration, etc.)
- Proper distinction of the category and the sub category of visional labor to prevent installing too much lighting capacity.
- Considering the complex impact of the quantitative and the quantitative lighting parameters on the process of viewing, it is possible to decrease the illumination (which requires increased energy consumption) to a certain level by improving the other parameters such as lighting uniformity, preventing direct and indirect glitter, etc.
- Giving priority of the combined lighting system. Better lighting levels are achieved with comparatively lowest energy consumption due to the proximity of the lighted surfaces to the local light sources that provide 80 to 90% of the necessary lighting. Vertical surfaces and surfaces situated by a certain angle are better lighted, as well as the surfaces of hollow objects; There are a number of methods for improving the quality of lighting.
- Applying of light sources with a significant luminous output : metal halide lamps (for higher rooms), fluorescent lamps , lamps of BS-type (when requirements to color transmission exist), in some cases- high pressure sodium lamps, some types of haloid lamps (when less lighting is necessary).
- Choosing lighting devices with higher efficiency and appropriate color distribution. The lowest possible fixture mounting height should be chosen for overall lighting; and the proximity of the light sources to the illuminated surface should not influence the light's quality parameters such as

uniformity, lack of direct glitter, etc. If it is possible, special units for controlling the optimal work temperature of the lamps should be installed. The heat rejected by the lighting installation should be included in the air conditioning balance.

- Appropriate materials, as well as the appropriate painting and interior surface processing lead to higher reflection factors of the light flow, and thus better illumination and light uniformity is achieved.

- If the natural lighting of the rooms is good enough, then it is possible to reduce the operating period of the lighting system. During transition periods from natural to artificial lighting, or when the natural lighting is insufficient, either only one part of the artificial lighting can be switched on, or only the lighting in certain zones.

- The steps listed above can be performed only if an appropriate control exists (including automatic lighting control and photocells). It gives opportunities to switch off the entire installation or only some of its parts, to change the luminous output of the lamps in the different zones.

- The coefficient of over installed capacity should be decreased to decrease the total energy consumption. It can be best performed by applying complex steps (technical and technological) for reduction of the working environment's pollutants such as dust and vapors and improvement of the room's micro climate.

Some other ways that exist are: regular cleaning of the light reflecting surfaces and the light sources (including the windows), removing the lamps that are beyond their optimum lighting period. For that reason during the design of the building safe and easy ways for cleaning should be anticipated.

The interior surfaces should be cleaned and painted regularly in order to recover their reflection. The entire lighting system should be changed when it becomes outdated.

For better assessment of the energy efficiency that is achieved some parameters that are closely linked with the lighting efficiency such as production output and quality, data for some specific groups of diseases and accidents, psychological and emotional conditions of the personnel.

The Role of Automatic Control Systems in increasing the Energy Efficiency

Assoc. Prof. Ivan Dragotinov, PhD

1. The lecture concerns two extensive issues, much related to the Energy savings in the technological processes control:

A. Basic features and resources of the automatic control systems of the technological processes.

B. Technical solutions review of the Automatic Control, aiming Energy efficiency.

The lecture will proceed in the following order:

1.1. Discussion of basic terms, characteristics and principles.

1.2. Explanations of the different processes, using schemes and slides.

1.3. Demonstration of the systems, already discussed (items 1.1; 1.2) by means of computer simulation.

1.4 Open discussion and answering questions that have arouse concerning items 1.1-1.3. and the beforehand given written materials.

Lecturing hours:

2.1 Control of the technological process. Static and dynamic regime. Manual and Automatic control. Different kinds of controllers. - 1 hour

2.2 Basic dynamic properties and evaluation of the way the technological systems work. - 1 hour

2.3 Different kinds of technical solutions in the process of control, towards energy efficiency. - 1,30 hours

2.4 Demonstration of the systems and their features, already discussed by means of computer simulation.

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DIRECT DIGITAL CONTROL SYSTEMS

Dipl. Eng Evgeni Genchev, MSc

1. DDC Basics

According to the definition of The American Society of Heating, Refrigeration and AirConditioning Engineers (ASHRAE) Direct Digital Control (DDC) is a closed loop control process implemented by a digital computer [1].
DDC is a major trend in Heating, Ventillation and Air Conditioning (HVAC) control and energy management today, gradually replacing the pneumatic and the electro-mechanical control systems that have been commonly used prior to the invention of this technology.
From the theory of automatic control view, one of the greatest advantages of DDC is the opportunity to implement PID (Proportional-Integral-Derivative) control laws.
The pneumatic and the electro-mechanical control systems are inherently proportional. As the theory of automatic control says, the proportional law of control can never exactly achieve the given setpoint - always an offset from the setpoint must be present in order to be proportionally amplified and used to control the actuators in the system.
Adding an integral component to the proportional law of control provides for exactly achieving the setpoint. Provided the gain factor of this component is properly chosen it is possible to eliminate overshoots of the setpoint and minimize swings around it that are common in proportional systems. One can easily see that HVAC control can greatly benefit from PI (Proportional-Integral) laws of control.
The presence of a derivative component helps provide quick reaction to changes in the object controlled which proves very useful in the case of dynamic processes.
To cut the long story short, PID control gives the opportunity for optimal control.
It should be admitted that PID control can be implemented using analog electronic regulators, but using digital controllers offers still further control algorithm enhancement - it can now be made adaptive. The achieved performance of control can be periodically assessed and PID control parameters be modified to improve performance, thus the control system becoming a self-teaching one. Adaptive control has a great advantage over the conventional one in cases of very complicated and dynamic processes that are hardly subject to a formal description.
Apart from the control point of view, DDC systems offer other advantages that prove very essential: flexibility, reliability and ease of use.

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DDC flexibility is a consequence of the fact that the control algorithms are implemented in software. As a result changes in these algorithms can be made without doing any mechanical work. If DDC conrollers are networked it is not even necessary a person to reach the controller's site, that is algorithms can be changed remotely. In this case it is also possible to remotely track the algorithm's behaviour and tune it to obtain ultimate results.
It goes without saying that electronic systems are more reliable than mechanical or electro-mechanical ones; digital systems add still more reliabilitiy as their intelligence offers extensive capabilities of self-test.
The ease of use is of great importance in the case of large energy management systems. Digital computers can provide a superb user interface; provided the DDC controllers in the system are networked the system's operator can be quickly and easily presented information of local nodes and the system as a whole.

2. DDDC Systems Architecture

MIni-computers and Programmable Logic Controllers (PLCs) had been used for energy management purposes since the late 60's, but in 1973 two events took place that prepared the background for extensive DDC implementation.
The first event was the oil embargo imposing increased energy management quality. The usage of digital controllers proved inevitable due to the great number of system variables that had to be taken into account by the control algorithms in order they to be adequate to the new state of things.
The second event was a technological one - it was in 1973 when the first easy-to-use microprocessors became commercially available. The new, microprocessor-based computer systems offered drastic reductions of price, size and energy consumption with respect to mini-computers; something more - the increasing use of microprocessors brought about a steady and rapid trend of their prices dropping. Nevertheless their performance rapidly increased and in the end of the 70's reached that of the mini-computers in the beginning of that same decade.
As the use of microprocessors was decreasing digital computers' prices, computer-based energy management systems' architecture underwent basic changes.
In the days of mini-computers, the price and the size of a digital computer were so substantial that one could not afford using more than one computer to implement DDC in a Building Automation System (BAS) or an Energy Management and Control System (EMCS). So the financial considerations imposed the model of centralized computing (Fig. 1).
By the beginning of the 80's the lowering microprocessor systems' costs and the increase in their performance made the concept of DDDC (Distributed Direct Digital Control) practically applicable.

DDDC utilizes the idea of distributed computing; a typical DDDC system is a hierarchical one built of controllers networked within each other (Fig. 2) [2].
Four levels of hierarchy are defined: Sensor/Actuator, Distributed Controller, Island Host and Master System Operator Interface (SOI).
The Distributed Controller level consists of small, cheap, stand-alone controllers so situated that wiring costs are minimized (that is, in the proximity of the transducers and the actuators involved). Each of them is working on a number of local control tasks. The number of tasks depends on the computing power of the controller and the control algorithms to be implemented; something usual is a controller to be devoted to the control of a boiler plant only, for example.
Two types of distributed controllers can be distinguished: Equipment Level Controllers (ELCs) and Zone Level Controllers (ZLC).
ZLC are highly specialized. They control a single unit of a definite type of equipment; as their implementation is known in advance, they usually are to a high extent pre-programmed with the appropriate control algorithms. It is something usual ZLCs to come with the equipment they control; statistics says that in 1992 20% of the VAV boxes have been shipped with built-in ZLCs [3].
The number of Input/Output (I/O) lines and their type (analog, digital, counter, Pulse Width Modulation (PWM), etc.) is known in advance and they are usually a small number. The fact that a ZLC controls only one unit does not mean it carries out a simple control algorithm - controlling some of the units requires enough computing power to keep busy even a high-performance microprocessor system.
ELC are general-purpose controllers. Unlike a ZLC, an ELC is capable of controlling several equipment units at a time. As a result ELCs have extended I/O capabilities; they usually provide at least 8 inputs and outputs, their number being easily increased by means of adding expansion modules to the ELC. As the need for I/O lines type is not known in advance, ELC inputs usually are universal - they can be easily reconfigured to become digital, analog, counter, etc. Outputs are to some extent flexible too. ELCs are to a much greater degree programmable than the ZLCs to provide maximum flexibility.
The term "point" is defined within the Distibuted Controller level - the value of a point corresponds to that at an input/output. Points are usually given names to indicate their geographical position and physical meaning, e.g. "Floor1 Room117 Temperature" ot "Outside Air Temperature".
Here is the moment to point out the most essential advantages of DDDC over centralized DDC.
It is not uncommon for a BAS or an EMCS to contain hundreds of pieces of equipment that must be controlled; besides that these pieces may be distributed over a large area (e.g. in a plant). One can easily imagine the extreme inconvenience and the substantial cost to wire all the needed sensors and actuators to the place where the computer is situated. DDDC is a solution to that problem.
A centralized DDC system will not be easily expanded. Besides the additional wiring, present central computer resources may prove insufficient imposing seriuos investments to increase them, even by means of replacing the computer.

This means that all control actions will be suspended for a substantial period of time. By contrast, expanding a DDDC system is much more easier. New distributed controllers are installed at appropriate locations, much less additional wiring is needed and the expansion process does not in any way disturb system's functionality.

Finally, the system reliability topic will be addressed. Computer failures in the case of a centralized DDC will suspend all the control actions in the system. With DDDC only the control at the corresponding location will be disturbed so DDDC systems are more reliable.

The functions of the Island Host level substantially differ from those of the Distributed Contoller level. Though most Island Hosts provide some limited I/O capabilities, the primary functions of the controllers at this level are system data maintenance, system-wide coordination and communication with the SOI.

There are two types of system data: global and shared.

Evidently there exist pieces of data that are used by numerous controllers within a DDDC system. The value of a point may be essential not only to the distributed controller it is situated at but to many others too. The outside air temperature is a good examle. Its value is of basic importance to many HVAC control algorithms throughout a building and the corresponding distributed controllers drive their outputs according to the control algorithms using this value. This is possible due to the network linking the controllers within the system.

It should be noted, though, that it is not commonly the case the value of outside air temperature to be directly retrieved from the distributed controller the corresponding sensor is connected to. In such cases a pseudo point is created at the Island Host that contains a copy of the value of the physical point ("physical point" stands for the input of the corresponding distributed controller). Thus the controllers that need the value of outside air temperature communicate with the Island Host and do not involve the distributed controller where the physical point is to be found in intensive network actions. It's only the Island Host that periodically inquires the controller for the value of the point in order to keep it up-to-date, to refresh it. Thus the value of outside air temperatute has become global system data.

Pseudo points are often not simply a copy of a physical point but contain the result of processing the data gathered from one or several points. This is done usually to provide the distributed controllers with frequently used functions of several point values. An example can be the value of total system kilowatt demand.

Another example of global system data is the system time. Real time is of primary importance in a BAS or an EMCS; many controllers within the system need its value. Computer real-time clocks provide extensive time information - from second to year, automatic leap year correction and daylight savings enable/disable. This offers opportunities to implement sophisticated time scheduling algorithms. Only some of the distributed controllers have real-time clocks; the others maintain the real time data in their memory. Island Hosts broadcast real time data over the network and the distributed controllers

synchronize their real-time clocks or real time data to the Island Host real time. Thus all the processes within the system are controlled according to an uniform time base so potential problems caused by clock inaccuracies at different controllers are cancelled out.
It is very common the control algorithm running on a controller to need the value of a point situated at another controller. This is evidently a specific case of global system data and is regarded as shared system data.
It is a common capability of an Island Host to provide automatic logs of point values. These logs are useful in enhancing the control algorithms and in debugging the control programs.
It goes without saying that coordinaton is very essential for an energy management system. Control strategies like Optimum Start/Stop, Demand Limiting and Load Shedding require that the Island Host be capable of initiating the execution of specific control algorithms on any of the distributed controllers. Island Hosts can usually override local control programs at the distributed controllers and control their outputs directly.
Island Hosts communicate with the SOI to provide three basic functions: programming, monitoring and alarming.
It should have become clear by now that DDC is used to implement sophisticated control algorithms so the question how DDC systems are programmed is of primary importance. Two trends are present in this area: Equation Driven programming and Library Loop Control programming.
The Equation Driven programming is close to the usual computer programming manner. The control algorithms are programmed using equation languages providing arithmetic, boolean and relation operations. This offers extreme flexibility as it allows unrestricted modifications of the control algorithms.
Essential drawbacks of this metod exist. Sometimes using an equation language proves unnecessary complex (e.g. when programming time shedules). The extreme flexibility of the metod is often not used to a full extent for the algorithms controlling some pieces of equipment are quite standard and they are unlikely to be changed in the future. In such cases libraries of strategies are used; these libraries contain pre-programmed control loops that are easy to be tailored to the current application. Using libraries of strategies greatly decreases the time and the cost of software development.
The flexibility of the Equation Driven programming poses another important problem. As the programmer fully determines the control algorthm, testing it's behaviour under any possible conditions is absolutely needed. Extensive testing may take a great amount of time especially with complex algorithms. Once again using libraries of strategies helps solve this problem. The control loops contained in the library have been thoroughly tested and found fully reliable.
As one may expect, Equation Driven programming is mainly used in ELCs as it helps utilize their flexibility. It should be noted that DDC controller designers aim at extremely easy user programming. To achieve this each DDC controller has built-in software controlling the hardware resources; this software handles inter-controller communication, input signals' conversion according to user-defined

formulae (e.g. converting the electrical signal provided by a thermocouple to degrees Fahrenheit or Celsius so that user can view the input signal directly as temperature), maintain a proper duty-factor at PWM outputs to produce an user-defined analog value, etc. The user takes the control of hardware resources for granted; he is only expected to perform algorithmization and consequently code the produced algorithm in the programming language used.

The other trend, Library Loop Control, is quite adequate for ZLCs. In this case control loops have been already programmed, tested and deposited in the controller's program memory. The user is allowed only to change the essential parameters of an algorithm (setpoints, time scheduling, etc.).

All the controllers from both the Distributed Controller and Island Host level can be programmed from the SOI using the network. Programming includes downloading control programs, enabling/disabling their execution, setting alarm limits. It's quite in place here to add that the system operator is given the opportunity to override local control on outputs and switch to manual control.

The monitoring capability of Island Hosts provides the system operator at the SOI with information of current system status and with the automatic logs performed by the Island Host; thus all the data throughout the system is available in one place.

Current system status information may be provided in the form of a group containing the values of the points at a defined controller. Often the user can define a custom group of points situated throughout the whole system that are logically inteconnected.

Log parameters can be defined by the operator. In all cases the log interval is definable (seconds, minutes, hours, etc.). Some systems support programming log start/stop times.

As the SOI is used to program all the controllers in the system and point logs are available at the same place, this aids control algorithms' enhancement and debugging.

Two another types of logs provided by an Island Host are of primary importance to system administration: operator logs and override logs.

Up to now we talked about a single system operator but usually this is not the case. The system can be operated by many persons with different privilege levels. Each of these persons logs on the system after entering his name and personal password; on their basis the operator is given the corresonding access rights within that session.

The top privilege level operators are enabled to unrestrictedly program the system, view logs, override local control, etc. He can view and change lower privilege level operators' passwords and access rights in order introduce new operators or change other operators' influence over the system's operation.

System's maintenance staff, security guards and building tenants usually have lowest privilege levels. They are not given the right to change programs but they must at least be able to override control on some outputs and switch to manual control.

Evidently some possibilities exist that operators impair system functionality, cause system malfunction or hardware failures, intentionally or not. An example can be given with devices that require minimum on or minimum off times, otherwise they will be damaged. Improper use of control override may violate these restrictions. It may also happen that operators disable the executions of certain control loops thus violating optimal energy management.

Proper system administration requires that track be kept of such actions for penalty or billing purposes. Viewing the operator logs and the override logs can determine the operator that caused the malfunctions; similarly, if the operator proves to be one of the building tenants, he or she can be additionally charged to recover the cost of the additional energy consumption.

Alarming capabilities of Island Hosts are extremely important for system's functionality and maintenance. Limits can be programmed in order point values to be constantly checked against them and alarms to be fired in case these limits are violated. Digital points can be used to fire alarms using electro-mechanical alarm systems.

Alarms are mostly used to signal hardware malfunctions (concerning controllers, sensors, actuators, etc.) to the system operator. Controllers may aid the system operator in determining the failure that caused the alarm. After the alarm has been fired the corresponding controller may assess the values of points concerning the process and come out with a decision sparing the operator's time to view point logs.

It is generally possible specific actions to be triggered by alarm firing, e.g. under the form of starting control loops preventing the failure to influence system's functionality as a whole. The most frequently example given in that aspect is the failure of the outside air temperature sensor. Such failure will severely affect all the HVAC control algorithms throughout the building. As soon as this failure is detected the pseudo point at the Island Host containing the outside air temperature can be stopped from refreshing and given a constant value adequate to the time of year. Thus the concept of global system data helps increase system's fault tolerance.

It's common for Island Hosts to provide communication with a remote SOI via a modem. Many BAS in the USA are managed over dial-up telephone lines. In this case the Island Host can be programmed to initiate a dial-up sequence in cases specific alarms are fired.

The system operator then answers the call and views the monitoring information provided by the Island Host. If the alarm hase been fired by a hardware failure he can send the appropriate type of maintenance staff with the proper instrumentation, spare parts and a clear idea of what to do.

Smoke sensors can fire an alarm initiating a dial-up of the fire department. In case the system software registers an intruder, the police number number can be dialled. In both the latter cases the system operator can be also dialled to initiate appropriate control actions if needed. In case of fire the HVAC system can be used for pressurization to help exstinguish the fire, for example (this topic will be addressed more extensively later).

A new manner of remote human-machine interaction became recently possible with the availability of voice modems. These modems are capable of playing prerecorded voice messages over the phone line after establishing a connection; at the same time they are capable of reporting Dial Tone Multi Frequency (DTMF) signals coming from the remote side. Using these capabilities, it is possible to organize a "conversation" between the system operator and the SOI. The voice modem is used to dial up and report by voice the cause for the alarm. The system operator can instruct the system what to do by means of DTMF dialing. In this way the system operator no more needs a computer and a modem but just a touch-tone phone.

This manner of interaction is very convenient to provide access of building tenants to the DDDC system. A typical example is their ability to override time scheduling for their zones so that they can occupy them on evenings and weekends. The system uses the tenant-provided information to maintain comfort only in the zones that will be occupied; other zones are kept at setback temperature. The same information is used for billing purposes.

The possibility of remote system administration is one of the explanations why a separate SOI level is present in the DDDC architecture. Many other reasons justify the need for a dedicated SOI computer.

First of all, the system operator should be given the ability to run the personal computer spreadsheet programs he is used to. Using the available information from the system, this will help illustrate trends, perform calculations, etc. The system should provide interface to these spreadsheet programs on a file basis: Island Hosts usually provide the logs in suitable formats, e.g. DIF (Data Interchange Format).

Second, the system operator should be offered convenience. He prefers to use the input-output devices common of a personal computer: a CRT monitor, a common keyboard and a mouse, if possible. The system operator must be offered an user-friendly interface, and this will need much computing resources.

It becomes obvious that a personal computer is the most applicable hardware platform for a SOI. Usually an IBM PC is used.

A very essential part of the SOI functions are the file ones. They give the system operator the opportunuty to store system files on the SOI computer disk. Such files are the programs at the distributed controllers; their copies on the disk are used when the controllers must be reprogrammed or when their non-volatile memory has failed. Another example of system files are the logs; storing them on the SOI computer disk frees the memory of the distributed controllers and makes the information more conveniently accessible. Usually special functions exist that treat all the contents of a controller memory as a single object to provide easy controller backup/restore possibilities.

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3. DDDC Networks

The most widely used network topology in DDDC systems is the bus one (Fig. 3). All the controllers are connected to a single cable; only one is allowed to "talk" at a moment, else the message will be corrupted.

Despite that only one can "talk" over the bus at a time, it is not a bottleneck in the system. For each DDDC system, the physical media used to implement the network and the network software in the controllers provide a definite, adequate maximum time to deliver a message across the network. This ensures prompt system actions when network messages are used to produce control decisions or directly control outputs. To cut the long story short, the system's response time is defined like in any real-time control system.

Before we address the most usual problem encountered when building a DDDC network, two network terms should be introduced: "segment" and "node".

The network topology shown on Fig. 3 is the most simple bus. DDC controllers are wired to the network cable consequtively. No branches are present in the network and no other devices are present in it besides the controllers. In this case the term "segment" stands for the overall cable length and the term "node" can mean only "controller".

For any type of physical medium, limitations exist on the maximum segment length and the maximum number of nodes on a segment. These limitations are imposed by the fact that the signal attenuates as it propagates along the segment. Special types of devices called "repeaters" can be used to overcome any of this two limitations. Repeaters are in fact bidirectional boosters and each of them must be considered a node. Each repeater starts a new segment, allowing for another maximum segment length and another maximum number of nodes. Repeaters are available from the DDDC system manufacturers.

A DDDC system may incorporate multiple buses of different types. In some systems, several Island Hosts and/or several SOIs are present. Usually each of the Island Hosts has its own bus linking it to distributed controllers. Another type of bus interlinks the SOIs and the Island Hosts (Fig. 4). The latter bus offers more speed than the former one and is usually implemented using another type of medium.

Several types of physical medium are currently used to implement the network(s) within the DDDC systems.

The first type of medium is the space rather than a cable. In cases when the DDC controllers are distributed over large premises, e.g. large plants, wiring costs are rather high and radio communication is sometimes used instead of cables. Specialized radiomodems are available at moderate prices to aid implementing radio networks.

The second type of medium is readily available in any building - it is the power line itself. The information to be transmitted over the network is used to modify the voltage over the power line (the term used is "to modulate" the voltage). Receivers conversely demodulate the voltage changes to retrieve the transmitted data. Unfortunately, this most convenient of all types of medium is the most

rarely used one; its main drawbacks are low reliability, low communication speed and the relatively small distances over which connection can be established. Power lines are in most cases a very noisy environment, even if the electrical appliances connected to them are compliant to the most severe electromagnetic compatibility standards - these standards have not been developed with data transmission over the power lines in mind. Hence the low communication speed and the low reliability.

The third type of medium is the coaxial cable. This type of medium offers high communication speed and reliability but its price is comparatively high. In fact the communication speed offered by the coaxial cable is much more than needed to interconnect ELCs and ZLCs so the use of this type of medium for such purpose is not economically justified. Coaxial cable is usually used to interconnect Host Islands and SOIs as in this case more intensive information exchange takes place.

The fourth type of medium is the optic fibre. This media offers still higher communication speed and reliability than the coaxial cable as it is completely unaffected by electromagnetic interference. Optic fibre's price is high; what was said of coaxial cable's applications holds for optic fibre too.

The fifth type of medium is the so-called "twisted pair". It consists of two isolated conductors, twisted around each other at a constant step of 6 turns per inch to provide shielding from electromagnetic interference. The twisted pair is the standard cable recently used to build telephone connections within buildings in the USA, so its price is fairly low. Sometimes the abbreviation UTP (Unshielded Twisted Pair) is used for there exists a shielded version of this type of cable (STP - Shielded Twisted Pair); the STP offers improved noise immunity resulting in greater distance over which connection can be established. Even the UTP has adequate noise immunity and communication speed for DDDC systems. Presently, UTP is the most common medium used to interconnect ELCs and ZLCs to Island Hosts. Predominantly the RS485 standard for signal levels is observed when using UTP. It defines a maximum segment length of 1200 meters (4000 ft.) and maximum 32 nodes on a segment. It was mentioned already that repeaters can be used to bulid greater networks. Many DDDC manufacturers define a limit of more than 32 nodes so repeaters are not frequently used.

Unfortunately, at present no standards exist concerning DDC systems' network protocols. Different manufacturers' DDC units are to a great extent incompatible. This problem is solved by means of special network devices called "bridges". Bridges' primary function is to link networks using incompatible protocols. As network bridges essentially raise network cost, intensive work is under way to adopt standards defining a common protocol for DDDC networks. Such a protocol must meet numerous requrements specific to the control applications; no existing protocol in any communication area fully meets them. Nevertheless ASHRAE considers MAP (Manufacturing Automation Protocol) developed by General Motors as the potential standard [4].

4. DDDC Strategies

The DDDC technology allows useful control strategies to be carried out. Some of them will be briefly discussed below to illustrate the abilities of DDDC systems [5, 6].

4.1. Time Scheduling

Using real time data the HVAC and lightning equipment can be controlled to switch beween different sets of setpoints for occupied and unoccupied periods. These periods can be defined according to several criteria:
- Time-Of-Day (TOD) Scheduling - the periods are defined within time of day
- Day-Of-Week Scheduling - the periods are defined as days of week
- Holiday/Yearly Scheduling - the periods are defined using any dates during the year; this can complement the day-of-week scheduling with regard to holiday scheduling

These criteria can be used in conjunction with each other to obtain ultimate flexibility.
Usually building tenants are allowed to override time scheduling for the zones they occupy in order to use them after working hours and on holidays

4.2. Demand Limiting and Load Shedding (DLS)

Often a certain limit of power consumption (usually concerning electric energy) is settled by the power plant and the user and for the period the power consumption exceeds this limit, the price of power is substantially increased.
This forces the user to switch off (shed) non-critical pieces of energy consuming equipment for certain periods of time and subsequently switch them on (restore them) to avoid the violation of the predefined energy consumption limit.
The DLS strategy requires careful estimation of system information in order not to affect vital production processes or dramatically impair HVAC and lightning comfort. Three types of DLS strategies can be outlined:
- "round-robin" - the pieces of equipment are shed/restored on a "first off - first on" basis; obviously pieces of equipment of equal importance are encompassed by such a strategy
- priority - the basis used is "first off - last on" to provide priority between the pieces of equipment
- temperature - the load closest to setpoint is shed first

4.3. Minimum On - Minimum Off Times

Certain types of equipment require that they remain on a certain amount of time once started and remain off a definite period of time once stopped. In case these restrictions are violated, device malfunction or failure may occur. Individual minimum on and minimum off times can be predefined for each piece of equipment to be observed when controlling them.

4.4. Duty Cycling

A control point can be defined as one of two types in order to control the duty cycling of a piece of equipment:
- temperature compensated: duty cycling is performed to maintain a setpoint within a dead band;
parameters defined are total cycle length, high temperature and low temperature
- time dependent: the piece of equipment is switched on and off for fixed amounts of time; parameters defined are total cycle length and off cycle length

4.5. Optimum Start/Stop (OSS) / Night Setback

OSS / Night Setback is a widely implemented control strategy in BAS. It concerns zones that are not permanently occupied. In such zones different temperature setpoints are maintained during occupied and unoccupied periods. The unoccupied periods are at nighttime (hence the term "night setback"), weekends and holidays.
For this purpose HVAC equipment is started a certain amount of time before the start of the occupied period in order the occupied level of comfort to be reached by the time of this start; respectively, it may prove possible to stop it a certain period of time before the start of the unoccupied period to reach the unoccupied setpoint just at the time of this start. The simplest solution is to set start/stop times fixed throughout the year to meet the worst weather conditions. Energy savings can be achieved if outside air temperature and parameters specific to each zone (internal temperature, heating/cooling capacity and rate of heat loss/gain) are taken into account to estimate the optimal start/stop times and OSS is implemented on a zone-by-zone basis. Sometimes OSS decisions are based on data gathered in the past to form the so called "building history"; thus the OSS algorithm is made adaptive.

4.6. Hot Water / Chilled Water Reset

This control strategy varies the temperatures of hot water and chilled water according to the present heating/cooling requirements. These requirements are estimated using the value of the outside air temperature, present thermal gain/loss and having night setback in mind. As the outside air temperature raises, heating requirements drop and hot water temperature can be decreased; as the outside air temperature lowers, cooling requirements drop and chilled water temperature can be increased. During unoccupied periods the temperature of hot water can be decreased and that of the chilled water can be increased. Obviously implementing this strategy in single zone/multizone HVAC systems can result in considerable savings. A three-way valve can be used in the hot water/chilled water loops to implement this control startegy.

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4.7. Boiler/Chiller Optimization

In a plant where multiple boilers or chillers are used, its overall efficiency can be improved by properly distributig the load between them. With boilers, partial loading must be avoided; as much boilers as possible should work near the rated load. This can be controlled by means of the burner firing mode. With chillers, it can prove more efficient if they work only partially loaded, so the load must be distributed between them.

4.8. Free Cooling

This control strategy uses outside air to cool and ventilate the building. This is possible if the enthalpy (total heat content) of outside air is lower than that of the internal air and cooling is needed. Free cooling saves the energy spent on meeting the cooling requirements.

4.9. Recirculation

This control strategy provides for rapid warm-up upon heating and rapid cool-down upon cooling. For this purpose outside air dampers are kept fully closed and return air dampers fully open during system start-up. With heating, the term "morning warm-up" is also commonly used.

4.10. Hot Deck/Cold Deck Temperature Reset

This control strategy concerns dual duct HVAC systems. Having in mind the information gathered in the zones with maximum heating/cooling requirements, the minimum hot and cold deck temperature difference can be established under which these requirements will still be met. Obviously this will lead to maximized system efficiency.

4.11. Motor Speed Control

The speed of fan and pump motors can be varied to reduce air and water velocity as loads decrease. Speed control can be achieved either by using a two speed motor controlled by a digital output or by a variable speed drive controlled by an analog output.

4.12. Duty Logs

DDDC systems can provide extensive duty logs concerning any piece of equipment within the system. Duty logs are very useful for maintenance purposes and help fine-tuning the control algorithms. One of the goals most often pursued is to minimize the times a piece of equipment is cycled on and off; this usually results in longer equipment life.

4.13. Alarm Monitoring and Reporting

Examples have already been given how the DDDC systems' capabilities of alarm monitoring and reporting can be utilized. It must be stressed once more that this enormously aids maintain system's functionality and promptly react in cases of malfunction.

4.14. Pressurization

Pressurization is a comparatively new control strategy. Its essence is to maintain different pressure in zones in order to control the air exchange between them. Two examples will be given to illustrate the usage of pressurization.
The first example concerns restaurants. If the pressure in the kitchen is kept lower than in other zones, odours from it will not penetrate in them and spoil comfort.
Pressurization comes very handy in cases of fire. If the pressure at floors below and above the fire are kept higher than at its area, this will starve the fire for oxygen and help exstinguish the fire.

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Performance Contracting

1. Introduction

Performance contracting erupted on the scene in the late 1970s and has since proved itself as a way for an organization to take advantage of energy cost saving opportunities. Now it is a viable energy financing and service mechanism for any type of organization, for it guarantees results. The performance contracting industry is dynamic. Sorting through a range of options to bring you effective procedures and practices in use today was a most challenging task for many people. It is so, for energy efficiency should be considered as an investment, not an expense.
Investing in energy efficiency can free money that are now being spent for wasted energy. Energy efficiency in effect, generates "revenues" that can be redirected to new spheres of use. There is an old truism that fits the case best: "Energy efficiency takes money to make money". This makes the role of performance contracting extremely important. For performance contracting is not only a deal; it is also an important decision, as well as managing a business risk.

II. Performance Contracting - The Concept

Three are the basic terms that are the central concepts of innovative financing for energy efficiency projects - energy services companies, performance contracting and third party financing.

- ESCOs are the most often private companies that provide comprehensive energy efficiency or load reduction services to customers that own or operate facilities such as factories and buildings.

- Performance Contracting most often refers to the practice of providing energy savings to a customer for a fee, the level of which depends on the amount of energy saved.

- Third Party Financing is the funding of energy savings investments by an outside company, using energy savings to pay for the investment.

III. What is an ESCO

Any definitions of an ESCO will not be precise. ESCO is not only an equipment supplier, a bank, or an engineering contractor - an ESCO is usually all of this together. Basically it is an energy solution provider that provides investment upgrade infrastructure; manages design and installation; guarantees performance in financial terms; ensures continuing performance. To summarize, ESCO is a partner with the customer for many years in a "long-term marriage".

Together with the investor they form the energy efficiency project teams, where the three participants are closely linked.

An ESCO project is performance based when its compensation is tied to the amount of energy actually saved, For this reason ESCOs are totally different from consulting engineers specializing in energy improvements, who are typically paid a fee for their advice rather than being paid for the results their recommendations may yield. The consulting engineers take no risk while the ESCOs compensation is entirely at risk - unless they produce results.

IV. Performance Contracting - The Essence

As a concept, performance contracting appeared in the late 1970s and early 1980s, as an agreement for energy financing services, so that each party in the deal could get a percentage of the savings - The ESCO received a share to cover its costs and make a profit, and the owner, who also received a share, as an independent to participate. Since each party received a share of the energy cost savings, the procedure became known as "shared savings".
This concept worked well until the 1980s, when energy prices began to drop.
In "shared savings" contracts ESCOs used to finance the project either from their own funds or by borrowing from a third party.
With lower prices, it took longer than predicted for the firm to recover its costs, which made some of the firms unable to meet their payments to their suppliers. The " Shared savings" concept was in trouble. Thus the industry focus turned to the so-called "guaranteed performance"; and performance contracting emerged as the favored name. These guaranteed savings were basically achieved through municipal lease, standard lease, or installment purchase, which became the favored vehicle for financing energy efficiency projects. Now, when an ESCO guarantees savings, it does not get paid unless
the ESCO performs as predicted. That is the essence of performance contracting.

Performance contracting is defined by the following key attributes:
- Performance contracting offers turnkey services
- Performance contractors are compensated based on measured results
- Most of the technical, financial and operational risks are borne by the performance contractor.

V. Third party financing

Third party financing is the funding of the energy saving investments by an outside company, using energy savings to pay for the investment. Usually the ESCO will obtain funding for the investment from a third party such as a bank
or leasing company. This financing is typically arranged by the ESCO, but it is the customer that borrows the money - not the ESCO. The ESCO has no

contractual relationship with the bank financing the project. It is the customer who has duty of repayment on the loan.

Third party financing was developed to help companies to finance efficiency investments. The advantage is that the customer does not have to put any cash out to finance the initial investment. It merely has to make payments to the performance contractor.
Generally, a company may finance a project in one of the three fundamental ways: self-financing, debt-financing, or third party financing.