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ENERGY AUDITING - IMPORTANT PREREQUISITE FOR THE SUCCESS OF ENERGY CONSERVATION*

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1. INTRODUCTION

The overall development in any country is closely related to energy. This relation is particularly emphasized in developing countries. According to the United Nations definition developing countries (DC) are those countries which need financial and/or technological assistance for their future development.

There is only one generally accepted parameter for defining a development level: the Gross National Product (GNP) per capita, but any figure chosen to make the distinction is highly arbitrary. Anyway, it is a widely accepted opinion that the development is a direct function of GNP growth.

Energy is an input for producing specific goods and services, whose total sales in a country are expressed by the GNP. There is no doubt that a certain GNP growth requires a certain growth of energy input. This relation is called elasticity. The amount of energy needed for a certain GNP growth or progress depends on the socio-economic pattern of the individual country and population growth as a corrective parameter.

Today, most of the energy consumed is obtained from fossil fuels (coals, oil, natural gas). The world has a finite size. Its resources, including fossil fuels, are finite in quantity and are being depleted at an ever increasing rate. In addition, fossil fuels have an adverse effect on the environment. They cause air pollution, acid rains, acid smog and greenhouse effect, which could play havoc with climate and geography, resulting in lowering the quality of life. It therefore becomes necessary to find a way to replace the fossil fuels.

But this necessity became firstly clear after the 1973 sudden oil price increase, and later on because of increased environmental pollution.

As the first consequence of the 1973 oil shock, energy conservation emerged. At the 11th World Energy Conference, energy conservation was defined as:

......a policy embodying the actions to be taken to ensure the most efficacious use of finite energy resources. Example of such actions are energy savings, rational use of energy, substitution of one form of energy by another, e.g. fossil fuels by solar, wind, geothermal, etc. energy.

As soon as 1978 "Energy Auditing" was introduced into the standard dictionary. The term energy auditing is used to denote a study of a facility which has to determine one or all of the following:

1. to determine how and where energy is being used or converted from one form to another,

2. to identify opportunities to reduce energy usage,
3. to evaluate the economics and technical practicability of implementing these reductions,
4. to formulate prioritized recommendations for implementing process improvements to save energy.

The initial impetus toward conservation after 1973 carried with negative stigma - reduced energy consumption meant deprivation of varying degrees (cooler homes, less leisure travel, etc.) and a major restructuring of the life-styles of consumers in the oil-importing countries. In fact much of the early drop in energy and specially in oil demand was price induced rather than conservation born of new processes and changes in technology. With time and availability of capital or credit, energy consumption was reduced through conservation based on greater efficiency in utilization. Today, energy efficiency became a usual way of thinking.

But this new term which appeared here, has to be defined. It can be defined in the sense of the first and second law of thermodynamics:

a) based on the first law:

$$\eta = \frac{\text{energy delivered as work}}{\text{energy absorbed by the system}},$$

b) based on the second law:

$$\varepsilon = \frac{\text{availability out in product}}{\text{availability in}},$$

availability being defined as the ability of a system to do the useful work and it is the maximum work that system could perform in going from its existing state down to a state of equilibrium with its surroundings.

An industrial plant can be viewed simply as a system to which raw materials, energy and labor are provided and from which material goods, waste materials, and always, waste energy are obtained. The waste energy is generally heat energy that is rejected to the surroundings because of the cyclic nature of many plant processes. It is worthwhile from an energy and cost savings viewpoint to minimize the heat actually rejected to the atmosphere. However, according to the second law of thermodynamics, a certain amount of heat must be returned to the environment for cyclic devices, hence, total reclamation of waste heat may not be possible.

Overall efficiencies of industrial plants are strongly influenced by the thermal efficiencies of their components. Figure 1. shows some estimated limits of the thermal efficiencies for a host of processing devices in terms of process temperature. Process involving higher temperatures have very high thermal losses. Yet with new equipment designed with energy conservation in mind, it will be possible to move toward the maximum efficiency line, thus saving large quantities of energy.

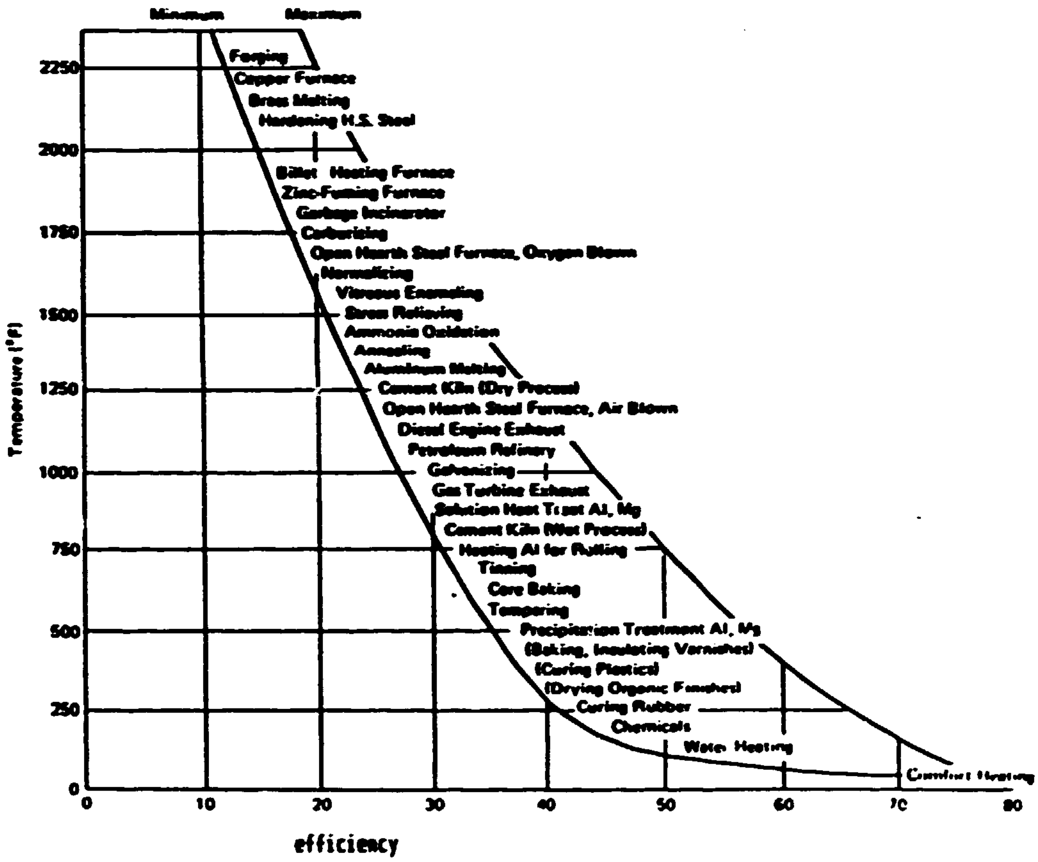


Figure 1. approximated efficiency of industrial processes

1.1. Resume

Energy conservation and energy efficiency emerged in the 70-ies as an answer to the rising energy supply problems. Energy audit appeared at the same time as a set of procedures for the determination of energy flows in industry, partial or overall plant efficiency, and opportunities to reduce energy bills. While detailed procedures for energy auditing may vary somewhat from industry to industry and even from plant to plant within an industry, certain basic elements are common to all comprehensive energy audits, regardless of the nature and size of the operation. These will be defined in the following text.

2. ENERGY CONSERVATION PROJECT PLANNING

Companies can lower their energy costs substantially by the implementation of the energy conservation program, but, there are no shortcuts. First of all, an energy audit has to be done to find out how the complete plant currently stands from an energy point of view, in order to be able to determine the possibilities of energy savings and energy recovery.

It is a known fact, approved by experience, that a modern industry which lacks skilled personnel, adequate monitoring instruments and functioning maintenance programs and which has not invested in preventive maintenance always has great possibilities of reducing its energy costs dramatically. It is unfortunately a particularly common case in developing countries.

Another important factor is to ensure that the measures to be taken are carried out in the correct order. This means that one starts by housekeeping and low-investment measures which will gain fast results. That is convenient for DC because they usual suffere from lack of funds for higher investment in energy conservation programs.

But regardless of the measures which are supposed to be taken, the scope of the project must be determined at the start. An example could be a country which is very depend upon a certain branch of industry and is therefore very interested in lowering energy costs in this field. The government can have an energy conservation project carried out in this branch alone. Another example could be a group of similar companies which decided to carry out a conservation project at one of these, with the intention of applying the experience thus gain at the remaining companies in the group.

When planning the scope of the project it is important to specify the goals and results which should be arrived at and to determine time and cost frameworks. This should be done during the preliminary planning stage. It should also be decided as to which people are to be involved in the project and what their responsibilities should be and also the area where expert aid is to be utilized.

When it comes to the realization of an energy conservation project, certain work procedures must be followed in order to achieve satisfactory results:

1. energy audit,
2. energy balance,
3. measures to reduce energy utilization,
4. energy and cost calculation for all measures,
5. priority list of measures,
6. training and information,
7. follow up of implemented measures.

3. THE ENERGY AUDIT

An energy audit must be carried out at the factory or industry in order to be able to determine the energy flows within the industry. The manner in which this is executed depends on the size of the object to be audited. If the project covers the whole branch of industry and a large number of factories it is perhaps enough to perform a number of general inspections of the plants concerned, whereas in the case of a project of a more limited scope it is easier to execute more exact and comprehensive measurement.

In order that the energy audit be effective, it is very important that the aim of the project be well defined to ensure that the results truly provide the necessary data needed for the basis of an evaluation of saving potential. It is essential that the qualified experts are available for this part of the project. The knowledge required is, first and foremost in the fields of measurement technique, but also knowledge and experience in e.g. process technique can be necessary.

An audit can be executed in several stages. For example, a general audit in a certain country might suggest that an energy conservation project would be best suited for a certain branch of industry or a certain region of the country. Then a more detailed audit might be carried out at a specific company within that branch or in that region in order to attain a more solid basis for continued work on project.

There are generally two types of energy audit:

1. short or overview audit,
2. diagnostic audit.

3.1. Short energy audit

There is no universally accepted definition of what a short audit is or how it is conducted. Certainly it should be considered mainly as an information gathering exercise. Except for very large sites the whole exercise ought not to take more than one or two days plus the time necessary to prepare the report. The important thing to remember is that an audit is not an end in itself but a prelude to other activities.

Regarding the conduct of the audit, the important thing is to ensure that nothing significant is omitted. For that purpose an useful checklist in a form of a questionaria is included as an Appendix. The main part of the energy audit can be conducted on a normal working day but should be followed up soon after with a brief audit during silent hours. This will reveal the extent to which things are not switched off, and without the noise of machinery hidden losses are easier to detect. If a set of site drawings exists then a copy should be taken on an audit so that the location of a major plant, pipelines etc. can be marked on it and the drawings generally updated.

Although the short audit is mainly an information gathering exercise, it usually throw up a number of recommendations. These can be divided into different categories:

1. simple maintenance tasks which should put in hand as quickly as possible, e.g. steam leaks, air leaks, damaged insulation,

2. items which need to be looked regularly to ensure they are working satisfactorily. A check list of this should be drawn up to monitor the frequency with which they need to be checked, by whom and what is to be looked for,

3. areas where employees are causing energy waste either in space heating or in process uses where management need to determine the best approach,

4. the information on each major energy consumer in the plant should be gathered,

5. the existing meters should be noted and it should be ascertained whether they are working and if anyone takes readings from them,

6. recommendation which will require further assessment, where management has to decide what additional information will be needed and how to obtain it. This leads naturally to the next stage, the diagnostic energy audit.

3.2. The diagnostic energy audit

In the diagnostic audit the additional measurements are installed on all or selected major items of the plant and the energy consumption is monitored simultaneously over a fixed period of time to gain a picture of the average pattern of energy use of the whole site.

The result of the energy audit should be an energy balance and a detailed study of this allows an evaluation to made in regard as to which energy conservation measures should be implemented.

Energy balance may be presented in a number of a different ways e.g. in table or diagram form. Usually, the most perspicuous manner in which to present an energy balance is in a Sankey diagram. Such a Sankey diagram for a factory is shown below.

Such a diagram is useful because it gives an immediate visual impression of energy flows in the factory, and enables the identification of priority areas to be tackled in future energy saving campaign. The diagram often contains closed loops which indicate the extent to which heat is being recovered and reused.

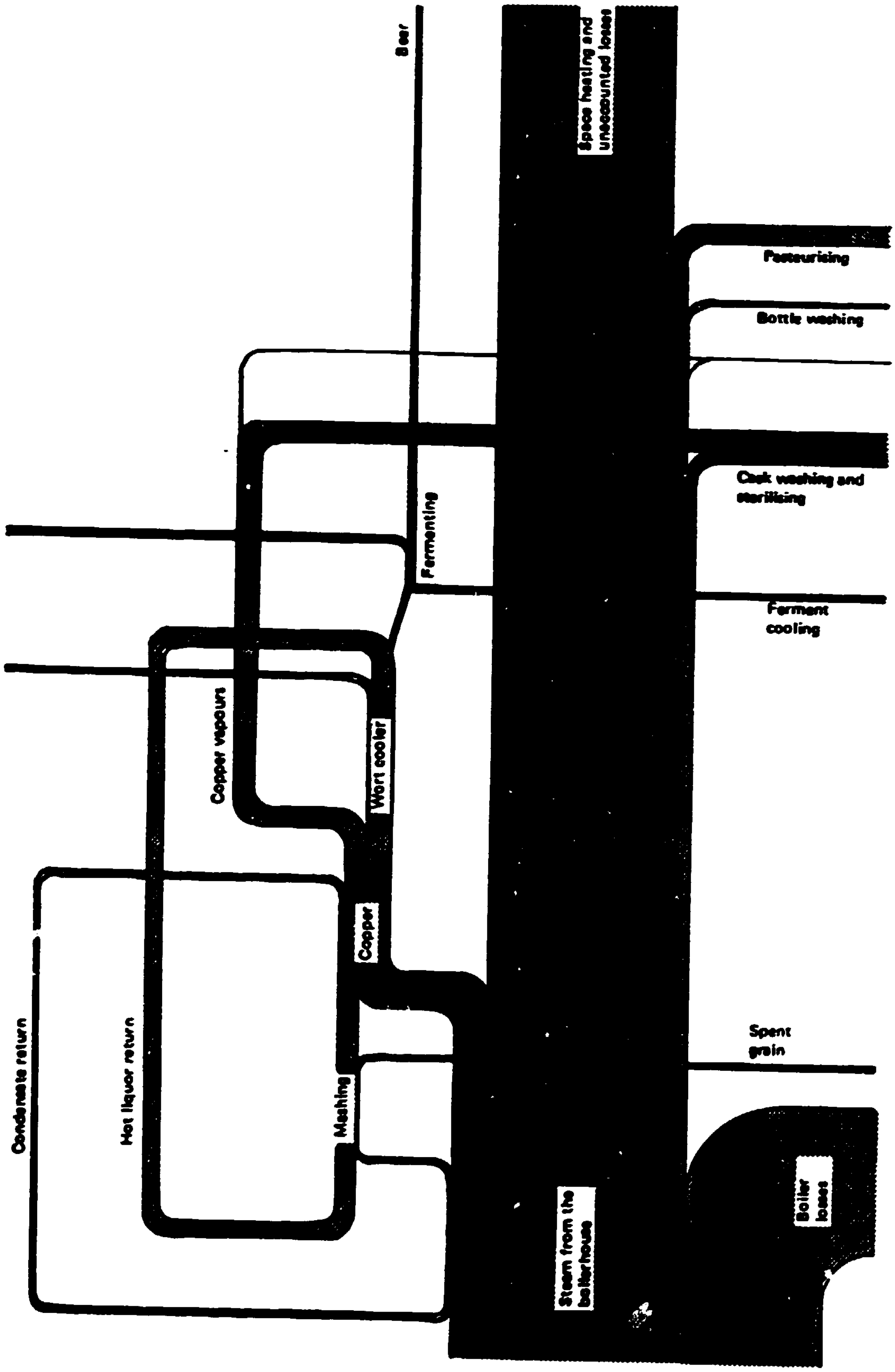


Figure 2. An example of a Sankey diagram

3.3. How to start an energy audit

The more accurate the picture management has of its current energy consumption, the better placed it will be to identify areas of potential saving. This means knowing not only how much is spent on energy in different forms, but also what quantities this buys, what is it used for, how efficiently is used and which uses are essential and which are not.

Obtaining this information is much simpler than is sometimes realized. The figures necessary for a basic appreciation will almost certainly be to hand within the organization, and a prerequisite to establishing the energy plan is to charge someone with the responsibility of collecting and presenting them. Existing information is likely to be of three kinds:

1. bills for fuel, electricity and water,
2. information from electricity, steam or water meters around the site,
3. production information.

Firstly, attempt to complete Table 1 for fuel and energy used in particular establishment for the last financial year. Tables 2, 3, and 4 suggest an initial approach to collecting information on energy use by various sectors which can then be audited separately. The larger the energy consumption,and the greater the total energy cost,the more detailed breakdown required.

3.3.1. Getting started by using information from bills

There are two pieces of information on energy use to be drawn from bills:

1. the quantity used,
2. the amount of money paid for it.

In general it is more convenient to manage energy in terms of physical quantities then in terms of cost because physical units should not be subject to annual escalation. On the other hand it is nearly always easier to convey the importance of energy and arouse management interest in it by talking in terms of cost.

For each fuel electricity and water it is worthwhile preparing a breakdown of the tables 1 - 4, showing the consumption in physical units and cost for each month. Expressed in this way the amount of variation during the year can be seen. If overall costs are rising, this tables will reveal whether this is due to changes in unit cost or changes in level of consumption. By examining the trend through the year some indication can be obtained as to the effect of variation in seasons.

For electricity it is also useful to note down the maximum demand figure. Maximum demand is based on an assessment of the maximum amount of electricity used in any one half hour period (or 15 minutes) in the month and form the basis for part of the charges

Table 1. Quantity of energy used and its cost for the last financial year

Type of energy	Tonnes	Litres	MJ	kWh	Price/unit	Cost	Common basis MJ (kWh)	Cost per MJ (kWh)
Solid fuel								
Liquid fuel								
Gaseous fuel								
Electricity								
Other								
Total								

Table 2: Environmental

Type of energy	Offices	Factory	Warehouses
Energy use			
Lighting (kWh)			
Hot water MJ (kWh)			
Space heating MJ (kWh)			
Number of hours in actual use/month			
Space heating ratio $MJ/m^2/month$			

Table 3: Transport

Type of energy	Internal transport	Delivery, etc.
Petrol (litres)		
Diesel (litres)		
Lube oil (litres)		
LPG (MJ or kWh)		
Electricity (kWh)		
Vehicle mileage		
Freight carried (tonnes)		
Oil/petrol		
Consumption (per tonne km)		
Cost of fuel (per tonne km)		

Table 4: Production

Type of energy	Machine shop consumpt. cost	Process A consumpt. cost	Process B consumpt. cost	Boiler house consumpt. cost
Energy use:				
Electricity (kWh)				
Lighting				
Machines				
Compressed air				
Heating				
Gas MJ or kWh				
Oil				
litres or MJ (kWh)				
Solid fuel inc. waste				
Process heat and power				
Steam				
kg or MJ(kWh)				
Electricity (kWh)				
Units of output				
Total energy used[1]				
(kWh or MJ)				
Total energy cost				
Energy used/unit of output				
Energy cost/unit of output				

[1]Table 4 is only one way of examining the breakdown of energy use it should be adapted to meet the particular circumstances of company. The main point is to measure the energy use and analyse breakdown of that use.

indicated on the bill. It is advisable to determine whether the the maximum demand charge still corresponds to consumption levels.

In the case of water, if consumption increased in one month and that increase persisted, it is indicative of undetected leak which is causing unnecessary expense.

In a factory where energy is used for processes a great deal can be learned by examining the relationship between energy and production. This can make use either of information from bills or of other information collected on site.

One thing which can be examined is the influence of weather, and the most immediate way to do this is to look at summer months separate from the winter months.

Having collected and analyzed energy use and costs data the next stage is to examine ways in which the audit procedure can be improved and opportunities for energy saving identified.

4. METERING AND MEASUREMENT

Once all the existing information is acquired and understood, it remains to collect measuring data about energy flows inside the factory. Meters are used to measure the flow of steam, water, oil, gas and electricity. Thus, this form oh measurement is sometimes referred to as metering.

Metering results can be used to compile an energy profile that can:

1. aid in establishing and refining energy use by product line, department or area,
2. establish and improve energy use accountability,
3. allow measurement of cost reduction,
4. help determine equipment capŜability and load factors for future modifications and plant expansion,
5. provide data for analyzing results that vary from established standards.

In addition, an energy profile likely will reveal areas where conservation projects are more beneficial.

There should be a number of stationary measuring instruments at a plant in order to enable regular monitoring and operation of equipment and processes. But the majority of industries today lack measuring instruments that are in working order and this renders impossible efficient energy use.

As a rule, a plant where the energy situation is under control and which has a regular follow up program and many implemented energy savings measures, possesses a number of carefully chosen measuring instruments that are checked methodically. The fact that a plant lacks measuring instruments or possesses unsuitable or ones that are out of order generally indicate there is an immediate need for energy study to be carried out and energy saving potentials are good. Good instrumentation facilitates an energy study and enhances the results.

Unfortunately, measuring instruments are very expensive and this is way it is appropriate to draw up a plan regarding which instruments are required. These instruments should be rated according to their degree of urgency and importance and consequently purchased over a period of say a year or a number of years.

First and foremost, those existing instruments at a plant should be checked to ensure that they are correctly installed and functioning properly.

The requirements for measuring instruments varies from plant to plant in regard to type and number, but, the most common and most useful ones which should be purchased first are:

- electric energy meters,
- water meters,
- oil gauges,
- steam flow meters,
- heat meters,
- temperature gauges,
- pressure gauges,
- O_2 or CO_2 meters.

When purchasing measuring instruments it is necessary to draw up a basic requirement specification for the instruments. The requirement specification must give e.g. pipe diameters, dimensioning flows, average flows, maximum and minimum temperatures, pressure and requirements regarding measurement accuracy. Tenders for the desired measuring instruments should be requested from suppliers and these should be checked against the requirement specifications to ensure that these shall be met. There must be a description regarding installation as well as instruction on handling, calibration etc. supplied with each measuring instrument. These must be followed carefully to ensure that the measurements are conducted with accuracy stated by the supplier.

4.1. Measuring equipment

Measuring, metering, monitoring and automatic control equipment in varying combinations is required to operate a process efficiently. The prime requirement for all these functions is an instrument that can accurately sense the measured variable and that display the value, or transmit a signal for interpretation by other devices. An instrument , as a primary element, is composed of some type of sensing devices in contact with the fluid or substance, an amplification unit and physical unit which indicates the measurement or translates the sensing impulse into some kind of power or motion.

The originally developed sensing elements were self-contained units which sensed the measured variable and displayed it in unit such as °C, kPa and kg/h. With time it became apparent that benefits would result from the use of transmitters and transducers that permitted remote indicators, more complex control loops and central control rooms.

A transmitter is defined as a device that sense a process variable through the medium of primary element, and has an output whose steady state value is a predetermined function of the process variable. The primary element may be separate or integral part of the transmitter.

A transducer is a device which receives information in the form of one quantity and converts it to information in the same or another quantity. An example would be the conversion of a 4-20 mA signal from a transmitter to a pneumatic signal.

A pneumatic transmitter is a device that senses a process variable and translates the measured value into an air pressure which is transmitted various receiver devices for indication, recording, control or alarm purposes.

Most measuring and controlling devices work together via a compatible signal transmission system. Just as English or French are a form of communication, so too are the 4-20 mA or 21-103.5 kPa (gauge) signal transmission systems. For computers there are many forms of communication such as serial, parallel, RS 232, IEEE 488 etc. The majority of instruments communication is based on pneumatic or electronic analog signal transmission for short to medium distances.

In this paper only a simplified description of some instrumentation will be provided and a detailed one can be found in a number of handbooks and manuals.

However, to advanced measuring instruments should be avoided. A complicated measuring instruments is often more difficult to calibrate and handle than a more straightforward, simple one. So, the most simple, most durable and most commonly used in industry have been selected. These description do not in any way claim to be complete, but can be of help in starting initial measuring activities in industries.

4.2. Electric energy meters

There is usually at least one electric energy meter at every plant - a meter which indicates total energy utilization. This is installed by the power supplier who uses it as basis for debiting.

A similar type of meter , a kWh meter, is the simplest to use to measure individual electric power users which are of special interest. These could be large cooling or air compressors or other large motors having long operation times.

The kWh integrate electrical output and time so that by reading the meter at two different points in time one can find out how much electrical energy has been used during that time period.

The kWh meter consist mainly of a mounted aluminum plate and two spools. A counting mechanism registers the total number of revolutions of the plate, integrates the output and shows the total amount of electrical energy which passed through the meter.

The price of a kWh meter of up to 100 A is approx. US $ 130. Above this the addition of a current transformer is required. The deviation of the meters is +/- 1.5%. AEG, Landis&Gyr, Siemens and Iskra-YU are some of the manufactures in this field.

kWh meters are mostly installed just for the most important individual electricity users. As for the rest a good understanding of the energy consumption of an electrical installation may be obtained by the occasional manual measurement of power output using ordinary A-, V-, and W-meters or clip-on meters (see fig. 3).The ordinary meters can be connected directly or via a current or voltage transformer (see fig. 4), single or three-phased. When using a clip-on meter, measurement is made around one phase only.

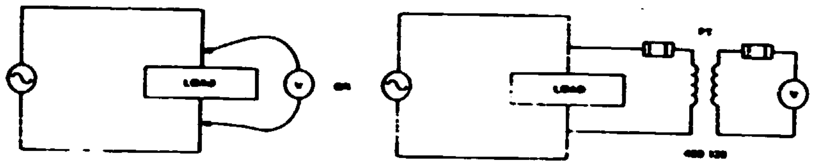
If the voltage and current are measured only, the $\cos\varphi$ has to be known (usually .75 - 1) and the output power can be determined as follows

$$P = V \cdot I \cdot \cos\varphi \qquad \text{or} \qquad P = \sqrt{3} \cdot V \cdot I \cdot \cos\varphi ,$$

for a three-phase system, with V and I being voltage and current respectively.

The output power may be measured even directly using a clip-on wattmeter, which costs approx. US $ 550. The total energy utilization of a process or a machine can later be calculated by multiplying the power requirement of the machine by its operating time.

Figure 3. Clip-on A-meters



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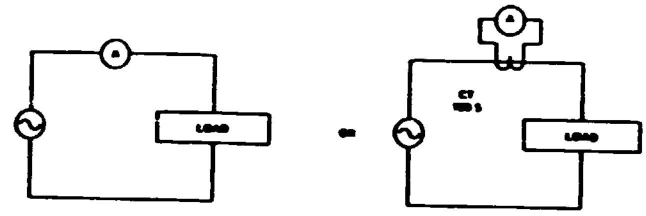

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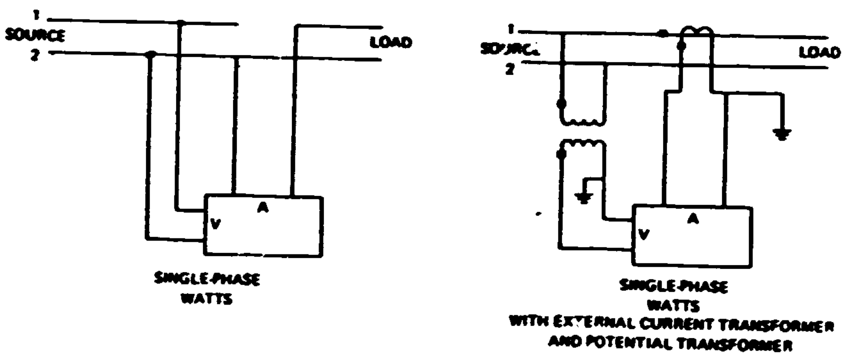

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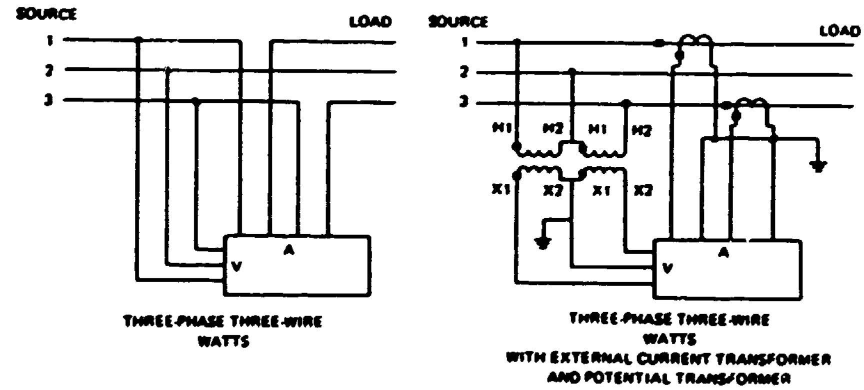


(d)

Figure 4. Connecting V-, A- and W-meters

4.3. Flow measurement

4.3.1. Liquid flow measurement - volumetric meters

This type of meters measure the liquid volume directly with good accuracy (0.5 - 1%) over very wide flow ranges of at least 10:1. These meters are often used for applications where the measured flow is to be used for billing purposes.

There are many different volumetric meters e.g. turbine wheel, lamellar wheel, oval wheel or impeller meters. Such a meter has one or more measurement chambers of known volume which is alternatively filled or emptied. The number of times the chamber is filled is registered by a counting mechanism and this number is then multiplied by chamber volume. In this way the volume of liquid flowing through the meter in a certain time is provided.

However, these meters always have a certain range of capacity which must be respected if the stated accuracy is to be fulfilled. When, for example, a water meter is ordered the maximum water flow must be given and the probable average which is to be measured. Also, the water temperature and pipe dimensions where the meter is going to be installed must be stated. Water meters should be installed both for the total cold and hot water consumption and for individual users of interest. The hot wa' :r meters can withstand a temperature of 120 °C.

In order to check how much energy is used in preparation of hot water or by an individual hot water user a table such as the one shown below can be filled in.

Table 5 Data for hot water consumption checking

DATE	TIME READING /m³/	CONSUMPTION /m³/	HOT WATER TEMPERAT. /°C/	ENERGY CONSUM. /kWh/	AVERAGE OUTPUT /kW/

The energy utilization is calculated as follows

$$Q = \frac{V \cdot \rho \cdot c_p \cdot (T_{hw} - T_{cw})}{3600}$$

where Q is energy utilization (kWh), V hot water consumption (m^3), T_{hw} and T_{cw} temperature of hot and cold water respectively (°C), ρ water density at average temperature (kg/m^3) and c_p water heat capacity at average temperature (kJ/kg°C).

If the meters give the volume in other units than m^3 than the table in Appendix 2 can be used to convert the quantity into m^3.

The meter must be installed so that there is a straight line of pipe in front of it so as to avoid measurement errors. It is advisable to install a filter in front of the meter and the straight distance between the filter and the meter should be at least 5 x diameter of the pipe.

Note that a water meter for hot water can also be used as a condensate meter. In this case it should be placed after the filter which is normally in the pipe leading from the condensate tank.

The price of the impeller cold water meters are from 50 - 650 US $ for the diameter range from 25 - 150 (mm), and for the hot water meters from 180 - 8500 US $ for the same diameter range.

Spanner-Pollux and Bopp&Reuther are two of the manufacturers in this field.

4.3.2. Heat meters

It is very practical to install heat meters for hot water or heating water boiler where there is both a feed line and the return pipe. A heat meter consists basically of a water meter, temperature gauges in the feed and return pipe, and a counting mechanism - an integrating unit which shows directly how much heat energy in kWh or GJ units has been generated by the boiler.

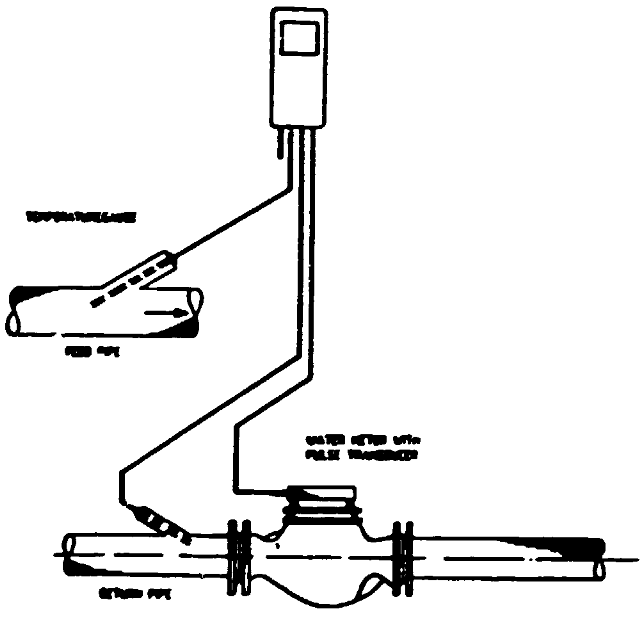


Figure 5. Basic build up of a heat meter

Of course heat meter can be installed in the case of an individual user e.g. heat exchanger, where there is a feed line and return pipe.

Heat meters are only installed for heating and hot water boilers and important individual users. Occasional heat measurements are effected by measuring the temperature difference and the water flow separately.

The price of a complete heat meter i.e. water meter, temperature gauge, plunge pipe, contact and integration functions is from US $ 400 - 1100 for the pipe diameters from 25 - 150 (mm).

An example of a manufacturer in this field is Pollux, W. Germany and ATM Yugoslavia.

4.3.3. Orifice flow measurement

An orifice is a pr mary element which is a round flat metal plate with a hole. This plate is clamped between the pipe or duct flanges at right angles to the fluid flow to cause a restriction to the flow (fig. 6). An increase in fluid velocity through the orifice hole is accompanied by a decrease in static pressure, and the higher the velocity the lower the pressure. This results in a pressure difference across the orifice which will vary with the flow rate. This pressure difference can be converted to a flow indication by a flow measuring instrument.

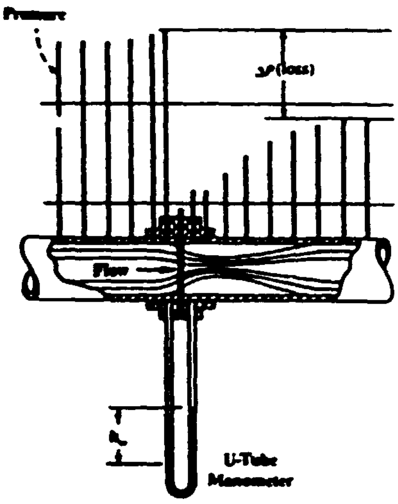


Figure 6. Orifice flow measurement

If one wants to measure the steam flow, then the steam pressure and temperature at the meters must be determined in order to be able to calculate the energy quantity that the steam is equivalent to. However, in the case of saturated steam knowledge of one of these parameters is sufficient. The temperature of the feed water must also be known. As a steam water tank should maintain a certain overpressure, the feedwater should have a temperature of 105 - 110 ^oC. A temperature of under 100 ^oC in the feed water tank indicates that the water is not degased, which in turn leads to corrosion problems in the boiler, steam and condensate system.

There are steam tables available which can be of help when calculating the amount of energy required to generate steam at a certain pressure from feed water at a certain temperature. These tables show the energy content of the steam and condensate and the heat of evaporation at different pressures and temperatures.

All flow gauges must be installed at a point in the pipe where the flow is undisturbed. The manufacturers supply guide lines as to installation, normally stating the requisite length of straight pipe that be before and after the gauge. These requisite lengths are usually expressed as a multiple of the pipe diameter. An example of this could be as follows. A steam pipe of 100 mm diameter should have a straight length of pipe 7 x the diameter after the gauge and 10 x the diameter before the gauge. In this case there must be a straight length of pipe of at least 0.7 m after and 1.0 m before the steam flow meter.

A requirement specification when purchasing a steam flow meter should include the steam pressure, steam temperature, pipe dimensions, maximum steam flow and average steam flow. If a flow gauge is to be purchased separately a desired differential pressure must be stated which is compatible with the differential pressure gauge to be used. It is important to state whether the flow gauge is to be equipped with recording or integrating equipment.

Approximative prices for orifice plates are from US $ 340 - 440 for diameters from 25 - 200 mm. Prices include impulse tube, gate valve and condensate vessel but exclude counter flanges, bolt joints and gaskets which are supplied by local supplier.

4.3.4. Pitot tubes flow measurement

It is not always practical, not even possible, to measure fluid flow by an orifice. It is particularly the case with flue gas flow measurement. For such a purpose Pitot tube is very convenient solution. It measures an average gas velocity based on the principle that a medium flowing towards an open tube causes an increase in pressure inside that tube. The total pressure of an air stream in duct is the sum of the static pressure exerted on the sidewalls of the duct and the velocity pressure of the moving air (fig. 7). The illustrated Pitot tube is common device for measuring the velocity pressure. To ensure measuring accuracy many measurements must be taken in accordance with traverse details shown (fig. 8). The velocity pressure should be calculated for each traverse position and the readings averaged. The velocity pressure in a duct can be calculated.

$$V' = 0.764 \cdot \left(\frac{T \cdot P_v}{B} \right)^{0.5} \quad (m/s)$$

where V'is average velocity, T temperature (K), P_v velocity pressure (Pa), B barometric pressure (kPa-absolute), 0.764 equation constant and conversion of units.

The volume flow rate can then be calculated.

$$Q = V' \cdot A_d \cdot 1000 \quad ,$$

where Q is volume flow rate (L/s), A_d area of duct (m^2), 1000 conversion of units.

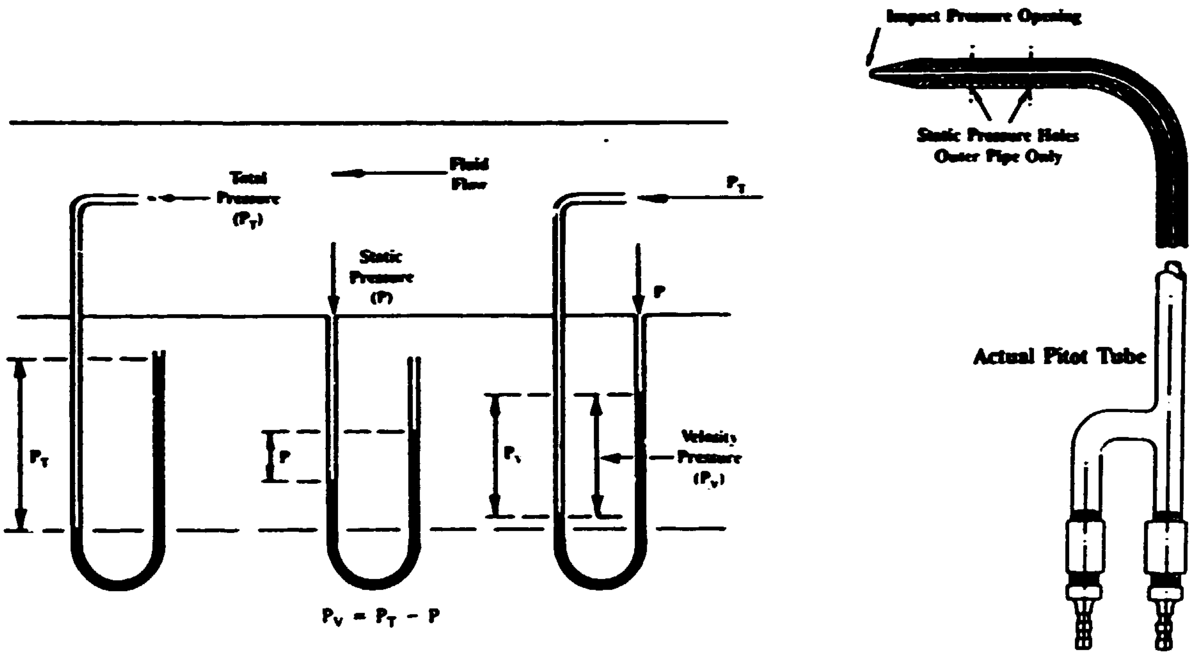


Figure 8. Pitot tube flow measurement

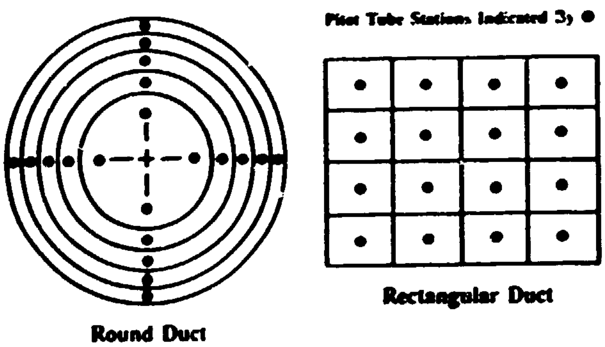


Figure 9. Pitot tube stations in ducts for accurate measurement

When using a Pitot tube it is important to take into account the following:

-the measuring probe must be directed exactly in the direction of the current. Deviations result in extensive measurement errors.

-the most suitable application of the Pitot tube is for measurement of relatively strong gas flows on account of the fact that the dynamic pressure otherwise may be to small to measure. To achieve better accuracy of measurement an inclined U-tube manometer can be used.

-the measurement method may be sensitive when used in hot or humid gases. Condensation can take place in the manometer connection hoses and this could result in measurement errors.

-certain types of Pitot tubes can be sensitive to dust and other pollution in the medium to be measured. There are, however, special types of Pitot tubes which can be utilized in such cases.

Measuring with Pitot tube is a very cheap method of determining the flow because the equipment is relatively simple and can even be self-made.

A ready manufactured Pitot tube could command a price of approx. US $ 520 which would include calibration and auxiliary equipment (manometer, hoses, etc.). The great disadvantage of the Pitot tube is that the dynamic pressure may be difficult to measure for small gas flows (<10 - 15 m/s). In these cases measurements using an anemometer are a more accurate alternative.

4.3.5. Measurement of temperature

There are many different methods by which temperature may be measured, both with direct reading instruments and with measuring instruments which are later connected to some form of registrating or indicating instruments.

The most common , by far , are liquid thermometers and thermocouples. Sometimes it can be appropriate to use a pyrometer for very high temperatures.

Temperature measurement in the case of gas flow is mostly carried out by boring a hole in the gas duct and inserting the thermometer or its measurement probe. In the case of temperature measurement of gases or liquids under pressure, measuring the outer surface temperature of the pipe through which the media flows must often be accepted. The surface temperature gauge must be well insulated to avoid measurement errors due to the temperature of the surroundings.

4.3.5.1. Liquid thermometers

Liquid thermometers are a straightforward and cheap way to measure temperatures. One disadvantage of this method is the inability to measure extremely high or low temperatures. Another disadvantage is that the value attained can change if the thermometer is not kept in the media while is being read. Reading should therefore , as far as it is possible, be carried out in situ. Continuous registrating is impossible with this direct reading method. Therefore, the method is unsuitable for detection of variation in temperatures during a longer time period, but, is suitable when only occasional measurement in easily accessible flows are required.

The accuracy of the measurement varies with the size of the range of measurement of thermometer. Greater accuracy than +/- 0.1% is difficult to achieve with normal mercury thermometers used for manual measurements.

4.3.5.2. Thermocouples

A thermocouple consists of two metal wires joint together at one point (fig. 9). Here an electric voltage arises which is dependent on the material in the wires and the temperature at the fusing point. This voltage is measured with the mV-meter and the results is read in mV or ^{o}C directly. In some cases the voltage is not linear dependent on the temperature and then a calibration curve must be drawn up and the temperature read off as a function of voltage . It is also important to maintain a part of the thermocouple which does not measure the temperature at a definite temperature in order to achieve accurate measurement results. Earlier it was done with the aid of an ice bath, but nowadays it is effected electronically by compensation in the reading unit.

It is important as in the case of all other measuring instruments, to choose an appropriate range of measurement. This depends on the combination of metals according to the table given below.

Table 6 Measuring ranges of thermocouples

Thermocouple	Range of temperature ^{o}C
copper/constantan	-200 - +400
iron/constantan	-200 - +700
nickelchrome/constantan	-200 - +700
nickel/nickelchrome	-200 - +1100
chromel/alumel	-200 - +1200
platinum/platinum-rhodium	0 - +1600
iridium/rhodium-iridium	+1500 - +2000

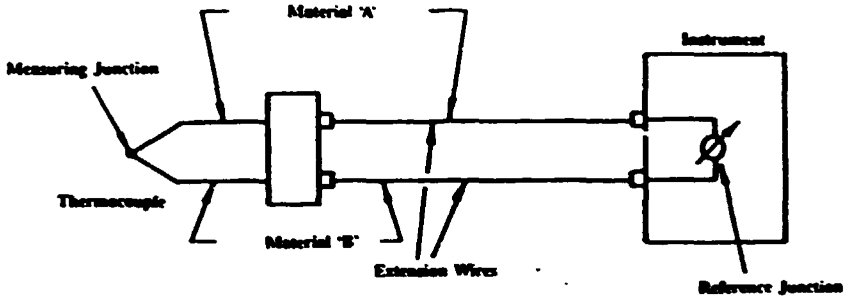


Figure 9. Thermocouple temperature measurement

Thermocouples are easy to use and the signals are easy to convert and store. Calibration is also straightforward by means of an ice bath or boiling water.

At the time of purchase measuring probes both for insertion measurements and for outer surface measurements should be bought. It should be ensured that data on the accuracy of measurement and probe reaction time etc. are supplied with the instruments.

There are many different manufacturers of such instruments as described above e.g. Technoterm, Testoterm, etc. Prices, depending on measurement accuracy and ranges, and selection of probes are between US $ 200 and 550.

4.3.6. Humidity measurement

Relative humidity is the actual amount of moisture in an air at any given temperature, divided by greatest amount of moisture of the same air could hold without condesation. The moisture content of a gas must be known in order to determine energy content of the gas. The cheapest way of achieving this is to determine wet and dry temperature of the gas and then to read the absolute and relative humidity of the gas from a Mollier diagram for moist air. This is still the most suitable for measurement in ducts where two thermometers ca be inserted without great difficulty. Wet cotton should be wound around one of the thermometers and this is used to determine the wet temperature of the air. It is important to check that the cotton is damp and to await a stable temperature reading in order to obtain relevant results. The dry temperature is measured in a similar way but the thermometer here is not wound in cotton.

Evaporation takes place from the wet thermometer and cools it if the relative humidity of the air is less than 100% and this results in the two thermometers showing different temperatures.

This temperature difference is a measurement of the relative humidity of the gas.

The air moisture data with the addition of dew point temperature (temperature at which moisture will condensate out of the air for a given specific humidity and pressure, as air moisture temperature is reduced) shown together graphically form a psychrometric chart. It sets the ground for well-planed air conditioning systems.

Lines of constant dry bulb temperature are almost vertical. Constant dew-point temperature lines are horizontal. Constant wet-bulb temperatures slope downward to right. Constant % humidity lines are curved. Before using chart one must know any two values.

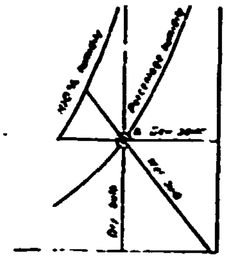


Figure 10.

The easier way is to measure the moisture content with a direct reading electronic instrument. Such an instrument consists of a measuring probe and a digital or analog pointer instrument. In most cases the temperature can be measured using one of a number of such instruments and all the information required to determine the energy content of the gas obtained. These instruments are easy to handle and calibrate. They provide a greater accuracy of measurement than the wet and dry thermometer method. Also, no conversion is required or readings from diagrams since the humidity can be directly read in %. There are many different manufacturers of this type of electronic measuring devices described above e.g. Technoterm, Testoterm etc., and prices are generally in the US $ 300 - 500 range.

4.3.7. Flue gas analysis

Measuring products of combustion from a fossil fuel combustion system is important for determining efficiency. The three products commonly measured are oxygen (O_2), carbon dioxide (CO_2),, and carbon monoxide (CO).

The excess air for a combustion process can be established with an O_2 or CO_2 measurement (fig. 11). Review of the curves shows that fuel type is important in translating a CO_2 reading into excess air, whereas with O_2 the fuel effect is minor. CO is combustible product which indicates unburned fuel. Figure 12 indicates how quickly the heat loss increases as the excess air is reduced to the point of having significant CO in the flue gases.

The measurement of O_2 content is preferred to that of CO_2, when it is a question of stationary , continuous measurement. A modern O_2 meter works with a zirconium oxide cell which together with a probe is placed in the flue gas flow. It is insensitive to dust and temperature. Accurate CO_2 measurement instruments work on the

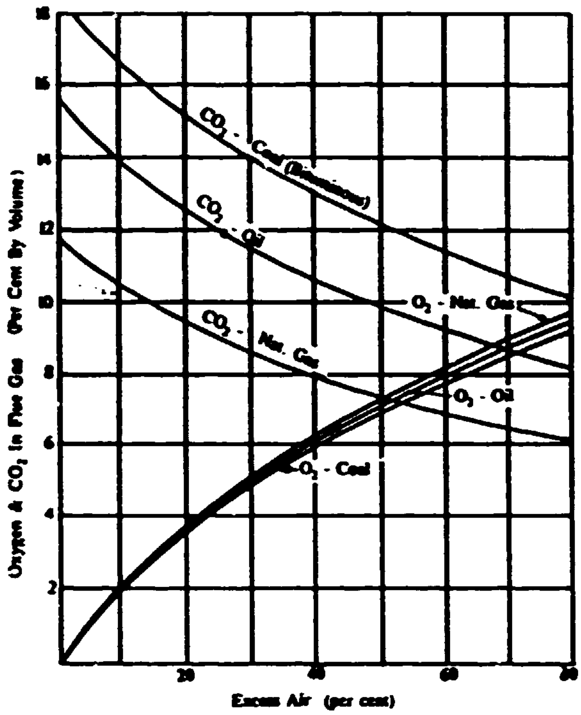


Figure 11. Per cent O_2 and CO_2 versus excess air

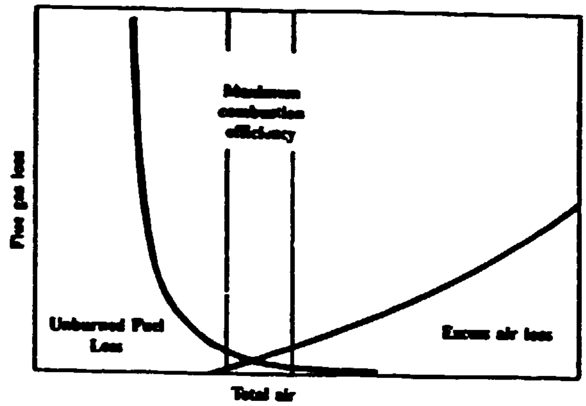


Figure 12. Zone of maximum combustion efficiency

infrared absorption principle. The measurement chamber is very sensitive to damp and contamination. The measurement system involves the extraction of gases and their decondesation and filtration. The extrication system is sensitive to blockage and leakage.

The prices for O_2 analyzers are up to 6000 US $, depending on the manufacturer (Westinghouse , Amtek, Instrumatic, etc.).

The Fyrite CO_2 analyzers are suitable for a portable measurement of combustion efficiency. In theory, approx. 16% of CO_2 can be attained in the flue gases, but, normally it is between 11 - 12%. A certain amount of flue gas is conducted into a graduated vessel where it is washed with KOH and the CO_2 is absorbed (fig. 13). The volume of th- flue gas is hereby reduced and this reduction can later directly be read off as CO_2 percentage of the gas.

It is important to ensure that:

-the CO_2 content is measured directly after the boiler to avoid measurement errors due to the inflow of air into the flue,

-instruments are set to zero prior each measurement and that the lye in the instrument is regularly checked and possibly changed,

-the correct amount of flue gas is induced into the instrument in order that relevant measurement should be obtained.

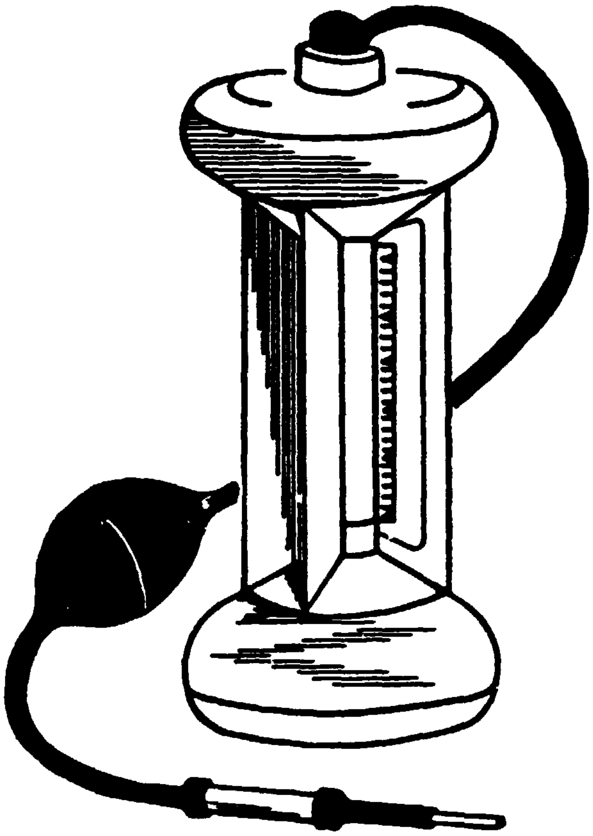


Figure 13. Fyrite CO_2 analyzer

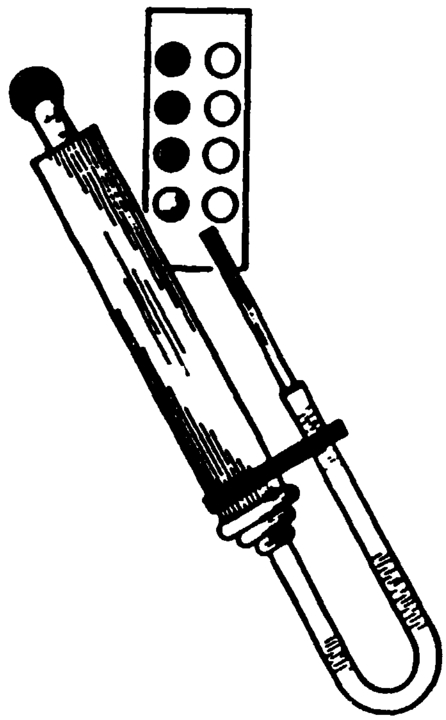


Figure 14. Soot content gauge

The soot content and CO content can, when a lower degree of accuracy is demanded, be measured with the aid of a pump of known volume. The latter is used to pump a known volume of gas through a Draeger tube when the CO content is to be determined and through a white filter paper when the soot content is to be determined. The soot content is obtained by comparing the shade of gray of filter paper with a standardized scale (1 - 10) which is supplied with the instrument, while the CO content can be directly read on the graduated Draeger tube. The soot content count should be about 1 for light oil and maximum 3 for heavy oil.

The use of electronic measuring instrument, which simultaneously measures combustion temperature, flue gas temperature and oxygen content of the flue gases, is an excellent method of measuring the efficiency of a boiler. The instrument is programmed to show directly the boiler efficiency if the fuel type is known. The instrument may also be used to measure the CO content. Such an instrument including auxiliary equipment costs from 1000 US $ up, depending on the characteristics. Make: Testoterm.

Murphy's law:

1. If it can fail, it will.
2. If it can be hooked up wrong, someone will do it that way.
3. If it can be operated incorrectly, someone will run it that way.

4.4. Stationary measurement

In each factory a kind of metering system exists whose ultimate goal is to assist plant personnel in managing the energy required to produce a specific product or service. Monitoring and reporting energy consumption allows for close control while minimizing expenses. Another goal is to provide historical energy consumption data to aid in projecting future loads and developing standards for the next year. Such data are essential to financial forecasts and operating budgets.

Unless energy consumption is measured it is next to impossible to know where to direct conservation efforts. A metering system provides the vital ingredient to a successful energy management program.

Taking meter readings on a more frequent basis, perhaps as often as each shift, can reveal useful information such as:

- meter misreadings,
- meter error,
- load changes due to production changes,
- most and least efficient shifts,
- need for maintenance.

Bearing in mind the above mentioned Murphy's Law regular maintenance is very important because metering equipment must provide correct data to be useful. There is no better way to develop trust in the data than by regular calibrating the instruments. Simple checks can be done by general maintenance personnel or instruments can be sent out to repair shops on a periodic basis. Calibration records are useful for assessing the performance of the instruments. They can identify the need for more or less frequent calibration checks, or possibly the need for instrument replacement.

4.5. Preparation of measurement plan for energy auditing

For conducting a diagnostic energy audit, the installation of additional measurements, beside the stationary ones, is required. In order that a measurement be meaningful, the measurement results must represent that which was intended to be measured.

There is a direct relationship between the extent of data collection and consolidation, and the subsequent evaluation of energy conservation opportunities. While an insufficient data base may prevent the identification of several energy saving opportunities, a too extensive one may prove unnecessary and wasteful by diverting funds and time from more rewarding conservation opportunities.

To assure that neither too much nor too less measurement be taken, a measurement plan has to be prepared taking into account the following factors:

-purpose of measurement,
-forseenable retrofitting actions,
-constraints for implementation.

These factors should be find out during the short energy audit and visual inspection of a factory. A well prepared measurement plan will assure that the data gathered will serve as a good ground for determination of energy saving opportunities.

But, only the correct results are useful results, so the requirements which must be fulfilled in order to attain correct measurement results include:

-use of true instruments,
-use of appropriate methods,
-selection of a time when a representative results may be obtain,
-correct processing of the results.

These applied both to stationary and additional measuring instruments.

The measuring instruments must have an accuracy which is in accordance with the demands made on the measurements. The range of measurement of an instrument should appropriately wide. If the instruments hardly reacts then naturally the results will not be very accurate.

The instrument deviation which should be given in the instrument manual, is often stated in % of max reading. If the deviation is given to be +/- 2% of max reading, the relative deviation for a 10% deflection reading is only +/- 20%. The aim should be to attain large readings when using the instruments the deviations of which are given in this way e.g. most flow meters.

There is no reason to use instruments having unnecessarily great accuracy when it comes to manual measuring instruments. Precision instruments are expensive and often easily damaged when handled carelessly. The accuracy of the results is normally determined more by manner in which the measuring equipment is used, the manner in which the measurement is executed and the measurement results are processed, then by accuracy of measuring instrument. Measurement should always be as direct as possible. Avoid determining a value, the required measurement result,as the difference between or sum of other results.

It is important to choose a representative time for execution of the measurement, especially for manual measurements. Generally, the measurement result which is of interest is that which represent the normal operation at the plant. Therefore checks should be made to see that production is normal and that all units usually in operation are actually in operation prior to starting the measurements. Also, the plant should be running undisturbed for long enough to be in equilibrium before measurement activities begin. The state of equilibrium can take a number of days to attain in some large processing industries while at smaller plants a few hours may be sufficient time.

Anyway, when executing the measurements the mentioned Murphy's law should always be kept in mind.

4.6. Data acquisition and data processing systems

The basic purpose of measurement is to provide process variable information such as temperature, flow, pressure, etc. The term process denotes a plant facility or operation where there is a change of matter or conversion of energy. A process variable is a quantity or condition that influences a process. In addition a measured variable can be defined as a quantity, property or condition that is measured, and a sensing element is a device which is responsive to the value of the measured variable.

Up to now we have described some measuring instruments which are designed to respond to certain measured variables and to produce an output that indicates their values.

To assess the effectiveness of energy use in operation of equipment or processes, all measured data have to be acquired and processed. Data acquisition is a process by which data from several location is collected together before it is processed, and data processing is a process of data interpretation and analysis on a routine basis to produce the information required.

These operations almost always (but not necessarily) involve computers. If the computers are involved we denote them as data acquisition and data processing systems.

Data acquisition systems are designed to interface a computer to the correct circuits or equipment in order to collect data from external sources.

An example of data acquisition system configuration is given in figure 15. This system is developed and used by a team at Faculty of Electrical Engineering Zagreb. It consists of a number of various peripherals around the host computer, which may be any personal computer, but to recommend is IBM PC or compatible.

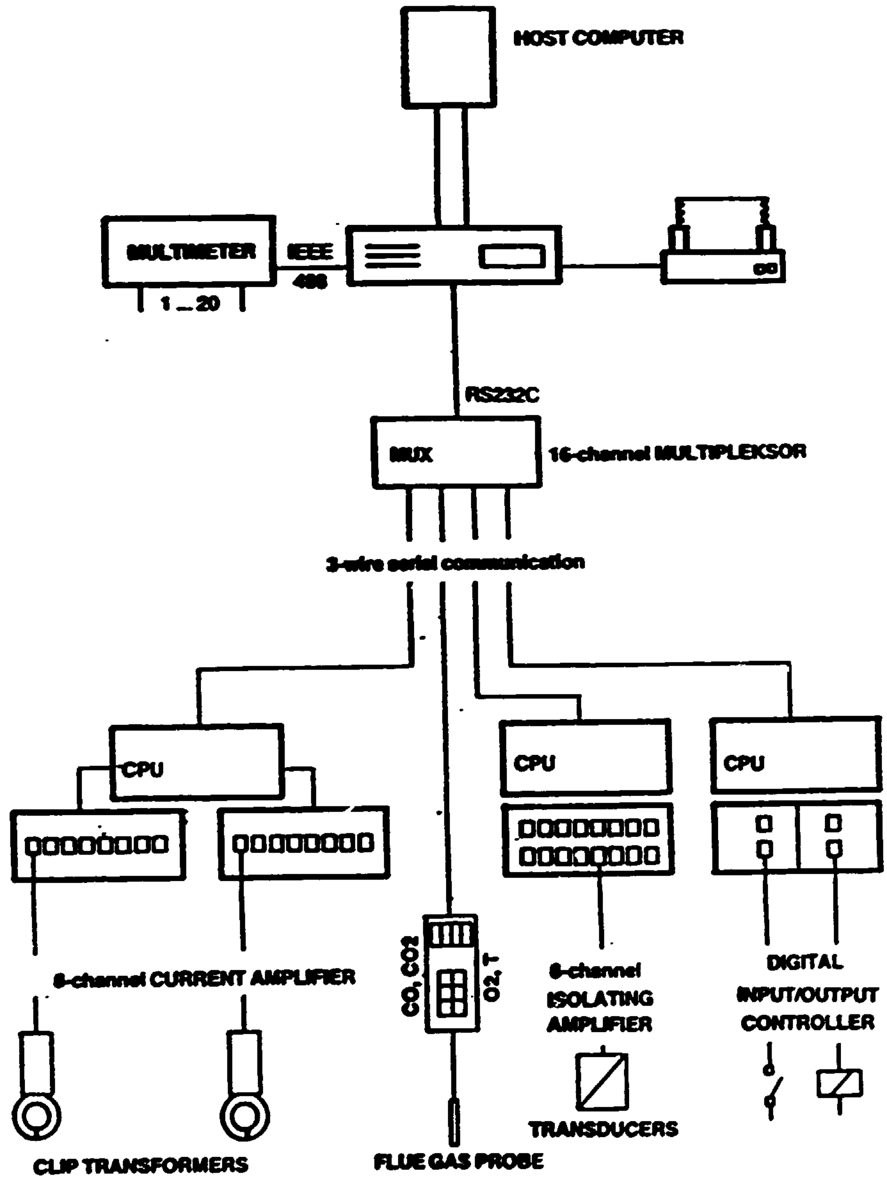


Figure 15. An example of data acquisition system configuration

The data acquisition system is of modular and distributed processing design.

Modularity means that it consists of various modules which can be combined according to the needs for energy auditing. One module represents an 8 channel system for electricity consumption measurement with clip-on A-meters. If it is necessary to measure more than 8 channels, two or more modules can be applied. The other module is for standard 0- or 4 - 20 mA signals which are the usual outputs from the transducers. The next modules is suitable for signals from thermocouples, etc.

A microprocessor unit can be attached to any module and it takes care of data conversion from all the inputs and data transmission to the main computer. Because of the modular and distributed design it is possible to do very complex measurement in large plants with a lot of measuring points.

Such systems are usually accompanied with a software package for initialization of the data acquisition system. The initialization means telling the computer how many modules there are, what are the measuring quantities and corresponding constant factors, what are the time intervals between successive measurements, how many quantities will be measured and stored, etc.

Once the data are gathered and stored into the computer, it has to be processed. That means it has to be interpreted and analyzed in order to be compared with standards or optimal values to assess the real effectiveness of energy use and energy saving potentials.

5. EXECUTION OF ENERGY AUDITING

A diagnostic energy audit is physical measurement of energy use in a factory. A detailed analysis of the information collected from individual items of plant is then undertaken to assess the efficiency of energy use.

The disadvantage of this approach is that it calls for a large initial input of capital to by meters, without any guarantee that useful information will emerge from the exercise and that it will eventually lead to the savings. The high cost and uncertain return serve as a discentive to many companies to undertake an energy audit. Also, in order to account for all the energy used, all the meters need to be installed and this can disrupt production. Such an exercise also calls for a great amount of effort before it produces a tangible result.

But, on the other hand energy auditing is a necessary prerequisite for the success of an energy conservation program. Then, what is the solution? As the first step, a short energy audit has to be done to identify possible energy savings and to enable the preparation of a proper measurement plan.

Secondly, one approach which has quite a long history and good success, emerged in Canada under the name "Energy Bus". After that, it was adopted in EEC countries, and latter on further elaborated in the frame of UNIDO/UNDP project "Industrial Energy Conservation", to be more adjusted to the needs of the developing countries.

The main idea was to form an interdisciplinary team of experts equipped with necessary measuring instruments, capable of performing energy auditing on the field in industry. The role of the energy bus itself could be just to carry around the instrumentation and the crew, but also to promote efficient energy use and to serve as a mobile training center. This additional role of energy bus is very important since it makes people aware of possible ways for energy savings, and prepare them to work with , and to operate improved and new equipment and processes.

The services of the energy bus and its crew to the companies could be supported by some government funds, but generally, a part of expenses should be charged to the companies.

However, these charges will be considerably lower then the investments necessary if a company decides to start an energy audit by itself from the scratch, and the results attained will be more reliable.

6. REPORTING THE ENERGY AUDITING RESULTS

All the results of an energy audit have to be summarized into a report. The report should reveal a clearer picture in terms of a breakdown of energy use into major areas such as building heating, air conditioning, fuel used in boilers, fuel in furnaces, major process uses such as drying, evaporation, refrigeration, metal melting, heat treatment, etc. As a prelude to comprehensive monitoring and target setting the report should eventually reveal the extent to which energy use is weather-related, production related or not related to key factors at all.

An energy balance brings together all the measurement results in the form of the important energy flows. These are presented regarding size and quality. An energy balance can be presented in tabular form, as a histogram, pie chart or Sankey diagram. The Sankey diagram is the only diagram which apart from showing incoming and outgoing energy flows, also shows how energy is split up within the plant. Naturally, an energy balance cannot present all the information resulting from an energy audit, and must have different tables as appendices to it.

A quantity which is also good to follow is the specific energy utilization, that is the energy utilization per unit produced. All energy forms used are converted to one and the same unit e.g. kWh. The quantities of different types of energy used are measured during a certain time period, e.g. a week, all are converted to kWh, added together and divided by the quantity of production during the same period, and this latter quantity is expressed in units produced, m^3 or tons. Units produced can be expressed in many different ways, differing from industry to industry. One suitable forma for a urea plant is as utilized energy/ton urea produced and a suitable form for a rubber tire factory is utilized energy/number of standard tires produced.

It is also possible to calculate the specific energy number for each individual type of energy.

Apart from the energy balance and the specific energy numbers there should be detailed daybooks where measurement reading from stationary measuring instruments as well as results from manual measurements are entered regularly. It is , for example, of importance to have a good boiler daybook, but, also daybooks for the cooling plant and important processes are of value.

All this goes to show that measuring instruments can be utilized in different ways, but, that all of them are a prerequisite for efficient and economic energy conservation.

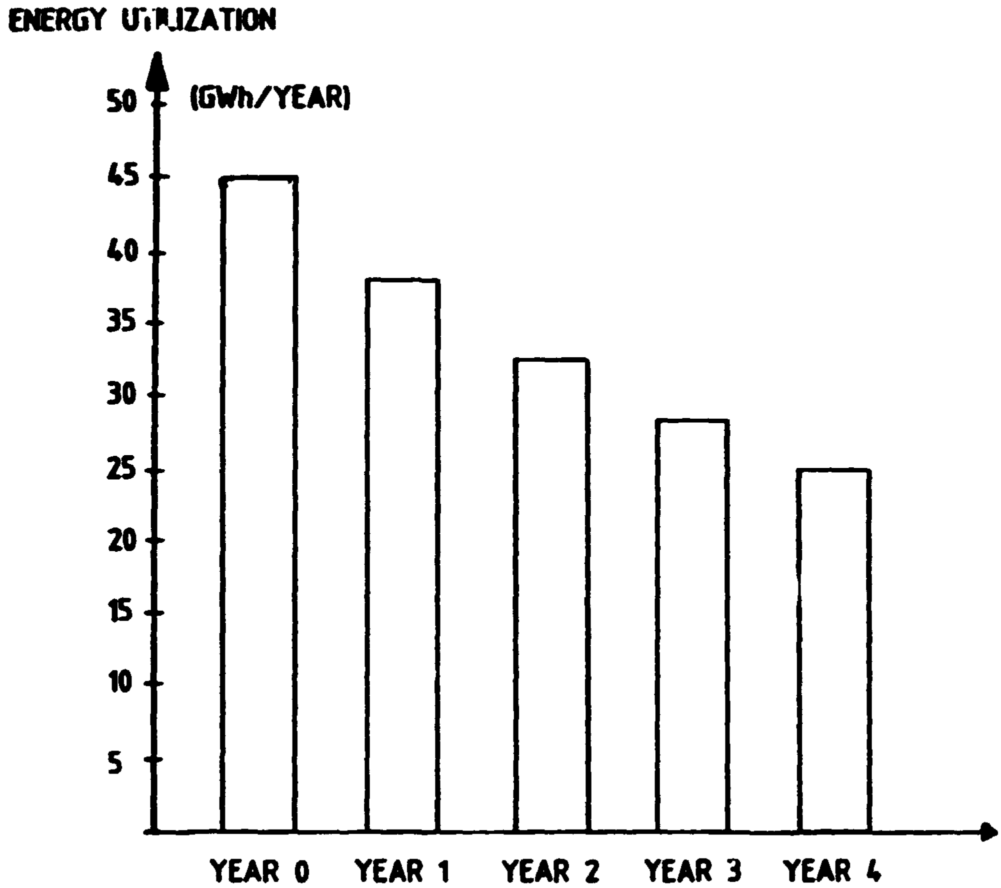
Finally, based upon the results of energy auditing, the measure recommendations for energy savings are to be prepared. These measures can be presented in the form of annual measure package, for example as in figure 16.

Using the energy balance and other data, it is possible to make energy and cost calculations for all the measures from the packages, and to draw the priority list of measures in order of profitability. It is important that all type of measures which reduce energy costs are evaluated, very simple measures aimed at cutting down on wastefulness, recovery measures, process changes and changeover to cheaper energy sources.

The first measures to be implemented should be aimed at putting right the unsatisfactory state of affairs due to poor maintenance. It is often the case that the largest part of the possible savings is achieved by implementing various simple measures, e.g. checking and calibrating instrumentation, adjusting automatic control devices, improving insulation, replacing the steam traps, etc.

After that, exploitation of waste heat in condensate or low pressure steam and/or installation of measurement and control systems in certain stages of production can be consider, but, it requires careful investment calculations. Measures aimed at recovery of waste heat can sometimes account for the largest energy savings at factories having large quantities of unexpolited waste heat.

The third type of measure which can reduce energy costs is a changeover to a cheaper form of energy. Generally, this involves replacing one type of fuel with a cheaper type. If the price of electricity is high, then one should, as far as possible, try to replace electricity with other forms of energy.



	PRESENTATION OF MEASURES	ANNUAL INSTALLATION COSTS (US $)	ANNUAL ENERGY COST SAVINGS (US $)	PAYBACK PERIOD (YEARS)
YEAR 1	----------	240.000	400.000	0,6
YEAR 2	----------	420.000	350.000	1,2
YEAR 3	----------	968.000	440.000	2,2
YEAR 4	----------	600.000	200.000	3,0

Figure 16. Presentation of the annual measure package

Anyway, considerable economic gains have resulted when energy conservation projects have been carried out in this way. The good results have been confirmed by the many industries which have implemented the measures proposed. These actual instances show that energy utilization at a factory can be reduced by 25 - 40% at the cost of very reasonable investment and that, as a rule, energy utilization can be reduced by at least 10% with simple measures having payback periods of well under one year.

7. THE FOLLOW-UP PROGRAM

The most important factors affecting industrial energy utilization are:

- -maintenance,
- -possibilities of controlling and measuring energy utilization,
- -qualified staff trained in energy technique,
- -factory design.

If a lack exists in any of these areas it is highly probable that the energy waste will occur, and the measures for energy savings will gain no results.

A necessary condition to retain an achieved energy saving is a careful and regular follow-up program to ensure control of the company's energy position. According to the company's work schedule, the organization of its energy activities and training of personnel in such matters are all part of an energy conservation project. It has been shown to be imperative that there is one person within the company who has responsibilities for energy matters in order to achieve a satisfactory result and well implemented measures.

It is also essential that the company management realizes the importance of the role played by the person responsible for energy matters in determination of company results. This person might well have, as an aid, an energy saving committee who help by stimulating interest in energy questions in the various departments. The post of such a person in charge of energy matters is usually referred to as an energy manager.

He should have a practical technical background in order to be able to carry out his duties in the best possible manner. Several qualities come most readily to mind which the energy manager will need to develop. Firstly, he must be a good communicator having the ability to listen as well as talk. He should possess or develop the ability to use simple language and analogies as illustration to ensure effective communication with all levels of people from director to machine operator. He must be a good administrator able to correlate factual data and information on energy matters, usage and equipment. Without such information there is no framework within which to manage, take decision and justify expenditure. He must also be able to prepare clear, interesting and concise reports.

Finally, he must have a good understanding of people. The attitudes of individuals towards energy and its methods of use are vastly different. Many are reluctant to change without good cause their established practice or habits. In addition, they are unlikely to welcome being informed that they are using energy inefficiently. The approach must therefore be suitable diplomatic, and the energy manager must be thick-skinned in order to withstand the occasional and inevitable reaction. The key objectives for the energy manager are summarized in the table below.

Table 8. The role of the energy manager

1. develop and maintain an energy accounting and audit system

2. coordinated the efforts of all energy users in the organization helping them from a source of sound information to set realistic targets

3. provide sound technical and specialist advice to all departments within the organization on energy saving equipment and techniques to promote the efficient use of energy

4. liaise with other group and organization in the field of energy conservation

5. appraise and advice upon government funding and other schemes applicable to the company

6. examine and advice upon any political, legislative and regulatory measures relating to energy and assess the possible impact on the company's products and activities

7. remain up-to-date on the changing circumstance in energy field and advice management of the possible effects on the company

8. CONCLUSION

This paper presents the role of, and a way to perform, an energy audit in the realization of energy conservation programs. Some factors which might be characteristic for developing countries have been taken into account. These are:

- usually unsuitable maintenance,
- lack of skilled manpower,
- instrumentation which usually does not work properly,
- the energy sector in the factories is not adequately organized,
- lack of funds for investments in energy savings,
- old, energy eating, technologies.

All these factors assure the great energy saving potential, and also point the direction for the initial steps in starting an energy conservation project. These should be the realization of the house-keeping and low investment energy saving measures. It is important for two reasons:

1. These measures will gain fast results and money saving as a consequence. This money, or a part of it, can be then reinvested in the more costly measures or in a follow-up program.
2. The results achieved will gain the confidence of the people in the energy saving program, and they will be more cooperative, particularly if a kind of motivation scheme is developed.

The next important thing is training. Sometimes, it pays more to train people to operate and maintain equipment and processes properly, than to buy new equipment.

In the frame of the already mentioned UNIDO/UNDP project "Industrial Energy Conservation", a training network exists with three training centers established which cover all aspects of energy matters: energy policy and energy management on country level, energy aspects of process design and energy auditing and energy management on factory level. The experience gained sofar in this project could be of great interest to other developing countries, too, and could certainly form a good basis for cooperation.

APPENDIX I

Short Energy Audit - Control Questionnaire

Name of company ____

Location ____

Official(s) interviewed ____

A Control of energy

1 Who is responsible for energy management?
Position in organisation
Who does he/she report to
Full time or part time
Qualifications, relevant experience
Staff

2 How is energy consumption reviewed?
From head office or on location
Continuously or periodically
According to a plan or irregularly

3 If periodically, when was last review?

4 How is energy consumption analysed:
by department;
by product;
by source;
by month or number of working days (shifts) per month
by costs;
between lighting, hot water, space heating, power, refrigeration etc.;
between office, factory, warehouse, transport etc.

5 Does analysis identify the relationship between consumption of energy and level of activity?

6 What units of measurement are used?
(It may be useful to convert consumption of different sorts of energy into one unit - also into money.)

7 (a) What are the metering contro'. arrangements?
(N.B. This question includes:
how frequently are readings taken;
to what extent is there sub metering;
what records are kept?)
(b) Is sub metering adequate?
(c) Should an energy management system be installed?
(d) Would central data logging be cost effective?

8 Is there an energy consumption forecast/budget?

9 Have standards been set - i.e, standard energy consumption for each process or building?

10 Is consumption compared with:
previous periods;
other locations;
other companies;
other industries?
(Does the comparison take account of weather conditions and days worked?)

11 Has the management set targets:
for absolute levels of consumption;
for levels of consumption based on activity;
for levels of idle time;
for percentage cuts in consumption?

12 (a) Does management consider information on energy consumption an essential part of the management information system?
(b) If not, why not?

13 What steps have been taken by way of propaganda or education of employees, to promote energy conservation?

14 What steps are being/have been taken in re-cycling energy --
reclamation of energy as heat from air, water, hot products etc;
using waste as a fuel?

15 To what extent is planned maintenance in operation?

16 How often are different classes of plant inspected or tested e.g. for corrosion, cracking, fouling, leaks, malfunctioning steam traps, inaccurate or inoperative control devices?

17 (a) Is there a list of energy saving investments under review, ranked in order of priority, with detailed costing and pay-back calculation?
(b) If not, why not?

18 Has a Sankey diagram been prepared?

B Sources of energy

1 What are the sources of energy used?
Coal of other solid fuels
Gas
Electricity
Liquid fuels
Other

2 (a) What tariffs are used?
(b) Why?
(c) When were they last reviewed?
(d) Can off-peak tariffs be used?
(e) Can you cut maximum demand?
(f) Can you improve power factors where it is economical to do so?

C Use of energy

1 Buildings
(a) Is insulation adequate
roof walls;
floors;
doors;
windows;
(b) For what period are buildings heated and lighted:
hours per day;
days per year;
(c) Is heating controlled manually;
by thermostat, time clock etc?
(d) What is the temperature?
(e) Could the temperature be reduced?
(f) Does temperature vary from one part of the building to another?
(g) Is ventilation excessive (often the major cause of heat loss)?
(h) Are parts of the building heated unnecessarily?
(i) Are energy eficient lighting fittings and controls used?

2 Oil storage
(a) How are storage tanks heated?
(b) Are they kept at most economic temperature?
(c) Are they adequately insulated?

3 What are areas of high energy consumption?

4 What further steps are being considered to optimise savings?

5 Processes

(a) Are pipes and tanks adequately lagged?
(b) Is condensate recovered?
(c) Is boiler and furnace efficiency tested?
(d) Are process temperatures at lowest essential level?
(e) Is the optimum blowdown on boilers maintained?
(f) Is refrigeration plant operating efficiently?
(g) Are there leaks of steam, hot water or compressed air?

D Records of consumption

1 Produce detailed analysis of energy consumed over the most recent year. Show the account, and cost per unit, of each fuel. (This will be used for the purpose of the current audit and for providing a base line for comparsion with later years.)

2 Review existing records of consumption and determine if adequate information is available to management.

3 Produce Sankey diagram.

4 Compare consumption with:

(a) other locations;
(b) previous periods;
(c) budget.

5 Compare standard consumption to actual for each process or operation, and identify losses and improvements.

6 Test meter readings against records.

7 Test records against invoices.

E Maintenance

1 Review records of maintenance engineer.

2 Determine whether he works on a planned maintenance basis and consider whether he should do so.

3 Check that all control mechanisms are effective and frequently tested.

4 Consider whether further instruments would be useful in measuring or controlling particular parameters (e.g. electricity consumption, temperature, pressure, humidity, flow rate).

5 Determine whether maintenance is adequate (e.g. annual cleaning of boilers is unlikely to be sufficient to avoid fouling and corrosion of tubes, check for carbon monoxide production from gas burners).

6 Consider how maintenance could be improved:
(a) more skilled manpower;
(b) design change (e.g. fitting of by-pass facilities, pipe line strainers, sight glasses, etc.)

7 (a) Review fuel storage and handling.
(b) Consider whether temperatures are adequate or excessive.

F Environment

1 Review space heating
(a) determine whether occupied volume per person is the minimum feasible, and whether any unoccupied space is unnecessarily heated
(b) check that heating installation has fast response to control
(c) check that control devices are protected from unauthorised interference
(d) check that temperature, air movement and ventialtion are not excessive
(e) check whether temperature gradients exist in tall buildings
(f) ensure windows are not used for temperature control in heated buildings
(g) check insulation throughout plant, including tanks and pipe runs, roofs, walls, doors, windows etc. floors.
(h) check that systems are properly integrated (i.e. heating and cooling plants do not conflict)
(i) review heating installation, and consider improvements in control.
(N.B.: The purpose of this audit step, in conjuction with 'A' above, is to determine when and how much heat is lost, with a view to recommending remedial action, if appropriate.)

2 Review lighting
(a) consider if the most efficient form of lighting is used for each purpose
(b) check lighting levels do not exceed the

recommendations

(c) is proper use made of natural daylight?

G Electricity

1 Review tariffs or contracts for supply of energy

(a) ensure the most appropriate tariffs are used, discus with suppliers if appropriate.

2 Check all reascnable steps are taken to minimise peak demands for electricity, e.g.:

(a) re-shedule tasks to off-peak periods

(b) use an emergency type diesel or gas turbine driven generator as booster/alternative to electricity, preferably including vaste heat recovery

(c) monitor consumption precisely

(d) use maximum demand meter

3 Consider the feasibility of using night rate electricity.

4 Consider sub metering and use of portable vatt meter so that consumption can be broken down into controllable units, i.e. cost centres, thereby making some individual personally responsible.

H Personnel

1 Consider if specialist vorkers are adequately trained and motivated, e.g.:

energy manager

maintenance engineer

furnace operator

instrument engineer

2 Review energy conservation propaganda or education, e.g.:

posters

house magazines

circulars

requests for suggestions from employees

talks and short courses

I Capital investments

1 Review energy related capital projects under consideration

(a) check calculation of return/pay back

(b) review arguments for and against making the investment,

(c) check that tax implications and any grants are correctly taken into account.

2 Review refurbishment of major energy using equipment such as furnaces, boilers and process equipment:

(N.B.: About 86 per cent of all energy used by industry is converted in boilers or furnaces.)

(a) consider whether they should be replaced

(b) consider whether they should be modified:

by pre-heating air,

by adding metering facilities,

by recovering waste heat, by improved insulation,

by replacing burners turndown capability which is useful is there is a fluctuating load/demand

by adding economisers,

by returning condensate to boilers,

by improved controls,

(c) consider size vis-a-vis demand,

(d) determine whether use of cooling water is restricted to an economic level,

(e) consider conversion to coal for processes and boilers to reduce energy costs.