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IDENTIFYING ENERGY SAVING OPPORTUNITIES WITH A PORTABLE ENERGY AUDITING KIT

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Studies and Research Division

and the

UNIDO/CSSR Joint Programme for International Co-operation in the
Fields of Ceramics, Building Materials and Non-metallic
Based Industries

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1. INTRODUCTION

Extensive experience already exists with energy auditing by using mobile systems in industry in industrialized countries and such systems are being introduced in many developing countries. The building materials industry belongs to energy intensive ones, where energy costs form a significant part of total manufacturing costs, accounting for up to 30 per cent of the total. Efficient utilization of energy and reduced specific energy consumption are the goals of energy management, the integral part of which are the energy audits in production plants which help to find ways to reduce energy comsumption, increase production and improve the quality of final products by supplying the important data for plant management.

Energy buses and mobile diagnostic units are tools for conducting energy audits. A portable energy auditing kit represents a special type of auditing system, being set up from necessary small instruments easy transported which may be particularly important in the case of developing countries where industries frequently suffer the lack of instruments to monitor energy flows in technological process.

This paper gives the information on different approaches to energy auditing, focusing on portable energy auditing kit instrumentation and experience gained on identifying energy saving opportunities by means of energy auditing.

2. PRINCIPLES AND STEPS OF ENERGY AUDITING

Despite the common idea of energy savings, different approaches to energy auditing have existed since the beginning of its exercising. While some users promote orientation to enterpreneurial problems of energy conservation, the others base their activites on an engineering approach. The first type of audit usually involves a one day visit in a production plant, with the activities carried out in the following sequence:

- A preliminary discussion with the company's representatives to survey the situation in the energy related matters in the company
- A tour through the plant during which the audit engineers pay attention to all cases of unjudicious use of energy
- Measuring and/or looking up necessary energy related data
- Calculating and discussing the possible energy savings
- Preparing a report and discussing it with management

The company visited gets a complete audit report with all the required data and calculations. This type of audit concentrates on energy saving measures, excluding technlogical problems and proposing simple technical solutions. As to the more complicated technical problems identified, the client is usually recommended to contact a qualified consultancy company.

The engineering approach, applied for example by the MDU - Mobile Diagnostic Unit of the Research Institute for Ceramics, Refractories and Non-metallic Raw Materials in Pilsen, Czechoslovakia, represents a combination of both energy saving measures and technological improvements. This type of an audit lasts usually about one week and uses data obtained from the plant

and, mainly, data produced by the auditing personnel. The audit results in a final report which includes, aside all the data and calculations, detailed recommendations of the measures to be taken to save energy, improve product quality and increase production. The final report is discussed with the plant management and the recommendations are realized by the client, if necessary with technical assistance of auditing personnel in a follow-up stage. The final report of the audit serves also as objective supporting material for decision-makers in planning reconstruction or modernization the equipment or substitution of one type of fuel by another.

Heat consuming units such as kilns, furnaces, driers, heat exchangers, and boilers are usually the main focus of auditing personnel, being the principal energy consumers in building materials industry. Nevertheless, the attention is also paid to electrical appliances, heating systems, fuel storage, etc.

The current situation in energy auditing leads towards a sectoral approach, i.e. towards a detailed analysis of individual energy intensive industrial sectors. Complex audits analyze both energy flows in technological process and conditions of thermal treatment of manufactured materials and products.

The collected data, both from the manufacturer's records and by measurements, supply detailed information on following subjects:

- Course of thermal treatment by products (firing curve, drying curve)
- Temperature distribution in the cross-sections of kilns and driers

- Pressure conditions
- Composition of flue gasses, especially as far as CO_2, O_2, and CO concentrations are concerned to access the efficiency of the combustion process
- Total heat input and heat inputs of individual units
- Heat losses, such as flue loss, loss through the surface of the equipment, by accumulated heat, by cooling air, by exhausted drying medium, technological loss, etc.
- Relative moisture contents of dried products and drying media entering and leaving the unit or line
- Total production of a technological line or an individual unit (kiln, drier, boiler) within a certain period.

After the data are analyzed by computer, the final report is elaborated including the recommendations concerning:

- Energy conservation,
- Quality improvement through better thermal treatment, and
- Increasing the output of the production lines and specific pieces of equipment.

The report includes recommendations on possible modernization or reconstruction of the equipment as well as improvements in operational and ordinary house-keeping activities which can result in energy savings. The co-operation of the client with the auditing personnel is necessary, especially if more complicated measures are to be realized during the implementation period and for evaluation of the results. This follow-up activity is beneficial also for the auditing personnel who can see the effect of their recommendations in practice.

3. PRACTICAL EXPERIENCES AND BENEFITS

Mobile energy auditing has proved to be a successful venture. So far about 11,000 of audits have been carried out by eleven energy buses of the European Community identifying on average potential energy savings of 10 to 20 per cent per audit. The enrgy savings identified by the MDU used in Czechoslovakia fluctuate usually from 10 to 30 per cent. Economic savings over the last six years resulting from quality improvement and production intensification represent about 20 million Czechoislovak crowns.

The idea of a sectoral approach has been accepted recently in the European Community, focusing more closely on a selected number of individual subsectors which is more similar to the idea of MDU.

The current situation in energy auditing can be characterized as a developing system heading towards sectoral approach, i.e. towards a detailed analysis of individual energy-intensive industrial sectors by mobile means. Experienced personnel form an indispensable part of audits, being able to analyze the data obtained and elaborate advice for the client.

The equipment used provides for:

- Temperature measurements
- Pressure and volume flow measurements
- Humidity measurements
- Electrical measurements
- Chemical analyses of gases (e.g. flue gases)
- Recording and processing of measured data.

Portable computers are used in mobile auditing systems for data processing, evaluation, modelling and sensitivity analyses.

As mentioned above, diagnostic measurements represent a very important part of industrial energy management. Benefits of realized recommendations can be classified as direct and indirect.

Direct benefits

(a) Energy conservation realized through:

- Adjustment of burning conditions
  (adjustment for optimal air flow, adjustment of the outlet temperature of burners, etc.)

- Adjustment of pressure conditions
  (reduction of excess pressure in the firing zone brings about reduced penetration of kiln atmposphere into the inspection tunnel)

- Adjustment of firing curve
  (if temperature in some parts of the kiln is higher than necessary, its reduction brings about lower heat loss)

- Adjustment of entrance and exit air locks, etc.

(b) Quality improvement and reject reduction accomplished through:

- Firing curve optimization

- Temperature equalization in the cross-section (by the use of mixing fans, pressure curve adjustment, etc.).

(c) Increased output which can be relaized through:

- Optimization of setting (with optimal heat transfer to and from fired material)

- Temperature equalization in the cross-section of the unit, firing curve optimization (it enables in some cases to shorten firing cycle and thus increase the output).

(d) Substitution of fuel used:

Detailed knowledge of thermal treatment of the material gained by diagnostic measurement enables successful substitution of fuels. Accomplished substitution is followed by a second measurement to allow for optimal adjustment of the unit to the new fuel.

Indirect contributions

Besides direct contributions, indirect benefits can be achieved by diagnostic measurements. Detailed technical information about heat consuming unit serves as the basis for:

- Constructional improvements

- Decisions about the stage of modernization

- Recommendations on waste heat utilization (utilization of heat escaping from cooling zone, by combustion products, etc.)

Case studies

The following practical examples of energy auditing within UNIDO projects in Sri Lanka further illustrate the auditing process.

Several energy audits in the ceramic industry were completed in Sri Lanka in the years 1984 and 1985 utilizing the experience of the UNIDO-Czechoslovakia Joint Programme. The first case study elaborated here is an energy audit on a muffled tunnel kiln firing sanitary ware.

This resulted in the adjustment of firing conditions and pressure curves in burning chambers. Oil consumption was reduced by 30 per cent in the first phase, while production was increased by 14 per cent. Specific energy consumption was reduced by 39 per cent. The conditions were created for further production increase by 20 per cent in the second phase. In addition, a simple heat exchanger was suggested to be installed on the exhaust of combustion products from the kiln, reclaiming part of their heat. Basic technical data before and after the first stage of adjustment are as follows:

	Before adjustment	After adjustment
Type:	Muffled tunnel kiln, firing furnace oil	
Product:	Vitreous China Sanitaryware	
Daily output (kg)	1,800	2,050
Firing temperature (°C)	1,200	1,200
Firing cycle (hours)	36	31.5
Oil consumption (liters/day)	1,852.3	1,275.0
Specific energy consumption (kJ/kg)	39,113	23,738

Resulting energy savings: 577.3 liters of fuel oil per day.

The proposals leading to the adjustment comprised:

- Adjustment of firing conditions by the amount of secondary air for burners
- Adjustment of pressure curves in burning chambers in relevant dampers.

By the two-step adjustment the optimum firing conditions were reached.

Proposals for further improvements were:

- Installation of a heat exchanger on the exhaust of combustion products; the heat obtained would be used for drying;
- Increase of the loading density by a new pattern of loading (two prototype kiln cars with increased capacity by about 50 per cent are already in use with successful results).

An additional four energy audits were completed in the autumn 1985 on a tunnel kiln firing crockery bisquit, glost tunnel kiln firing wall tiles, on a tunnel kiln firing floor tiles and on a tunnel kiln firing low tension electric insulators. The immediate energy savings on two kilns reached the equivalent of $US 8,900 per month. Waste heat utilization for combustion air preheating on the kiln firing insulators, adjustment of cooling air and exhaust of combustion products, together with increased output of the kiln reduced its specific energy consumption by 48 per cent. Adjustment of pressure conditions and air/fuel ratio on the glost tunnel kiln firing wall tiles resulted in energy conservation of more than 15 per cent. The expected energy savings resulting from the measures recommended in the case of the kiln firing crockery bisquit were from 5 to 15 per cent. Fuel oil preheating by the waste heat, reduction of air excess at burners and improvement of loading uniformity were the main measures recommended. Adjustment of firing conditions on the kiln for floor tiles and improved setting on kiln cars reduced rejects by 40 per cent.

The results of these case studies show that energy auditing by means of portable energy auditing kits can be a very effective activity. Pay-back periods are usually shorter than one year.

4. PORTABLE ENERGY AUDITING KIT AND INSTRUMENTATION SUPPLIERS

The portable energy auditing kit is a special form of auditing means. It is designed to measure all necessary variables for energy audits with minimum requirements on the transport of instruments. The complete set is easily transportable by air, weighing 60-70 kg brutto and being packed in 3-4 separate cases. The idea of a portable energy auditing kit resulted mainly from the need for energy audits in developing countries where some (especially small-scale) industries are not equipped with sufficient instrumentation. An ordinary pick-up or even a car can be used for local transport of the kit from plant to plant.

The portable energy auditing kit was designed by the UNIDO-Czechoslovakia Joint Programme for International Co-operation in the Field of Ceramics, Building Materials and Non-metallic Minerals Based Industries in Pilsen, exploiting also the experience of the Research Institute for Ceramics, Refractories and Non-metallic Raw Materials in Pilsen. It is described in Appendix 1.

Auditing preplanning, including the duration of the visit, is decided on the basis of the "Technical Questionnaire" which is to be filled in by the counterpart in advance (given as Appendix 2).

APPENDIX 1

Possible composition of energy kit instrumentation and suppliers[a/]

A. Temperature measurements	Supplier (producer)
- Flexible thermocouples NiCr-Ni (8 pcs)	Oesterr. Philips Industrie GesmbH Triester Str. 64 Postfach 217 A-1101 Vienna Austria
- Recorder Philips Transocomp. with accessories	Same
- Thermocouples PtRh 10-Pt (length 1,600 mm - 4 pcs)[b/]	Same
- Compensating lead wires NiCr-Ni (4 x 150 m)[b/]	W.C. Heraeus GmbH Herausstr. 12-14 D-6450 Hanau Federal Republic of Germany
- Compensating lead wires PtRh 10-Pt (4 x 150 m)[b/]	

a/ The specification of equipment in this annex is only mentioned by way of illustration and does not constitute an endorsement of specific suppliers or equipment.

b/ These items of equipment should be supplied by the counterpart after negotiations on the measurement conditions. They are not very portable.

- Digital pocket thermometer Therm 2220 - 3 and 2 probes	Ahlborn Mess und Regelungstechnik Eichenfeldstr. 1-3 Postfach 1260 D-8150 Holzkirchen Federal Republic of Germany
- Digital pocket thermometer Therm 2222-2 incl. probes	
- Infrared thermometer "Thermopoint"	AGA Infrared Systems S-18211 Danderyd Sweden

B. Pressure and volume flow measurements

- Electronic micromanometer EDM 2,500 M with accessories	AIRFLOW Lufttechnik GmbH Postfach 1208 D-5308 Rheinbach Federal Republic of Germany
- Pitot's tube (D=10 mm, l=1,500 mm)	
- Anemometer Testovent 4000 incl. 2 probes	Same

C. Moisture measurements	Supplier (producer)
- Digital hygrometer TESTO 6400 with 2 probes (for gases and solids)	TESTOTERM GmbH Geblergasse 94 A-1170 Vienna Austria

D. Chemical analyses of gases

- Electronic analyzer for CO_2 with set of filters and ceramic tubes

  VEB Junkalor
  Altener Str. 43
  45 Dessau
  German Democratic Republic

- Fuel efficiency monitor

  Neotronics Ltd.
  Parsonage Road
  Takeley
  Bishop's Stortford
  Herts CM 226 PU
  United Kingdom

E. Computing technique

- Programmable calculator Sharp PC 1401
- Printer Sharp CE-126 P
- Cassette recorder Sharp CE-152

  REMA Commerz
  Handelsges.m.b.H.
  Computer Organization
  Mölkergasse 4
  A-1080 Vienna
  Austria

F. Auxiliary material

- Special literature
- Set of tools
- Protective aids

Total cost of above instruments is about $US 35,000.

APPENDIX 2

Description of the technical questionnaire for industrial energy audits

This specification of initial information assists in planning and preparation of the audit

(1) Country, company (mailing address, phone and telex numbers), responsible manager, kind of production

(2) Type of equipment to be tested, producer of the equipment (if known)

(3) Characteristics of the equipment to be tested

(4) Technical parameters
   (a) Energy supply (voltage, el. network frequency, gas pressure, temperature of delivered medium as e.g. drying air, etc.)
   (b) Thermal process on the equipment

(5) Year of putting the equipment into operation or the last general repair

(6) Description of the present technical conditions of the equipment

(7) Kind of the product, its qualitative or technological properties

(8) Firing (drying) curve of the thermal process
   (a) Projected
   (b) According to the current situation

(9) Average output of the equipment

(a) Projected

(b) Actual

(10) Technical parameters and consumption of fuel (energy)

(11) Method of current energy consumption measuring, available measuring equipment

(12) Contributions expected:

- Energy conservation
- Quality improvement
- Production intensification

(13) Basic drawings - assembly drawings, conception studies, prospectuses of the producer, guaranteed parameters, layouts, etc. (if available)

References and further reading

Z.A. Engelthaler and M. Novy, Energy Management in Ceramic Industry - lecture and publication, Czecholovak Ceramic Works, Prague, 1982

M. and V. Novy, Z. Vorácek, Diagnostic Mobile Unit, UNIDO-Czechoslovakia Joint Programme, Pilsen, 1986, JP/301/86

M. Novy, Diagnostic Mobile Unit, UNIDO-Czechoslovakia Joint Programme, Pilsen, 1982, JP/132/82

M. Novy, Heat Diagnoses Made on Tunnel Kiln and Belt Drier, UNIDO, Vienna, 1984

M. Novy, Experience Gained on New Development in Energy Auditing, UNIDO-Czechoslovakia Joint Programme, Pilsen, 1987, JP/334/87

M. Novy, Technical Report: Kiln Design and Fuel Engineering, Project US/SRL/78, UNIDO, Vienna, 1984

J. Müller and M. Novy, Technical Report: Energy Conservation Aspects in Ceramic Industry of Sri Lanka, Project DP/SRL/82, UNIDO, Vienna, 1985

Team of authors, Energy Audit No. 1 and 3, Commission of the European Communities, Luxembourg, 1983, 1984

B. Jones, The case for portable energy monitoring and recording equipment, IMechE Conference Publications 1985-6, Energy and the Process Industries, Mechanical Engineering Publications Limited, London, 11-13 June 1985