ENERGY CONSERVATION IN INDUSTRY: MOTOR DRIVES

Priyantha D C Wijayatunga [1] and D A U Daranagama [2]

1.Department of Electrical Engineering, University of Moratuwa
2.Energy Conservation Fund

ENERGY CONSERVATION IN INDUSTRY: MOTOR DRIVES

Priyantha D C Wijayatunga[1] and D A U Daranagama[2]
[1]Department of Electrical Engineering, University of Moratuwa
[2]Energy Conservation Fund

ABSTRACT

A significant proportion of electrical energy generated is utilised in industrial motor drives in addition to it being used for electric lighting and heating. Also, oversized and under-utilised motors in the industrial sector are a common occurrence in Sri Lanka as a result of poor design and inappropriate replacement of equipment. These provide great opportunities for energy savings in motor drives particularly due to the fact that modern designs offer improved energy efficiencies in motor drive systems. This paper examines the present electricity consumption levels in motor drives used in the industrial sector and explores the opportunities for improvement by analysing data obtained through an industrial consumer survey carried out by personal visits to different industrial installations. The paper concludes with estimates of energy savings in the industrial sector as a result of possible energy efficiency improvements in industrial motor drives.

INTRODUCTION

Electrical energy is mainly used for lighting, heating and to drive motors particularly in the industrial sector. A significant proportion of electrical energy generated is consumed by electrical motor drive systems. This provides an opportunity to save a considerable amount of energy by proper selection of motors. The electric motor being a device converting electrical energy to rotating mechanical energy, the only form of power consumed is electricity while the output is the useful mechanical energy and mechanical energy losses within the motor. The losses within the motor can vary between 5% and 25% of the input power.

Modern motors are designed and manufactured using high quality materials and improved technology. For many years, the trend in motor manufacture has been to produce smaller and lighter motors in order to bring down the unit costs and no significant attention was given to efficiency and the power factor improvement beyond the levels required to achieve allowable temperatures. One of the major reasons for this trend is the higher priority given by the users for price, reliability, availability and quick delivery of motors as against operating costs. Thus energy efficiency did not rank at the top of purchaser concerns.

With the increasing cost of electric power and more emphasis on energy conservation, motor manufacturers have been addressing the area of energy efficiency improvement in electric motors to the levels that would lead to significant savings in energy.

Energy efficient motors are designed to generate a given mechanical power output with minimum mechanical and electrical losses within the motor. These energy efficient machines contain more copper and iron and have low frictional

and wind losses in comparison to their counterparts with standard designs. Although, Energy efficient motors typically cost more than standard motors, the benefit of lower operating cost can often offset the price premium [6,7,8].

ELECTRICITY CONSUMPTION TRENDS

Energy is a vital input to the national economic activity. Electricity is a major component within the energy sector. The electricity sector consists of three main consumer groups and few others having relatively low consumption levels. The main groups are the industrial consumers, households and the commercial sector. Electrical energy consumption has been increasing over the years with the total electricity sales in 1985 standing at 2060 GWh while it has increased to 3865 GWh in 1995 recording an increase of 1.9 times within a period of 10 years. The annual average growth rate of total electricity demand has been around 6.6 % during this period. The share of the electricity consumption in the industrial sector during the same period increased from 872 GWh to 1689 GWh at an average annual rate of 7.03 % [1,2,4].

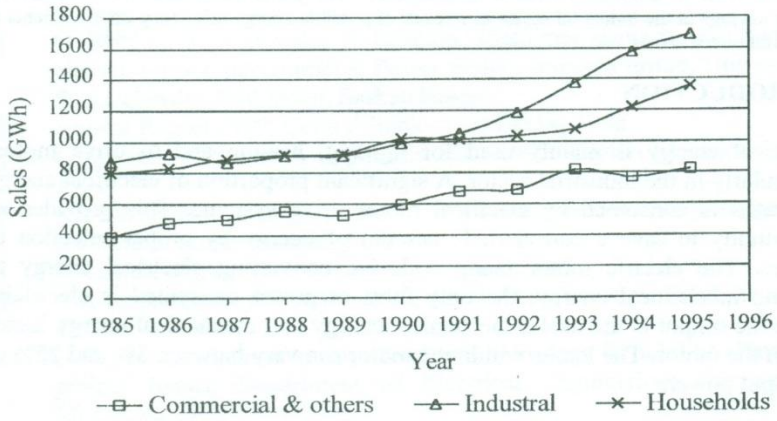

Figure 1: Sectoral electricity consumption growth over the years

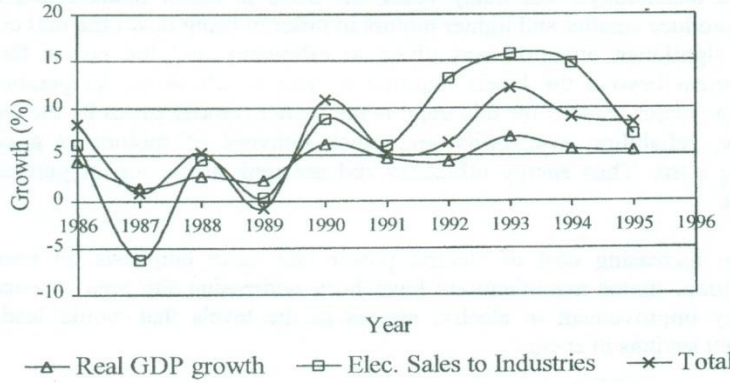

Figure 2: Variation of growth rate in the economy and electricity sector

As can be seen from figure 2 the economic growth in country is strongly correlated to the electricity consumption. In 1985 it required 18.807 MWh to produce one million rupees worth of national output while it has increased to 23.012 MWh in 1995 in current rupee terms. The electricity intensity of the industrial consumers grew from 7.95 MWh per rupees million to 10.05 MWh per rupees million in 1995 [3].

These changes in the electricity intensity can be due to two reasons

a) Changes in the structure of the economy and of electricity use, possibly with more energy consuming industries being established resulting in reduction in the overall economic efficiency of electricity use.
b) Decline in technical efficiency of electricity use.

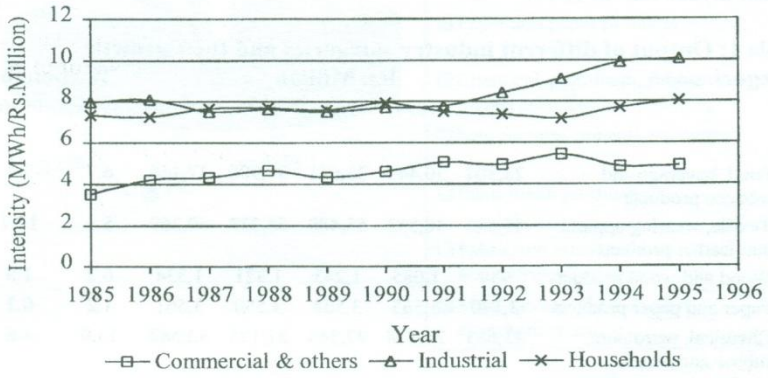

Figure 3: Electricity intensity in different sectors

These factors indicate that a strong emphasis on energy conservation and a move towards less energy intensive industries is necessary to bring down the electricity intensity in industry.

SRI LANKA INDUSTRIAL SECTOR

The industrial sector in Sri Lanka can be classified into nine categories. They are

1. Food, Bevarages and Tobacco
2. Textile, Wearing Apparel & Leather
3. Wood, Wood production & Furniture
4. Paper, Paper Production, Printing, Publishing
5. Chemical, Petroleum, Rubber & Plastics
6. Non-metallic mineral
7. Basic Metal
8. Fabricated Metal Production Machinery & Equipment
9. Other Manufacturing Industries

Overall Trends

The industrial sectors grew by 10.3% in 1997, reflecting a significant expansion of both export oriented and domestic market oriented industries. Textiles and garment, the largest sub-sector in manufacturing, grew by 19%. Its share in GDP rose from 4.5% in 1996 to 5.1% in 1997. Its share in value addition in the industrial sector, which had remained around 38% during the last four years, increased to 41%. Many other industrial sector activities also reflected higher output levels. Among others, plastic, paints, milk products, tea processing, beverages, confectionery products, meat products, electrical items, batteries and rubber products, showed significantly high growth rate during the year. The manufacturing sector contributed 29% to the overall economic growth in 1997. Private sector industrial output grew by 12% compared to 7% in 1996. The Central Bank's Annual Survey of Industrial Production of 470 firms revealed an expansion in industrial sector capacity by 5%, in line with the growth of overall private investment in 1997.

Table 1: Output of different industry categories and their growth

Categories	Rs. Million					% change	
	1993	1994	1995	1996	1997(a)	1996	1997(a)
1. Food, beverage and tobacco products	28,304	30,445	33,641	35,908	37,146	6.7	3.4
2. Textile, wearing apparel and leather products	45,540	48,333	55,480	58,332	69,269	5.1	18.7
3. Wood and wood products	939	1,085	1,243	1,321	1,334	6.2	1.0
4. Paper and paper products	3,140	3,565	3,508	3,550	3,561	1.2	0.3
5. Chemical, petroleum, rubber and plastic products	23,683	25,838	27,543	31,135	32,582	13.0	4.6
6. Non-metallic mineral products	10,349	11,643	12,516	13,360	13,914	6.7	4.1
7. Basic metal products	1,178	1,568	1,377	1,636	1,671	18.8	2.1
8. Fabricated metal products, machinery and transport equipment	5,203	5,931	6,139	6,252	7,437	1.8	18.9
9. Manufacture products not elsewhere specified	2,366	2,617	3,005	3,443	3,904	14.5	13.4
Total	120,702	131,025	144,452	154,937	170,818	7.3	10.3

SAMPLE SURVEY AND ANALYSIS

A survey was carried out to identify the different kinds of motors used in industrial sector of Sri Lanka in order to collect their nameplate data and electricity consumption details of different companies. A sample of twenty-seven companies was selected to visit, on the basis of electricity intensity. Each of the nine industrial categories was divided into three electricity intensity levels. The intensity levels are

1. Electricity intensity less than 5%
2. Electricity intensity more than 5% and less than 15%
3. Electricity intensity more than 15%

One company from each of these intensity levels in each industrial category constitutes a sample of twenty-seven companies. Of the selected sample of twenty seven, only ten institutions responded positively to personal visits by the researchers which resulted in group 7, basic metal products, being completely left out.

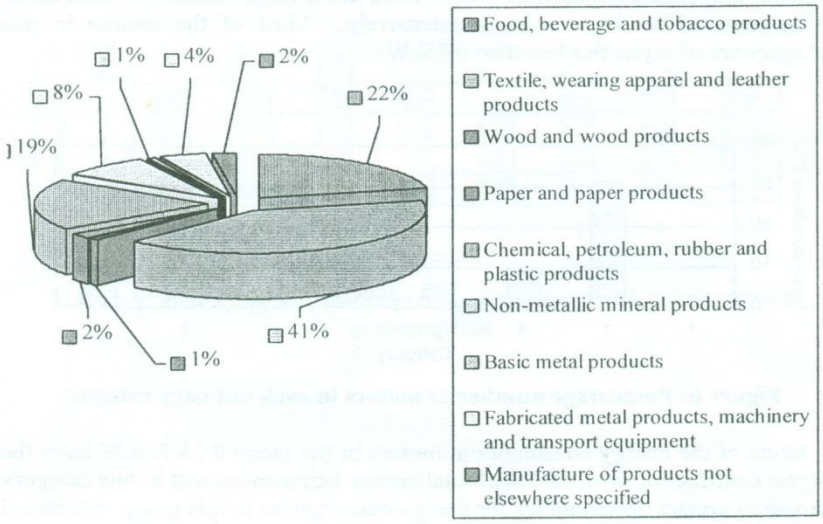

Figure 4: Composition of Industrial Production

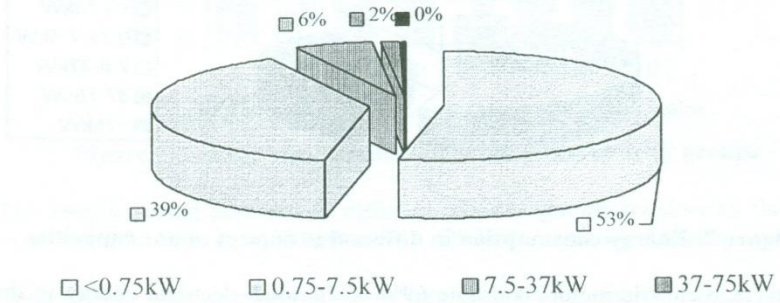

Figure 5: Distribution of different capacities of motors within the sample

Survey Results

Identification of motor population of different power rating ranges and their energy consumption is important in determining the saving potentials of different motor categories. Estimates of motor population of different power rating ranges within the sample are shown in figure 5.

It can be seen that most of the motors in the industry are of small capacities and those exceeding 75kW represents only around 0.3% of the total number of motors in the sample. The highest number of motors are used in the Textile, Apparel and Leather industries where there are a large number of companies using powered sewing machines extensively. Most of the motors in this category are of capacities less than 0.75kW.

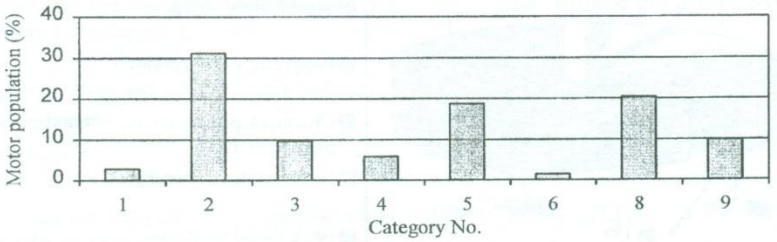

Figure 6: Percentage number of motors in each industry category

In terms of the energy consumption, motors in the range 0.75-7.5kW have the largest contribution with 35.6% of total energy being consumed in this category providing greater opportunities for energy conservation in this group. Estimated motor energy consumptions are shown in the figure 7.

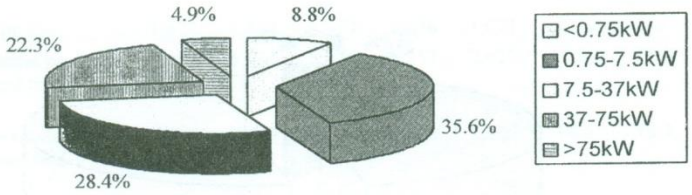

Figure 7: Energy consumption in different groups of motor capacities

On average electric motors consume 69% of the total electrical energy in the industrial sector. The contribution of motors to overall electricity consumption in each industrial category is shown in figure 8.

Although the category of wood, wood products and furniture has the highest motor energy consumption, its saving potential is relatively low because of the low motor population within that category.

Energy saving potential

The calculation of conservation potential of motors in the industry is done on the basis of National Electric Manufacturers Association (NEMA) standards. The existing standard motors in the industry are assumed to be at the average efficiency of the NEMA standard motors. Corresponding improvement in the existing standard motors are assumed to be the nominal efficiency values given for the energy efficient motors on NEMA standard MG1- 12.55A.

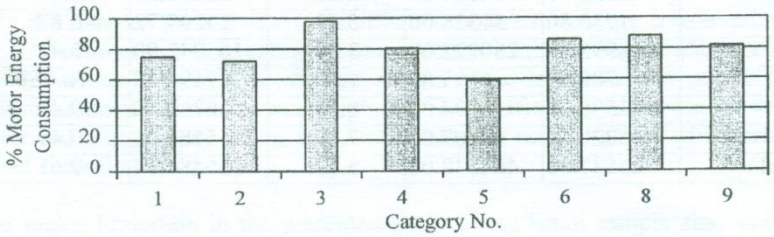

Figure 8: Electricity consumption in motors against total electricity consumption

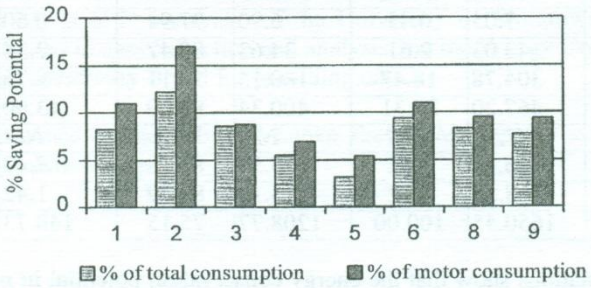

Figure 9: Energy saving potential in different industry groups

The energy saving potential in different industry groups considering that the existing motors are replaced with energy efficient motors are shown in figure 9.

Total energy saving potential in motors is 5.3% of total electrical energy consumption in the industry. It is also 7.6% of the total motor energy consumption in the industry. The highest motor energy saving potential is in the Textile, apparel and leather category. This category has a large number of small power motors where the possibility of efficiency improvement is high compared to large motors.

These results can be extended to the national situation and the corresponding figures are given in table 3.

Table 2: Energy saving potential in motors in different industry groups in the sample

Category No.	Energy Saving potential	Total Energy Consumption		Motor Energy Consumption	
	KWh	kWh	%	kWh	%
1	1915.44	23340.00	8.21	17451.12	10.98
2	2356.67	19270.00	12.23	13863.56	17.00
3	2932.41	34184.00	8.58	33478.20	8.76
4	1730.80	31328.00	5.52	25209.72	6.87
5	8993.59	280722.00	3.20	165942.90	5.42
6	788.64	8393.00	9.40	7192.38	10.96
8	1590.70	19094.00	8.33	16760.80	9.49
9	5229.59	68207.00	7.67	55581.46	9.41
Total	25537.85	484538.00	5.27	335480.14	7.61

Table 3: Projected national energy saving potential in motors within different industry groups

Category No.	Total Energy Consumption		Motor Energy Consumption		Conservation Potential	
	GWh	%	GWh	%	GWh	%
1	196.24	11.89	146.73	74.77	16.10	8.21
2	485.54	29.42	349.29	71.94	59.38	12.23
3	7.05	0.43	6.90	97.94	0.60	8.56
4	43.03	2.61	34.63	80.47	2.38	5.52
5	304.78	18.47	180.15	59.11	9.76	3.20
6	467.20	28.31	400.34	85.69	43.90	9.40
7	*41.95*	*2.54*	*N/A*	*N/A*	*N/A*	*N/A*
8	86.11	5.22	75.59	87.78	7.17	8.33
9	18.57	1.12	15.13	81.49	1.42	7.67
Total	1650.45	100.00	1208.77	75.15	140.73	8.75

These calculations show that the energy conservation potential in motors in the Sri Lanka industrial sector is around 141 GWh, which amounts to approximately 9% of the total electrical energy consumption in the industry. These values are likely to be higher if the industrial category of Basic Metals is also considered in the calculations.

Cost of Efficiency Improvement

The energy efficient motors are around 20-30% higher in cost compared to standard motor [7] whereas the efficiency gain is in the range of 2-8% [9]. For instance a 10hp (7.46kW) standard motor costs US$ 614 and a same capacity efficient motor costs US$ 795. The corresponding efficiency values are 86.5% and 91.6% [9]. If it is assumed that the average daily loading of the motor is 75% with 8hours of daily operation and 300 days annually, the additional

investment will be paid back within less than 5 years at an average electricity cost of Rs 4.75 per kWh. It is considered that an import tax of 50% is imposed on motors. The pay back period will be halved if one considers a two-shift operation in the industry leading to 16hrs of daily operation.

CONCLUSIONS

It can be seen from this study that industrial motor drives consists of a significant a component of industrial electrical energy consumption providing a vast opportunity for energy efficiency improvement in the sector. These efficiency gains can be achieved through proper sizing of motors, having variable speed controls and using energy efficient motors. This paper addressed only the issue of the use of energy efficient motors for energy conservation in the industrial sector. The energy conservation potential through replacement of existing motor drives with efficient motors alone is around 9% of the total industrial electrical energy consumption. These efficiency gains can be vastly improved with proper sizing and replacement of motors along with variable speed controls.

The major limitation in the presented study is the small sample size and the absence of relevant data from one of the industry categories. Further, the estimation of proportion of electricity consumption in motors is based on walk-through audits conducted in the selected sample.

ACKNOWLEDGEMENT

The authors are grateful to Mr H D Chaminda, Mr P S D Dabare, Mr G J Susantha and Mr U N Dahanayake of the University of Moratuwa for their assistance extended in data collection and analysis and the Energy Conservation Fund & Ceylon Electricity Board for providing data.

Financial Assistance extended by Sri Lanka Energy Managers Association is also gratefully acknowledged.

REFERENCES

1. Sri Lanka Energy Balance-1996, Energy Conservation Fund, Sri Lanka, 1997

2. Statistical digest, Ceylon Electricity Board, 1997

3. Annual Report 1997, Central Bank of Sri Lanka, 1998

4. Long Term Generation Expansion Plan 1997, Ceylon Electricity Board, 1997

5. KKYW Perera, Energy status of Sri Lanka; Issues-Policy-Suggestions, , Institute of Policy Studies, 1992

6. John C Andreas, "Energy Efficient Electric Motors", Second Edition, Marcel Dekker Inc, New York, USA, 1996

7. David Walters, "Energy Efficient Motors-Part 1", IEE Power Engineering Journal, London, Volume 13, Number 1, February 1999

8. David Walters, "Energy Efficient Motors-Part 2", IEE Power Engineering Journal, London, Volume 13, Number 3, April 1999

9. http://www.energy.ca.gov/water/motors.html, Energy-Water Connection California Energy Commission, Sacramento, USA

Annex A

Industries in different sub-groups within the industrial sector

1. Food, Beverages and Tobacco
   - 1.1 Meat Products
   - 1.2 Diary Products
   - 1.3 Vegetable Products
   - 1.4 Fish Products
   - 1.5 Oil and Fat Products
   - 1.6 Grain mill products
   - 1.7 Bakery products
   - 1.8 Sugar refined
   - 1.9 Cocoa, chocolate, sugar confectionery
   - 1.10 Food prod. N.E.C.
   - 1.11 Distilled Bottled Spirits
   - 1.12 Wine industry
   - 1.13 Malt industry
   - 1.14 Soft drinks
   - 1.15Tobacco

2 Textile, Wearing Apparels & Leather
   - 2.1 Spinning & Weaving Textile
   - 2.2 Made-up Textile Goods
   - 2.3 Knitting Mills
   - 2.4 Carpets & Rugs
   - 2.5 Cordage, Rope & Twine
   - 2.6 Textile N.E.C.
   - 2.7 Wearing Apparels
   - 2.8 Tanneries & Leather Finishing
   - 2.9 Prod. Of Leather
   - 2.10 Footwear

3 Wood, Wood production. & Furniture
   - 3.1 Saw Mills & Articles
   - 3.2 Wood/Cane Containers/Boxes
   - 3.3 Wood/Cork Prod. N.E.C.
   - 3.4 Furniture

4 Paper, Paper Prod., Printing, Publishing
   - 4.1 Pulp, Paper, Paper Board
   - 4.2 Paper Containers & Boxes
   - 4.3 Paper & Paper Board Articles
   - 4.4 Printing & Publishing

5 Chemical, Petroleum, Rubber & Plastics
   - 5.1 Basic Inds. Chemicals
   - 5.2 Fertiliser & Pesticide
   - 5.3 Synthetic, Plastic Materials
   - 5.4 Paint & Varnish
   - 5.5 Drugs & Medicines
   - 5.6 Soap, Cosmetics
   - 5.7 Chemical Products N.E.C.
   - 5.8 Petroleum
   - 5.9 Miscellaneous Prod. of Petroleum
   - 5.10 Rubber Prod
   - 5.11 Plastic Prod.

6 Non-metallic Mineral
   - 6.1 Pottery & Earthware
   - 6.2 Glassware
   - 6.3 Structural Clay Prod.
   - 6.4 Cement, Lime & Plaster
   - 6.5 Non-metallic Mineral Prod.

7 Basic Metal
   - 7.1 Iron/ Steel Base Industries
   - 7.2 Non-ferrous Metal Industries.

8 Fabricated Metal Prod. Machinery & Equipment
   - 8.1 Hand Tool & General Hardware
   - 8.2 Furniture & Fixtures (Metal)
   - 8.3 Structural Metal Prod.
   - 8.4 Fabricated Metal Prod.
   - 8.5 Engines & Turbines
   - 8.6 Agriculture Machinery
   - 8.7 Metal & Wood Work Machinery
   - 8.8 Special Industrial Machinery
   - 8.9 Office Machinery
   - 8.10 Machinery & Equipment
   - 8.11 Elect. Industrial. Machinery
   - 8.12 Radio, TV, Communication Eqpt.
   - 8.13 Machinery & Eqpt. (Households)
   - 8.14 Electrical Apparatus
   - 8.15 Ship Building
   - 8.16 Railways
   - 8.17 Motor Vehicles
   - 8.18 Motorcycles & Bicycles
   - 8.19 Transport Eqpt.
   - 8.20 Professional Scie. Eqpt.
   - 8.21 Photographic & Optical Eqpt.
   - 8.22 Watches & Clocks

9 Other Manufacturing Industries
   - 9.1 Gem & Jewellery
   - 9.2 Musical Eqpt.
   - 9.3 Sport Eqpt.