Department of Minerals and Energy Pretoria

# Capacity Building in Energy Efficiency and Renewable Energy

Report No. – 2.3.4 - 31

**Energy Efficiency: Industrial Norms and Standards**

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September/2005

Department of Minerals and Energy Pretoria

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## Energy Efficiency: Industrial Norms and Standards

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# Abbreviations and Acronyms

| | |
|---|---|
| **AC** | Alternating Current |
| **ASTM** | American Standard for Testing Materials |
| **BEE** | Black Economic Empowerment |
| **CaBEERE** | Capacity Building in Energy Efficiency and Renewable Energy |
| **CB** | Capacity Building |
| **CEF** | Central Energy Fund |
| **COP** | Coefficient of Performance (dimensionless) |
| **DANIDA** | Danish International Development Assistance |
| **DDG** | Deputy Director-General |
| **DEAT** | Department of Environmental Affairs and Tourism |
| **DK** | Kingdom of Denmark |
| **DKK** | Danish Kroner |
| **DME** | Department of Minerals and Energy |
| **DTI** | Department of Trade and Industry |
| **ECG** | Electronic Control Gear |
| **EE** | Energy Efficiency |
| **EEAIA** | Electrical Energy Allied Industries Association |
| **EDI** | Electricity Distribution Industry |
| **EI** | Energy Intensity |
| **ESETA** | Energy Sector Education Training Authority |
| **ESI** | Electricity Supply Industry |
| **EUI** | Energy Use Intensity |
| **FFFA** | Fossil Fuel Foundation Association |
| **FIDIC** | International Federation of Consulting Engineers |
| **HVAC** | Heating, Ventilation and Air Conditioning |
| **IDC** | Industrial Development Corporation of South Africa |

| | |
|---|---|
| **IPM** | International Project Manager |
| **kWc** | Kilowatts cooling (cooling power) |
| **kWi** | Kilowatts input (input power) |
| **LCC** | Life Cycle Cost |
| **LPD** | Lighting Power Density in $W/m^2$ |
| **NT** | National Treasury |
| **NER** | National Electricity Regulator |
| **NGO** | Non-Governmental Organisation |
| **Pa** | Static pressure in Pascals |
| **PDI** | Previously Disadvantaged Individual |
| **PM** | Project Manager |
| **PQ** | Pre-qualification |
| **PSC** | Project Steering Committee |
| **PTT** | Project Task Team |
| **QA** | Quality Assurance |
| **RE** | Renewable Energy |
| **RED** | Regional Electricity Distributor |
| **RSA** | Republic of South Africa |
| **RSI** | Overall thermal resistance in metric units $m^2\,°C/W$ |
| **SA** | South Africa/South African |
| **SALGA** | South African Local Government Association |
| **SANGOCO** | South African Non-Governmental Organisations’ Committee |
| **SAPOA** | South African Property Owners’ Association |
| **SARS** | South African Revenue Services |
| **SMME** | Small, Medium and Micro Enterprises |
| **SP** | Service Provider |
| **ST** | Short Term Adviser |
| **TA** | Technical Assistance |
| **TC** | Technical Committee |
| **TIASA** | Thermal Insulation Association of South Africa |
| **TOR** | Terms of Reference |
| **VAT** | Value Added Tax |
| **VAV** | Variable Air Volume |
| **wg** | Static pressure in inches water column |
| **ZAR** | South African Rand |

# Details of Service Provider, Client and Funder

EnerWise Africa has undertaken this assignment in association with Africon Engineering International and Marbek Resource Consultants. EnerWise Africa, a South Africa based firm, has a broad based experience in energy efficiency related issues and has worked extensively in this field in South Africa. Africon Engineering International, which is one of South Africa's largest and most experienced engineering and professional service firms, has a long history of involvement in infrastructure life cycle, from policy and planning through to design, construction and operation and maintenance, including in the energy sector. Marbek Resources Consultants is one of Canada's leading energy and environment consulting firms. Since 1983, the firm has provided consulting services to government, utility and private sector decision-makers in support of sustainable development, both in Canada and internationally.

The EnerWise team was subcontracted to the Consultant, COWI, a leading international consulting group, which operates in the engineering, environmental science and economics fields and is managing the CaBEERE programme on behalf of the Client.

The client and funder, the Danish International Development Agency (DANIDA), has been involved in South Africa in an environmental support programme since 1995, and has during this period assisted a number of activities and projects with both government and civil society structures.

The recipient of this project is the South African Department of Minerals and Energy. The Industrial Norms and Standards assignment was project managed by a Project Task Team (PTT), which was drawn from DME, CaBEERE, FFFA, TIASA and EEAIA.

# Foreword

In the foreword to the March 2005 Energy Efficiency Strategy of the Republic of South Africa, former Minister of Minerals and Energy Phumzile Mlambo-Ngcuka states:

> *"In South Africa we take energy for granted, with the consequence that our energy consumption is higher than it should be. Whilst our historically low electricity price has contributed towards a competitive position, it has also meant that there has been little incentive to save electricity.*
>
> *So in many respects we start with a clean slate with little energy efficiency measures having taken place, apart from many years of work by universities and other research institutions that have pointed the way. The White Paper on Energy Policy (1998) recognized that standards and appliance labelling should be the first measures to put in place in implementing energy efficiency. Indeed such prescriptive-type measures provide the framework on which any energy efficiency strategy is based. At the same time consumers of energy also need to perceive the cost-benefits they can derive from energy efficiency measures and it is here that demonstrations are essential. The Industrial and Mining Sectors are the heaviest users of energy, accounting for more than two-thirds of our national electricity usage. Here lies the potential for the largest savings by replacing old technologies with new, and by employing best energy management principles."*

The targets outlined in the Energy Efficiency Strategy include:

- Nationally - final energy demand reduction of 12% by 2015
- Industry and Mining sector – final energy demand reduction of 15% by 2015.

DME has established that Industrial and Mining Sectors account for 47% of total end-user energy demand in South Africa.

For decades, South Africans have paid among the world's lowest prices for electricity. However, the country's Electricity Supply Industry (ESI) is undergoing fundamental restructuring in order to address inequities and complexities in the pricing of electricity delivered to consumers, compounded by an impending exhaustion of excess generation capacity. This creates a timely set of opportunities for implementing energy efficiency measures.

# Executive Summary

The Department of Minerals and Energy (DME) in South Africa is responsible for the formulation of strategies and drafting of policies for the country's energy sector. The project – Capacity Building in the DME in Energy Efficiency and Renewable Energy (CaBEERE) – resulted from a dialogue between the DME and Danida between 1999 and 2001. This project aims to enhance the capacity and performance of the DME through assistance in the development of programmatic approaches through strategies and actions plans for Energy Efficiency (EE) and Renewable Energy (RE) in transparent co-operation with relevant stakeholders. The overall objective of the CaBEERE project is increased use of EE and RE throughout South Africa to maximise the contribution of the energy sector towards sustainable development.

In this assignment, the immediate objective was to ensure that appropriate standards for energy efficiency are identified, adopted and adhered to by industry, thereby yielding improvements in operational energy. To put things in context, the Energy Efficiency Strategy of the Republic of South Africa makes provision for the use of Norms and Standards for Horizontal Technologies within the Industrial Sector Programme. The Horizontal Technologies being addressed for norms and standards are:

- Non-utility steam-raising boilers, fired by fossil fuels
- AC electric motors
- Thermal insulation of hot pipework, namely steam pipework

Whereas energy efficiency measures in South Africa have been hampered by the relatively low cost of electricity, the imminent exhaustion of the excess generating capacity in the country necessitates that resources are garnered to provide much needed additional power in the near future. This implies that electricity tariff increases henceforth may be more than the relatively marginal annual hikes that have characterised the energy sector.

This report presents a summary of the scan of selected international and domestic standards, codes of practice and programmes including options and recommendations of the three horizontal technologies - non-utility steam-raising boilers, fired by fossil fuels, AC electric motors and thermal insulation of hot pipework, namely steam pipework.

The review of the international standards was expanded to address jurisdictional activities, particularly labelling programmes. For AC motors, technical inputs have been provided for a labelling programme. With respect to non-utility steam raising boilers, fired by fossil fuels, the scan ascertained whether or not minimum efficiency standards have been developed in other jurisdictions. Additionally, the report contains technical input to a commissioning test for boilers.

## Conclusions

*AC Electric Motors*

Internationally, AC motors have no mandatory Standards, but have good efficiency test methods. However, voluntary programmes have been established that include labelling and only look at minimum efficiency levels at rated output. Best practices in purchasing and O&M are used on Codes with focus on efficiency.

Efficiency of AC motors has a direct bearing on the costs to produce the machine. Increasing or specifying minimum efficiency levels would therefore increase the capital costs associated with owning an AC machine. On the other hand, the increase in efficiency would reduce the operating costs associated with owning of the machine. The real efficiency of a motor is very dependent on the actual application of the motor, i.e. it is determined by the actual duty point of the motor. As such, the specification of efficiency at rated output would therefore not guarantee that the actual application of the motor would result in the best efficiency possible, as motors are seldom operated at their design duty.

It is pertinent to note that an electric motor is useless on its own as it is there to drive another machine to perform an intended function, i.e. drive a pump, etc. As standard motors are generally the more efficient component in the system, greater gains in the use of energy can be achieved by adopting a more holistic approach.

*Non-utility steam-raising boilers, fired by fossil fuels*

The research study established that most boilers do not run at full capacity and that if the load is low, special measures can be instituted to save energy by:

- Installing a smaller boiler which runs at higher efficiency
- Installing localized heating where required
- Using lowest steam pressure required.

It emerged during the scan that for larger boilers, international boiler programmes are putting less emphasis on specifying minimum efficiency levels and more on designing a holistic approach that looks at measures to improve efficiency in all aspects of the boiler system. The rationale for moving away from simply specifying a minimum efficiency is that in industrial applications, boilers are selected based on many criteria that will affect efficiency, such as the application, fuel availability, cost, etc. In view of all of these issues, applying a blanket prescriptive approach to minimum efficiency can lead to poor decisions in the long run

The study team's evaluation of international programmes for steam-raising boilers shows that many boiler programmes share the same characteristics. In general, programmes aimed at smaller boilers (residential and small commercial) will specify minimum energy efficiency requirements while programmes aimed at larger, industrial boilers are more comprehensive and cover the whole steam system.

*Thermal insulation of hot pipework, namely steam pipework*

Considering the fact that insulation pipe was not constructed on site, any technical regulation with respect to pipeline insulation has to be an installation code of practice and maintenance code of practice.

**Recommendations**

The research study recommends

*AC Electric Motors*

- Energy efficiency and power factor labeling of AC motors above 1.1 kW.
- A Technical Committee be set-up to develop an energy efficient design and life cycle code of practice.
- A holistic and integrated approach be developed for South Africa that does not only consider the motor at rated duty point, but would consider the motor at its actual operating duty point and would also consider the improvement in the efficiency of the total machine and not only the driving machine.
- That certain abnormalities in the motor industry be regulated through legislation, e.g. that only motors complying with a minimum requirement may be labelled as an energy efficient motor.
- Those certain shortcomings in the motor rewind industry, such as efficiency testing and labelling, which should be mandatory be addressed.

This would require additional requirements for the motor, such as specifying the minimum efficiency and the maximum "droop" in the efficiency curve. This would require the adoption of a code of practice regarding the optimisation of the motor and load taking due cognisance of the actual application.

*Outline to a "Code of Practice" for "Users of AC Motors and Driven Equipment*

It is proposed that the following outline to a "code of practice" for "Users of AC Motors and Driven Equipment" should addressed:

1. Scope
2. Financial Modelling Criteria
3. Evaluating System Life-cycle Costs
4. Repair Costs and Procedures

The pursuit of a "code of practice" route will ensure that all stakeholders will benefit from a win-win situation, while avoiding the tendency of finding loopholes as a way of avoiding implementation

*Non-utility steam-raising boilers, fired by fossil fuels*

It is recommended that the standards used in South Africa are international and should be adopted. Furthermore, there should be:

- Mandatory boiler efficiency testing when commissioning new steam-raising plant, and
- Linking of monitoring and verification (M&V) of boiler efficiency to the M&V programmes being rolled out in the context of the Air Quality Act.

*Outline to a "Code of Practice" for Users of Boilers and Steam distribution systems*

It is proposed that the following outline to a "code of practice" for "Users of Boilers and steam distribution systems" be addressed:

1. Scope
2. Financial Modelling Criteria incorporating utility as well as process parameters
3. Evaluating System Life-cycle Costs
4. Repair Costs and Procedures
5. Boiler operation and the role of the boiler attendant
6. Boiler safety and statutory boiler inspections
7. Disposal of ash, surface pollution (in addition to air pollution) and blowdown water

The pursuit of a "code of practice" route will ensure that all stakeholders will benefit from a win-win situation, while avoiding the tendency of finding loopholes as a way of avoiding implementation

*Thermal insulation of hot pipework, namely steam pipework*

- That a locally-developed code of practice for insulated pipes by Sasol be adopted, but with modification to become thermal performance based as opposed to being thickness based.
- Standards used in South Africa are international and should be adopted
- The existing SABS Technical Committee on Energy Efficiency: SC 5120.61K should be used on issues pertaining to standards and codes of practice.

It is further recommended that the following ASTM standards be adopted as SANS standards:

C335-05a: Standard Test Method for Steady-State Heat Transfer Properties of Pipe Insulation
C547-03: Standard Specification for Mineral Fibre Pipe Insulation
F2165-02: Standard Specification for Flexible Pre-Insulated Piping
C610-05: Standard Specification for Molded Expanded Perlite Block and Pipe Thermal Insulation
C585-90 (2004): Standard Practice for Inner and Outer Diameters of Thermal Insulation for Nominal Sizes of Pipe and Tubing (NPS System).

The scope for these standards is found in Appendix A.

The various standards and codes of practice should be administered within the SABS Technical Committees. The final phase of the project will be the compilation and submission of technical material to the SABS committees for inclusion within the new standards.

# 1 Introduction/Background

## 1.1 Background and Overall Objectives of the CaBEERE Project

In South Africa, the formulation of strategies and drafting of policies for the country's energy sector is the responsibility of the Department of Minerals and Energy (DME). The project – Capacity Building in the DME in Energy Efficiency (EE) and Renewable Energy (RE) – resulted from a dialogue between DME and Danida (formerly Danced) over the years 1999 to 2001. The aim of the project is to enhance DME's capacity and performance through assistance in the development of programmatic approaches through strategies and actions plans for EE and RE in transparent co-operation with relevant stakeholders.

The overall objective of the CaBEERE project is the increased use of EE and RE throughout South Africa to maximise the contribution of the energy sector towards sustainable development. Immediate objectives are that DME and pertinent stakeholders are resourced and capacitated to formulate and facilitate implementation of strategies and legislation promoting EE and RE production and use in both rural and urban areas.

### 1.1.1 Immediate Objectives of this Assignment

The objective of the Industrial Norms and Standards project is to ensure that appropriate standards for energy efficiency are identified, adopted and adhered to by industry, thereby yielding improvements in operational energy. To put things in context, the Energy Efficiency Strategy of the Republic of South Africa makes provision for the use of Norms and Standards for Horizontal Technologies within the Industrial Sector Programme. The Horizontal Technologies to be addressed for norms and standards are:

- Non-utility steam-raising boilers, fired by fossil fuels
- AC electric motors
- Thermal insulation of hot pipework, namely steam pipework

## 1.2 Definition of a Horizontal Technology

The term horizontal technology applies to any technology that is applicable or prevalent within a wide range of industries or applications.

## 1.3 Structure of the Report

The report is divided into three sections as follows:

- International and Domestic Scans
- Options and Recommendations
- Draft Inputs and Codes of Users of AC Motors and Driven Equipment

This report presents summaries of the most applicable international test standards, codes of practice, and programmes related to energy efficiency in AC Motors, Steam Boilers, and Pipe Insulation. The standards, codes and programs chosen for summary were originally listed on the "Short List" included in our earlier report entitled International Scan of Test Standards, Codes of Practice, and Programmes (May 2005).[1]

[1] The "master list" (long list) of test standards, programmes, and codes of practice was first presented in our earlier report entitled *International Scan of Test Standards, Codes of Practice, and Programmes* (May 2005). For the sake of completeness, the updated version of this "master list" is presented in Appendix A.

# 2 Selected Standards, Codes and Programmes: Summary

## 2.1 International Standards, Codes and Programmes

The following lists identify the test standards, codes of practice, and programs identified for more detailed examination from the last stage of this project. The entries in the short list were selected based primarily on relevance (considering, for instance, scope or nature of the standard/code/programme).

Table 1 - International Programmes and Codes – AC Motors, Boilers, Insulated Pipes

| | Name | Region | Jurisdiction | Rationale | Last Update | Ref No. |
|---|---|---|---|---|---|---|
| Motor Programs | FIDE seal | Mexico | The National Commission of Energy Saving | Labelling program with minimum efficiency levels. | | |
| | MEPS Program (Minimum Energy Performance Standards) | Australia, New Zealand | State Government | Labelling program with minimum efficiency levels linked to standards. | 2005 | |
| | Voluntary Agreement of European Committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP) | European Union | European Committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP) | Labelling program with three efficiency levels. | | IEC 34-2 |
| | NEMA Premium EE motors program | USA | National Electrical Manufacturer's Association (NEMA) | Labelling program for premium efficiency motors. | | |
| Boiler Programs | Energy Efficiency Regulations | Canada | Natural Resources Canada | Minimum efficiency levels. | | |
| | Express Efficiency Program | USA | Pacific Gas and Electric Company | Minimum efficiency levels. | | |
| Motor Codes | Energy Savings with Electric Motors and Drives | UK | Department of Environment | Includes purchasing and O&M best practices. | | |
| | How to Buy an Energy Efficient Electric Motor | USA | Department of Energy | Includes purchasing and O&M best practices, plus recommends efficiency levels. | | |
| Boiler Codes | Economic Use of Coal-fired Boiler Plant | UK | Department of Environment | Includes Operation and Maintenance best practices for coal boilers. | | |
| | Energy Efficient Operation of Industrial Boiler Plant | UK | Best Practice Programme | Includes Operation best practices and expected boiler efficiencies by type. | | |
| | Energy Efficiency Manual | USA | author DR Wulfinghoff, published by Energy Institute Press | Covers: equipment scheduling and operating practices, boiler plant efficiency measurement, air-fuel ratio, burner and fan systems, draft control, firesides and watersides, combustion gas heat transfer and heat recovery, condensate/feedwater/water treatment, fuel oil systems, steam and water leakage, conduction and radiation losses, system design for efficient low-load heating | 1999 | ISBN 0-9657926-7-6 |
| | How to Buy an Energy Efficient Commercial Boiler | USA | Department of Energy | Includes purchasing and O&M best practices, plus recommends efficiency levels. | | |
| Pipe Insulation Codes | The Economic Thickness of Insulation for Hot Pipes | UK | Best Practice Programme | Covers many insulation materials, with formulas, charts, and tables for determining thickness. | | |
| | Process Plant Insulation | UK | Department of Environment | Covers many insulation materials, with tables for determining thickness. | | |
| | Economic Thickness of Insulation | USA | US Department of Energy | Covers design and installation of pipe insulation. | | |

Table 2 - International Standards

| | Name | Region | Jurisdiction | Ratonale | Last Update | Ref No. |
|---|---|---|---|---|---|---|
| AC Motors Standards | Energy Efficiency Test Methods for Phase Induction Motors | CSA | | | 1998 | CSA C390 |
| | CSA C747 – Energy Efficiency Test Methods for Single and Three phase Small Motors | CSA | | | | CSA C747 |
| | Rate and Performance | Europe | | | 2003 | IEC 60034-1 |
| Boiler Standards | Industrial & Commercial Gas-Fired Package Boilers | CSA | | | 2001 | CANI-3.1-77 |
| | Gas Fired Low pressure Steam and Hot Water Boilers | CSA | | | 2000 | CSA 4.9-2000 |
| | Oil fired Steam and Hot Water Boiler for Commercial and Industrial Use | CSA | | | 2001 | B140.7.2-1967 |
| | Boilers and pressure vessels – Registration of Codes and Standards to promote international recognition – Part 1: Performance requirements | ISO | | | | ISO/CD TS 16528-1 |
| | Boilers and pressure vessels – Registration of Codes and Standards to promote international – Part 2: Standards fulfilling the requirements of Part 1 | ISO | | | | ISO/CD TS 16528-2 |
| | Steam Boilers | UK | Electrical Contractors Association | Part 1 Appendix B – Accuracy of Boiler Tests deals with errors in determination of efficiency | 2004; Part 1 (1987) Updated Nov 1996 | BS845 |
| | Stationery shell boilers of welded construction | ISO | | | | ISO 5730 |
| Pipe Insulation Standards | Thermal Insulation, Polystrene, Boards and Pipe Covering | | | | | CAN/ULC-S701-01 |
| | Flexible Elastomeric Unicellular Thermal Insulation, Sheet and Pipe Covering | | | | | CAN/COSB-51 40-95 |
| | Thermal insulation Bonded preformed man-made mineral fibre pipe sections | ISO | | | 2001 | ISO 8142 1990 |

## 2.2 Domestic Standards, Codes and Programmes

The following lists identify the test standards, codes of practice, and programs identified for more detailed examination from the last stage of this project. The entries in the short list were selected based primarily on relevance (considering, for instance, scope or nature of the standard/code/programme).

Table 3 - Domestic Standards and Codes – AC Motors, Boilers, Insulated Pipes

| | Name | Region | Jurisdiction | Rationale | Last Update | Ref No. |
|---|---|---|---|---|---|---|
| AC Motor Standards | Methods for determining losses and efficiency of rotating machinery | SA | South African National Standards | Test method for all rotating machinery | | SABS 1804-1,2,3&4 |
| Boiler Standards | No standard found | | | | | |
| Pipe Insulation Standards | Thermal Transmission Properties of Thermal Insulation | SA | South African National Standards | | | |
| Pipe Insulation Codes | Insulation - Hot Service and Personnel Protection | South Africa | Sasol | Covers requirements for the design, materials and application of insulation in hot service piping, vessels and equipment for heat conservation, insulation for sound control, fire protection, process control and personnel protection. | Feb-03 | SP-80-1A Revision 1 |

# 3 The Summary Templates

Appendices A and B of this document provides summaries of each of the programmes, codes of practice, and test standards identified in Tables 1 and 2. Three different templates were developed for consistent reporting on each of the standards, codes and programmes. For classification purposes, all three templates begin with a header box that identifies the title, the region, the technology, and the category (i.e. whether it is a standard, code or programme). After the header box, the subheadings for the templates use the following format:

- **Programmes**: Background; Scope; Program Description; Energy Levels; Related Programs (if applicable); and Results.

- **Codes of Practice**: Background; Scope; Basic Principles; Design & Selection; Operation & Maintenance; Systems Approach.

- **Standards**: Background; Scope; Standard Description; Objective; Proposal; Assessment; and Options. The International templates include Marking and Recommendations.

# 4 Options and Recommendations

## 4.1 AC Motors

### 4.1.1 Standards (Domestic)

Through the adaptation of IEC 60034 South Africa has adopted one of the leading standard motor specifications in the world. The other domestic specification on AC motors, SANS 1804, entrenches the requirements of IEC 60034.

Although being one of the leading motor specifications in the world, IEC 60034 does not specify efficiency levels other than specifying the test methods to prove the actual efficiency of motors.

Efficiency of AC motors has a direct bearing on the costs to produce the machine. Increasing or specifying minimum efficiency levels would therefore increase the capital costs associated with owning an AC machine. On the other hand, the increase in efficiency would reduce the operating costs associated with owning the machine.

The actual efficiency of a motor is very dependent on the actual application of the motor, i.e. it is determined by the actual duty point of the motor. As such, the specification of efficiency at rated output would therefore not guarantee that the actual application of the motor would result in the best efficiency possible as motors are seldom operated at their design duty.

The second factor to consider is that an electric motor is useless on its own as it is there to drive another machine to perform the intended function, i.e. drive a pump, etc. The electrical supply to the motor is also a contributor to the total losses in the system. The transformers in the supply system are electromagnetic machines with very similar characteristics to the induction motors. As standard motors are generally the more efficient component in the system, greater gains in the use of energy can be achieved by adopting a more holistic approach, which includes the supply system, the motor and the driven machinery.

### 4.1.2 Standards (International)

Internationally, AC motors have no mandatory efficiency Standards, but have good efficiency test methods. However, voluntary programmes have been established that include labelling and only look at minimum efficiency levels at rated output. Best practices in purchasing and O&M are used on Codes with focus on efficiency.

## 4.2 Codes of Practice – Energy Efficient Motors

### 4.2.1 Introduction to Motor Efficiency

*This section covers the basics of motor efficiency and the cost implications as well as the energy savings characteristics. It also explains the importance of looking at the life-cycle costs and not just the purchase price.*

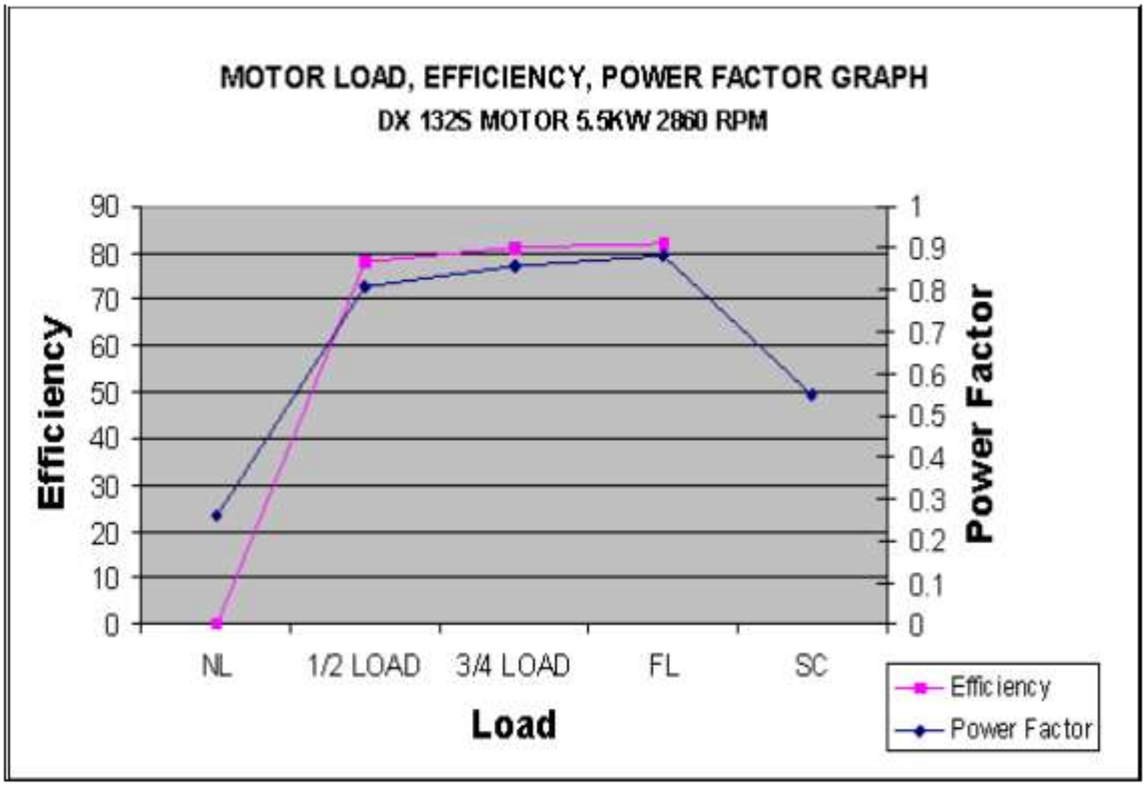
All motors convert electrical power input into mechanical power, but some do it more efficiently than others. Motor efficiency is defined as the ratio of mechanical power output to the electrical power input, expressed as a percentage. For most motors, the purchase price represents only 4-5 % of its lifetime cost; the remaining 96-95 % of this cost is for purchasing electricity to operate the motor. Due to the long duty cycles of most industrial motors, even a 1 or 2 percent improvement in motor efficiency does result in substantial energy savings. Due to favourable energy tariffs in South Africa, the reduced energy cost is insufficient to offset the additional capital cost of a high efficient motor relative to a standard motor.

It's not surprising that the ongoing costs of operating induction motors are so often overlooked. Induction motors are often installed in out of the way locations around the plant where they operate reliably and generally quietly. The large number of motors operating in industrial plants also makes it difficult to identify the best opportunities for energy savings. The choice of techniques and equipment to reduce energy consumption in motor systems can also lead to confusion. A range of options exists from low-cost measures such as time switches to sophisticated variable speed drives (VSDs). All of these factors can obscure the potential of energy saving opportunities. The effects of efficiency are however far more pronounced if the total long term life-cycle costs are considered.

The direct kW losses measured through the efficiency method is not the only lost energy cost when considering electric motors or any other electric load, which does not operate at unity power factor. Although these additional "losses" are being incurred outside of the motor, they are directly attributable to the electric motors operation. The size of these losses can be directly associated with the Power Factor (pf) at which the machine operates. Any programme aimed at improving efficiency, would therefore not be complete if it did not also address the power factor of the machine at the same time.

Figure 1 shows the relationship between efficiency and power factor versus load.

**Figure 1: Motor Load, Efficiency and Power Factor**




The average life-cycle of a new motor is in the order of 10-15 years. At this point, the motor is seldom discarded, but is invariably repaired and rewound. The cost of such a repair and rewind is of the order of 80-90% the price of a new motor and therefore attractive for the end-user. Normally, in the rewinding process, the owner gives very little technical input and the rewinding shop invariably does not rewind the motor to the OEM specification. In some cases, motors still get rewound, even if their magnetic circuit has been damaged, giving rise to reductions in efficiency. These factors result in the reduction of the efficiency of the motor. Depending on the quality of the rewind and the quality of the end-user specification, the reduction in efficiency can be substantial – in the order of 10%.

Other factors that must be considered when evaluating motor efficiency is the fact that motor efficiency and power factor are load dependent. Due to the fact that motors are made in standard sizes, and designers invariably allow for a safety margin, it is highly unlikely to find a motor that operates at its full load point. Experience shows that most motors are loaded in the range of 60-85% with a mean of about 75% load.

## Comparing Regular and Efficient Motors

*This section compares the efficiencies of a standard and a premium high efficiency motor on the market in South Africa. It also includes a table showing the payback time and savings from choosing an efficient motor over a standard one as well as a table of recommended motor efficiencies.*

In South Africa the price of a high efficiency motor may be 20-25 percent more than that of a standard model, depending on motor size, type, availability and manufacturer. However, for a typical industrial application of 6,000 annual operating hours, the simple payback period is in the order of 6 to 10 years, depending on the loading of the motor. Table 4 compares the total life-cycle costs of a standard 55 kW motor with those of an equivalent high efficiency motor operating at 6000 hr/yr for a typical industrial application. The electricity cost is based on Eskom Megaflex tariff, which is representative of most industrial clients.

Table 4 shows the life cycle costs for both a standard and high premium efficiency motors operating at full load and at 75% full load. It is seldom that a motor operates at 100% load. As can be seen in table 4, it may be difficult, if not impossible to get industry to accept high efficiency motors in South Africa on financial grounds only. The situation is different in the European and US markets due to the marginal difference in price between standard and high efficiency motors and the relatively high cost of electricity compared to South African tariffs. It would therefore be necessary to investigate the introduction of incentives, which could reduce the cost differential of associated with purchasing and operating either a standard high efficient motors.

Table 4 - Comparison of Life-cycle Costs of a 55kW Standard and equivalent High Efficient Motor

| | **Standard Efficiency Motor** | | **Premium High Efficiency Motor** | |
|---|---|---|---|---|
| | **Full Load** | **75% Load** | **Full Load** | **75% Load** |
| Capital Cost (R) | 15,700.00 | | 18,870.00 | |
| Annual Cost of Electricity (R) | 73,080.26 | 55,681.88 | 72,601.65 | 55,349.61 |
| 10 year Life Cycle cost (R) | 508,548.54 | 390,875.22 | 508,193.28 | 391,509.74 |
| Net Savings (10 years) (R) | | 634.52 | 355.25 | |
| Simple Payback Period (yr) | | | 6.62 | 9.54 |
| Discounted Payback Period (yr) | | | 9 | 14 |

<u>Basis for the financial comparison:</u>

Electricity Tariff: Eskom MegaFlex
Utilisation: 6000 hrs/year evenly spread across the metering periods
Discount Rate: 10%
Inflation: 5%
Motor Prices: Leading motor supplier including typical market discounts

**Table 5** gives the comparison of the life cycle costs for a rewound 55 kW standard motor, assuming a 2% loss in efficiency and 0.1 reduction in power factor against a premium high efficiency motor operating 6000 hr/year. It can be seen that the situation changes very rapidly and the additional payback is achieved in less than 2 years (discounted and straight line).

Table 5 - Comparison of Life-cycle Costs of a 55kW Rewound Standard and equivalent High Efficient Motor

| | Rewound Motor | | Premium High Efficiency Motor | |
|---|---|---|---|---|
| | Full Load | 75% Load | Full Load | 75% Load |
| Capital Cost (R) | 14,000.00 | | 18,870.00 | |
| Annual Cost of Electricity (R) | 77,627.42 | 59,109.72 | 72,601.65 | 55,349.61 |
| 10 year Life Cycle cost (R) | 537,757.64 | 412,513.81 | 508,193.28 | 391,509.74 |
| Net Savings (10 years) (R) | | | 29,564.35 | 21,004.07 |
| Simple Payback Period (yr) | | | 0.97 | 1.30 |
| Discounted Payback Period (yr) | | | 2 | 2 |

<u>Basis for the financial comparison:</u>

Electricity Tariff: Eskom MegaFlex
Utilisation: 6000 hrs/year evenly spread across the metering periods
Discount Rate: 10%
Inflation: 5%
Motor Prices: New: Leading motor supplier including typical market discounts
Rewound: Major Gauteng based motor rewinder

On of the major problems in South Africa, is to distinguish between standard and high efficiency motors. As there is no guideline or legal framework in place which defines what a standard efficiency motor is and what a high efficiency motors is. As a result it has been noted that motors sold as a high efficiency motor from one supplier has a lower efficiency compared to a standard motor from a different supplier. This can be very misleading to the unsuspecting non-technical buyer.

A second problem is that in accordance with SANS 1804, efficiency tests are a Type Test for new motors and in accordance with SANS 1561-1 efficiency tests are not mandatory for rewound motors (only required for test category IT3). As the efficiency of a motor is very much dependant on the quality of the rewind, the end user has no idea of what the efficiency of his rewound motor is.

### 4.2.2 Purchasing Energy Efficient Motors

**Selecting an Efficient Motor**

*This section covers what makes a motor efficient and where motor losses come from, what one needs to look for, and a description of motor selection tools.*

The main elements of an induction motor are the stator and rotor cores (a stack of iron laminations), an insulated stator winding, and rotor conductors formed by the casting of an aluminium cage into the rotor core. Induction motors can be open or enclosed. In totally enclosed induction motors, ventilation is achieved through an external fan that blows air over the frame to cool its external surfaces.

Power losses in induction motors are classified into two categories: fixed losses and variable losses. Fixed losses are due to friction and windage loss as well as magnetic loss in the stator and rotor cores, and are independent of the motor load. Variable losses are proportional to the motor load and are due to resistive losses in the stator and rotor conductors, and stray losses caused by components of stray flux.

High efficiency motors are built with superior materials, such as high-quality silicone steel laminates, and are manufactured with optimized designs. The result is more work output for the same amount of energy consumed. Due to their improved design, high efficiency motors usually also have higher service factors, longer insulation and bearing lives, lower waste-heat output and less vibration than standard motors. In fact, due to their greater reliability, manufacturers typically provide longer warranties for their most efficient models.

One should consider purchasing an energy efficient motor in any of the following circumstances[2]:

- For all new installations
- When purchasing equipment packages, such as compressors, fans, and pumps
- When major modifications are made to facilities or processes
- Instead of rewinding older, standard inefficient units
- To replace oversized and under-loaded motors

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[2] *Buying an Energy-Efficient Electric Motor*, U.S. Department of Energy Fact Sheet

- As part of a preventive maintenance or energy conservation programme.



To select the most appropriate motor for an application, one must know the motor type (size, speed and enclosure) and motor load (constant or variable). Whenever possible, obtain actual price quotes from motor distributors to calculate simple paybacks. Motors rarely sell at full list price. You can typically obtain a 20% to 60% discount from vendors, with specific prices depending on the distributor's pricing policies, the number and type of motors one buys, and fluctuations in the motor market. Always be sure to compare shop when purchasing motors.

All too often, purchasers oversize their motors, resulting in less efficient motor operation. Motors should be sized to operate with a load factor between 75 and 100 percent. Using a motor that is oversized for its application will result in a loss of efficiency.

When comparing the motor efficiency between competing products, always be sure to use a consistent measure of efficiency. Nominal efficiency is an average value obtained through standardized testing of a population of motors, while minimum guaranteed efficiency, (which is based on nominal efficiency), is slightly lower to take into account typical population variations. Minimum guaranteed efficiency is also less accurate, because the value is rounded. Nominal efficiency is the best rating to use for comparison, while other efficiency ratings, such as apparent and calculated, should not be used.

Motor purchasing decisions should be made on a lifetime least-cost basis. Use the following formula to estimate the annual savings resulting from purchasing a higher efficiency motor:

$$\textbf{Annual Savings} = \text{hrs} \times \text{kW} \times \%\,\text{FL} \times \text{R/kWh} \times (1/\eta_{std} - 1/\eta_{hem})$$

where:
- hrs = annual running time, in hours
- kW = motor rating, in kW
- % FL = fraction of full load at which the motor runs
- R/kWh = electricity cost in Rand/kWh
- $\eta_{std}$ = efficiency of standard motor at the load point
- $\eta_{hem}$ = efficiency of the higher efficiency motor at the load point

Some companies will agree to pay the higher capital cost for an efficient motor only if the payback falls within a specified period. To calculate payback use the following formula:

$$\textbf{Payback (years)} = \frac{R_{hem} - R_{std}}{(\text{Ann. Sav.} + \text{Main. Sav.})}$$

where:
- $R_{hem}$ = purchase price of the higher efficiency motor
- $R_{std}$ = purchase price of the standard efficiency motor
- Ann. Sav. = annual energy savings as calculated above
- Main. Sav. = annual maintenance savings due to purchasing a higher quality motor, if applicable

Setting up a computer spreadsheet to automate the above calculations will allow one to quickly compare competing motors and determine what is best for your site.

A useful energy-efficient motor selection and management tool is MotorMaster+®. This software programme was developed by the Washington State University Cooperative Extension Energy Program (the Energy Program), in partnership with the U.S. Department of Energy's Office of Industrial Technologies' BestPractices Programme. [http://www.oit.doe.gov/bestpractices/bestpractices.shtml] (formerly the Motor Challenge Program). Using a database of more than 24 000 motors from different manufacturers, this software programme allows one to compare price, full-load speed, and full- and part-load efficiencies before one select the best motor for an application. South Africa is affiliated to the Office of Industrial Technologies' Best Programme.

**The Motor Management Plan**

*This section covers the importance of having a motor management plan in place so that the right decisions are made when motors fail unexpectedly.*

The best time to purchase a high efficiency motor is when new plant capacity is planned or when a motor has failed and must be either replaced or repaired. Motors fail without warning, and in most industrial applications they need to be replaced quickly to minimize work disturbances. This is why it is always best to have a motor management plan in place ahead of time to ensure that a suitable replacement model is available. A motor management plan can be as simple as having a set of criteria for all repair/replace decisions. But ideally, it is better to make the repair/replace decisions in advance, starting with the motors with the most critical applications.

The first step in developing a motor management plan is to survey your motors. Gather nameplate information and obtain field measurements (voltage, amperage, power factor, operating speed) under typical operating conditions. Initially focus on motors that exceed minimum size and operating duration criteria. Typical selection criteria include[3]:

- Non-specialty motor
- Greater than 7.5 kW
- At least 2000 hours per year of operation
- Constant load (not intermittent, cyclic, or fluctuating)
- Older or rewound standard efficiency motors
- Easy access
- Readable nameplate.

After one has created a thorough inventory of one's motors, the motors are next divided into the following three categories:

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[3] *Buying an Energy-Efficient Electric Motor*, U.S. Department of Energy Fact Sheet

**Replace Immediately — Motors Offering Rapid Payback.** These include motors that run continuously (typically 8000 or more hours a year), are currently inefficient (including oversized motors), or those that must be reliable. If any of these conditions apply, then it is best to order an efficient replacement motor soon and install it at the next available opportunity, such as during a scheduled downtime. If the motor is very old, then chances are good that it has a very poor efficiency so switching to a high efficiency motor immediately would offer cost effective savings.

**Replace at Time of Failure — Motors with Intermediate Payback.** These motors don't offer enough energy savings to warrant immediate replacement, however it will be economical to replace them with a more efficient motor after failure. Now is the time to contact motor dealers to review the efficiency and prices of available motors. It is best to purchase the most cost-effective replacement model ahead of time to ensure that it will be available at the moment of failure. However, if the efficient motor can be obtained quickly through suppliers, or if the failed motor does not need to be replaced immediately, then it is sufficient to select the proper replacement motor without purchasing it.

**Leave Present Situation as is — Motors with Extended Payback.** These motors are already reasonably efficient or are used less than 2000 hours each year. Savings from these motors are not substantial. They can be rewound or replaced with a similar motor.

## Rewinding Failed Motors

Failed motors can often be repaired as an alternative to replacement, however rewinding the motor will lower its efficiency, typically by 0.5-2%. If one opts to have the motor rewound instead of replaced, have it rewound only at reliable repair shops that use low temperature (under 700°F) bake out ovens, high quality materials, and a quality assurance programme (e.g. ISO-9000). Ask the repair shop to conduct a core loss or loop test as part of their rewind procedures.

## Operating Motors for Energy Efficiency[4]

*This section covers operational issues such as choosing the right belts and gears, and using proper lubrication.*

**Motor Speed.** Every pump and fan has a design speed, and variations from that speed can reduce efficiency and increase energy consumption. Always select a new motor with an operating speed that has a full-load rpm rating equal to or less than the motor being replaced. In some instances, minor speed variations can be adjusted by changing the pulley size (for belt-driven equipment) or by trimming impellers (for direct-drive pumps). For fluctuating

[4] See *Guide to Energy-Efficient Commercial Equipment*, the American Council for an Energy-Efficient Economy (ACEEE), 2000, and *Buying an Energy-Efficient Electric Motor*, the U.S. Department of Energy's (DOE's) Motor Challenge, 1996.

loads with long duty cycles, an adjustable speed drive can help minimize energy consumption.

**Power Quality.** Incorrect voltages or phase balances, current leaks, and harmonics in the electrical supply can all reduce motor reliability and efficiency. Studies have estimated that improvements to electric supply systems can result in a 1 to 5 percent savings in motor loads, along with improved reliability and extended motor life.[5]

**Belts.** V-belts are the most common method of connecting a motor to its load, but three other types of belts can actually offer greater efficiency. Clogged V-belts, flat belts and synchronous belts can offer improved efficiency when one considers their unique operating characteristics. A recent study has shown that replacing V-belts with clogged V-belts can reduce energy consumption by 0.4 to 10.0 percent, with typical payback ranging between one and five months.

**Lubrication.** Premium lubricants have provided energy savings of 3 to 20 percent in gear reducers, compressors and motors. They also extend the life of your motor system by improving resistance to deterioration.

## Maintaining Motors for Energy Efficiency

*This section deals with maintenance issues such as predictive maintenance and proper record keeping.*

The maintenance needs of induction motors are generally minimal, however small investments in regular maintenance throughout the life of your motor can have large savings by maintaining the motor efficiency and postponing failure. Combined with a good record-keeping system, the result can be less down time. The following maintenance tips can help keep your motor operating at its optimal efficiency:

- Motor bearings should be greased in accordance with the manufacturer’s instructions.
- Ensure that the motor shaft is aligned correctly to reduce running losses, bearing wear, noise and vibration.
- Keep the motor clean to ensure that the heat generated within the motor is effectively removed. Keep all fan inlets and frame surfaces clear of deposits.
- Ensure that the airflow over the motor is not obstructed. Even a small increase in the stator winding temperature can produce a loss in efficiency as well as shortening the life of the motor insulation.
- Use modern infrared optical sensors or vibration sensors to predict when a failure is likely to occur.

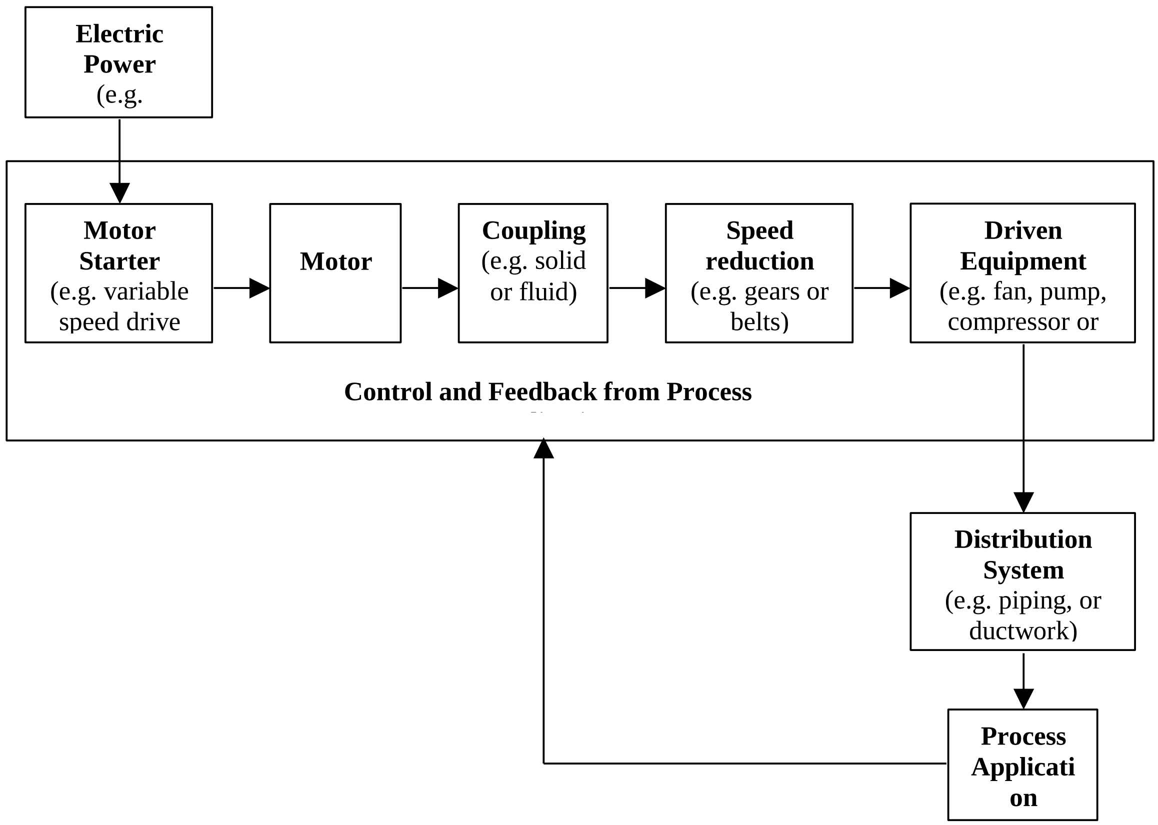
[5] ACEEE, Elliott, 1995.

**Efficient Motor System Fundamentals**

*This section describes how all of the elements in a motor system interact and affect energy use.*

Despite all of this focus on selecting an efficient motor, it is important to remember that a motor is just one part of a larger system designed for a specific process application. If any of the elements of the system are not designed properly, then the system will remain inefficient regardless of what type of motor is used. Common elements in all systems include power input, energy conversion equipment, control mechanisms, and some form of output designed to meet process demands. The schematic below (figure 2) shows all of the interconnected components of a motor system.

**Figure 2: Components of a Motor System**




By looking at all of the components together as a system one can accurately and efficiently match the system output to the industrial process requirements. The system approach can obtain energy savings of 20% - 50% compared with savings of 3% to 15% with component efficiency improvements.

**Motor Starter- Variable Speed Drives**

An induction motor is a fixed speed device when operated from a constant frequency and constant voltage supply, however, several techniques are available that can vary the speed which can better match the motor output to the application. This is useful because it is the work done by the driven machine (which is proportional to the speed) that determines the motor power consumption. A variable speed drive (also known as an inverter or VSD) works by converting the AC mains supply to DC using a rectifier. The VSD alters the frequency and voltage supplied in such a way as to enable the induction motor to run efficiently at different speeds. VSDs can have manual controls or automatic controls using feedback loops from the process application. Automatic controls on VSDs are ideal for providing efficient motor output for situations where there is a varying demand. VSDs can save 50% of the energy used by a motor or more in scenarios where there is a variable load.

Multiple speed motors (MSMs) are another, lower cost alternative for applications where the drive has 2 – 4 distinct operating conditions.

**Coupling and Speed Reduction- Pulleys and Gears**

The least expensive method to reduce the speed of driven equipment is by changing the pulley or gear ratio. The savings can be substantial compared to the small cost of a pulley change, resulting in a payback of only a few days. If distinct levels of speed are needed it is possible to install a multiple speed pulley block to allow the output to be altered during use.

**Driven Equipment - Pumps**

Pumps provide the force to move a liquid through a piping system. Peak pump efficiency is only possible at one particular flow and pressure. Operating a pump at low speed, low capacity or at high head will all significantly reduce efficiency. The following tips will help one to maximize pump efficiency.

- It is worth the added expense to select a well-manufactured pump. Most of the methods that manufacturers use to reduce the price also decrease efficiency.
- If the pump is consistently under-loaded, install a smaller impeller or trim the existing one.
- When more than one pump is designed in parallel it can make the whole system progressively less efficient.
- Maintain the pump according to the manufacturer’s specifications. Without maintenance pump efficiency can fall by up to 10%.
- For larger pumps it is worthwhile to set up a condition monitoring programme to determine the optimum time for refurbishment.

**Driven Equipment- Fans**

Fans provide the means to move air through a system of ductwork. Fans should be selected for the greatest efficiency in a given application. Existing fans should be examined to ensure peak operation with a minimum of loss. The following tips will help maximize fan efficiency.

- Keep air filters clean to minimize pressure drops.
- Avoid any unnecessary pressured drops in ducting.
- Clean the blades regularly.
- Outlet dampers are an inefficient method of controlling flow. It is more efficient to alter the pulley ratio to adjust fan speed.
- Where a bank of fans exists, switch units on and off to suit the demand.

**Driven Equipment- Compressed Air Systems**

Compressed air is distributed throughout plants via a pipe network and is widely used in processes and to operate equipment. Compressed air is versatile and convenient, however, it is one of industry's most expensive energy sources. The following tips will help to maximize the efficiency of compressed air systems.

- Leakage is the single largest waste of energy associated with compressed air usage. In a typical plant air leaks account for 20% of the total air usage. Tighten connections, replace cracked hoses and install pressure-driven drain valves. Check for leaks regularly and repair promptly.
- Measure leaks using an ultrasonic leak detector. Applying a soapy water solution to the joints, valves and fittings and looking for bubbles will allow one to detect the exact location of leaks.
- Use the lowest pressure possible. If an application requires higher air pressure than the rest of the system, consider using a separate compressor or booster that is sized for the function.
- Consider installing a small compressor for use during low demand periods.
- Relocate air intakes outdoors to provide the cleanest, driest and coolest air possible.

**Distribution Systems- Piping and Ductwork**

Piping or ductwork is often necessary to carry the working fluid or air from the driven equipment to the process application. The distribution system is an often overlooked aspect of the complete motor system. Losses in the distribution system due to leaks or unnecessary pressure drops can add up and force the motor to work harder for the same amount of process output. The following tips will help to minimize losses in the distribution system.

- Make checking for leaks a part of the maintenance plan. Repair leaks immediately.
- Minimize the number of sharp bends in pipework.
- Zone the system and isolate pipework sections when not in use,
- Remove or shut-off permanently unused pipework.

## Energy Saving Checklist[6]

The following Energy Saving Checklist is a handy summary of important factors to consider when one is trying to optimize motor efficiency in your plant.

**1. Is the equipment still necessary?**

- Requirements change over time and the equipment may no longer be necessary.
- Check that the system is doing a useful and required job.

**2. Can the motor be turned off?**

- Switch the motor off, either manually or with timers, when the motor is not needed.
- Use sensors to determine the motor load so that the motor is switched off when 'idling'.

**3. Can the motor load be reduced?**

- Check that the transmission between the motor and the system is efficient.
- Check that the driven system (e.g. pumps, fans) is efficient.
- Check for system losses due to pipework, ducting, insulation, etc.
- Check that the control system is working properly.

**4. Can motor losses be minimized?**

- Always specify higher efficiency motors wherever feasible.
- Have a motor replacement plan ready in case of failure.
- If a motor is repaired, ensure that it is a quality repair to reduce losses.
- Avoid the use of oversized motors.
- Check power quality issues such as voltage imbalance, harmonic distortion, or a poor power factor.

**5. Can the load be slowed down?**

- Use variable speed drives (VSDs) wherever feasible.
- Use multiple speed motors where distinct duties exist.
- Optimize the pulley or gear ratio where applicable.

## Outline of Codes for Users of AC Motors and Driven Equipment

### Introduction

Ac motors are inherently efficient, with standard motors above 4 kW and 22 kW having efficiencies above 80% and above 90% respectively. Increasing efficiencies above these 'threshold' values comes at huge costs as it involves the use of better magnetic materials and tighter tolerances which are all the more difficult to achieve in smaller motors, due to dimensional constraints.

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[6] Based off of the checklist in the Good Practice Guide, *Energy Savings With Electric Motors and Drives*, Department of the Environment, Transportation and Regions, UK, 1998.

On the other hand, driven equipment usually have efficiencies in the range 60 to 80% with the mean in the late 60s and early 70 %. It is also possible to select alternative equipment, albeit at a larger capital cost, with higher efficiencies. In the normal course of events, the driving force in selecting equipment is the capital cost, with efficiency playing a limited role.

If a total cost of ownership approach or life-cycle cost criteria is used in equipment selection, it would in most cases result lead to different results. This would lead to a win-win situation as both the owner and the electricity supply authority would save.

As illustrated by table 5, substantial gains can also be achieved in the motor economy through rewinding electric motors. Due to the fact that rewinding forms part of the life-cycle cost, it should also be addressed.

The pursuit of a “code of practice” route will ensure that all stakeholders will benefit from a win-win situation, while avoiding the tendency of finding loopholes as a way of avoiding implementation.

The proposed “code of practice” for “Users of AC Motors and Driven Equipment” should address the following:

5. Scope
6. Financial Modelling Criteria
7. Evaluating System Life-cycle Costs
8. Repair Costs and Procedures.

### 4.2.3 Programmes - Key Programmes Design Issues

This section of the report will describe the key programme design issues facing motor labelling programmes and offer options for a path forward. The issues to be discussed include: Type of Motor, Size of Motor, Governing Body, Mandatory VS Voluntary, Types of Efficiency Labels, Energy Efficiency Levels, and Other Programme Features.

### 4.2.4 Introduction to Motor Labelling Programmes

A comparison of international motor efficiency labelling programmes was undertaken to determine key characteristics and trends in programme design. The analysis of past programmes shows that there are many ways to design a labelling programme for motors, and that a well thought out programme has the potential for substantial savings.

**Type of Motor**

AC motors can be classified in different ways. They can be classified by the number of phases of the electrical supply (generally single-phase or three phase), and by motor technology (e.g. synchronous or induction motors).

**Single-Phase VS Three-Phase**

Three-phase (or polyphase) motors are used in high power applications where a polyphase electricity supply is available. The phase differences between the three phases of the polyphase electrical supply create a rotating electromagnetic field in the motor. Three-phase motors are more common in industrial applications.

**Synchronous VS Induction Motors**

The two most common types of AC motors are synchronous and induction motors. In induction motors a moving magnetic field induces a current to flow in the rotor. All induction motors are characterized by the fact that when no load is applied to the motor, the rotor rotates at a slightly slower rate than the mains frequency. This is because the rotor must "slip" backwards against the moving magnetic field in order to induce any current in the rotor. The slip increases (and the motor speed decreases) as the load on the motor increases. Induction motors are typically used in applications requiring high torque, but little accuracy, such as fans and pumps. In synchronous motors the rotors themselves are magnetized. The rotors in these motors do not require any induced current so they do not slip backward against the mains frequency. Instead, they rotate synchronously with the mains frequency. Because of their highly accurate speed, such motors are usually used to power mechanical clocks, audio turntables, and tape drives. Most motor programmes identified cover three-phase induction motors.

Motor programmes also sometimes differentiate between open and closed motors, and motors with 2, 4, 6, or 8 poles. It is typical for a motor programme to include all of these different configurations within its scope (possibly differentiating between them in cases where energy efficiency levels are specified).

**Size of Motor**

Motors that are smaller than 0.75 kW are not common to industrial applications and are generally not covered by motor programmes. These small motors tend to be sold pre-assembled as part of an integrated unit (e.g. fans, toys). The upper limit of the motor sizes included in efficiency programmes varies from one programme to another. For NEMA in the U.S. and the Mexico FIDE programme the upper limit is 373 kW, in the Australian MEPS programme the upper limit is 186.5 kW and in the EU CEMEP programme the upper limit is 89.5 kW. Motors larger than 373 kW are more rare and would be built on a custom basis according to the specifications of the application.

**Governing Body**

Labelling programmes may be run by government departments, or they may also be administered by a third-party, such as a manufacturer's association or a standards body. There are differing opinions about whether or not buyers view governments as a credible source for 'green' information. While governmental labelling programmes may have funding and support that an independent programme may lack, government control of a labelling programme can introduce policy issues or constraints that do not arise in the case of an independent programme.

Most of the examined motor programmes are implemented by non-government organisation and supported by the government. For example, FIDE, which is a private non-profit organisation, is in charge of the FIDE programme in Mexico. The European Committee of Manufacturers of Electrical Machines and Power Electronics run the CEMEP programme. The National Electrical Manufacturers Association of the US is also a non-government organisation. Contrasting with these three programmes, the MEPS programme in Australia is managed by the National Appliance and Equipment Energy Efficiency Committee, which reports to other government structures and is ultimately directed by the Ministerial Council on Energy.

**Mandatory VS Voluntary**

The policymakers must decide whether the labelling programme should be mandatory or voluntary. NEMA Premium EE Motor Programme, CEMEP programme, and FIDE seal are voluntary programmes. While none of the motor programmes reviewed involved mandatory energy efficiency labelling of motors,[7] there is substantial international experience with mandatory labelling programmes for other types of equipment.

**Types of Efficiency Labels**

There are three different kinds of energy labels in use: endorsement labels, comparative labels, and information only labels.

*Endorsement labels* offer essentially a "seal of approval" that a product meets certain pre-specified criteria. They generally are based on a yes-or-no cutoff, and offer little additional information. Endorsement labelling programmes help consumers distinguish among similar products with a single seal of approval for those products that meet or exceed the established criteria. The NEMA and FIDE programmes from US and Mexico all use this kind of labelling scheme. The European CEMEP programme also uses endorsement labels; however they specify three different endorsement levels.

*Information only labels* provide information on the technical performance of the single labelled product, and offer no simple way to compare energy performance relative to a benchmark or between products. These types of labels are rarely used, as they are not consumer friendly.

*Comparative labels* typically provide standardized information to report on the labelled model's energy performance characteristics and often includes the model's performance as compared to

similar models. These labels allow consumers to compare energy use between all available models in order to make an informed choice.

[7] Although the MEPS programme of Australia is a mandatory programme, it does not involve labelling of motor efficiency.

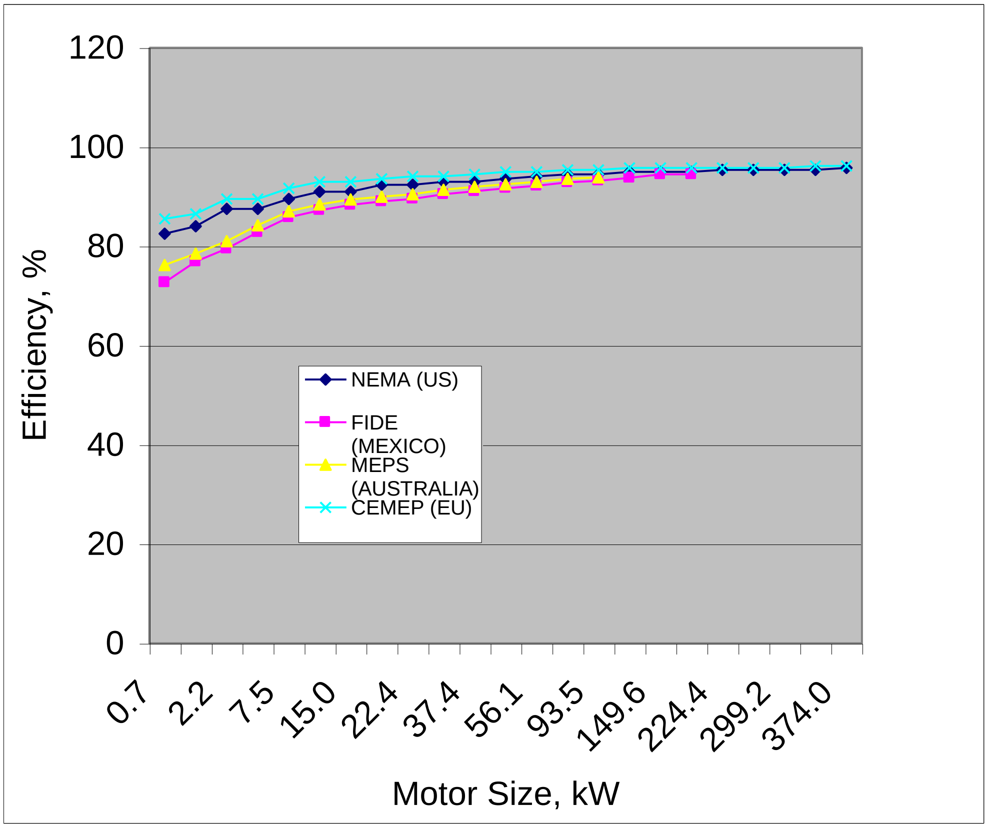
The choice of which of the label scheme to use depends on local consumer knowledge and attitudes. Endorsement labels require the least thinking by the consumer but also provide the least information. Comparative labels provide more information about energy use, if well designed and implemented, and can provide a consistent basis for buyers to consider energy efficiency from one purchase to another. Furthermore, they can provide a clear basis for other market-transforming programmes such as utility demand-side management incentives.

**EE Levels**

Endorsement labels require energy efficiency levels to be defined – the minimum level of efficiency required for the motor to be designated as “energy efficient”. This level might be set at a minimum acceptable level, or at higher levels to indicate “premium” efficiency products. As noted above, a labelling programme could also designate several levels to allow tiered labelling.

Motor programmes with efficiency levels specify different efficiencies depending on the motor size and type. Figure 3 below compares the efficiency levels for four programmes for 4-pole motors. As the table below shows, the NEMA “premium” motor efficiency levels are the most stringent, while the Australian minimum energy performance levels are the least stringent (but note that the Australian levels are used in a mandatory minimum efficiency programme, not as endorsement levels in a labelling programme).

**Figure 3: A Comparison of Motor Efficiency Levels**




For more detailed tables showing the actual efficiency levels for each programme, please see the Summary of Motor Programmes, in Appendix B of the *Summary of International Test Standards, Codes of Practice and Programmes*, submitted June, 2005.

**Other Programme Features (Purchasing Advice, O& M, etc)**

Most motor labelling programmes reviewed offer other resources beyond the labelling alone. Examples include advice on purchasing, operations and maintenance, as well as other tools such as motor solutions software that calculates and compares the life cycle cost of different motor alternatives.

Some programmes offer financial incentives to entice participants to purchase efficient motors. The FIDE programme offers financial incentives for companies that buy electric motors carrying the FIDE seal. For motors between 0.746 kW and 373 kW, a maximum of $48.26/kW is entitled as a reimbursement.

### 4.2.5 Recommendations

Considering the above it is therefore recommended that a holistic and integrated approach be developed for South Africa that does not only consider the motor at rated duty point, but that would consider the motor at its actual operating duty point and would also consider the improvement in the efficiency of the total machine and not only the driving machine.

This would require additional requirements for the motor, such as specifying the minimum efficiency and the maximum "droop" in the efficiency curve and it would require the adoption of a code of practice regarding the optimisation of the motor and load taking due cognisance of the actual application.

As the total life cycle of a motor will in all likelihood contain more than one motor rewind, it is also necessary to address the loss of efficiency during the rewind.

Current labelling requirements do not require sufficient information regarding efficiency. For new motors only the full load efficiency and power factor are normally indicated on the motor label and for rewound motors the efficiency and power factor is not indicated at all on the motor. This makes it very difficult for the plant owner to make informed decisions regarding future motor rewinds and simple design decisions.

The recommended approach is to have a phased approach. The phases are briefly outlined below:

**Phase1:** Institute a mandatory labelling programme through which it becomes mandatory for all motors sold in South Africa to have a certified label which gives the motor efficiency and power factor at full load, 75% load and at 50% load. For rewound motors it is recommended that it becomes mandatory that all rewound motors include an efficiency and power factor test and that at the first rewind of the motor a rewind efficiency data plate be affixed to the motor making provision for at least 5 rewinds and that at each rewind it becomes mandatory for the re-winder to stamp the efficiency and power factor of the motor after the rewind for full load, 75% and 50% load onto the name plate. The third action for the first phase would be to make it illegal to refer to a motor as a high or premium or improved efficiency motor unless it complies with one of the internationally recognised improved efficiency motor programmes.

In conjunction with the above it is recommended that a code of practice be developed for the South African market, which addresses the optimisation and minimisation of life cycle costs for new plant design and operation.

These recommendations would require the following:

- The required legislation
- Modifications to SANS 1804 and SANS 1561

- The development of the required code of practice.

It is also strongly recommended that consideration be given to make these requirements equally applicable to transformers.

**Phase 2:** Develop acceptable minimum efficiency and power factor requirements for standard and improved efficiency motors in the South African context. Once these standards have been accepted by the industry through the SABS Technical Committee, that these standards be introduced on a voluntary basis with the only mandatory requirement being that only motors complying with the minimum requirements for improved efficiency may be named as such.

## 4.3 Non-utility Fossil Fuel Fired Steam-raising Boilers

### 4.3.1 Standards

The standards refer to BS 845 Part 1:1987 and Part 2: 1987 and includes the application of a concise procedure using an indirect method to determine efficiency to within ±2%. This method is convenient for use on thermodynamically simple boiler installations. Part 2 includes a comprehensive procedure using both the direct and indirect methods to determine efficiency to within ±2%. This method is applicable to all boilers generally above 44 kW output. It is relevant and can be applied to South African boiler installations without alterations. The standard describes a method whereby efficiency is determined to a prescribed accuracy. The standard does not prescribe efficiencies of different types of boilers. It is therefore a method of determining efficiency and not a benchmark to determine the relative efficiency of a specific boiler.

### 4.3.2 Codes of Practice

The following provides the basis for measuring boiler plant efficiency and the reduction of energy consumption of boilers. These Codes of Practice can be applied to boiler systems in South Africa without any changes.

**Boiler plant efficiency measurement**

This subsection advocates the testing of boiler efficiency on the following basis:

1) Testing efficiency on continuous basis
2) Installing the correct measuring equipment
3) Calibrating equipment frequently
4) Training operators in the use of efficiency measuring equipment

**Air fuel ratio**

Air fuel ratio is an important operating standard and should be optimized by:

1) Optimizing the specific air fuel ratio
2) Automating the controls which controls the air fuel ratio

3) Adjusting and repairing air fuel controls to run optimally

**Burner and fan system**

The burner and fan systems of a boiler contribute to the efficiency of a boiler and should be in optimum condition:

1) The burner and fan systems should be clean and optimally adjusted
2) All air leaks should be eliminated
3) Change fans to variable speed fans

**Draft control**

Draft control is also an aspect that influences efficiency and should be controlled for maximum efficiency.

**Fire side and water side**

The heat exchange between fire side and water side is important for boiler efficiency and should be optimized by:

1) Cleaning fuel side
2) Installing soot blowers
3) Optimizing soot blowers
4) Cleaning waterside
5) Avoiding leaving water side deposits when deactivating a boiler

**Combustion gas heat transfer and heat recovery**

Energy savings are possible by:

1) Flue gas heat exchanger
2) Economiser
3) Condensing economizer
4) Turbulators

**Condensate, feedwater and water treatment**

Energy can be saved through optimizing condensate, feedwater and water treatment. The following needs to be done:

1) Testing and treating boiler water
2) Using a specialist company for water treatment
3) Installing automatic blowdown control
4) Maximizing condensate return.

## Fuel oil

Fuel oil plays an important cost element in the boiler system and can be optimized by:

1) Choosing the right temperature for the oil
2) Choosing the most economic heat source

## Steam and water leakage

Steam and water leakages are one of the major losses of energy in a steam system. Leakage should be eliminated by:

1) Monitoring boiler water system loss
2) Repairing leaks
3) Using the most efficient steam traps
4) Servicing steam traps regularly.

## Conduction and radiation losses

Energy can be lost through conduction and radiation. The loss should be eliminated by:

1) Insulating all thermal bridges
2) Keeping insulation in good standing
3) Keeping vapour barrier in good standing
4) Insulating hot surfaces

## Efficient low load heating

Most boilers do not run at full capacity and if the load is low, special measures can be instituted to save energy by:

1) Installing a smaller boiler which runs at higher efficiency
2) Installing localized heating where required
3) Using lowest steam pressure required (Wulfinghoff, 1999).

## Recommendations

It is proposed that the following outline to a “code of practice” for “Users of Boilers and Steam Distribution Systems” be addressed:

1. Scope

2. Financial modelling criteria incorporating utility as well as process parameters

3. Evaluating system life-cycle costs
4. Repair costs and procedures
5. Boiler operation and the role of the boiler attendant
6. Boiler safety and statutory boiler inspections
7. Disposal of ash, surface pollution (in addition to air pollution) and blowdown water

The pursuit of a “code of practice” route would ensure that all stakeholders would benefit from a win-win situation, while avoiding the tendency of finding loopholes as a way of avoiding implementation.

### 4.3.3 Programmes

**Introduction to Boiler Programmes**

The study team’s evaluation of international programmes for steam-raising boilers shows that many boiler programmes share the same characteristics. In general, programmes aimed at smaller boilers (residential and small commercial) will specify minimum energy efficiency requirements while programmes aimed at larger, industrial boilers are more comprehensive and cover the whole steam system.

**Key Programme Design Issues**

This section of the report will describe the key programme design issues facing boiler programmes and offer options for a path forward. The issues to be discussed include: Fuel Type, Size of Boiler, Low-Pressure VS High-Pressure, Governing Body, Mandatory VS Voluntary, Specifying Minimum Efficiency Requirements, and Other Boiler Programme Features.

**Fuel Type**

Fuel types for boilers can be classified into four general categories: Gaseous fuels, liquid fuels, solid fossil fuels, and all other solid fuels. Each of these fuel categories has characteristics that will affect efficiency and with it, programme design. Gaseous fuels, for instance, are the cleanest burning, whereas liquid and solid fuels will require more maintenance to ensure that the burners operate at peak efficiency. Biomass fuels have a high moisture content, which can also affect efficiency. Table 6 below compares typical full-load and low-load efficiencies of various fuels.

Table 6 - Typical full-load and low-load efficiencies of various fuels

| Fuel Type | Full-Load Efficiency | Low-Load Efficiency |
|---|---|---|
| Coal | 85% | 75% |
| Oil | 80% | 72% |
| Gas | 75% | 70% |
| Biomass | 70% | 60% |

Of the two programmes summarized in the *Summary of International Test Standards, Codes of Practice, and Programmes* project deliverable, the Canadian Energy Efficiency Regulations applies to gas and oil-fired boilers, while the Express Efficiency Program in the United States specifies a blanket efficiency applicable to all boiler fuel types.

**Size of Boiler**

Boilers can be broadly classified into four size categories: Less than 2,930 kW, 2,930 – 29,300 kW, 29,300 – 89,700 KW and greater than 89,700 KW. Boilers less than 10 KW are small units that are typically purchased off the shelf. These units are typically not used in industrial applications. Boilers from 2,930 – 29,300 KW tend to be liquid or gas fuelled, while boilers from 29,300 – 89,700 KW are made for all types of fuels. Boilers larger than 89,700 KW are more common in utility applications. These large units are more rare and are custom made for specific applications. Boiler programmes will typically not include units over 89,700 KW.

**Low-Pressure VS High-Pressure**

Boilers can be specified as either low-pressure (under 5.2 x $10^5$ N/$m^2$g) or high-pressure (over 5.2 x $10^5$ N/$m^2$g). Low-pressure units are typically smaller with standard, off-the-shelf designs. High-pressure boilers are more common in industrial applications. These units are typically custom built to the application. Low-pressure systems can be regulated with minimum energy performance standards; however, it is much more difficult to apply standards to high-pressure boilers because each one is unique and specific to its application.

**Governing Body**

The same broad issues apply in administering boiler programmes as in administering motor programmes. However, mandatory minimum efficiency regulations by definition are the responsibility of government. Government may designate a professional association or other independent party to administer elements or make contributions to the programme (e.g. ASHRAE in the United States).

**Mandatory VS Voluntary**

Boiler efficiency programmes can be mandatory or voluntary; however for larger boilers in particular the voluntary approach predominates. In part this may be due to industry opposition to mandatory alternatives, and greater industry acceptance of programmes that demonstrate the benefits of having an efficient boiler plant.

In addition, mandatory programmes by necessity must be very specific in terms of scope. In order to specify a mandatory efficiency the programme must be very detailed when describing what the standard applies to (e.g. coal-fired, steam-raising fire-tube units from 100 – 300 KW must have an efficiency above a certain value). Voluntary programmes can be much more general, and can apply to a broader range of systems. For example, any industry with any type of boiler plant would be eligible to apply for a programme that offered a boiler plant audit.

**Specifying Minimum Efficiency Requirements**

Minimum efficiency levels for boilers are regulated in Canada and the United States for boilers under 300 KW. Minimum efficiency requirements are also used in some programs, such as the Express Efficiency Program, to specify levels for financial incentives. For larger boilers, however, international boiler programmes are putting less emphasis on specifying minimum efficiency levels and more on designing a holistic approach that looks at measures to improve efficiency in all aspects of the boiler system.

The rationale for moving away from simply specifying a minimum efficiency is that in industrial applications boilers are selected based on many criteria that will affect efficiency, such as the application, fuel availability, cost, etc. In the face of all of these issues, applying a blanket prescriptive approach to minimum efficiency can lead to poor decisions in the long run. For example, biomass boilers will have an efficiency that is inherently lower than coal; however in some applications biomass may be the preferred approach (from an environmental perspective, for instance).

Putting too much of a focus on the nameplate efficiency of a boiler can also be misleading, and will not yield the same benefits as a comprehensive systems approach. The efficiency gains that can be realized through specifying a minimum efficiency unit are modest compared to the gains possible through a system audit. For example, specifying a minimum efficiency may ensure that an 80% efficient boiler is chosen over a 76% efficient boiler, offering a 5% improvement. Results from the SteamSaver Program undertaken by Enbridge (a large gas utility in Canada) indicate that a boiler plant audit will save on average 12%, and a steam trap audit will save an additional 8% in addition[8]. For another example, consider that more energy would be lost from an efficient boiler that is over-sized than from an inefficient, properly sized boiler.

**Other Boiler Programme Features**

Boiler programmes may also feature some or all of the following:

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[8] Personal Communications, Bob Griffin, Enbridge SteamSaver Program.

1. Resources and information to help make the business case for an energy efficient boiler plant. Resources can include publications on energy efficiency, best practices, case studies and software tools that help to calculate the potential savings from purchasing an efficient boiler.
2. Subsidies to cover part of the cost of a boiler plant audit to identify energy saving projects, their cost and payback.
3. Incentives to cover energy efficiency features in new installations. Features can include a more efficient boiler, economizers, blow-down heat recovery, “right-sizing” the boiler and installing meters.
4. Subsidies to cover part of the cost of a steam-trap survey to identify faulty or blocked traps.
5. Incentives for doing a combustion tune-up.
6. Incentives for metering and energy management.
7. Insulation survey to identify costs and payback of adding additional insulation.

## 4.4 Insulated Pipes

### 4.4.1 Standards

The standards used in South Africa are international and should be adopted.

### 4.4.2 Codes of Practice

The SABS advised that since insulation pipe was not constructed on site, any technical regulation with respect to pipeline insulation has to be an installation code of practice and maintenance code of practice. The installation code of practice and maintenance code of practice presented below were gleaned from Sasol’s Insulation – Hot Service and Personnel Protection – which is recommended for adoption with modification to become thermal performance based as opposed to being based on thickness.

**Installation Code of Practice**

*Removable Reusable Thermal Insulation Jackets*

The jacket manufacturer shall provide an installation drawing for large covers, which consist of multiple pieces. Each jacket piece shall be labelled with a part number on the installation drawing, and the part number shall be included on the jacket identification tag. However, unless specifically requested for replacement purposes, installation drawings are not required with flange and valve covers

*Quality Control*

Scans for hotspot and proper installation shall be submitted to the company by the contractor, after the system is put into production and the insulation activities signed off as completed; if the quality standard as specified in the specific contract is met. Any additional requirements for testing and verification of quality should have prior agreement to the commencement of the insulation work. Should any deviation from the code of practice be found during agreed guaranteed period, the insulation contractor shall rectify same free of charge.

**Maintenance Code of Practice**

*Personnel Protection*

In process areas operating at a temperature of 65°C and higher Personnel protection shall be provided on uninsulated piping and equipment operating at a temperature of 65°C and higher when, due to their location, they present a safety hazard to operating personnel.

Further, shields and guards may be used in lieu of insulation when dissipation of heat is desirable. For personnel protection in offsite areas, no insulation is normally required; but it should be considered for locations with frequent maintenance activities.

*Removable Reusable Thermal Insulation Jackets*

For insulated items requiring scheduled inspections or regular maintenance**,** removable reusable flexible insulation jackets should be considered. The following are examples of typical applications:

- Flanges and flanged valves.
- Piping through the first valve from heat exchangers, pumps, and turbines, provided the valve is not more than 4600 mm (15 feet) from the piece of equipment.
- Vessel nozzle flanges and nozzle necks up to the permanent insulation.
- Vessel manways and inspection openings.
- Removable heat exchanger channels, channel covers, and shell covers.
- Pumps, turbines, and compressors.

*Thermal Insulation Application*

Removable reusable insulation shall be provided for items such as valves and flanges that require regular maintenance service. Insulation thickness inside the box or flexible jacket shall be at least equal to adjacent pipe insulation**.**

*Weatherproofing Application to Piping*

Items such as valves and flanges, which require regular maintenance service, shall be provided with removable or flexible insulation covers, when insulated for exposure protection insulation is specified. Insulation thickness shall be equal to adjacent pipe insulation**.**

**Recommendations**

The Code of Practice of Sasol should be adopted, but modified to reflect thermal performance based instead of being thickness based.

### 4.4.3 Programmes

There are no international and domestic programmes for insulated pipes.

[3] Personal Communications, Bob Griffin, Enbridge SteamSaver Program.

# Appendix A
## International Scans

## 1. AC Motors

### 1.1 Standards

1.1.1 Impact Assessment for Minimum Energy Performance Standards for Electric Motors (New Zealand / Australia)
1.1.2 Energy Efficiency Test Methods for Three Phase Induction Motors (Canada)
1.1.3 Energy Efficiency Test Methods for Single and Three Phase Small Motors (Canada)
1.1.4 Rating and Performance Methods for losses and Efficiency of rotating electrical machinery form tests – Polyphase Induction Motors (Europe)
1.1.5 Rating and Performance Methods for losses and Efficiency of rotating electrical machinery form tests – Synchronous machines (Europe)

### 1.2 Codes of Practice

1.2.1 Energy Savings with Electric Motors and Drives (UK)
1.2.2 How to buy an Energy Efficient Electric Motor (US)

### 1.3 Programmes

1.3.1 FIDE Seal (Fideicomiso para el Ahorro de Energia Electrica) (Mexico)
1.3.2 MEPS Programme (Minimum Energy Performance Standards) (Australia)
1.3.3 Voluntary Agreement (CEMEP) (European Union)
1.3.4 NEMA Premium Efficiency Electric Motors Program (US)

## 2.Boilers

### 2.1 Standards

### 2.2 Codes of Practice

2.2.1 Economic Use of a Coal-Fired Boiler Plant (UK)
2.2.2 Energy Efficient Operation of Industrial Boiler Plant (UK)
2.2.3 Energy Efficiency Manual (US)
2.2.4 How to buy an Energy- Efficient Commercial Boiler (US)

### 2.3 Programmes

2.3.1 Energy efficiency Regulations (Canada)
2.3.2 Express Efficiency Program (US)

## 3.Insulated Pipes

### 3.1 Standards

### 3.2 Codes of Practice

3.2.1 The Economic Thickness of Insulation for Hot Pipes (UK)
3.2.2 Process Plant Insulation (UK)
3.2.3 Economic Thickness of Insulation (US)

### 3.3 Programmes

# 1. Technology: AC Motors
## 1.1 Category: Standards
### 1.1.1 Title: Impact Assessment for Minimum Energy performance Standards for Electric Motors
### Region: New Zealand/ Australia

**Background** This report provides an impact assessment for proposed changes to minimum energy performance standards (MEPS) for motors falling within the scope of the joint Australian New Zealand Standard AS/NZS 1359.5. These are three-phase induction motors with output ratings from 0.73 kW up to but not including 185 kWh. They are used in a wide range of applications, including airconditioning and ventilation systems, pumps, mechanical drives and compressors. The new regulation would take effect from 2006.

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**Scope** The assessment is based on an economic analysis of the New Zealand electric motor industry and evaluates the compliance costs to the industry of meeting the more stringent MEPS levels. The proposed MEPS level will reduce electricity losses by 10 - 20% for most motors covered by AS/NZS 1359.5. Overall 70% of existing motors within its scope will require modifications to meet the more stringent MEPS levels.

**Standard Description:** The proposal is an element of the National Energy Efficiency and Conservation Strategy (NEECS). NEECS is part of New Zealand's Climate Change Policy, targeting the energy efficiency of consumer appliances, industrial and commercial equipment. The energy used by motors accounted for about 7.6% of New Zealand's gross greenhouse emissions in 2000. However the proposed efficiency measures can only reduce the heat and other energy losses within the motor itself, since the rest of the energy is effectively used by the various types of machinery that are driven by motors. Motor losses account for about 0.9% of gross emissions.

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**Objective**: The Energy Efficiency and Conservation Authority (EECA) is responsible for implementing NEECS, coordinating its activities with Australia via the joint Australia/New Zealand National Appliance and Equipment Energy Efficiency Committee (NAEEEC). The proposal would substantially complete EECA's strategy for motors, which includes energy labeling and information activities, alignment with international test procedures, and preliminary Minimum Energy Performance Standard (MEPS) that have applied to three-phase motors since 2002. NAEEEC has adopted a policy of adopting 'world's best regulatory practice'. This involves setting MEPS at levels broadly comparable with the most demanding MEPS adopted by trading partners of Australia and New Zealand, but following that lead with a lag of several years. Canada and the United States provide the lead for motors, having adopted comparable standards in 1997. Given New Zealand's status as an importer of electrical appliances and equipment, it is considered inappropriate to take the lead or to otherwise adopt standards that put New Zealand significantly at odds with its trading partners.

The actual efficiency benchmarks proposed correspond closely to the European Union's 'Efficiency 1' or EFF1 level. This is appropriate since, like Europe and many of New Zealand's trading partners in Asia, New Zealand's power system operates on a frequency of 50 Hz, and traditional suppliers have strong European connections. North America is on 60Hz. Hence, while the proposal is to follow the North American lead in mandating high efficiency, the actual benchmarks are European.

**Proposal:** The proposed measures will require about 70% of existing models to be withdrawn from the market. Motor losses will need to be reduced by 10-20% for most motors that are borderline compliant with the existing 2002 MEPS, with larger reductions for some smaller motors.

**Assessment:** Nationally, the proposed regulation is expected to deliver net benefits of $34 million in present value terms and a benefit/cost ratio of 2.2. A significant investment is required from users, costed at $27 million in present value terms. There will also be once-off costs of adjustment for suppliers, put at $2 million. The additional cost to government is virtually zero, since the effect of the regulation is to strengthen a MEPS regime that is already in place.
The balance of benefits and costs to users is variable, depending on the types and size of motors that they use and the intensity of use. For example, the returns are markedly higher in the industrial sector than in the commercial sector, reflecting the longer hours of operation in the former.

The overall assessment depends critically on the relationship between the percentage reduction in motor losses, and the percentage increase in the cost of motors that deliver those reductions. The report draws on a number of studies to assess this tradeoff. While suppliers have suggested that the cost effects have been underestimated, the proposal remains cost-effective under their alternative estimates of cost impacts.

**Other options:** Minimum levels of energy efficiency could be further increased. However New Zealand would then be setting the pace for the rest of the world and the inherent risks are unacceptable. In particular, the empirical basis for assessing further increases is minimal; there would be strong supplier resistance; and significant gaps would appear in the range of products that are available to New Zealand. New Zealand is a small market, relying completely on imports, and there is no prospect that new models would be developed to meet specific New Zealand requirements.

The option of implementing MEPS by voluntary agreement was also considered, given that the European Union has adopted the voluntary approach. However that model is not a viable alternative to the proposed regulation. In particular, the European agreement is much less ambitious compared with the level and scope of the efficiencies that will be required in New Zealand.

**Recommendations:** It is recommended that New Zealand implement the proposed mandatory minimum energy performance standards.

## 1.1.2 Title: Energy Efficiency Test Methods for Three Phase Induction Motors
## Region: Canada
## Technology: AC Motors Category: Standards

**Background**
This Standard was prepared by the Subcommittee on the Performance of Three-Phase Induction Motors, under the jurisdiction of the Technical Committee on Industrial Equipment and the Strategic Steering Committee on Performance, Energy Efficiency, and Renewables and has been formally approved by the Technical Committee.
The purpose of this Standard is to specify test methods for three-phase induction motors to determine energy efficiency in support of an informative programme. This Standard is written using metric units of measurement in accordance with the International System of Units (SI).

**Scope**
This Standard specifies the test methods to be used in measuring the energy efficiency of three-phase induction motors, in support of a consumer/user information programme.
The method of determining and marking the nominal efficiency values is also specified.

***Note:*** *The test methods contained in this Standard are not limited to specific types of motors, but, where this Standard is referenced in regional legislation, some specific motor types may be included or excluded from the regulations. Legislated requirements for a given jurisdiction supersede the requirements of this Standard and neither should be used without the other.*

This Standard applies to three-phase induction motors rated 0.746 kW at 1800 rpm (or equivalent*) and greater.
**An equivalent motor is a motor with the same torque output but with different kilowatt output and speed.*

The test methods detailed in this Standard for three-phase induction motors are categorized in relation to specific kilowatt ratings according to the following:

| Motor | Test methods |
|---|---|
| 0.746 to 37.5 kW at 1800 rpm or equivalent | (1) |
| Over 37.5 to 150 kW at 1800 rpm or equivalent | (1) or (2) |
| Over 150 kW at 1800 rpm or equivalent | (1), (2), or (3) |

**General Requirements**

The construction of induction motors to be tested to this Standard shall comply with the following CSA Standards:
(a) C22.2 No. 100;
(b) C22.2 No. 77 (where applicable); and
(c) C22.2 No. 145: Class I, Groups C and D; Class II, Groups E, F, and G (where applicable).

**General Test Requirements — Electrical Measurements**

(a)Unit of Measure
All quantities are root-mean-square (rms) values unless otherwise indicated.

(b) Power Supply
The source of supply should approach sine waveform and should provide balanced phase voltages. The
voltage waveform deviation factor shall not exceed 10%

(c) Frequency
Rapid changes in frequency shall not be tolerated on input-output tests, since such variations are transmitted to the output measuring devices. Any departure from rated frequency directly affects the efficiency obtained by using Test Method (1). The frequency shall be maintained within ±0.5% of the value required for the test being conducted, unless otherwise specified

(d) Instrument Selection
The instruments used in measurements shall be selected to give readings well up on the scale, that is, where a fraction of a division is easily estimated and where such a fraction is a small percentage of the value read. The indicating instrument shall be calibrated to limit errors to no greater than ±0.5% of full-scale deflection and be traceable to national standards within the last 12 months
Digital readout or computer printout instruments capable of the equivalent accuracy of measurement may be used.

(e) Instrument Transformers
When current and potential instrument transformers are used, corrections shall be made, when necessary, for ratio errors in voltage and current measurements, and for ratio and phase-angle errors in power measurements. The errors of instrument transformers shall be no greater
than 0.5%.

(f) Voltage
The voltages shall be read at the motor terminals. Tests shall be made only when the voltage unbalance and the variation from rated voltage does not exceed ±0.5%. The percent of voltage unbalance equals 100 times the maximum voltage deviation from the average voltage divided by the average voltage

(g) Current
The line currents to each phase of the motor shall be measured. If the line currents are unequal, the arithmetic average value shall be used in calculating motor performance from the test data.

(h) Power Input
Power input to a three-phase motor may be measured by using two single-phase wattmeters connected as in the two-wattmeter method or one polyphase wattmeter or three single-phase wattmeters. The total power read on a wattmeter shall be reduced by the amount of the I2R loss in the voltage circuits of the instruments whenever this loss is a measurable portion of the total power read.

(i) Power Output
Mechanical power output measurements shall be made with accuracy. If dynamometer measurements are used, coupling and bearing friction plus inertia errors shall be compensated for Properly sized dynamometers shall be used, such that the coupling and friction losses of the

dynamometer, measured at the rated speed of the motor being tested, shall not be greater than 15% of the rated output of the motor being tested. Calibrated shafts with torque deflection may be used to determine power output.

(j) Performance Requirements
Motors required to meet the minimum performance requirements of this Standard shall meet or exceed the nominal efficiency values specified in Tables 2 and 2A, at either 75% or 100% of the rated load, when tested in accordance with Test Method 1. These requirements are dependent on legislation, and may vary from region to region. Users should consult the authority having jurisdiction.

<u>Test Methods</u>
The following three different test methods have been used to determine the energy efficiency, namely, (a) Input-Output Method with Indirect Measurement of the Stray-Load Loss and Direct Measurement of the Stator Winding (I2R), Rotor Winding (I2R), Core, and Windage-Friction Losses,
(b) Input Measurement Method with Direct Measurement of All Losses
(c) Equivalent Circuit Calculations with Direct Measurement of Core Loss, Windage-Friction Loss, and Stray-Load Loss

<u>Marking</u>
The nominal efficiency at 100% of the rated load (full load) shall be marked on the motor in accordance with Clause (i) below. Where 75% of the rated load is used to meet the requirements of Clause (j) under General Tests Requirements, then the nominal efficiency at this load point shall also be marked.

(a) Determining Nominal Efficiency
The nominal efficiency value shall be selected from Column A in Table 3 when the motor operates at its rated voltage, frequency, and related load point, and shall be not greater than the average efficiency of a large majority of the population of motors of the same design. The actual motor efficiency value shall be not less than the associated minimum value specified in Column B.

## Recommendation

This standard discusses test methods used in order to determine the energy efficiency of a three-phase induction motor. It is further discussed that the actual motor efficiency shall not be less than the minimum value specified in the Column B of Table 3 below. However, this only serves as a guideline to determine whether a particular motor is energy efficient or not. Therefore, only test methods 1 and 2 briefly discussed above shall be applicable to the South African Industry.

**Table 1**

Rated Full-Load Temperature

| **Insulation** | **Temperature, EC** |
|---|---|
| A 75 | 75 |
| B 95 | 95 |
| F 115 | 115 |
| H 130 | 130 |

| Table 3: Nominal Efficiency Tolerance | |
|---|---|
| **Column A Nominal Efficiency** | **Column B Minimum Efficiency Based on 20% loss** |
| 99.0 | 98.8 |
| 98.9 | 98.7 |
| 98.8 | 98.6 |
| 98.7 | 98.5 |
| 98.6 | 98.4 |
| 98.5 | 98.2 |
| 98.4 | 98.0 |
| 98.2 | 97.8 |
| 98.0 | 97.6 |
| 97.8 | 97.4 |
| 97.6 | 97.1 |
| 97.4 | 96.8 |
| 97.1 | 96.5 |
| 96.8 | 96.2 |
| 96.5 | 95.8 |
| 96.2 | 95.4 |
| 95.8 | 95.0 |
| 95.4 | 94.5 |
| 95.0 | 94.1 |
| 94.5 | 93.6 |
| 94.1 | 93.0 |
| 93.6 | 92.4 |
| 93.0 | 91.7 |
| 92.4 | 91.0 |
| 91.7 | 90.2 |
| 91.0 | 89.5 |
| 90.2 | 88.5 |
| 89.5 | 87.5 |
| 88.5 | 86.5 |
| 87.5 | 85.5 |
| 86.5 | 84.0 |
| 85.5 | 82.5 |
| 84.0 | 81.5 |
| 82.5 | 80.0 |
| 81.5 | 78.5 |
| 80.0 | 77.0 |
| 78.5 | 75.5 |
| 77.0 | 74.0 |
| 75.5 | 72.0 |
| 74.0 | 70.0 |
| 72.0 | 68.0 |
| 70.0 | 66.0 |
| 68.0 | 64.0 |

| Table 3: Nominal Efficiency Tolerance | |
|---|---|
| **Column A Nominal Efficiency** | **Column B Minimum Efficiency Based on 20% loss** |
| 66.0 | 62.0 |
| 64.0 | 59.5 |

## 1.1.3 Title: Energy Efficiency Test Methods for Single and Three Phase Small Motors
## Region: Canada
## Technology: AC Motors Category: Standards

**Background**

This standard was prepared by the Sub Committee on Small motors, under the jurisdiction of the Technical Committee on Industrial Equipment and the Standards Steering Committee on the performance of Electrical Products, and was formally approved by these committees. It has been approved as National Standard of Canada by the Standards Council of Canada. The purpose of this Standard is to specify test methods for small horsepower single phase motors to determine their energy efficiency

**Scope**

This standard specifies the test methods to be used in measuring the energy efficiency of small single phase and three phase rotating motors. This Standard includes but is not limited to the following motor types:
(a) Capacitor (permanent – split)
(b) Capacitor (capacitor-start, capacitor-run)
(c) Capacitor – start
(d) Split phase
(e) Split phase start, capacitor run
(f) Shaded pole
(g) Repulsion
(h) Repulsion-induction
(i) Repulsion-start-induction-run
(j) Reluctance
(k) Universal
(l) Dc (these type of motors include an integral converter that operates on alternating current)
(m) Permanent magnet
(n) Brushless Dc
(o) Inverter driven motors
(p) Polyphase induction motors
In addition, this standard applies to three phase motors rated up to 0.746kW at 1800r/min and single phase motors rated up to 7.5kW.

**General Requirements**
The construction of motors to be tested to this Standard shall comply with CSA Standard C22.2 No 100.

## General Test Requirements

All quantities shall be root mean square (rms) values unless otherwise indicated.

*(a) Power Supply*

The source of power supply should closely approach sine waveform and, for testing of three phase motors, shall provide balanced phase voltages.

*(b) Frequency*

Rapid changes in frequency shall not be permitted on input-output tests, as such variations are transmitted to the output measuring devices.

(c) Instrument Selection
The indicating instruments used in measurements shall be selected to give indications well up on the scale.

(d) Instrument Transformers
When current and potential instrument transformers are used, corrections shall be made when necessary for ratio errors in voltage and current measurements.

(e) Voltage
The voltage shall be read at line connections

(f) Current
Line current to the motor and any controlling or conditioning equipment shall be measured at the line connections.

(g) Power
Power input shall be measured at the line connections

(h) Mechanical Power
Mechanical power output measurements shall be made with the greatest of care and accuracy.

(i) Dynamometer Sizing
If dynamometer measurements are used, a correction factor shall be calculated to allow for coupling and bearing friction and inertia errors.

(j) Ventilation
Air over motors shall be supplied with sufficient ventilation during the test to maintain a 75±5°C winding temperature at full load.

## Test Method

All testing shall be performed in room ambient temperature. Nevertheless, the following procedure is applied when determining efficiency of the motor.
(i) Install thermocouples in the motor in the winding end heads.
(ii) Apply rated voltage, frequency, and full load to the motor until thermal equilibrium is reached.
(iii) Measure and record the data prior to changing the motor load, so as to record observed torque, input power and speed in r/min.

(iv) Adjust the dynamometer to the minimum dynamometer load and operate the motor with rated voltage and frequency applied until the input power is stabilised, so as to record the observed torque output.
(v) Disconnect the dynamometer from the motor and with rated voltage and frequency applied, so as to measure the input power at no load.
(vi) Calculate the dynamometer correction factor and finally calculate the efficiency using the following equation:

*Efficiency* = $(T_{measured} + T_{dynoCF})/ (9549 \times P_{in})$
Where,
$T_{measured}$ = measured torque
$T_{dynoCF}$ = dynamometer correction factor
$P_{in}$ = input power
r/min = motor speed

**Marking**

The nominal efficiency at full load shall be marked on the motor in accordance with Column A of Table 1 (as depicted overleaf), where the actual motor efficiency value shall not be less than the associated minimum value specified in Column B.

**Recommendation**

This standard discusses a test method used in order to determine the efficiency of single phase or three phase motors. The actual motor efficiency shall not be less than the minimum value specified in the Column B of Table1 below. However, this only serves as a guideline to determine whether a particular motor is energy efficient or not. Therefore, the test method briefly discussed above, shall be applicable to the South African Industry.

**Table 1**
**Nominal Efficiency Tolerance**
(See Clause 6.)

| Column A Nominal efficiency | Column B Minimum efficiency | Column A Nominal efficiency | Column B Minimum efficiency |
|---|---|---|---|
| 99.0 | 98.9 | 80.0 | 77.0 |
| 98.9 | 98.8 | 78.5 | 75.5 |
| 98.8 | 98.6 | 77.0 | 74.0 |
| 98.7 | 98.5 | 75.5 | 72.0 |
| 98.6 | 98.4 | 74.0 | 70.0 |
| 98.5 | 98.2 | 72.0 | 68.0 |
| 98.4 | 98.0 | 70.0 | 66.0 |
| 98.2 | 97.8 | 68.0 | 64.0 |
| 98.0 | 97.6 | 66.0 | 62.0 |
| 97.8 | 97.4 | 64.0 | 59.5 |
| 97.6 | 97.1 | 62.0 | 57.5 |
| 97.4 | 96.8 | 59.5 | 55.0 |
| 97.1 | 96.5 | 57.5 | 52.5 |
| 96.8 | 96.2 | 55.0 | 50.5 |
| 96.5 | 95.8 | 52.5 | 48.0 |
| 96.2 | 95.4 | 50.5 | 45.5 |
| 95.8 | 95.0 | 48.0 | 43.0 |
| 95.4 | 94.5 | 45.5 | 40.5 |
| 95.0 | 94.1 | 43.0 | 38.0 |
| 94.5 | 93.6 | 40.5 | 35.5 |
| 94.1 | 93.0 | 38.0 | 33.0 |
| 93.6 | 92.4 | 35.5 | 30.5 |
| 93.0 | 91.7 | 33.0 | 28.0 |
| 92.4 | 91.0 | 30.5 | 25.5 |
| 91.7 | 90.2 | 28.0 | 23.0 |
| 91.0 | 89.5 | 25.5 | 20.5 |
| 90.2 | 88.5 | 23.0 | 18.0 |
| 89.5 | 87.5 | 20.5 | 15.5 |
| 88.5 | 86.5 | 18.0 | 13.0 |
| 87.5 | 85.5 | 15.5 | 10.5 |
| 86.5 | 84.0 | 13.0 | 8.0 |
| 85.5 | 82.5 | 10.5 | 5.5 |
| 84.0 | 81.5 | | |
| 82.5 | 80.0 | | |
| 81.5 | 78.5 | | |

## 1.1.4 Title: Rating and Performance: Methods for determining losses and efficiency of rotating electrical machinery form tests – Polyphase Induction Motors
## Region: Europe
## Technology: AC Motors Category: Standards

**Background**

The IEC technical committee 2 has prepared this standard: Rotating machinery. Furthermore, it has been drafted in accordance with the ISO/IEC Directives, Part 2. Furthermore it is intended to establish methods of determining efficiencies from tests, and also to specify methods of obtaining particular losses when these are required for other purposes

**Scope**

This standard applies to dc machines and to a.c synchronous and induction machines of all sizes within the scope o IEC Publications 34-1. The principles can, however, be applied to other types of machines such as rotary convertors, a.c commutator motors and single phase induction motors for which other methods of determining losses are generally used.
*Note*: Emphasis will be put on a.c synchronous and induction machines only

**Losses**

The total losses may be taken as the sum of the following component losses:

(a) Constant losses, are as follows,
(i) losses in active iron, due to friction
(ii) and total windage loss in the machine

(b) Load losses, are as follows
(i) $I^2R$ losses in primary windings,
(ii) $I^2R$ losses in secondary windings
(iii) and electrical losses in brushes (if any)

(c) Additional load losses, which are losses introduced by load in active iron and other metal parts other than the conductors and Eddy current losses in primary or secondary winding conductors caused by current dependent flux pulsation

**Determination of Efficiency**

(a) The efficiency can be calculated from the total losses, which are assumed to be the summation of the losses obtained in the following manner:
(i) For constant losses, efficiency can be calculated by performing the following three different tests, namely,

1 No-load test at rated voltage,
2.Calibrated machine test,
3 No-load tests at variable voltage.

(ii) For load losses, two test, i.e. load test and load test at reduced voltage (applicable to cage rotors) shall be used together with calculated values to determine the efficiency. The calculated values are as follows, resistance, current and temperature.

The total loss measurement shall be used to determined efficiency. This shall be achieved by performing the following tests:
(i) Braking Test
(ii) Calibrated machine test
(iii) Mechanical back-to-back test
(iv) Electrical back-to-back test

**Test Methods**

Tests can be grouped in one of the three following categories:
(a) Input-output measurement on single machine
(b) Input and output measurement on two machines connected back-to-back.
(c) Measurement of the actual loss in a machine under a particular condition.

Nevertheless, the following tests shall be done:
(i) Calibrated machine test
(ii) Zero power factor test
(iii) Retardation method
(iv) Electrical back-to-back test
(v) Calorimetric test

**Recommendation**

This standard discusses test methods used to determine constant and load losses that in turn, are used to determine efficiency of polyphase motors. All the tests briefly discussed above shall be applicable to the South African Industry.

## 1.1.5 Title: Rating and Performance: Methods for determining losses and efficiency of rotating electrical machinery form tests – Synchronous machines
## Region: Europe
## Technology: AC Motors Category: Standards

**Background**

The IEC technical committee 2 has prepared this standard: Rotating machinery. Furthermore, it has been drafted in accordance with the ISO/IEC Directives, Part 2. Furthermore it is intended to establish methods of determining efficiencies from tests, and also to specify methods of obtaining particular losses when these are required for other purposes

**Scope**

This standard applies to dc machines and to a.c synchronous and induction machines of all sizes within the scope o IEC Publications 34-1. The principles can, however, be applied to other types of machines such as rotary convertors, a.c commutator motors and single phase induction motors for which other methods of determining losses are generally used.
*Note*: Emphasis will be put on a.c synchronous and induction machines only.

**Losses**

The total losses may be taken as the sum of the following component losses:

(a) Constant losses are as follows,
(i) Losses in active iron, an additional no load losses in other metal parts.
(ii)Losses due to friction (bearings and brushes), not including any losses in a separate lubrication system.
(iii) The total windage loss in the machine including power absorbed in integral fans, and in auxiliary machines.

(b) Load losses are as follows
(i) $I^2R$ losses in primary windings,
(ii) $I^2R$ losses in starting or damping windings.
(iii) and electrical losses in brushes (if any)

(c) Excitation circuit losses are as follows
(i) $I^2R$ losses in the excitation windings and in the excitation rheostats.
(ii) All the losses in an exciter mechanically driven from the main shaft which forms part of the complete unit.
(iii) The electrical losses in brushes

(d) Additional load losses, are as follows:
(i) Losses introduced by load in active iron and other metal parts other than the conductors and Eddy (ii) current losses in primary winding conductors.

**Determination of Efficiency**

(a) The efficiency can be calculated from the total losses that are assumed to be the summation of the losses obtained in the following manner: The losses that make up the total losses are as follows:
(i) Excitation circuit losses
(ii) Constant losses.
For these losses, the following test shall be used to determine efficiency, namely,

Unity power factor test at rated voltage
Open circuit test
Retardation test
Unity power factor test at variable voltage
Variable cooling gas density test.
Calorimetric test
Additional load losses

(b) The total loss measurement shall be used to determined efficiency. This shall be achieved by performing the following tests:
(i) Braking Test
(ii) Calibrated machine test
(iii) Mechanical back-to-back test
(iv) Electrical back-to-back test
(v) Zero power factor test

**Test Methods**

Tests can be grouped in one of the three following categories:
(a) Input-output measurement on single machine
(b) Input and output measurement on two machines connected back-to-back.
(c) Measurement of the actual loss in a machine under a particular condition.

Nevertheless, the following tests shall be done:
(i) Calibrated machine test
(ii) Zero power factor test
(iii) Retardation method
(iv) Electrical back-to-back test
(v) Calorimetric test

**Recommendation**

This standard discusses test methods used to determine constant and load losses that in turn, are used to determine energy efficiency of synchronous motors. All the tests briefly discussed above shall be applicable to the South African Industry

## 1.2 Category: Code of Practice
## 1.2.1 Title: Energy Savings with Electric Motors and Drives
## Region: United Kingdom
## Technology: AC Motors

**Background:** This Code of Practice is part of a series produced by the Government under the Energy Efficiency Best Practice Programme. The aim of the programme is to advance and spread good practice in energy efficiency by providing independent, authoritative advice and information on good energy efficiency practices.

**Scope:** AC induction motors. The code is intended for small industrial managers involved in the design/selection/operation/replacement decisions regarding motors.

**Basic Principles:** The code states that the three key energy efficiency measures for reducing power losses from AC induction motors are using higher efficiency motors, careful motor repair, and sizing motors correctly. New motors can be made that are more efficient at little incremental cost by the use of new materials, better design and more attention to the manufacturing process.

**Design and Selection:** The code offers advice on motor sizing and purchasing. It describes all the factors that need to be considered when making a repair/replace decision. The code details a systematic action plan that should be used to inform the repair/replace decision. The guide also describes the benefits of multiple speed motors and motors with variable speed drives.

**Operation and Maintenance:** The code describes control methods designed to shut-off the motors when not in use. There is also advice on setting the starting frequency limits to lower the added maintenance or repair costs arising from the extra wear on the motor due to more frequent switching on and off. The code describes what is necessary for a good motor maintenance programme and a good motor management policy.

**Systems Approach:** The code describes ways to improve system efficiency by reducing the load and improving transmission efficiency.

## 1.2.2 Title: How to Buy an Energy Efficient Electric Motor
## Region: United States
## Technology: AC Motors Category: Code of Practice

**Background:** The Department of Energy's Federal Energy Management Program (FEMP) works to reduce the cost and environmental impact of the Federal government by advancing energy efficiency and water conservation, promoting the use of distributed and renewable energy, and improving utility management decisions at Federal sites. The programme targets US federal government purchases. It encourages the agencies to buy energy efficient electric motors as well as other efficient products. By doing so, agencies can realize substantial operating cost savings, prevent pollution, and save taxpayer dollars.

**Scope:** The code of practice covers AC motor selection for federal buildings. The code is primarily targeted towards federal managers making the equipment purchasing and selection decisions.

**Basic Principles:** The code describes the basic principles associated with energy use due to motors and recommends the MotorMaster+ energy cost calculator. It is an energy efficient motor selection and management tool including a catalogue of over 20,000 AC motors. This tool features motor inventory management tools, maintenance log tracking, efficiency analysis, savings evaluation, energy accounting, and environmental reporting capabilities.

**Design and Selection:** The code recommends that federal managers specify a motor that exceeds the NEMA (National Electrical Manufacturers Association) Premium Efficiency requirements and carry the NEMA Premium label. The programme also advises on the advantages of selecting motors with variable speed drives.

**Operation and Maintenance:** The code has a short section with tips on motor operation and maintenance.

**Systems Approach:** There code does not deal with systems issues related to efficient motor selection and operation.

## 1.3 Category: Programmes
## 1.3.1 Title: FIDE Seal (Fideicomiso para el Ahorro de Energía Electrica)
## Region: Mexico
## Technology: AC Motors

**Background:** In the year 1990, the Fideicomiso para el Ahorro de Energía Electrica (FIDE, the Trust for Electric Energy Saving) was founded with the goal to promote rational electric energy use and energy saving. FIDE is a private non-profit organisation. Its technical Committee is formed through a series of electric utilities, industry associations and CONAE (The Comisión Nacional para el Ahorro de Energía, the National Commission for Energy Saving). The FIDE seal for energy efficient appliances is one of FIDE's main areas of activity.

**Scope:** The programme is intended primarily for three-phase induction motors among users in industry, agriculture and municipal services. Motors in the residential sector are low power units, not covered by the FIDE seal. Moreover, they are likely to be within household appliances where motor replacement is not a viable energy efficiency option.

**Program Description**: The FIDE seal is a voluntary identification of products that have been proven to have exceptionally low energy consumption. They are further proven to have a high reliability and quality. The seal not only serves to identify energy efficient products, but also to raise awareness in the general public of energy efficiency issues when shopping. Electric motors is one of the six types of applications of the programme.

FIDE administers a campaign to make products and the seal known to consumers, and to motivate them to buy the respective products. Manufacturers can also use the seal for promotional purposes. Users can reduce their electricity consumption and make use of financing incentives offered by FIDE for buying products with the seal. FIDE offers financial incentives for companies that buy electric motors that carry the FIDE seal. For motors between 0.746-373 kW, a maximum of $48.26/kW are reimbursed through the following mechanism. With the product, the buyer gets a coupon from the distributor or manufacturer of the equipment. This coupon is sent in to FIDE, together with a copy of the last electricity bill. FIDE then writes out a cheque that is deposited in the bank account of the equipment user.

The purpose of the programme is to offer incentives to users of electric motors so that they replace inefficient motors in use with new, high-efficiency motors that meet the standards of the FIDE seal (“Sello FIDE”). While Mexico has minimum efficiency standards covering electric motors, these standards determine motor efficiency at the time of purchase, without benefiting users of existing motors.

While voluntary and mandatory standards have improved the efficiency of new electric motors sold in Mexico since 1994, these standards have had little effect on motors that are in use and functional. Electric motors have very long life, and even when they face problems, users may rewind or otherwise repair them and continue their use. The programme activity comprises providing incentives to large energy users so that they may replace existing motors with energy-efficient models meeting the Sello FIDE standards. In the project scenario, given the proposed financial incentive, some users of inefficient electric motors would turn in their existing motors that are still in operation, and replace them with high-efficiency motors.

**Energy Levels:** The energy efficiency requirements of motors are summarized in the table below:

| FIDE Standard: Nominal Limit Efficiency Values for Closed and Open Energy Efficiency Motors | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nominal | Closed | | | | Open | | | |
| Power, kW | 2 Pole | 4 Pole | 6 Pole | 8 Pole | 2 Pole | 4 Pole | 6 Pole | 8 Pole |
| 0.746 | 75.5 | 82.5 | 80 | 74 | --- | 82.5 | 80 | 74 |
| 1.119 | 82.5 | 84 | 85.5 | 77 | 82.5 | 84 | 84 | 75.5 |
| 1.492 | 84 | 84 | 86.5 | 82.5 | 84 | 84 | 85.5 | 85.5 |
| 2.238 | 85.5 | 87.5 | 87.5 | 84 | 84 | 86.5 | 86.5 | 86.5 |
| 3.73 | 87.5 | 87.5 | 87.5 | 85.5 | 85.5 | 87.5 | 87.5 | 87.5 |
| 5.595 | 88.5 | 89.5 | 89.5 | 85.5 | 87.5 | 88.5 | 88.5 | 88.5 |
| 7.46 | 89.5 | 89.5 | 89.5 | 88.5 | 88.5 | 89.5 | 90.2 | 89.5 |
| 11.19 | 90.2 | 91 | 90.2 | 88.5 | 89.5 | 91 | 90.2 | 89.5 |
| 14.92 | 90.2 | 91 | 90.2 | 89.5 | 90.2 | 91 | 91 | 90.2 |
| 18.65 | 91 | 92.4 | 91.7 | 89.5 | 91 | 91.7 | 91.7 | 90.2 |
| 22.38 | 91 | 92.4 | 91.7 | 91 | 91 | 92.4 | 92.4 | 91 |
| 29.84 | 91.7 | 93 | 93 | 91 | 91.7 | 93 | 93 | 91 |
| 37.3 | 92.4 | 93 | 93 | 91.7 | 92.4 | 93 | 93 | 91.7 |
| 44.76 | 93 | 93.6 | 93.6 | 91.7 | 93 | 93.6 | 93.6 | 92.4 |
| 55.95 | 93 | 94.1 | 93.6 | 93 | 93 | 94.1 | 93.6 | 93.6 |
| 74.6 | 93.6 | 94.5 | 94.1 | 93 | 93 | 94.1 | 94.1 | 93.6 |
| 93.25 | 94.5 | 94.5 | 94.1 | 93.6 | 93.6 | 94.5 | 94.1 | 93.6 |
| 111.9 | 94.5 | 95 | 95 | 93.6 | 93.6 | 95 | 94.5 | 93.6 |
| 149.2 | 95 | 95 | 95 | 94.1 | 94.5 | 95 | 94.5 | 93.6 |
| 186.5 | 95.4 | 95 | 95 | 94.5 | 94.5 | 95.4 | 95.4 | 94.5 |
| 223.8 | 95.4 | 95.4 | 95 | 94.5 | 95 | 95.4 | 95.4 | 94.5 |
| 261.1 | 95.4 | 95.4 | 95 | 94.5 | 95 | 95.4 | 95.4 | 94.5 |
| 298.4 | 95.4 | 95.4 | 95 | 94.5 | 95.4 | 95.4 | 95.4 | 94.5 |
| 335.7 | 95.4 | 95.4 | 95 | 94.5 | 95.8 | 95.8 | 95.4 | 94.5 |
| 373 | 95.4 | 95.8 | 95 | 94.5 | 95.8 | 95.8 | 95.4 | 94.5 |

**Related Programs (if applicable):** Besides FIDE Seal ("Sello FIDE"), which is voluntary, Mexico has mandatory standards (called NOM) that define the minimum efficiency levels for selected energy using equipment that is sold in Mexico. Any equipment in the categories covered by standards must meet the relevant NOM standards. Minimum efficiency standards for motors were established in 1994, and tightened in 1997 and in 2002.

**Results:** In 1999, FIDE's incentive programs fostered savings of 554 GWh of electricity consumption and 152 MW of avoided capacity (CONAE 2001).

## 1.3.2 Title: MEPS Programme (Minimum Energy Performance Standards)
## Region: Australia
## Technology: AC Motors Category: Programme

**Background:** The National Appliance and Equipment Energy Efficiency Committee, consisting of officials from the Commonwealth, State and Territory government agencies and representatives from New Zealand, is responsible for managing the Australian end-use energy efficiency programme. The Committee reports to other government structures and is ultimately directed by the Ministerial Council on Energy.

**Scope:** All three phase electric motors from 0.73kW to 185kW manufactured in or imported into Australia must comply with Minimum Energy Performance (MEPS) requirements. MEPS does not apply to submersible motors, integral motor-gear systems, variable or multi-speed motors.

**Program Description:** Electric motors are among the products that are regulated on the basis of Minimum Energy Performance Standards (MEPS). This means that they have regulated minimum energy efficiency levels.

Currently, electric motors are not on the appliance-labeling list; however a motor solutions online self-assessment tool is available on the website of Australian Greenhouse Office of Department of the Environment and Heritage.

Overall, the Australian proposal is to adopt the North American approach to regulation but using EU efficiency benchmarks where possible. The North American approach is to explicitly regulate for high efficiency, whereas the EU approach is based on voluntary agreements at a lower level of efficiency. However, the EU has defined high efficiency motors (EFF1) for labeling purposes. This benchmark is familiar to the European manufacturers that are major suppliers in the Australian market and has been adopted for the 2006 MEPS wherever possible.

**Energy Levels:** The Minimum Energy Performance Standards requirements are set out as minimum efficiency levels. From 1 April 2006, MEPS levels for three phase electric motors will be revised to become more stringent. The "High Efficiency" level from 2001 will become the MEPS level on 1 April 2006. From 1 April 2005 a revised "High Efficiency" level also came into force. These new MEPS and high efficiency requirements together with transition arrangements are set out in detail in AS/NZS 1359.5-2004. The following table shows the current minimum efficiency requirements, the MEPS 2001 under test Method-A.

**Table A: Efficiency Levels for Three Phase Electric Motors - Test Method A**

| Rated output kW | Minimum efficiency% | | | |
|---|---|---|---|---|
| | 2 pole | 4 pole | 6 pole | 8 pole |
| 0.73 | 72.3 | 72.7 | 70.7 | 66.7 |
| 0.75 | 72.3 | 72.7 | 70.7 | 66.7 |
| 1.1 | 74.6 | 74.6 | 73.6 | 69.9 |
| 1.5 | 76.9 | 76.9 | 75.7 | 73.0 |
| 2.2 | 79.5 | 79.5 | 78.1 | 76.1 |
| 3 | 81.2 | 81.2 | 79.9 | 78.2 |
| 4 | 82.8 | 82.8 | 81.6 | 80.1 |
| 5.5 | 84.4 | 84.4 | 83.3 | 82.0 |
| 7.5 | 85.8 | 85.8 | 84.7 | 83.7 |
| 11 | 87.2 | 87.2 | 86.4 | 85.6 |
| 15 | 88.3 | 88.3 | 87.7 | 87.1 |
| 18.5 | 89.0 | 89.0 | 88.6 | 88.0 |
| 22 | 89.5 | 89.5 | 89.1 | 88.7 |
| 30 | 90.5 | 90.5 | 90.2 | 89.9 |
| 37 | 91.1 | 91.1 | 90.8 | 90.6 |
| 45 | 91.7 | 91.7 | 91.5 | 91.2 |
| 55 | 92.2 | 92.2 | 92.0 | 91.8 |
| 75 | 92.9 | 92.9 | 92.8 | 92.7 |
| 90 | 93.4 | 93.2 | 93.2 | 93.0 |
| 110 | 93.8 | 93.8 | 93.7 | 93.5 |
| 132 | 94.2 | 94.1 | 94.1 | 93.8 |
| 150 | 94.5 | 94.5 | 94.4 | 94.1 |
| <185 | 94.5 | 94.5 | 94.4 | 94.1 |

**Related Programs (if applicable):** The same efficiency levels are used as in the EU.

**Results:** Nationally, the proposed regulation is expected to deliver net benefits of $120m in present value terms and a benefit/cost ratio of 2.5. A significant investment is required from users, estimated at $70M in present value terms. There will also be one-off costs of adjustment for suppliers, put at $10M. The additional cost to government is virtually zero, since the effect of the regulation is to strengthen a MEPS regime that is already in place. The balance of benefits and costs to users is variable, depending on the types and size of motors that they use, and the intensity of use. For example, the returns are markedly higher in the industrial sector than in the commercial sector, reflecting the longer hours of operation in the former. The overall assessment depends critically on the relationship between the percentage reduction in motor losses and the percentage increase in the cost of motors that deliver those reductions. The RIS draws on a number of studies to assess this trade-off. While suppliers have suggested that the cost effects have been underestimated, the proposal remains cost-effective under their alternative estimates of cost impacts.

## 1.3.3 Title: Voluntary Agreement (CEMEP)
## Region: European Union
## Technology: AC Motors Category: Programme

**Background:** CEMEP is a Voluntary Agreement involving the European Committee of Manufacturers of Electrical Machines and Power Electronics. The European Commission and CEMEP have drafted the classification scheme with a voluntary undertaking by motor manufacturers to reduce the sale of motors with the current standard efficiency (EFF3).

The European Scheme to designate energy efficiency classes for low voltage AC motors has been in operation since 1999. This scheme established through cooperation between CEMEP and the European Commission is an important element of the European efforts to improve energy efficiency and thus reduce CO2 emissions.

**Scope:** The motors included in this scheme are defined as totally enclosed fan ventilated, three phase AC squirrel cage induction motors in the range 1.1 to 90 kW, having 2 or 4 poles, rated for 400V line, 50 Hz, SI duty class, in standard design.

**Program Description:** The classification scheme informs motor users, in a simplified visible manner about the importance of electric motor efficiency, making them more aware of the choice available when specifying or selecting motors. This is done by labelling motor nameplate and giving detailed information in catalogues.

**Energy Levels:** There are three classes of efficiency levels defined by two levels of efficiency per output and number of poles. They are designated as EFF3, EFF2, and EFF1 and labelled accordingly. The class definition for 2-pole motors is shown in the table below. Generally, EFF1 has better efficiency than EFF2 and EFF2 is more efficient than EFF3. Efficiency is expressed as percentage at full load and at ¾ load to be specified, together with the brand label in manufacturers' catalogues.

On average an EFF1 motor reduces energy losses by up to 40% and an EFF2 motor still reduces energy losses by up to 20%. The higher purchase cost of EFF1 motors can be recouped in a short time. EFF1 motors are recommended when operating hours and the cost of electricity result in economic savings. Class EFF2 guarantees a satisfactory efficiency at a minimum premium. As a general rule motors in class EFF3 offer a very low efficiency and represent an uneconomic investment in most of the situations, therefore they are not recommended.

Class definition for 4-pole motors, according to this agreement

| kW | *eff3 - motors* $\eta_N$ | *eff2 - motors* $\eta_N$ | *eff1 - motors* $\eta_N$ |
|---|---|---|---|
| 1.1 | < 76,2 | >= 76,2 | >= 83,8 |
| 1.5 | < 78,5 | >= 78,5 | >= 85,0 |
| 2.2 | < 81,0 | >= 81,0 | >= 86,4 |
| 3 | < 82,6 | >= 82,6 | >= 87,4 |
| 4 | < 84,2 | >= 84,2 | >= 88,3 |
| 5.5 | < 85,7 | >= 85,7 | >= 89,2 |
| 7.5 | < 87,0 | >= 87,0 | >= 90,1 |
| 11 | < 88,4 | >= 88,4 | >= 91,0 |
| 15 | < 89,4 | >= 89,4 | >= 91,8 |
| 18.5 | < 90,0 | >= 90,0 | >= 92,2 |
| 22 | < 90,5 | >= 90,5 | >= 92,6 |
| 30 | < 91,4 | >= 91,4 | >= 93,2 |
| 37 | < 92,0 | >= 92,0 | >= 93,6 |
| 45 | < 92,5 | >= 92,5 | >= 93,9 |
| 55 | < 93,0 | >= 93,0 | >= 94,2 |
| 75 | < 93,6 | >= 93,6 | >= 94,7 |
| 90 | < 93,9 | >= 93,9 | >= 95,0 |

**Related Programs (if applicable):** Not applicable.

**Results:** The effect of the programme would be to benchmark the actual results against a voluntary target of the participants, to reduce the market penetration of EFF3 motors (4-pole) in their joint sales by 30 percent by 2001 and by 50 percent by 2003.

Drives systems, optimized for high efficiency motors (EFF1) and VSD could avoid the need for several large power stations in Europe and the associated pollution. The replacement of all current EFF3 motors with EFF2 motors could save up to 6TWh per year. This means that with an electricity price of $0.05 per kWh, Europe could save $300 million per year or more.

## 1.3.4 Title: NEMA Premium Efficiency Electric Motors Program
## Region: United States
## Technology: AC Motors Category: Programme

**Background:** The Motor and Generator Section of the National Electrical Manufacturers Association (NEMA) established the programme to assist purchasers to identify higher efficient motors, to assist users to optimize motor systems efficiency, and to reduce electrical consumption and the associated pollution.

**Scope:** The programme applies to single-speed, polyphase, 0.746-373 kW, 2,4, and 6 pole, squirrel cage induction motors, NEMA Design A or B, continuous rated.

**Program Description:** If a manufacturer of electric motors is eligible for membership in NEMA, the company may join the NEMA Motor and Generator Section and sign a voluntary partnership agreement. For non-NEMA manufacturers, companies may sign a voluntary partnership agreement on a fee basis. Only partnering manufacturers may use the NEMA Premium label. The NEMA Premium label may be used with those products that meet or exceed the NEMA Premium motor efficiency guidelines. The label makes it possible for purchasers to identify with ease and confidence those products that are premium efficient.

**Energy Levels:** Products must meet or exceed the nominal energy efficiency levels presented below.

**Related Programs (if applicable):** Not applicable

**Results:** Based on U.S. Department of Energy data, it is estimated that the NEMA Premium motor programme would save 5,800 gigawatts of electricity and prevent the release of nearly 80 million metric tons of carbon into the atmosphere over the next ten years. This is equivalent to keeping 16 million cars off the road. At the same time, there has been a significant increase of the sales of the NEMA Premium labelled motors. The NEMA data shows that in 2001-2002 the total net units shipped went up approximately 30 percent. In 2002-2003 there was a 14 percent increase over the previous years. This suggests a growing demand for premium-efficiency motors.

| Nominal Efficiencies for "NEMA Premium" Induction Motors Rated 600 Volts or Less (Random Wound) | | | | | | |
|---|---|---|---|---|---|---|
| | Open Drip-Proof | | | Totally Enclosed Dan-Cooled | | |
| kW | 6-pole | 4-pole | 2-pole | 6-pole | 4-pole | 2-pole |
| 0.746 | 82.5 | 85.5 | 77 | 82.5 | 85.5 | 77 |
| 1.119 | 86.5 | 86.5 | 84 | 87.5 | 86.5 | 84 |
| 1.492 | 87.5 | 86.5 | 85.5 | 88.5 | 86.5 | 85.5 |
| 2.238 | 88.5 | 89.5 | 85.5 | 89.5 | 89.5 | 86.5 |
| 3.73 | 89.5 | 89.5 | 86.5 | 89.5 | 89.5 | 88.5 |
| 5.595 | 90.2 | 91 | 88.5 | 91 | 91.7 | 89.5 |
| 7.46 | 91.7 | 91.7 | 89.5 | 91 | 91.7 | 90.2 |
| 11.19 | 91.7 | 93 | 90.2 | 91.7 | 92.4 | 91 |
| 14.92 | 92.4 | 93 | 91 | 91.7 | 93 | 91 |
| 18.65 | 93 | 93.6 | 91.7 | 93 | 93.6 | 91.7 |
| 22.38 | 93.6 | 94.1 | 91.7 | 93 | 93.6 | 91.7 |
| 29.84 | 94.1 | 94.1 | 92.4 | 94.1 | 94.1 | 92.4 |
| 37.3 | 94.1 | 94.5 | 93 | 94.1 | 94.5 | 93 |
| 44.76 | 94.5 | 95 | 93.6 | 94.5 | 95 | 93.6 |
| 55.95 | 94.5 | 95 | 93.6 | 94.5 | 95.4 | 93.6 |
| 74.6 | 95 | 95.4 | 93.6 | 95 | 95.4 | 94.1 |
| 93.25 | 95 | 95.4 | 94.1 | 95 | 95.4 | 95 |
| 111.9 | 95.4 | 95.8 | 94.1 | 95.8 | 95.8 | 95 |
| 149.2 | 95.4 | 95.8 | 95 | 95.8 | 96.2 | 95.4 |
| 186.5 | 95.4 | 95.8 | 95 | 95.8 | 96.2 | 95.8 |
| 223.8 | 95.4 | 95.8 | 95.4 | 95.8 | 96.2 | 95.8 |
| 261.1 | 95.4 | 95.8 | 95.4 | 95.8 | 96.2 | 95.8 |
| 298.4 | 95.8 | 95.8 | 95.8 | 95.8 | 96.2 | 95.8 |
| 335.7 | 96.2 | 96.2 | 95.8 | 95.8 | 96.2 | 95.8 |
| 373 | 96.2 | 96.2 | 95.8 | 95.8 | 96.2 | 95.8 |

| Nominal Efficiencies for "NEMA Premium" Induction Motors Rated Medium Volts 5kV or Less (Form Wound) | | | | | | |
|---|---|---|---|---|---|---|
| kW | 6-pole | 4-pole | 2-pole | 6-pole | 4-pole | 2-pole |
| 186.5 | 95 | 95 | 94.5 | 95 | 95 | 95 |
| 223.8 | 95 | 95 | 94.5 | 95 | 95 | 95 |
| 261.1 | 95 | 95 | 94.5 | 95 | 95 | 95 |
| 298.4 | 95 | 95 | 94.5 | 95 | 95 | 95 |
| 335.7 | 95 | 95 | 94.5 | 95 | 95 | 95 |
| 373 | 95 | 95 | 94.5 | 95 | 95 | 95 |

## 2. Technology: Boilers
## 2.1 Category: Standards
## Title: X Determination of Efficiency to Prescribed Accuracy
## Region: UK

Category: Standards
Title: Determination of Efficiency to Prescribed Accuracy
Region: UK
Technology: Boilers

**Background:** The standard describes a method whereby efficiency is determined to a prescribed accuracy.

**Scope:** BS 845 determined to be comprehensive and readily applicable to the South African market

**Basic Principles:** Does not prescribe efficiencies of different types of boilers, and is not a benchmark to determine the relative efficiency of a specific boiler

*Part 1*: A concise procedure using an indirect method to determine efficiency to within ±2%. It is convenient for use on thermodynamically simple boiler installations.

*Part 2*: A comprehensive procedure using both the direct and indirect methods to determine efficiency to within ±2%. This is applicable to all boilers generally above 44 kW output. It is relevant and can be applied to South African boiler installations without alterations

## 2.2 Category: Code of Practice
## 2.2.1 Title: Economic Use of a Coal-Fired Boiler Plant
## Region: United Kingdom
## Technology: Boilers

**Background:** This is part of a series produced by the Government under the Energy Efficiency Best Practice Programme. The aim of the programme is to advance and spread good practice in energy efficiency by providing independent, authoritative advice and information on good energy efficiency practices.

**Scope:** Coal-fired boiler systems. The code is primarily intended for industrial managers in charge of the day-to-day operation of coal-fired boiler plants.

**Basic Principles:** The document provides guidance on the ways in which fuel and therefore money can be saved in the operation of boiler plants. The approach used examines the plant from fuel delivery, progressively through to the final heat output and identifies and quantifies the losses. Finally, a checklist of money saving procedures, a sample daily log sheet, and a weekly summary sheet are also provided. One example boiler is used to illustrate the significance of savings.

The code provides an explanation of heat losses from boilers, which include flue gas losses, radiation losses, incidental losses, and blowdown losses. It also details the factors affecting the efficient use of energy. The factors covered are: mechanical stokers, boiler thermal efficiency, flue gas losses, radiation loss, firing schedules, blowdown, water treatment, condensate recovery, steam and hot water services.

**Design and Selection:** The code offers more advice on operation than selection, however the discussion of boiler thermal efficiency will aid in boiler purchasing.

**Operation and Maintenance:** The code provides a checklist of money-saving procedures during boiler operation. There is also a lengthy discussion of issues related to fuel selection and usage.

**Systems Approach:** The code provides some background information, including fuel purchasing, stocking, coal and ash handling, and pollution control. The code also describes system layout when two or more boilers are connected in a system. It also offers advice on the steam distribution system and the efficient use of piping insulation.

## 2.2.2 Title: Energy Efficient Operation of Industrial Boiler Plant
## Region: United Kingdom
## Technology: Boilers  Category: Code of Practice

**Background:** This guide is part of the Good Practice Guide Series of the United Kingdom and is aimed at all users of boiler plant to illustrate opportunities for achieving substantial savings.

**Scope:** The boiler plant considered comprises small and medium-sized installations with individual outputs of up to 20MW, and fired conventional solid, liquid or gaseous fuels. Boilers in this range represent more than 90% of the total UK installed capacity.

**Basic Principles:** The code covers aspects of the design of steam and hot water systems, discusses boilers and combustion equipment and examines the potential for increased energy efficiency in the operation of boiler plant.

**Design and Selection:** The code describes different types of boilers and combustion equipment and examines the main types of boiler in current use. The advantages and disadvantages of the various fuels are discussed, and consideration is given to types of burner/combustion system and to the increasing significance of pollution control. This section of the Code includes some guidelines for boiler system selection.

**Operation and Maintenance:** The code examines the potential for increased energy use efficiency in the operation of boiler plant, ascertaining the potential for economizers, combustions air pre-heating, variable speed fan drives and integrated controls. The guide concludes by setting out step-by-step procedures for improving energy efficiency in boiler and system operation.

**Systems Approach:** One section of the code deals with aspects of the design of steam and hot water systems. It examines the relative importance of steam and hot water as heat transport media and discusses the efficiency both of steam distribution and condensate return systems and of hot water systems. The importance of correct feed water treatment, of adequate external insulation and of regular monitoring is stressed.

The main focus of the code is on the distribution and use of the steam or hot water produced, due to the fact that all the effort expended on making the boiler 80% or more efficient can be wasted by badly designed pipework systems or poor operational practices. The code stresses that more energy is wasted by poor design and operational practices in relation to feed water, steam and hot water distribution and use than by incorrect combustion conditions within a boiler. When analyzing an existing plant or deciding on new plant, the first task is to ensure that the distribution and use of the hot water or steam minimizes waste. Once this has been accomplished any improvement in the energy conversion efficiency of the boiler will have maximum effect.

## 2.2.3 Title: Energy Efficiency Manual
## Region: United States
## Technology: Boilers    Category: Code of Practice

**Background:** The Energy Efficiency Manual, written by Donald Wulfinghoff, offers up-to-date and practical solutions for energy planning applicable to building environments in one comprehensive volume. This summary deals only with the section of the manual specific to boiler plants.

**Scope:** The manual is intended for a wide audience and so the scope is intentionally broad. The manual covers many types and sizes of boilers with information that is useful for purchasers, operators or consultants.

**Basic Principles:** The manual has a lengthy introduction detailing all of the potential sources of losses in a boiler plant. The manual covers the theory of boiler operation as well as practical tips.

**Design and Selection:** The section on boiler plant efficiency offers advice on choosing the right boiler for the application.

**Operation and Maintenance:** There is a section in the manual on equipment scheduling and operation. The manual offers lots of specific tips related to energy efficient boiler operation and maintenance. Each section is broken down into measures related to specific operational practices.

**Systems Approach:** The manual uses a systems approach throughout. There are specific sections related to burner and fan systems, system design for efficient low-load, and steam and water leakage through system piping.

## 2.2.4 Title: How to Buy an Energy-Efficient Commercial Boiler
## Region: United States
## Technology: Boilers Category: Code of Practice

**Background:** This code of practice is a technology profile produced by the Department of Energy's Federal Energy Management Program (FEMP). FEMP works to reduce the cost and environmental impact of the Federal government by advancing energy efficiency and water conservation, promoting the use of distributed and renewable energy, and improving utility management decisions at Federal sites. The programme targets at the US federal government purchases. It encourages the agencies to buy energy efficient boilers as well as other efficient products.

**Scope:** The code covers low- and medium-pressure boilers used primarily in commercial space heating applications. It does not apply to high-pressure boilers used in industrial processing and cogeneration applications. The code is targeted towards federal managers making purchasing decisions.

**Basic Principles:** The code is primarily concerned with justifying the cost effectiveness of purchasing an efficient boiler. The centrepiece of the code is a table with recommended minimum efficiencies. This table is repeated here for convenience.

| Efficiency Recommendations | | | |
|---|---|---|---|
| **Product Type (Fuel/Heat Medium)** | **Rated Capacity (kW)** | **Recommended Thermal Efficiency ($e_t$)[b]** | **Best Available[c] Themal Efficiency ($e_t$)** |
| **Natural Gas Water** | 87.9-732.5 | 80%$e_t$ | 86.7$e_t$ |
| | 732.5-2,930 | 80%$e_t$ | 83.2$e_t$ |
| **Natural Gas Steam** | 87.9-732.5 | 79%$e_t$ | 81.9$e_t$ |
| | 732.5-2,930 | 80%$e_t$ | 81.2$e_t$ |
| **#2 Oil Water** | 87.9-732.5 | 83%$e_t$ | 87.7$e_t$ |
| | 732.5-2,930 | 83%$e_t$ | 85.5$e_t$ |
| **#2 Oil Steam** | 87.9-732.5 | 83%$e_t$ | 83.9$e_t$ |
| | 732.5-2,930 | 83%$e_t$ | 84.2$e_t$ |

Design and Selection: The code recommends that purchasers chose efficient boilers as specified by the table above. There is also a short section on sizing and part load performance.

**Operation and Maintenance:** The code offers a short paragraph on operations and maintenance tips. The code also links to The Boiler Efficiency Institute's manuals on boiler operation and maintenance.

**Systems Approach:** The code does not discuss boiler systems, however there are links to other web-based resources on the subject.

## 2.3 Category: Programmes
## 2.3.1 Title: Energy Efficiency Regulations
## Region: Canada
## Technology: Boilers

**Background:** Canada's Energy Efficiency Act was passed by Parliament in 1992 and provides for the making and enforcement of regulations concerning minimum energy performance levels for energy-using products, as well as the labelling of energy-using products and the collection of data on energy use. The Energy Efficiency Regulations are administered by the Natural Resources Canada (NRCan) Office of Energy Efficiency.

**Scope: The regulations apply to** self-contained gas-fired boilers and oil-fired boilers that use propane or natural gas, are intended for use in a low-pressure steam or hot water central heating system, and have an input rate of less than 88 kilowatts.

**Program Description:** All of the energy-using products included in the energy efficiency regulations must meet federal energy efficiency standards in order to be imported into Canada or manufactured in Canada and shipped from one province to another. Dealers are responsible for ensuring that each model of a regulated product that they manufacture for sale in another province, import into Canada, or sell or lease after the product has been imported or shipped interprovincially meets the energy efficiency standard set out in the Regulations. Depending on the product, dealers may also be responsible for ensuring that an EnerGuide label is affixed to each unit. As well, all energy-using products must carry an energy efficiency verification mark.

**Energy Levels**: Gas boilers in low-pressure steam systems must have a minimum AFUE of 75% or greater. Gas boilers in hot water systems must have a minimum AFUE of 80% or greater. Oil-fired boilers must have a minimum SEUE of 80% or greater.

**Related Programs (if applicable):** Not applicable

**Results:** Not available

## 2.3.2 Title: Express Efficiency Program
## Region: United States
## Technology: Boilers Category: Programme

**Background:** This programme is funded by California utility customers and administered by the state's investor owned utilities, which includes Pacific Gas and Electric Company and other utility companies.

**Scope:** Space heating boilers with capacities bigger than 21.98 kW, and less than 0.7325 kW qualify for the programme.

**Program Description:** Commercial, industrial, and agricultural account customers with an average monthly usage of 20,800 therms or less are eligible for the 2005 Express Efficiency programme. The total rebate limit for 2005 is $200,000 per account, per fuel, per year. Rebates are available for the replacement of older, inefficient gas equipment. The rebate rate varies according to equipment type. For boilers, the rebate rates are $1.00/MBtuh for space heating boilers, $5.10 x $10^{-3}$/kW for commercial boilers, and $6.82 x $10^{-3}$/kWfor process boilers.

**Energy Levels:** For space heating boilers, the efficiency requirements based on size and type are shown in the table below.

| Type | Input Rating (kW) | Required Efficiency |
|---|---|---|
| Steam | <0.0879 | AFUE >= 77% |
| Small Water | <0.0879 | AFUE >= 82% |
| Large | >0.0879 – 0.7325 | Thermal efficiency >= 84% |

Commercial boilers with capacities bigger than 21.97 kW qualify and must meet a minimum thermal efficiency of 84%. The minimum combustion efficiency is 82% for process boiler.

**Related Programs (if applicable):** Not applicable

**Results:** Not available

## 3.1 Category: Standards
## 3.2.1 Title: ASTM Standards
## Region: United States
## Technology: Pipe Insulation

None of the following ASTM standards has been adopted as SANS standards yet:

C335-05a: Standard Test Method for Steady-State Heat Transfer Properties of Pipe Insulation
C547-03: Standard Specification for Mineral Fibre Pipe Insulation
F2165-02: Standard Specification for Flexible Pre-Insulated Piping
C610-05: Standard Specification for Molded Expanded Perlite Block and Pipe Thermal Insulation
C585-90 (2004): Standard Practice for Inner and Outer Diameters of Thermal Insulation for Nominal Sizes of Pipe and Tubing (NPS System)

**Scope:**

**C335-05a: Standard Test Method for Steady-State Heat Transfer Properties of Pipe Insulation**

The above test method covers the measurement of the steady-state heat transfer properties of pipe insulations. Specimen types include rigid, flexible, and loose fill; homogeneous and non-homogeneous; isotropic and non-isotropic; circular or non-circular cross-section. Measurement of metallic reflective insulation and mass insulations with metal jackets or other elements of high axial conductance is included; however, additional precautions must be taken and specified special procedures must be followed.

The test apparatus for this purpose is a guarded-end or calibrated-end pipe apparatus. The guarded-end apparatus is a primary (or absolute) method. The guarded-end method is comparable, but not identical to ISO 8497.

**C547-03: Standard Specification for Mineral Fibre Pipe Insulation**

This specification covers mineral fibro insulation produced to form hollow cylinders for standard pipe and tubing sizes. The mineral fibre pipe insulation may be molded or precision v-grooved, with one or more walls split longitudinally for use on pipe temperatures up to 650°C.

For satisfactory performance, properly installed protective vapor retarders or barriers should be used on sub-ambient temperature applications to reduce movement of moisture through or around the insulation to the colder surface. Failure to use a vapor barrier can lead to insulation and system damage.

Flexible mineral fiber wrap products such as perpendicular-oriented fiber insulation rolls, non-precision or manually scored block or board, or flexible boards or blankets used as pipe insulation, are not covered by this specification.

**F2165-02: Standard Specification for Flexible Pre-Insulated Piping**

This specification covers flexible, pre-insulated piping commonly used to convey hot and cold fluids.

This specification establishes materials and performance requirements for flexible, pre-insulated piping intended for hot and chilled water applications.

Piping systems may include one or more carrier pipes within a common outer jacket. The text of this specification references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered part of this standard.

Units—The values stated in either inch-pound units or SI units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance of the standard.

**C610-05: Standard Specification for Molded Expanded Perlite Block and Pipe Thermal Insulation**

This specification covers molded expanded perlite block, fittings, and pipe thermal insulation intended for use on surfaces with temperatures between 27 to 649°C.

When the installation or use of thermal insulation materials, accessories, and systems may pose safety or health problems, the manufacturer shall provide the user appropriate current information regarding any known problems associated with the recommended use of the company's products; and shall also recommend protective measures to be employed in their safe utilization

**C585-90 (2004): Standard Practice for Inner and Outer Diameters of Thermal Insulation for Nominal Sizes of Pipe and Tubing (NPS System)**

This practice is intended as a dimensional standard for preformed rigid thermal insulation for pipes and tubing.

This practice covers insulation supplied in cylindrical sections, usually split into half-sections, and lists recommended inner and outer diameters of insulation having nominal wall thicknesses from 25 to 127 mm to fit over standard sizes of pipe and tubing.

This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate

## 3.2 Category: Code of Practice
## 3.2.1 Title: The Economic Thickness of Insulation for Hot Pipes
**Region: United Kingdom**
**Technology: Pipe Insulation Category: Code of Practice**

**Background:** This code of practice is made available by the UK Carbon Trust.

**Scope:** This code of practice is concerned with the economic thickness of insulation for hot pipes. In particular, pipes forming part of domestic and non-domestic heating and hot water systems, and process pipework are covered.

**Basic Principles:** The code provides considerable background information on the different materials used in pipe insulation. The code explains how to determine the thickness of insulation that will result in the optimum installation. It is intended to be only a brief guide, so references are made throughout to the extensive documentation available from the insulation industry and British Standards Institution (BSI).

**Design and Selection:** The code is primarily concerned with selecting the most cost effective pipe insulation. It offers sample calculations of payback associated with pipe insulation. The code describes three different methods of estimating economic thickness. The first uses specially prepared tables based on assumptions about every item of data required to estimate economic thickness. The second and more accurate method is the formulation of customized tables which do take account of specific details and which therefore provide a greater degree of confidence. The third method of estimating economic thickness is an algebraic solution. This requires mathematical manipulation skills, but it has the least number of assumptions and is the most flexible of the three methods.

Tables of the economic thickness of insulation for various types of application are included in the document. Values of the economic thicknesses have been tabulated for appropriate ranges of pipe sizes, pipe surface temperatures, and insulation thermal conductivities.

**Operation and Maintenance:** Not directly applicable except for a short discussion of how insulation is often not used out of fear that it will interfere with the piping system maintenance. The code describes approaches that would minimize this problem.

**Systems Approach:** Not directly applicable. It is recommended that the code be read in conjunction with Fuel Efficiency Booklet 19: 'Process plant insulation and fuel efficiency'.

## 3.2.2 Title: Process Plant Insulation
## Region: United Kingdom
## Technology: Pipe Insulation Category: Code of Practice

**Background:** This is part of a series produced by the Government under the Energy Efficiency Best Practice Programme. The aim of the programme is to advance and spread good practice in energy efficiency by providing independent, authoritative advice and information on good energy efficiency practices.

**Scope:** Process plant includes pipework, ducts, equipment and storage vessels. Practical advice on process plant insulation is given and is intended for use by experienced process plant personnel.

**Basic Principles:** The principal reasons for insulating process plant are discussed, and information is given on the different types of insulation and their properties. Extensive data are presented in tabulated form on the recommended thickness of insulation for optimum cost/benefit performance, and energy and costs savings are discussed quantitatively.

The document reproduces some tabulated data from British Standard BS 5422: 1990 Method for specifying thermal insulating materials on pipes, ductwork and equipment.

**Design and Selection:** The code recommends using a simple payback calculation to compare purchasing options. Typically, many companies would consider a payback period of two years reasonable. When determining the economics of particular insulation, the installation cost and the cost of the finishing materials should always be included.

This code also goes beyond the economic considerations and discusses safety concerns as well as the concerns of maintaining process steam or hot water above a certain temperature.

The code includes a lengthy discussion of finishes used in pipe insulation, depending on the specific circumstances of use.

**Operation and Maintenance:** Not directly applicable.

**Systems Approach:** Not directly applicable.

### 3.2.3 Title: Economic Thickness of Insulation
### Region: United States
### Technology: Pipe Insulation Category: Code of Practice

**Background:** This code of practice was developed by the National Insulation Association (NIA), a northern Virginia based trade association representing the mechanical and specialty insulation industry.

**Scope:** This code provides readily accessible information about the value to industry of thermal insulation on piping and flat surfaces wherever operating temperatures are above surrounding ambient conditions.

**Basic Principles:** The code provides a method for identifying the rate of thermal energy loss from an un-insulated surface. It provides a discussion of the economic and safety benefits associated with choosing the correct type and amount of insulation.

**Design and Selection:** The Code provides tables to economically justified insulation thicknesses based on calculations listed for specific physical and economic parameters. The code also recommends a more detailed engineering analysis when large surface areas or high temperatures are involved. Safety considerations are stressed as often being more important to insulation selection than economic considerations.

**Operation and Maintenance:** Not directly applicable.

**Systems Approach:** Not directly applicable.

# Appendix B

## Domestic Scans

## List of Scans

### 1. AC Motors

#### 1.1 Standards

**1. Technology: AC Motors**
**1.1 Category: Standards**
**1.1.1 Title: Induction Motors, Part 1**
**Sub Title: IEC Requirements**
**Region: South Africa**
**Technology: AC Motors Standard: SANS 1804 – Part 1**

**Note**: This part of the standard deals only with the IEC requirements and its applicability to AC induction motors. This specification includes a mandatory reference to SABS IEC 60034-2 (SANS 60034-2) which details test methods for amongst others the efficiency of induction motors. This standard, being an international standard is discussed in the report on international standards.

**1.1.2 Title: Induction Motors, Part 2**
**Sub Title: Low Voltage Three Phase Standard Motors**
**Region: South Africa**
**Technology: AC Motors** **Category: Standards**
**Standard: SANS 1804 – Part 2**

## Scope

This part of SANS 1804 specifies requirements for low-voltage three-phase alternating-current standard induction motors of the cage and wound-rotor (slip-ring) types, in frame sizes up to and including 315, for voltages up to and including 1 100 V between lines and at a frequency of 50 Hz.

## General Requirements

The following requirements shall be complied with:
(a) Mandatory requirements
(b) Lifting facilities
(c) Terminal boxes
(d) Terminal bases
(e) Dimensions of frames, shafts and flanges
(f) Clearances and creepage distances
When terminals are fitted with cable lugs of the size recommended by the motor manufacturer, the
distances between terminal assemblies, and between a terminal assembly and an adjacent metal part, shall be such that the clearances (measured in a straight air path) and the creepage distances (measured by the shortest path along the surface of any non-displaceable insulating barrier) are as given in table 1.

## Electrical and Physical requirements

These requirements shall be classified in accordance with the following:
(a) Allocation of rated output, shaft number and flange number
(b) Cooling of airstream-rated motors
(c) Flame Retardant and self extinguishing abilities
(d) Absorption resisitance
(e) Standard site conditions

## Tests

Through its reference to Part 1 of this standard, the test methods as detailed in SANS 60034-2 are mandatory. Please refer to the comment in the international standards document under IEC 60034-2.

**1.1.3 Title: Induction Motors, Part 3**
**Sub Title: Low Voltage Three Phase Intermittently rated wound rotor motors**
**Region: South Africa**
**Technology: AC Motors** **Category: Standards**
**Standard: SANS 1804 – Part 3**

**Scope**

This part of SABS 1804 specifies requirements for low-voltage three-phase alternating current intermittently-rated wound-rotor (slip-ring) motors, in frame sizes 100 to 450 for voltages not exceeding 1 100 V between lines and at a frequency of 50 Hz.

**General Requirements**

The following requirements shall be complied with:

(a) IEC Requirements
(b) Lifting facilities
(c) Terminal boxes
(d) Terminal Bases
(e) Dimensions of frames and shafts

**Electrical and Physical Requirements**

These requirements shall be classified in accordance with the following

*(a) Allocation of performance characteristics*
(b) Momentary excess torque
(c) Maximum permissible speed
(d) Flame-retardant and self extinguishing abilities
(e) Absorption resistance

**Tests**

No energy efficiency methods are outlined in this part of the standard other than the reference to SANS 1804-1, which makes the requirements of SANS 60034-2 mandatory.

**Marking**

The marking of all motors covered by this part of this specification shall comply with the applicable mandatory marking requirements specified.

**1.1.4 Title: Induction Motors, Part 4**
**Sub Title: Single Phase Induction Motors**
**Region: South Africa**
**Technology: AC Motors** **Category: Standards**
**Standard: SANS – Part 4**

**Scope**

This part of SABS 1804 specifies requirements for four types of single-phase alternating current induction motors of standard dimensions and of frame sizes up to and including 160, for voltages up
to and including 250 V at a frequency of 50 Hz or 60 Hz. The four types are:
a) split-phase;
b) capacitor start induction run;
c) capacitor start capacitor run;
d) capacitor start and run.

**General Requirements**

The following requirements shall be complied with:

(a) Mandatory Requirements
(b) Type
(c) Lifting facilities
(d) Terminal boxes
(e) Terminal Bases
(f) Clearances and creepage distances
(g) Dimensions
(i) Foot mounted motors
h) Disconnecting devices

**Electrical and Physical Requirements**

These requirements shall be classified in accordance with the following
(a) Allocation of rated output, frame size, shaft diameter and flange number
(b) Flame-retardant and self-extinguishing ability
(c) Absorption resistance

**Tests**

No energy efficiency methods are outlined in this part of the standard other than the mandatory reference to SANS 1804-1, which makes the requirements of IEC 60034-2 mandatory. This specification is discussed in the international summary.

**Marking**

Rating plates shall comply with the applicable requirements of SABS 1804-1, with the following additions:
(a) Adjacent to the symbols for frame size and designation of enclosure, the appropriate of the following symbols for the type of motor shall be marked:

– S (split-phase);
– C (capacitor start induction run);
– CK (capacitor start capacitor run); or
– K (capacitor start and run).

(b) Capacitor sizes shall, where applicable, be indicated on a rating plate.