INVESTIGATION OF ELECTRICAL ENERGY USE EFFICIENCY IN PEUGEOT AUTOMOBILE NIGERIA LIMITED

BY

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M.ENG/SEET/2008/1945

THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF ENGINEERING (M.ENG.) IN ELECTRICAL AND ELECTRONICS ENGINEERING (ELECTRICAL POWER AND MACHINES)

APRIL, 2012

DECLARATION

I hereby declare that this thesis titled: Investigation of Electrical Energy Use Efficiency in Peugeot Automobile Nigeria Limited is a collection of my original research work and it has not been presented for any other qualification anywhere. Information from other sources (published or unpublished) has been duly acknowledged.

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CERTIFICATION

This thesis titled: Investigation of Electrical Energy Use Efficiency in Peugeot Automobile Nigeria Limited by Akinwole, Oyewole Olabisi (M.Eng/SEET/2008/1945) meets the regulations governing the award of the degree of Master of Engineering (M.Eng) of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to God Almighty for his grace and loving kindness throughout the course of this work.

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May the good God bless you all.

ABSTRACT

Efficiency of energy utilization is one of the major issues in the global scene today, it entails reduction in energy required to increase production and provide better services. This research work investigates various ways and patterns through which electrical energy is being consumed in Peugeot Automobile Nigeria Limited. It identified the sources of energy wastage and suggested strategies to curb the negative trends. The study identifies lighting system as a major source through which energy is being wasted, hence efficient energy saving lighting systems are being proffered; also saving accrued were determined to justify their deployment. In the course of this work, an energy saving calculating tool was developed to calculate energy saving capabilities using energy efficient lamps. With ample devotion to the implementation of the recommendations made, the cost of energy per car will be drastically reduced with concomitant profits. In all more cars will be produced thus translating to more employment opportunities in the industry.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Engineering is the science of economy and conservation of energy stored up by nature for the use of man. It is the business of engineering to utilize this energy to the best advantage, so that there may be the least possible waste (William, 1908). Energy for obvious reasons is regarded as the prime mover of any economy, and the engine of growth around which all sectors of the economy revolve. Thus it becomes imperative that its development, management, and improvement must have predetermined plans and strategies that are capable of driving the economy towards a sure path of sustainable development (Aderemi, *et al.*, 2009). The aim of any industry anywhere is to make profits, increase productivity and reduce waste, conserve resources and enhance image. With ample devotion to tenets of cost reduction and deployment of energy efficient technologies and practices, all of these can be achieved. Andrew Walker, (2006) opined that by managing the demand in the network is a good way of saving expenditure on infrastructure, as the cost of this type scheme is considerably less than reinforcing or upgrading existing infrastructure.

Energy efficiency henceforth in such an industry will be a criterion for all equipment acquisition. That is, before any equipment consuming energy is procured, consideration will be given to its efficiency viz-a-viz power to be consumed by it. Manufacturers of equipment have keyed-in to this also by designing energy efficient systems; it is common place now to see printers, laptops carrying energy star labels. Plant systems are designed and fitted with appropriate controls and other components that optimize their end-use energy efficiency. By imbibing energy–efficient practices, all energy consuming systems are from time to time monitored, cleaned, adjusted, maintained and operated to ensure that they make the most efficient use of energy (CIPEC, 2010). Awareness are created within employees through systematic training and validation on how best to carry out daily operations and maintenance works using powerful methodology of Total Productive Maintenance (TPM).

As a result of technologies usually deploy in automobile industry, Induction motors, often referred to as "factory workhorse" is usually used. These motors, being inductive loads require a current flow to create magnetic fields to produce the desired work. This brings low power factor. A low power factor is expensive and inefficient. Utility companies do charge additional fees when the power factor is less than 0.95, it reduces electrical system's distribution capacity by increasing the current flow and causing voltage drops. Power factor correction brings the power factor of an Alternating Current (AC) system closer to 1. It is believed that improving power factor will increase energy efficiency and reduce cost. Also by acquiring energy efficient motors, 2 to 8% efficiency can be gotten compared with standard motors. They owe their higher performance to key design improvements and more accurate manufacturing tolerances.

Another system of note in an automobile industry is lighting system. About 21% of the world's electrical energy is used for lighting. That equals a whopping 12 Billions KWh per day. By replacing inefficient fluorescent fittings with Light Emitting Diode (LED) and compact fluorescent lighting, a lot of energy can be saved with concomitant cost reduction.

Employment of efficient energy programmes in an automobile manufacturing industry can bring about reduction in fossil fuel used by 12% with attendant reduction in greenhouse gasses by more than 70,000 tons of Carbon dioxide (CO_2). The emission reduction which can be of help in fighting climate change is equal to the emissions from the electricity use of more than 80,000 homes in a year.

1.2 AIM AND OBJECTIVES

The main aim and objectives of this work are:

(i) To audit electrical energy efficiency in the industry and proffer areas of improvement.

(ii) To unravel the cost saving opportunities and potentials.

(iii) To develop strategies for maintaining effective energy saving in the industry.

1.3 PROBLEM STATEMENT/MOTIVATIONS

It was shown in the factory records that the industry consumes average of 1 million litres of diesel annually, translating to a minimum of 33000 litres monthly. Going by the high cost of the commodity in Nigeria, a sum of ₦90 million was used for its procurement in 2010. It is on factory records that a whooping sum of ₦ 110 million was used to provide electrical energy in 2008, the breakdown of which shows that ₦70.12 million was used to buy diesel, another ₦37.57 million was used to pay electricity bills while maintenance of generating sets gulped ₦2.47 million; in the same year, the cost of electrical energy per car was ₦ 200,000.

The manufacturing sector in Nigeria has been bedevilled by this negative trend. This also majorly account for the closing down of some factories in Nigeria while a couple of others are relocating to other West African countries where cost of energy is affordable in order to break even.

Undoubtedly, the aforementioned situation has to be reversed for the continuance of business in our factories. Not yielding to this beckon will not augur well for our nation hence all hands must be on deck for this clarion call.

Altogether, going by the climate changes occasioned by ubiquitous emissions of green house gasses, one can not but carryout a research work towards ameliorating the negative trends.

1.4 METHODOLOGY

My familiarity with the equipment has been priceless in executing the research work. This also is made possible by my posting within the Peugeot plant- a factor that enables my day to day study of the problems. The production lines and the switch rooms powering them were identified. The transformers feeding the switch rooms were determined and carefully studied.

Other methods employed include the following,

1. Collection of data from records books and equipment name plates.
2. Statistical evaluation of the resulting data with ample use of charts, graphs, using MS Excel 2007.
3. Conclusions were drawn from the results obtained.

The aspect of counting equipment and fittings in the shop floor and work zones personally is an aspect that produces reliable data.

The collected data were entered into excel spreadsheet for analysis using excel formulas and programs. The visual result is made possible with charts made from the data. These charts litter this thesis.

1.5 SCOPE OF THE STUDY

The study is geared towards auditing energy consumption in the industry. It identifies where and how energy is being wasted; it proffers solution to the problems. The results lucidly calculate gains to be accrued when energy efficient systems are deployed. It is shown that by tackling the menace of inefficiency, cost of energy per car will be reduced.

1.6 ORGANIZATION OF THE THESIS

The first chapter gives general introduction to energy use efficiency in the industry. It comprises aim and objectives of the project, motivation and the methodology employed. Chapter two reviews the historical lanes on motor vehicle manufacturing in Nigeria which shows the pinnacle of car production in the country and its downward trends heralded by harsh government economic policy of Structural Adjusted Programme (SAP). Chapter three explains the materials and methods used. Chapter four shows the results obtained from the analysis while chapter five gives the conclusion and recommendation. The references and appendices were listed at the end of the report.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

Nigeria government involvement in the automotive industry dates from the second development plan period (1970 to 1974), when the two passenger car assembly plants were established. This was followed, during the third plan period (1975 to 1980) by the establishment of three more assembly plants for trucks and light commercial vehicles complemented by a fourth that was to specialise in tractors and other form equipment.

Six plants were established and were for the assembling of Peugeots (Peugeot Automobile Nigeria Limited), Volkswagen (Volkswagen of Nigeria Limited), Cars, FIAT (National Trucks Manufacturers), Steyr, Mercedes Benz and Leyland trucks and buses. Limited liability Companies (LLCs) were formed with total/major shares held by Federal, States, Corporate bodies and other Nigerians. The plants were conceived as profitable ventures capable of accruing to the government revenues in the form of various and increased tax yields and dividends.

Automobiles Peugeot (AP) is within the PSA group that manufactures the Peugeot and Citroën serial models. AP has been manufacturing these models for over a hundred years now in France and later, Britain, Spain, Africa, Asia and South America. PSA is organised into six subsidiaries semi-autonomous divisions, but the two vehicle manufacturing ones have their board. The divisions are: Automobile, mechanical engineering and services, human resources, financial services, Peugeot Automobile and Automobile Citroen divisions.

Peugeot serial models were selected for assembling in Nigeria because it has been determined that it possess total qualities that would ensure Reliability, Resilience and Longevity (RRL) in use. The initiative to establish Peugeot Automobile Nigeria Limited was taken by the then Federal Military Government under the leadership of General Yakubu Gowon, then as a Military Head of State. The idea was concretized on 6th October, 1969 when the government invited 16 reputable vehicle manufacturing companies in the world to submit proposal for the establishment of vehicle assembly plant in the country.

Twelve years before the initiative was taken, 1957 to be precise, Peugeot Cars made their first entry into Nigeria when about 100 units of the Peugeot 403 model were imported into the country by individuals. These cars soon became popular due to their legendary, reliability and suitability to Nigerian road conditions. The demand for Peugeot cars in Nigeria rose sharply again in the 1960s with the further introduction into the country of Peugeot 404 model. With the high demand of Peugeot products which was a mark of acceptability, it was therefore not surprising when on 7th May, 1971, Automobile Peugeot of France's proposal was selected out of those tendered by sixteen various vehicle manufacturers.

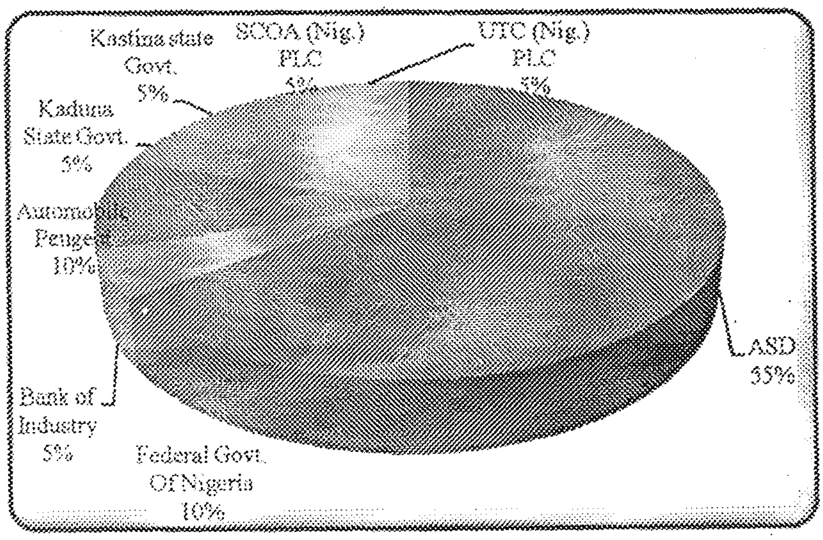

Figure 2.1: Peugeot Automobile Nigeria (PAN) Limited Current Ownership structure.

In 15th December, 1972, PAN was incorporated as Limited Liability Company with an authorized share capital of three million naira. Twenty seven months after incorporation, the assembly plant was commissioned by the then Head of State, General Yakubu Gowon on 14th March, 1975, though it commenced operations on 2nd March, 1975.

The company commenced production with an annual output of 60,000 cars. In the 1980s, the company production output improved substantially to 70,000 cars per annum and it had more than 2000 staff on its payroll. Its role in the industrial sector was one of significance due to heavy reliance on local suppliers with 70 local firms providing 37% of local content for domestic production.

2.1.1 Structural Adjustment Programme (SAP)

In 1986, the government of Nigeria introduced structural adjustment programme (SAP). This harsh economic policy commenced the regime that wiped off middle class that purchases bulk of cars manufactured. The policy sparked off difficulties experienced by automobile manufacturers in the country. In table 2.1, it is seen that PAN started with a production of 11,584 cars in 1975, it went up to 18,224 in 1976 and more than 27,000 in 1977.

After this year, the trend was smoother but rose dramatically in 1979 and up to 1984 when the range was 42,908 to 44,240 cars within the years. Decline became apparent in 1986.

Table 2.1: Peugeot Car Production Records in Nigeria

YEAR	CKD	CBU	TOTAL
1975	10362	1222	11584
1976	17441	783	18224
1977	25836	2065	27901
1978	19632	474	20106
1979	42856	52	42908
1980	60286	417	60703
1981	72696	4133	76829
1982	73846	1315	75161
1983	36843	135	36978
1984	44240	0	44240
1985	35992	0	35992
1986	26966	0	26966
1987	7294	29	7323
1988	9938	600	10538
1989	4707	692	5399
1990	8379	977	9356
1991	12170	1180	13350
1992	11252	504	11756
1993	7541	296	7837
1994	4991	265	5256
1995	3346	147	3493
1996	3650	269	3919
1997	4383	225	4608
1998	4689	479	5168
1999	5687	698	6385
2000	5943	999	6942
2001	6621	1382	8003
2002	2625	828	3453

(Source: PAN Limited Archives)

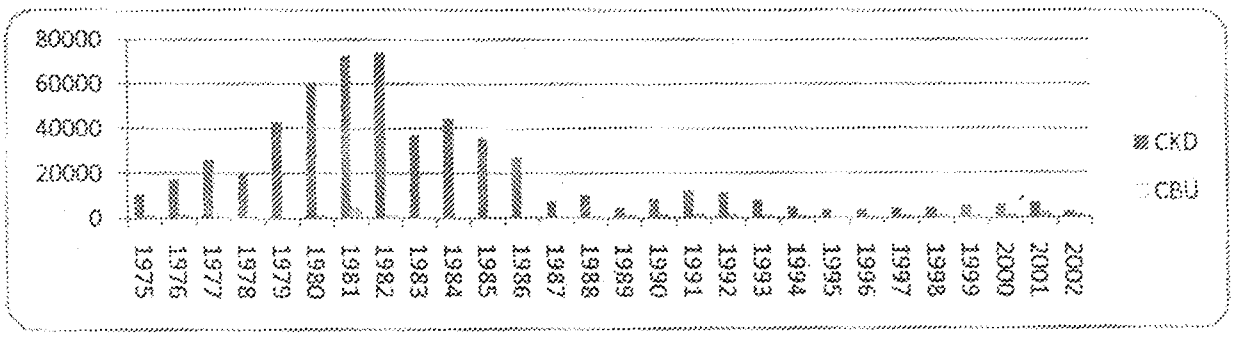

Figure 2.2: Peugeot Car production in Nigeria (CKD: Completely Knocked Down; CBU: Completely Built Unit)

2.1.2 Aim for Setting Up Peugeot Automobile Nigeria Limited

The main aim of setting up Peugeot Automobile Nigeria Limited was to ensure massive production of vehicles particularly cars, based on demand and the need to save the nation's foreign exchange resources. On long term basis, Peugeot plant was also intended to create employment opportunities for Nigerians to contribute significantly to the Gross Domestic Product (GDP). More importantly, the plant was to have multiplier effects, which could result in the development of various ancillary industries to manufacture different components for the vehicles. The long term goal was to ensure that the assembly plant depended increasingly more on local sources for all the components required for manufacturing cars and other related items for internal consumption and for export into other African countries.

It is in support of these, that the Federal Government took some positive actions to put in place clear policy guidelines that would redirect the development of the auto-industry generally in Nigeria. Those guidelines are documented in the National Automotive Policy which was lunched in August of 1993. Decree No.84 of 1993 established the National Automotive Council (NAC)

2.2 Electrical Power System and Loading Basics

In order to design an installation, the actual maximum load demand likely to be imposed on the power supply system must be assessed.

2.2.1 Installed Power (KW)

The installed power is the sum of the nominal power consuming devices in the installation. This is not the power to be actually supplied in practice. This is the case of electric motors where the power rating refers to the output power at its driving shaft. The input power consumption will evidently be greater. Fluorescent and discharge lamps associated with stabilizing ballasts are other cases in which the nominal power indicated on the lamp is less than power consumed by the lamp and its ballast.

The power demand (kW) is necessary to choose the rated power of a generating set or battery, and where the requirements of a prime mover have to be considered.

For a power supply from a Low Voltage (LV) public supply network, or through a Medium Voltage/Low Voltage (MV/LV) transformer, the significant quantity is the apparent power in KVA.

2.2.2 Installed Apparent Power (KVA)

The installed apparent power is commonly assumed to be the arithmetical sum of the Kilovolt-Ampere (KVA) of individual loads. The maximum estimated KVA to be supplied however is not equal to the total installed KVA. The apparent power demand of a load(which might be a single appliance) is obtained from its nominal power rating and the application of the following coefficients.

$$\eta = the\ per\ unit\ efficiency = \frac{output\ KW}{Input\ KW} \qquad (2.1)$$

$$Cos\varphi = the\ power\ \ factor = \frac{KW}{KVA} \qquad (2.2)$$

The apparent power KVA demand of the load.

$$Pa = \frac{Pn}{\eta \times Cos\varphi} \qquad (2.3)$$

From the value, the full load current Ia taken by the load will be

$$Ia = \frac{Pa \times 10^3}{V} \quad \text{(For single phase to neutral connected load)} \qquad (2.4)$$

$$Ia = \frac{Pa \times 10^3}{\sqrt{3} \times U} \quad \text{(For 3}\Phi\text{ balanced load)} \tag{2.5}$$

Where V = phase-to-neutral voltage (Volts)

U = phase-to-phase voltage (Volts)

It may be noted that strictly speaking the total KVA of apparent power is not the arithmetical sum of the calculated KVA ratings of individual loads (unless all loads are at the same power factor) It is common practice however, to make a simple arithmetical summation, the result of which will give a KVA value that exceeds the true value by an acceptable "design margin". When some or all of the load characteristics are not known, the values shown in Tables 2.2 and 2.3 below may be used to give a very approximate estimate of VA demands (individual loads are generally too small to be expressed in KVA or KW). The estimates for lighting loads are based on floor areas of $500m^2$.

Table 2.2: Estimation of Installed Apparent Power (Fluorescent Lighting Cos φ=0.86)

TYPES OF APPLICATION	ESTIMATED (VA/M^2) FLUORESCENT TUBE WITH INDUSTRIAL REFLECTOR	AVERAGE LIGHTING LEVEL ($1lux = 1m/m^2$)
Roads and highway storage areas, intermittent work	7	150
Heavy duty works: fabrication and assembly of very large work pieces	14	300
Day-to-day work: office work	24	500
Fine work: drawing offices high precision assembly workshop	41	800

(Source: Electrical Installation Guide: www.electrical installation.org)

Table 2.3: Power Circuits

TYPES OF APPLICATION	ESTIMATED (VA/M^2)
Pumping station compressed air	3 to 6
Ventilation of premises	23
Electrical convection heaters: private houses, flats and apartments	115 to 146 90
Offices	25
Dispatching workshop	50
Assembly work shop	70
Machine shop	300
Painting workshop	350
Heat treatment plant	700

(Source: Electrical Installation Guide: www.electrical installation.org)

2.2.3 Estimation of Actual Maximum KVA Demand

All individual loads are not necessarily operating at full rated nominal power nor necessarily at the same time. Factors Ku and Ks allow determination of the maximum power and apparent-power demands actually required to dimension the installation.

2.2.4 Factor of Maximum Utilization (Ku)

In normal operating conditions, the power consumption of a load is sometimes less than that indicated as its nominal power rating, a fairly common occurrence that justifies the application of a utilization factor (Ku) in the estimation of realistic values. This factor must be applied to each individual load, with particular attention to electric motors, which are very rarely operated at full load. In an industrial installation this factor may be estimated on an average at 0.75 for motors. For incandescent-lighting loads, the factor always equal to one. For socket outlet circuits, the factors depend entirely on the type of appliances being supplied from the sockets concerned.

2.2.5 Factor of Simultaneity (Ks)

It is a matter of common experience that the simultaneous operation of all installed loads of a given installation never occurs in practice, that is, there is always some degree of diversity and this fact is taken into account for estimating purposes by the use of a simultaneity factor (Ks). The factor Ks is applied to each group of loads (e.g. being supplied from a distribution or sub distribution board). The determination of these factors is the responsibility of the designer, since it requires a detailed knowledge of the installation and the conditions in which the individual circuits are to be exploited. For this reason, it is not possible to give precise values for general application.

2.2.6 Factor of Simultaneity for an Apartment Block

Some typical values for this case are given in table 2.4, and are applicable to domestic consumers supplied at 230/400V (3-phase 4-wire). In the case of consumers using electrical heat storage units for space heating, a factor of 0.8 is recommended, regardless of the number of consumers.

Table 2.4: Simultaneous Factors in an Apartment Block.

NUMBER OF DOWNSTREAM CONSUMERS	FACTOR OF SIMULTANEITY (Ks)
2 TO 4	1
5 TO 9	0.78
10 TO 14	0.63
15 TO 19	0.53
20 TO 24	0.49
25 TO 29	0.46
30 TO 34	0.44
35 TO 39	0.42
40 TO 49	0.41
50 AND ABOVE	0.4

(Source: Electrical Installation Guide: www.electrical installation.org)

2.2.7 Factor of Simultaneity for Distribution Switchboards

Table 2.5 below shows hypothetical values of Ks for a distribution board supplying a number of circuits for which there is no indication of the manner in which the total load divides between them. If the circuits are mainly for lighting loads, it is prudent to adopt Ks values close to unity.

Table 2.5: Factor of Simultaneity for Distribution Boards

NUMBER OF CIRCUITS	FACTOR OF SIMULTANEITY (Ks)
Assemblies entirely tested 2 and 3	0.9
4 and 5	0.8
6 TO 9	0.7
10 and more	0.6
Assemblies partially tested in every case Choose	1

(Source: Electrical Installation Guide: www.electrical installation.org)

Table 2.6: Factor of Simultaneity According to Circuit Function

Circuit Function		Factor of Simultaneity (Ks)
Lighting		1
Heating and air conditioning		1
Socket outlets		0.1 to 0.2
Lifts and catering hoist	For the most powerful motor	1
	For the second most powerful motor	0.75
	For all motors	0.6

(Source: Electrical Installation Guide: www.electrical installation.org)

It should be noted that Ks can be higher in the case of socket outlets of industrial installations. Also for lifts and hoist, the current to take into consideration is equal to the nominal current of the motor, increased by a third of its starting current.

2.2.8 Diversity Factor

The term diversity factor, as defined by IEC standards, is identical to the factor of simultaneity (Ks). In some English-speaking countries however diversity factor is the inverse of Ks, that is, it is always ≥1.

2.2.9 Choice of Transformer Rating

When an installation is to be supplied directly from a MV/LV transformer and the maximum apparent-power loading of the installation has been determined, a suitable rating for the transformer can be decided, taking into account the following considerations.

(a) The possibility of improving the power factor of the installation

(b) Anticipated extensions of the installation

(c) Installation constraints (e.g. temperature)

(d) Standard transformer ratings.

The nominal full-load current In on the LV side of a 3-phase transformer is given by:

$$In = \frac{Pa \times 10^3}{U\sqrt{3}} \tag{2.6}$$

where Pa = KVA rating of the transformer

U = phase-to-phase voltage at no load in volts

In is in Amperes.

For a single-phase transformer:

$$In = \frac{Pa \times 10^3}{V} \tag{2.7}$$

Where V = Voltage between LV terminals at no load.

Table 2.7: Apparent Powers for MV/LV Transformers and Related Output Current

Apparent Power(KVA)	237V	410V
100	244	141
160	390	225
250	609	352
315	767	444
400	974	563
500	1218	704
630	1535	887
800	1939	1127
1000	2436	1408
1250	3045	1760
1600	3898	2253
2000	4872	2816
2500	6090	3520
3150	7673	4436

(Source: Electrical Installation Guide: www.electrical installation.org)

2.2.10 Choice of Power-Supply Sources

In practice, connection to a MV source may be necessary where the load exceeds (or is planned eventually to exceed) a certain level-generally of the order of 250KVA, or if the quality of service required is greater than that normally available from a LV network. Moreover, if the installation is likely to cause disturbance to neighbouring consumers, when connected to a LV network, the supply authorities may propose a MV service.

Supplies at MV can have certain advantages: in fact, a MV consumer-

(a) Is not disturbed by other consumers, which could be the case at LV

(b) Is free to choose any type of LV earthing system.

(c) Has a wider choice of economic tariffs.

(d) Can accept very large increase in load.

2.2.11 Installed Power Loads

An examination of actual values of apparent-power required by each load enables the establishment of

(a) A declared power demand which determines the contract for the supply of energy.

(b) The rating of the MV/LV transformer, where applicable(allowing for expected increased load)

(c) Levels of load current at each individual board.

2.3 Induction Motors

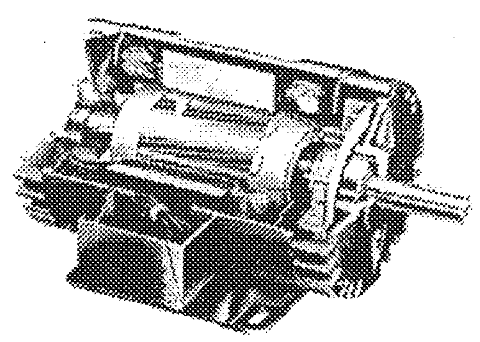

Plate I: Induction Motor

The nominal power in KW (Pn) of a motor indicates its rated equivalent mechanical power output. The apparent power in KVA (Pa) supplied to the motor is a function of the output, the motor efficiency and the power factor.

$$Pa = \frac{Pn}{\eta \times Cos\,\varphi} \tag{2.8}$$

2.3.1 Current Demand

The full-load current Ia supplied to the motor is given by the following formulae:

$$3\Phi \text{ motor } \; Ia = \frac{Pn \times 1000}{\sqrt{3} \times U \times \eta \times Cos\varphi} \tag{2.9}$$

$$1\Phi \text{ motor } \; Ia = \frac{Pn \times 1000}{U \times \eta \times Cos\varphi} \tag{2.10}$$

Where Ia = current demand (in Amps)

Pn = nominal power (in KW)

U = voltage between phases for 3-phase motor and voltage between terminals for single phase motors

η = per-unit efficiency i.e. $outputKW/inputKW$

Cos φ = power factor

2.3.2 Subtransient Current and Protection Setting

- Sub transient current peak value can be very high: typical value is about 12 to 15 times the rms rated value (Inm). Sometimes this value can reach 25 times Inm.

- Schneider Electric circuit-breakers, contactors and thermal relays are designed to withstand motor starts with very high sub transient current (sub transient peak value can be up to 19 times the rms rated value (Inm).
- If unexpected tripping of the overcurrent protection occurs during starting, this means the starting current exceeds the normal limits. As a result, some maximum switchgear withstands can be reached, life time can be reduced and even some devices can be destroyed. In order to avoid such a situation, oversizing of the switchgear must be considered.
- Schneider electric switchgears are designed to ensure the protection of motor starters against short-circuits.

2.3.3 Motor Starting Current

Although high efficiency motors can be found on the market, in practice their starting currents are roughly the same as some of standard motors. The use of start-delta starter, static soft start unit or variable speed drive reduce the value of starting current

2.3.4 Compensation of Reactive-Power (KVAR) Supplied to Induction Motors

It is generally advantageous for technical and financial reasons to reduce the current supplied to an induction motors. This can be achieved by using capacitors without affecting the power output of the motors. The application of this principle to the operation of induction motors is generally referred to as "power factor improvement" or "power factor correction" The apparent power (KVA) supplied to an induction motor can be significantly reduced by the use of shunt-connected capacitors. Reduction of input KVA means a corresponding reduction of input current (since the voltage remains constant).

Compensation of reactive-power is particularly advised for motors that operate for long periods at reduced power.

As noted above $Cos\varphi = \frac{KWinput}{KVAinput}$ so that a KVA input reduction will increase (i.e. improve) the value of Cos φ

The current supplied to the motor, after power-factor correction, is given by $I = \frac{Ia\ Cos\,\varphi}{Cos\,\varphi'}$

Where Cos φ is the power factor before compensation and cos φ' is the power factor after compensation, Ia being the original current.

2.4 Synchronous Motors

Synchronous motors can also be used to improve Power factor. When they are employed, an improved power factor may be obtained by adjusting the field excitation of the motors. Synchronous motors used in this manner are referred to as Synchronous condensers.

2.5 Energy Efficient Motors

Energy efficient motors are higher quality motors with increased reliability and longer manufacturer's warrantees, providing savings in reduced downtime, replacement and maintenance costs. Saving this energy and money requires the proper selection and use of energy-efficient motors. Energy efficient motors should be considered in the following instances:

- For all new installations

- When major modifications are made to existing facilities or processes.
- For all new purchases of equipment packages that contain electric motors, such as air conditioners, compressors etc.
- When purchasing spares or replacing failed motors.

2.6 Electric Motor Efficiency

It is defined by the motor manufacturer as how efficiently a motor turns electrical energy into mechanical energy. To the end user, motor efficiency percentage is important because it is directly related to the cost of operating the motor. The higher the motor efficiency percentage, the less power is required; using less power conserves energy and saves money.

The efficiency of a motor is the ratio of the mechanical power output to the electrical power input. This may be expressed as.

$$Efficiency = \frac{Output}{Input} = \frac{Input - Losses}{Input} = \frac{Output}{Output + Losses} \tag{2.11}$$

Design changes, better materials and manufacturing improvements reduce motor losses, making premium or energy efficient motors more efficient than standard motors. Reduced losses mean that an energy-efficient motor produces a given amount of work with less energy input than a standard motor.

2.7 Resistive-type Heating Appliances and Incandescent Lamps

The current demand of a heating appliance or an incandescent lamp is easily obtained from the nominal power Pn quoted by the manufacturer.

That is, Cos φ =1

For 3 phase case $Ia = Pn / \sqrt{3}\, U$ (2.12)

and single phase, $Ia = Pn / U$ (2.13)

where U = Voltage applied between the terminals of the equipment

Table 2.8: Current Demand of Resistive Heating and Incandescent Lighting in Ampere

Nominal Power(KW)	1-Φ 230V	3-Φ 400V
0.1	0.43	0.14
0.2	0.87	0.29
0.5	2.17	0.72
1	4.35	1.44
1.5	6.52	2.17
2	8.70	2.89
2.5	10.87	3.61
3	13.04	4.33
3.5	15.22	5.05
4	17.39	5.77
4.5	19.57	6.50
5	21.74	7.22
6	26.09	8.66
7	30.43	10.10
8	34.78	11.55
9	39.13	12.99
10	43.48	14.43

(Source: Electrical Installation Guide: www.electrical installation.org)

2.8 Fluorescent Lamps

The power Pn (Watts) indicated on the tube of a fluorescent lamp does not include the power dissipated in the ballast. Ballast is a mechanism that regulates the amount of electricity required to start a lighting fixture and maintain a steady output of light. The current is given by:

$$Ia = (P_{ballast} + P_n) / U \cos \varphi \tag{2.14}$$

Where U is the voltage applied to the lamp

2.8.1 Standard Tubular Fluorescent Lamps

With (unless otherwise indicated):

1. Cos φ = 0.6 with no power factor correction capacitor.
2. Cos φ = 0.86 with power factor correction (single or twin)
3. Cos φ =0.96 for electronic ballast.

If no power-loss value is indicated for the ballast, a figure of 25% of Pn may be used.

Table 2.9: Current Demands and Power Consumption of Fluorescent Tubes

Arrangement of lamps, starters and ballast	Tube power (W)	Current(A) at 230V Magnetic ballast Without PF correction capacitor	With PF correction capacitor	Electronic ballast	Twin length (ft)
Single tube	18	0.2	0.14	0.1	2
	36	0.33	0.23	0.18	4
	58	0.5	0.36	0.28	5
Twin tube	2 × 18		0.28	0.18	2
	2 × 36		0.46	0.35	4
	2 × 58		0.72	0.52	5

(Source: Electrical Installation Guide: www.electrical installation.org)

2.8.2 Compact Fluorescent Lamps

Compact fluorescent lamps have the same characteristics of economy and long life as classical tubes. They are commonly used in public places which are permanently illuminated (for example: corridors, hallways, bars etc.) and can be mounted in situations otherwise illuminated by incandescent lamps. Table 2.10 shows current demands and power consumption of compact fluorescent lamps.

Table 2.10: Current Demands and Power Consumption of Compact Fluorescent Lamps.

Type of lamp	Lamp power (W)	Current (230V)
Separated ballast lamp	10	0.008
	18	0.11
	26	0.15
Integrated ballast lamp	8	0.075
	11	0.095
	16	0.125
	21	0.17

(Source: Electrical Installation Guide: www.electrical installation.org)

2.9 Energy Efficient Lighting

About 21% of the world's electrical energy is used for lighting. That equals a whopping 12 Billions KWh per day. With emergence of LED technologies and compact fluorescent tubes, a lot of energy is being saved globally. Plate 2.0 shows some energy efficient fittings

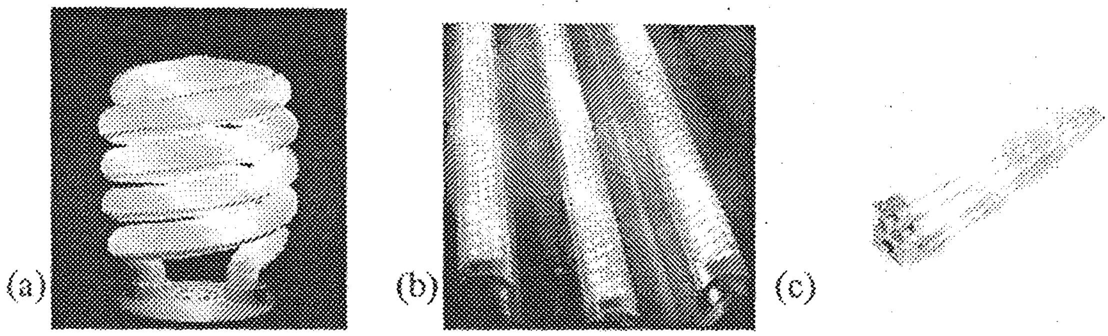

Plate II: Energy Efficient Fittings

2.10 Discharge Lamps

These lamps depend on the luminous electrical discharge through a gas or vapour of a metallic compound, which is contained in a hermetically-sealed transparent envelope at a predetermined pressure. They have a long start-up time, during which the current Ia is greater than the nominal current In. The power in watts indicated on the tube of a discharge lamp does not include the power dissipated in the ballast.

2.11 Luminous Flux

It is a measure of the power of light perceived by the human eye. The SI unit of luminous flux is lumen (lm). A single fluorescent light fixture that produces a luminous flux of 12000lumens might light a residential kitchen with an illuminance of 500 Lux. Lighting a larger area to the same illuminance requires a proportionately greater number of lumen.

2.11.1 Illuminance

It is a measure of how much luminous flux is spread over a given area or as measure of the intensity of illumination on a surface. A given amount of light will illuminate a surface more dimly if it is spread over a larger area, so illuminance is inversely proportional to the area. Toyota sets a standard of 100 lm/m^2 in the quality check areas

The SI unit of Illuminance is Lux and 1 Lux =1 lm/m^2

2.11.2 Luminous Efficacy

It is a figure of merit for light sources. It is the ratio of luminous flux to power. The luminous efficacy of a source is a measure of the efficiency with which the source provides visible light from electricity. The SI unit is lumen per watt (lm/w).

2.12 Energy Efficiency

Energy efficiency is the goal of efforts to reduce the amount of energy required to provide products and services. For example, insulating a home allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature. Installing fluorescent lights or natural skylights reduces the amount of energy required to attain the same level of illumination compared to using traditional incandescent light bulbs. Compact fluorescent lights use two-thirds less energy and may last 6 to 10 times longer than incandescent lights. Improvements in energy efficiency are most often achieved by adopting a more efficient technology or production process.

There are various motivations to improve energy efficiency. Reducing energy use reduces energy costs and may result in a financial cost saving to consumers if the energy savings offset any additional costs of implementing an energy efficient technology. Reducing energy use is also seen as a key solution to the problem of reducing greenhouse gas emissions. According to the International Energy Agency, improved energy efficiency in buildings, industrial processes and transportation could reduce the world's energy needs in 2050 by one third, and help control global emissions of greenhouse gases.

Energy efficiency and renewable energy are said to be the twin pillars of sustainable energy policy. In many countries energy efficiency is also seen to have a national security benefit because it can be used to reduce the level of energy imports from foreign countries and may slow down the rate at which domestic energy resources are depleted.

Making industry energy efficient is seen as a largely untapped solution to addressing the problems of pollution, global warming, energy security, and fossil fuel depletion. Many of these ideas have been discussed for years, since the 1973 oil crisis brought energy issues to the forefront. In the late 1970s, physicist Amory Lovins popularized the notion

of a "soft energy path", with a strong focus on energy efficiency. Among other things, Lovins popularized the notion of Negawatts—the idea of meeting energy needs by increasing efficiency instead of increasing energy production.
Energy efficiency has proved to be a cost-effective strategy for building economies without necessarily growing energy consumption.

Industry uses a large amount of energy to power a diverse range of manufacturing and resource extraction processes. Many industrial processes require large amounts of heat and mechanical power, most of which is delivered as natural gas, petroleum fuels and as electricity.

Electric motors usually run at a constant speed, but a variable speed drive allows the motor's energy output to match the required load. This achieves energy savings ranging from 3 to 60 percent, depending on how the motor is used. Motor coils made of superconducting materials can also reduce energy losses. Motors may also benefit from voltage optimisation.

Industry uses a large number of pumps and compressors of all shapes and sizes and in a wide variety of applications. The efficiency of pumps and compressors depends on many factors but often improvements can be made by implementing better process control and better maintenance practices. Compressors are commonly used to provide compressed air which is used for sand blasting, painting, and other power tools. According to the US Department of Energy, optimizing compressed air systems by installing variable speed drives, along with preventive maintenance to detect and fix air leaks, can improve energy efficiency 20 to 50%.

2.13 Renewable Energy

Renewable energy is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished). In 2008, about 19% of global final energy consumption came from renewables, with 13% coming from traditional biomass, which is mainly used for heating, and 3.2% from hydroelectricity. New renewable (small hydro, modern biomass, wind, solar, geothermal, and bio-fuels) accounted for another 2.7% and are growing very rapidly. The share of renewables in electricity generation is around 18%, with 15% of global electricity coming from hydroelectricity and 3% from new renewables. Wind power is growing at the rate of 30% annually, with a worldwide installed capacity of 158 Gigawatts (GW) in 2009,[1] and is widely used in Europe, Asia, and the United States. At the end of 2009, cumulative global photovoltaic (PV) installations surpassed 21 GW and PV power stations are popular in Germany and Spain. Solar thermal power stations operate in the USA and Spain, and the largest of these is the 354 Megawatt (MW) SEGS power plant in the Mojave Desert. The world's largest geothermal power installation is The Geysers in California, with a rated capacity of 750 MW. Brazil has one of the largest renewable energy programs in the world, involving production of ethanol fuel from sugar cane, and ethanol now provides 18% of the country's automotive fuel. Ethanol fuel is also widely available in the USA.

While many renewable energy projects are large-scale, renewable technologies are also suited to rural and remote areas, where energy is often crucial in human development. Globally, an estimated 3 million households get power from small solar PV systems. Micro-hydro systems configured into village-scale or county-scale mini-grids serve many areas. More than 30 million rural households get lighting and cooking from biogas made in household-scale digesters. Biomass cook stoves are used by 160 million households.

Climate change concerns, coupled with high oil prices, peak oil, and increasing government support, are driving increasing renewable energy legislation, incentives and commercialization. New government spending, regulation and policies helped the industry weather the global financial crisis better than many other sectors.

2.14 Economic Trends

All forms of energy are expensive, but as time progresses, renewable energy generally gets cheaper, while fossil fuels generally get more expensive. It has been explained that renewable energy technologies are declining in price for three main reasons:

First, once the renewable infrastructure is built, the fuel is free forever. Unlike carbon-based fuels, the wind and the sun and the earth itself provide fuel that is free, in amounts that are effectively limitless.

Second, while fossil fuel technologies are more mature, renewable energy technologies are being rapidly improved. So innovation and ingenuity give us the ability to constantly increase the efficiency of renewable energy and continually reduce its cost.

Third, once the world makes a clear commitment to shifting toward renewable energy, the volume of production will itself sharply reduce the cost of each windmill and each solar panel, while adding yet more incentives for additional research and development to further speed up the innovation process.

2.15 Energy Efficiency and Emission Reduction

Countries all over the world, Nigeria inclusive have floated agencies to monitor and enforce laws for the protection of their environment. Nigeria has National These Environmental Standards and Regulation Enforcement Agency (NESREA).

Environmental Protection Agencies (EPAs) have evolved international forum where environmental issues are discussed. For example, in December 2009, there was Copenhagen summit where Nigeria was greatly represented. Nigeria delegation was led by NESREA boss, Dr. Mrs Ngeri Benebo. Coincidentally, going by the importance attached to environmental issues, Forum for Chief Executive Officers of States Environmental Protection Agencies (FOCESPA) in Nigeria converged in Kaduna's ASAA Pyramid hotel between Monday 7th and Tuesday 8th December, 2009 for the conference themed: "Protecting the Environment through Effective Legislation and Enforcement". I was privileged to represent Peugeot Automobile Nigeria Limited at the inaugural session. The U.S. Environmental Protection Agency's Energy Star program has helped improve the energy efficiency of the auto manufacturing industry, which has cut fossil fuel use by 12% and reduced greenhouse gases by more than 700,000 tons of carbon dioxide, according to a recent report by the Nicholas Institute for Environmental Policy Solutions at Duke University. The emissions reductions, which help to fight climate change, equal the emissions from the electricity use of more than 80,000 homes for a year.

The report, Assessing Improvement in the Energy Efficiency of U.S. Auto Assembly Plants, affirms EPA's energy management strategy, particularly the importance of performance measurement and recognition for top performance. The report also demonstrates that the gap between top performing plants and others has closed and the performance of the industry as a whole has improved.

Central to this energy management approach is the Energy Star Energy Performance Indicator (EPI) for auto assembly plants, which enables industry to benchmark plant energy performance against peers and over time. Energy Star EPIs exist or are under development for more than 20 other industries. Across these industries, EPA has recognized nearly 60 manufacturing plants with the Energy Star label, representing savings of more than $500 million and more than 6 million metric tons of carbon dioxide equivalents annually.

The U.S. industrial sector accounts for more than 30 percent of energy use in the United States. If the energy efficiency of industrial facilities improved by 10 percent, EPA estimates that Americans would save nearly $20 billion and reduce greenhouse gas emissions equal to the emissions from the electricity use of more than 22 million homes for a year. Hundreds of industrial companies across more than a dozen manufacturing industries are working with EPA's Energy Star program to develop strong energy management programs, earn the Energy Star for their plants and achieve breakthrough improvements in energy efficiency.

2.16 CAR PRODUCTION PROCESSES

2.16. 1 Body shop Equipment and Processes

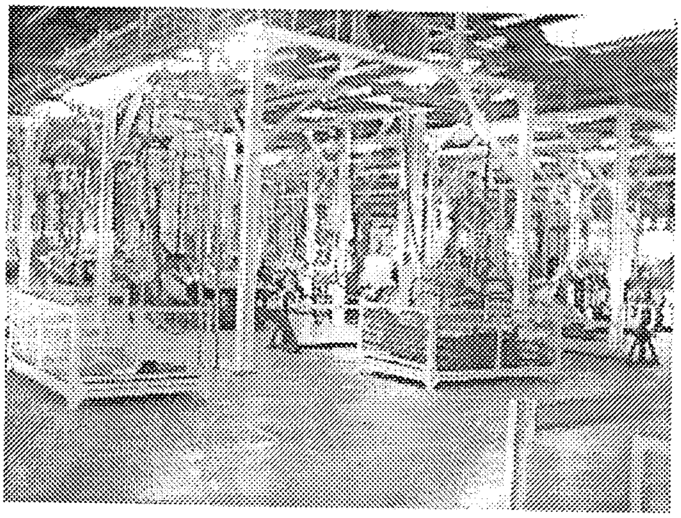

Plate III: Body shop Mainline

2.16. 2 Spot Welding Machine

Spot welding machine otherwise referred to as welding gun is the main machine in body shop for welding of car body's Completely Knocked Down (CKD) parts together. The machine comprises a control unit, a balancer, cooling unit, welding arms, welding rail. Fig 2.3

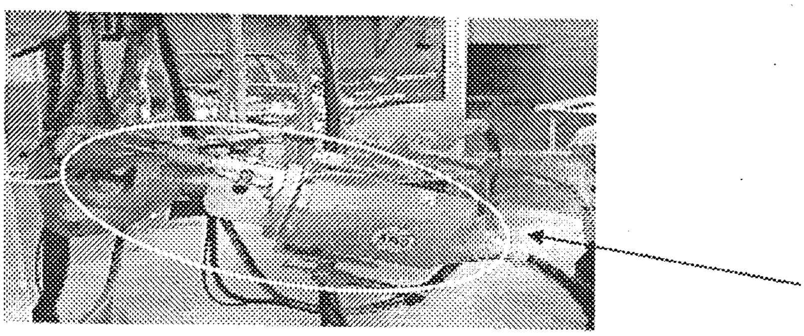

Plate IV: Spot Welding Machine

2.16. 3 The Control unit

It is a unit designed to control a manual welding gun. It is normally programmed from a computer connected to the RS232 connector on the front panel. The operating data such as the measured current, program number and fault code is displayed on a screen. The cabinet is built around a central brass plate used for distribution of air and water and also as a grounding device and cooler. The whole cabinet is protected electrically by a 125A thermal magnetic circuit breaker. Power unit for transformers is up to 75KVA with steady state current of 580 A

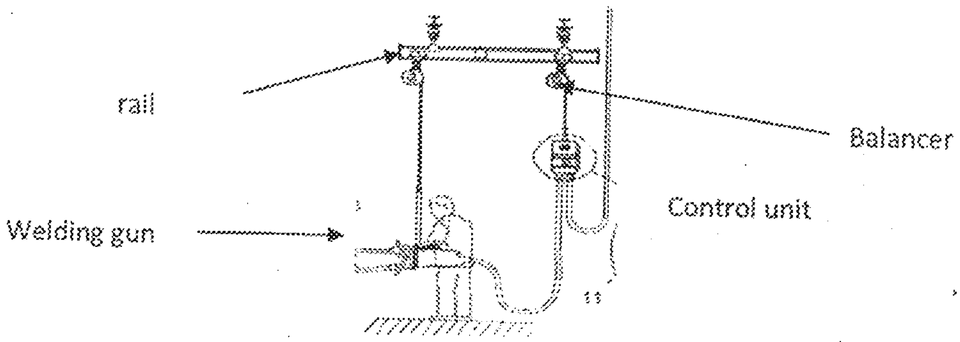

Fig. 2.4: Welding Gun Installation

2.16. 4 MIG Welding Machine

Apart from spot welding process, there is MIG welding. MIG refers to metal inert gas. It enables the welding of areas that spot welding can not be done effectively. Plate V
It comprises carbon dioxide gas and welding wire. Both are concentrated on the welding point by using MIG welding touch. 307 mainline contains five MIG welding machines.

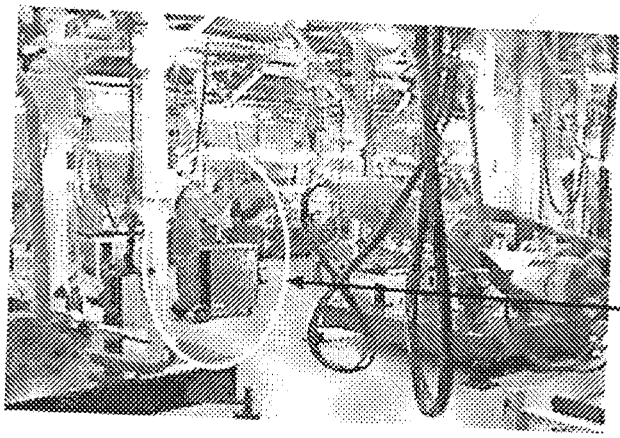

Plate V: MIG Welding Machine

2.16.5 Tucker Stud Machine

Tucker stud machine is another equipment on the line. It is being used for shooting stud on the car body. In this welding, neither spot welding machine nor MIG welding machine can be used.

2.16.6 Hoist Machine

Hoist machines enable car to be moved from one jig to the other on the mainline. The car body is borne on the hoist's hook. The button on the control pendant is operated to enable vertical travel of the hoist followed by horizontal travel via well arranged rail system. In this case, workers are shielded from physically carrying car bodies from one point to the other.

2.16.7 Jigs

Body shop mainline comprises jigs (supports) for holding firm car CKDs for welding process. A Jig is designed in accordance with welding process it would be performing. Plate VI. They consist of arrays of clamps for effective supports. Some jigs are manually controlled while some others are automatically controlled by using pneumatics.

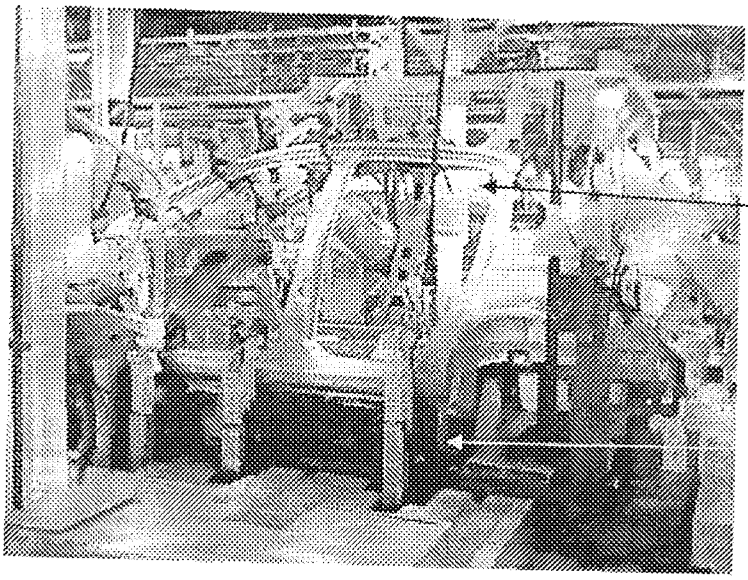

Plate VI: Final Jig

2.16. 8 Pneumatic Tools

As there are electrical tools, so also there are pneumatic tools. Pneumatic tools are used in body shop for tightening bolts and nuts, polishing and grinding car body. These tools are powered by compressed air at 5 to 6 bars generated from the factory's compressor. There is air pipeline networked throughout the factory. The air can be tapped from ubiquitous staubli in each workpost.

2.16.9 Ground Conveyor

The second major line in body shop is metal finish line. The line is a customer to mainline. Car elements like booths, doors and bonnets are fixed on the car body at metal finish line. In order to perform this operation and others, the car is engaged on a trolley which itself is engaged on the ground conveyor. Each worker performs predetermined operations on them and also makes corrections if there is any, so as to have good quality car. The quality of the car is measured at the exit of the line. Whenever a car is passed, it is given green label and ready for onward movement to paint shop otherwise a retouch process will commence.

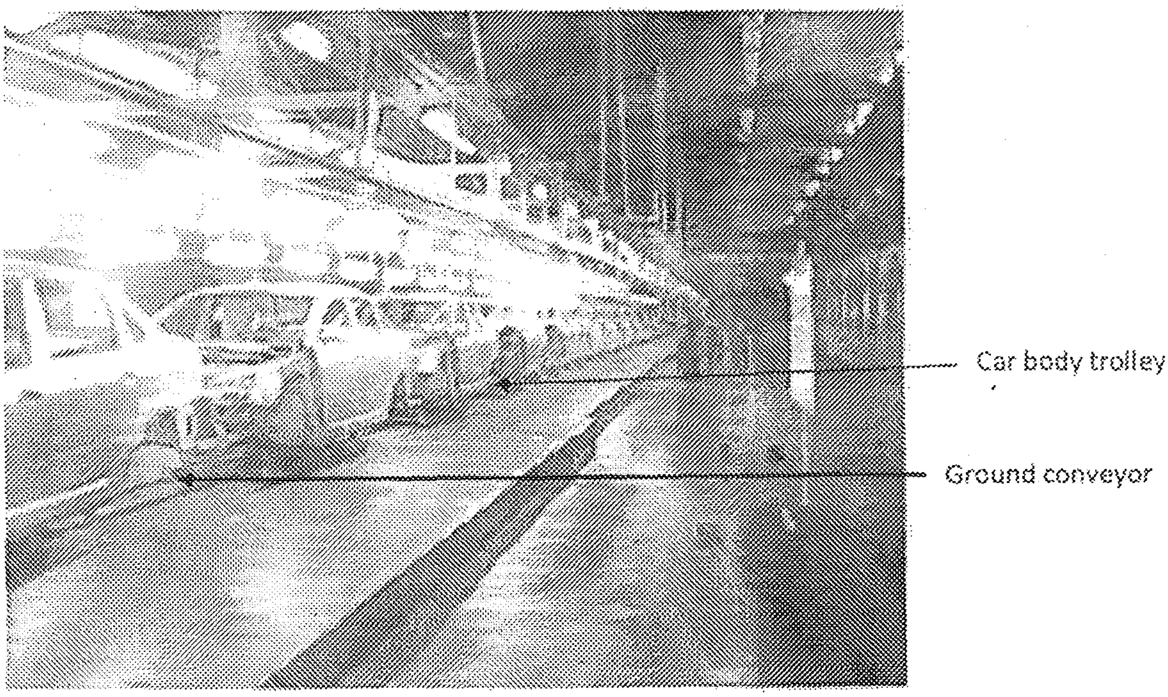

Plate VII: Metal Finish Line

2.17 Paint Shop Equipment and Operations

2.17.1 TTS and Hanging

TTS is an abbreviation formed from French language. Normally in English, it represent surface treatment tunnel. The first process in paint shop is called hanging. Here the car body from body shop is hung on an aerial conveyor for onward treatment in the surface treatment tunnel. The treatment is to prepare car body for electroplating using the process of Cataphoresis. In the tunnel, cars are washed with the aid of nozzles tilted at 45^0C with chemicals, treated with phosphates and rinsed with chromium.

2.17.2 Cataphoresis

In Cataphoresis, treated car body is electroplated; the car body is disengaged from the main aerial conveyor and engaged on the Cataphoresis carrier. The car body is made a cathode while the Cataphoresis bath comprises anode plates arranged at the periphery of the tank. The tank consists of about 50,000 litres of paint mixed with other chemicals. The car engaged on the carrier is dipped into the bath automatically and current from banks of rectifiers passed into the car. The whole process in sequence is timed, within 5mins. Paint is deposited on the car electronically. The treatment on the car allows it to have good aesthetic and to protect it from rust. The car is re-engaged on the main aerial conveyor for onward movement into an oven system for drying.

2.17.3 Oven

The oven is made of a tunnel with burner system positioned at the top. There is a duct that links the burner with the oven. Air is taking from the atmosphere with the aid of fan blowing at 30000m^3/h to circulate the heat within the oven thus maintaining the temperature at a set value. It should be noted that every process in paint shop is punctuated with drying operations done in oven. There are five oven systems in paint shop.

2.17.4 Mastic Zone

Mastic is a sealing material being applied on the car body. Every joining point of body parts consist of little opening that can compromise the quality of the car body. Sealing these areas will prevent ingress of moisture in case of rainfall and also seal the car against external unwanted noise. The mastic pneumatic machine uses compressed air for its operations and mastic application guns.

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In this zone, car under-body is protected from gravelling actions on the road by the application of a plastic material in molten form. Antigravel is sprayed on the car under body already on aerial conveyor. Here the car from the Antigrave is dried in an oven.

2.17.6 Dropping

Car body hung at the TTS entrance is dropped at dropping zone. All cars dropped are well parked at the parking zone in the shop. Each car is borne hence forth on a car body trolley. The next process is priming.

2.17.7 Dry and Wet Sanding Line

To make vehicle conducive for priming, process of drying and wet sanding are introduced. They are to ensure high quality system Peugeot brand is known for. Sanding involve the use of sand papering using hand or polishing machine laden with sand paper of convenient texture. Wet sanding involves application of liquid or chemical for sanding.

2.17.8 Primer Line

In primer line, primer paint is sprayed on the car; priming seals the car body thus eradicating little pores that may adversely affect the paint lustre. The line consists of spraying booth with a well conditioned air system for effective paint deposit. The output of the booth is passed through a primer oven. Painting is done by painters clad in special suits with nose masks, caps, gloves and safety shoes. The line consists of a ground conveyor. At the exit of oven, cars are prepared for Top coal 1 processes.

2.17.9 Top Coat 1 Line

Top coat 1 line is that one where the car is painted with its final paint (top) that will be seen by the customer. Like primer line, Top coal 1 comprises of spraying booths and oven.

2.18.1 Top Coat 2 Line

Top coat 2 line is just like top coal 1 and primer. The only difference is that Top coat 2 is for painting car accessories and plastics like bumpers, side mirror, fenders.

2.16 CAR PRODUCTION PROCESSES

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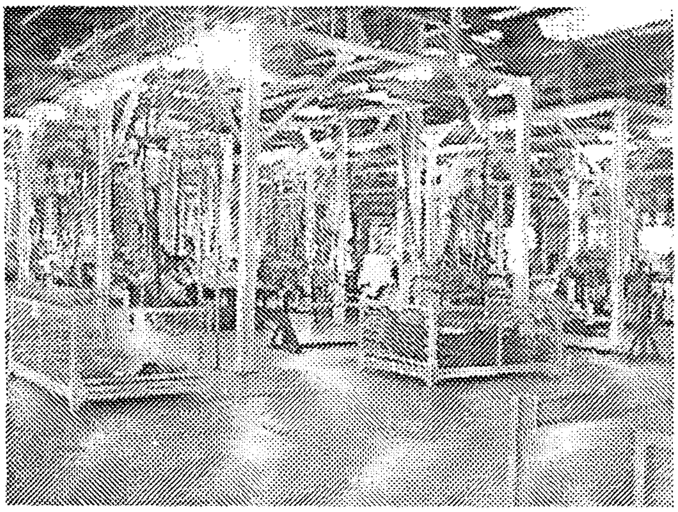

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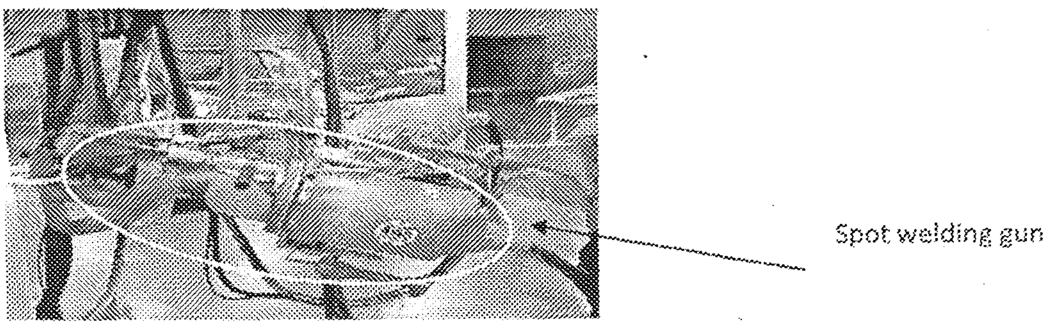

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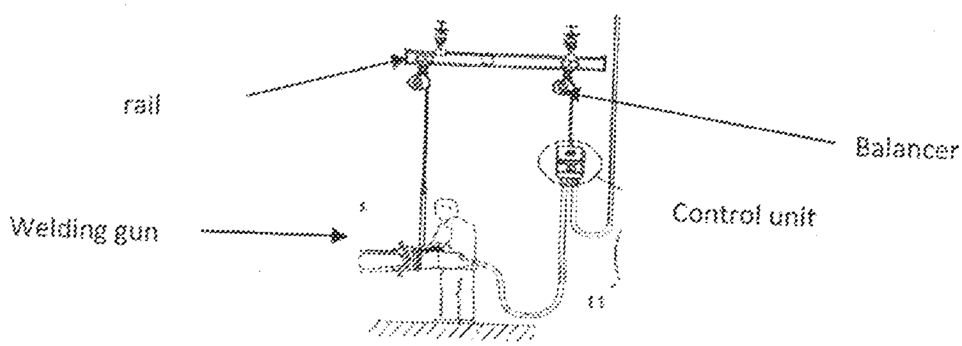

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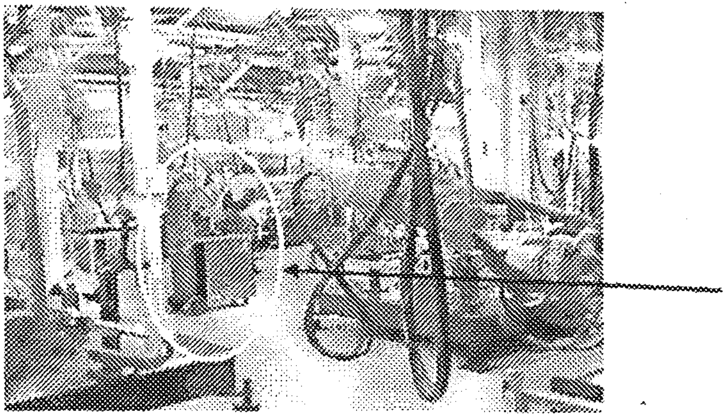

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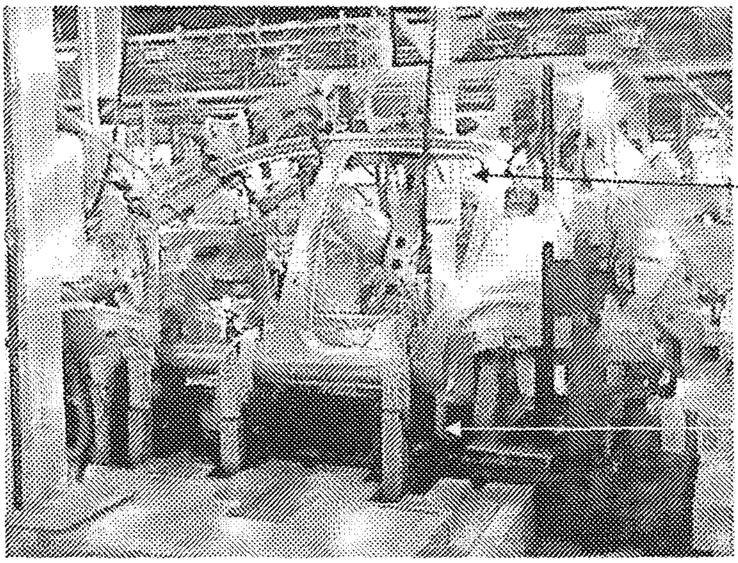

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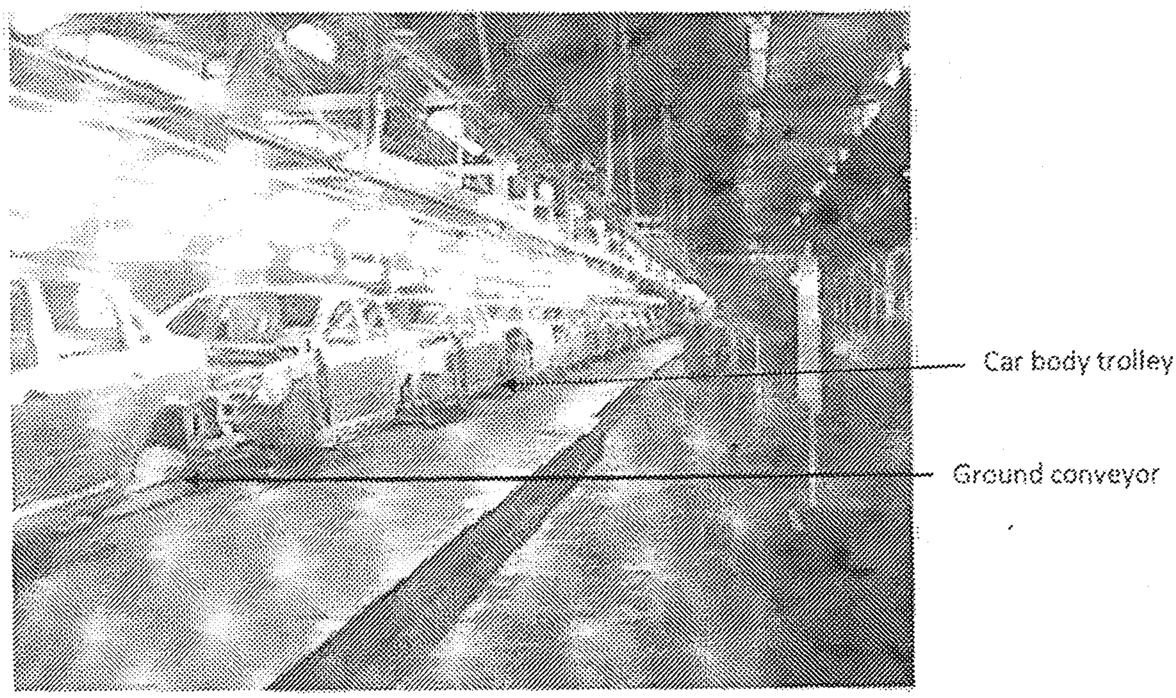

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Car body hung at the TTS entrance is dropped at dropping zone. All cars dropped are well parked at the parking zone in the shop. Each car is borne hence forth on a car body trolley. The next process is priming.

2.17.7 Dry and Wet Sanding Line

To make vehicle conducive for priming, process of drying and wet sanding are introduced. They are to ensure high quality system Peugeot brand is known for. Sanding involve the use of sand papering using hand or polishing machine laden with sand paper of convenient texture. Wet sanding involves application of liquid or chemical for sanding.

2.17.8 Primer Line

In primer line, primer paint is sprayed on the car; priming seals the car body thus eradicating little pores that may adversely affect the paint lustre. The line consists of spraying booth with a well conditioned air system for effective paint deposit. The output of the booth is passed through a primer oven. Painting is done by painters clad in special suits with nose masks, caps, gloves and safety shoes. The line consists of a ground conveyor. At the exit of oven, cars are prepared for Top coal 1 processes.

2.17.9 Top Coat 1 Line

Top coat 1 line is that one where the car is painted with its final paint (top) that will be seen by the customer. Like primer line, Top coal 1 comprises of spraying booths and oven.

2.18.1 Top Coat 2 Line

Top coat 2 line is just like top coal 1 and primer. The only difference is that Top coat 2 is for painting car accessories and plastics like bumpers, side mirror, fenders.

2.18.2 Quality Retouch Zone

Retouch zone is that zone where anomalies are corrected. Cars beyond correction in this line are returned for total recoat at top coat 1. All cars accepted by quality operatives are given green label which is hung on the car. These cars are taken to assembly shop for assembly processes.

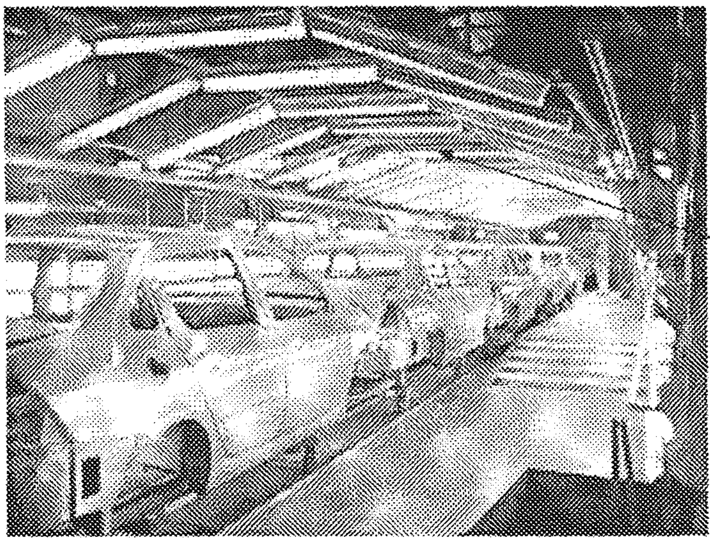


Plate VIII: Quality Acceptation Zone after Top Coat 1 Oven

2.19 Assembly Equipment and Processes

2.19.1 Trim line

All cars that have passed quality acceptation are brought into assembly shop. The first line is the trim line. Here car trimmings are assembled. Pneumatic tools are used majorly in trim line. Apart from trimming being fixed, cars are wired, bumpers, windscreens, light covers, dashboards are fixed into the cars. All these operations are made possible by engaging cars on the ground conveyor. Cars leaving trim line are passed into chassis line.

2.19.2 Chassis Line

By chassis line is a mechanical preparation zone. In this zone, engines are assembled using pneumatic tools, jigs and hoist machines. In the chassis line, car engines and rear suspension systems are installed by using mobile lifting platforms. Bipolar elevators are used to lift up cars for tyre fixing, brake fluid filling. Afterward, cars are engaged on ground conveyor for remaining processes like Air conditioning gas filling, radiator's coolant filling, power assisted steering fluid filling and fuel filling. In chassis line, car seats are put in place. The last process in the line is initialization process where cars are coded through a special coding machine and the engine is started.

2.19.3 Quality Acceptation Zone

Cars from chassis line are engaged on the ground conveyor for an in-depth quality checks. The cars are rough handled, doors banged hardly, headlight checked. These are done to detect any defect. If a defect is found, it has to be amended.

2.19.4 Shower Test

All cars produced are made to pass through shower test. A completed car is made to be parked inside a booth comprising nozzles impinging water on the car at a pressure of about 3 bars for about 10 minutes. The car is then checked for any ingress of moisture. If there is one, the problem must be amended before quality acceptation. The test is used to simulate heavy rainfall.

2.19.5 Test Track

All cars produced are to be driven through a test track. The track is used to simulate Nigeria roads conditions. Bumps are intentionally made on the road, produced car are made to run on them and also on a smooth portion. On the track is an artificial ramp to simulate hilly terrain, here, hand-brake is checked to ensure that the car will not slide off on a steep area if handbrake is engaged. In all, any unusual noise during the test will be corrected.

2.19.6 Road Test

Daily, two cars are randomly selected for road tests; two well trained drivers are engaged in driving the cars on the roads and make observations on their behaviours. Any abnormally is reported back to the factory for possible corrections on all cars produced on the same day. By doing this, human error committed by any worker can be corrected, thus preventing cumulative problems.

2.19.7 Quality Audit

All cars produced in a day will be randomly selected for audit. The audit is done by a well trained audit officer. He detects and apportions blames. Representative of workers from each shop attends the audit. The result is fedback into the shop for correction on erring work post of a particular worker that makes the error.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 ELECTRICITY

The factory is connected to the power grid through a 33/11 KV transformer substation within its premises. Also at inception in 1975, the power house was equipped with two units of 3MVA 11KV Cockerill generators. Both were synchronized to deliver 6MVA 11KV for distribution into the switch rooms. Years later, the capacity of the units drops to about 2MVA each and also one of them was scrapped due to unavailability of spares since the system has been grossly outdated.

In order to ensure steady power supply available for production and maintenance of the initial design capacity, three units of 2MVA 11KV FG Wilson generating sets were procured in 2008 to deliver 6MVA 11KV when synchronized.

The two supplies, that is, PHCN and generators, are terminated in a well secured HT room comprising a Power control room equipped with control consoles and mimic panels. The control facility also contains PHCN revenue meters for Active and Reactive power consumed. The electricity from the power house are distributed into the production shops and offices through strategically located switch rooms (A, B and C) Table 3.1. The tables 3.1 and 3.2 shows switch rooms in relation to their loads. It shows low power factor of the loads. It is on this premise, a power factor improvement solution will be proffered.

Table 3.1: Factory Transformers Parameters

Transformers	Switch Room	KVA Rating	Primary(V)	Secondary(V)	Secondary (A)
1	A	1500	11000	415	2000
2	A	1600	11000	415	2123
3	A	1500	11000	415	2000
4	B	1600	11000	415	2123
5	C	1600	11000	415	2123

Table 3.2: Switch Rooms Loads Pattern

	SW RM. A			SW RM B	SW RM C
	T1	T2	T3	T4	T5
U12	423	400	423	387	420
U23	422	401	422	388	423
U31	423	401	423	389	422
U1	241	231	241	223	245
U2	240	231	240	224	245
U3	241	232	241	224	245
I1	1197	848	1172	1374	78
I2	1435	851	998	1375	98.5
I3	1230	907	1163	1376	116
KW	673	465	649	720.6	64
KVAR	663	379	487	577.5	26.5
KVA	947	601	811	562	67.8
PF	0.71	0.78	0.8	0.78	0.921
FREQ.(Hz)	50	50	50	50	50

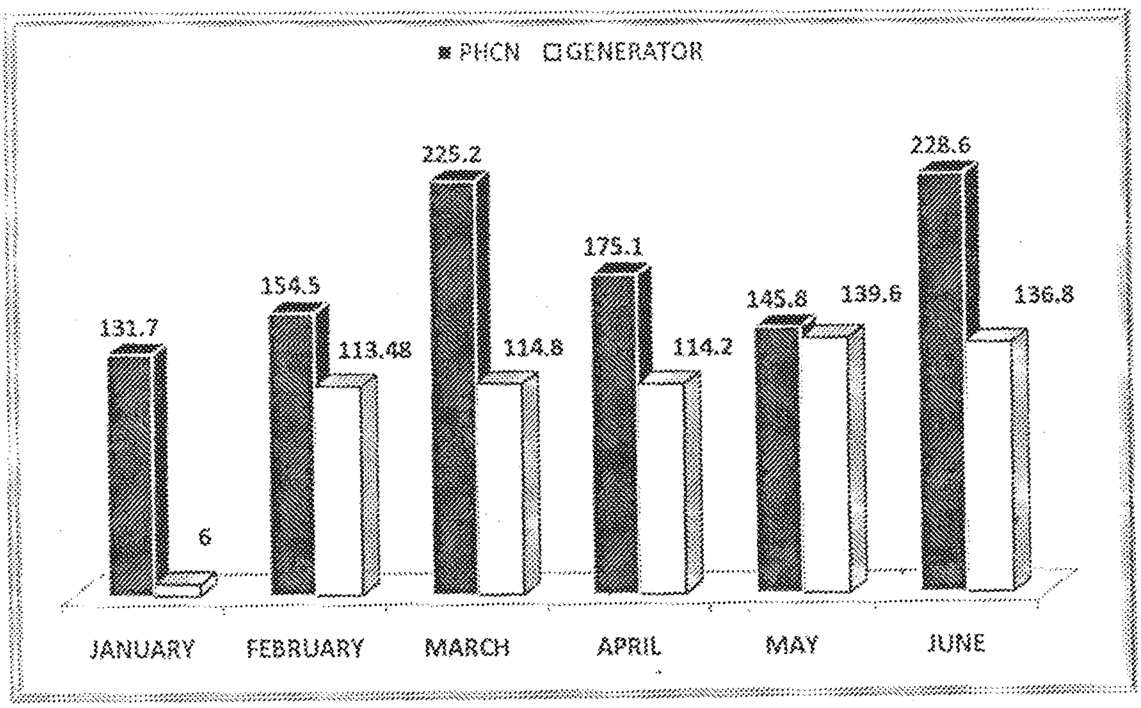


Figure 3.1: Factory Monthly Electricity Consumption in MWH for first half of 2010

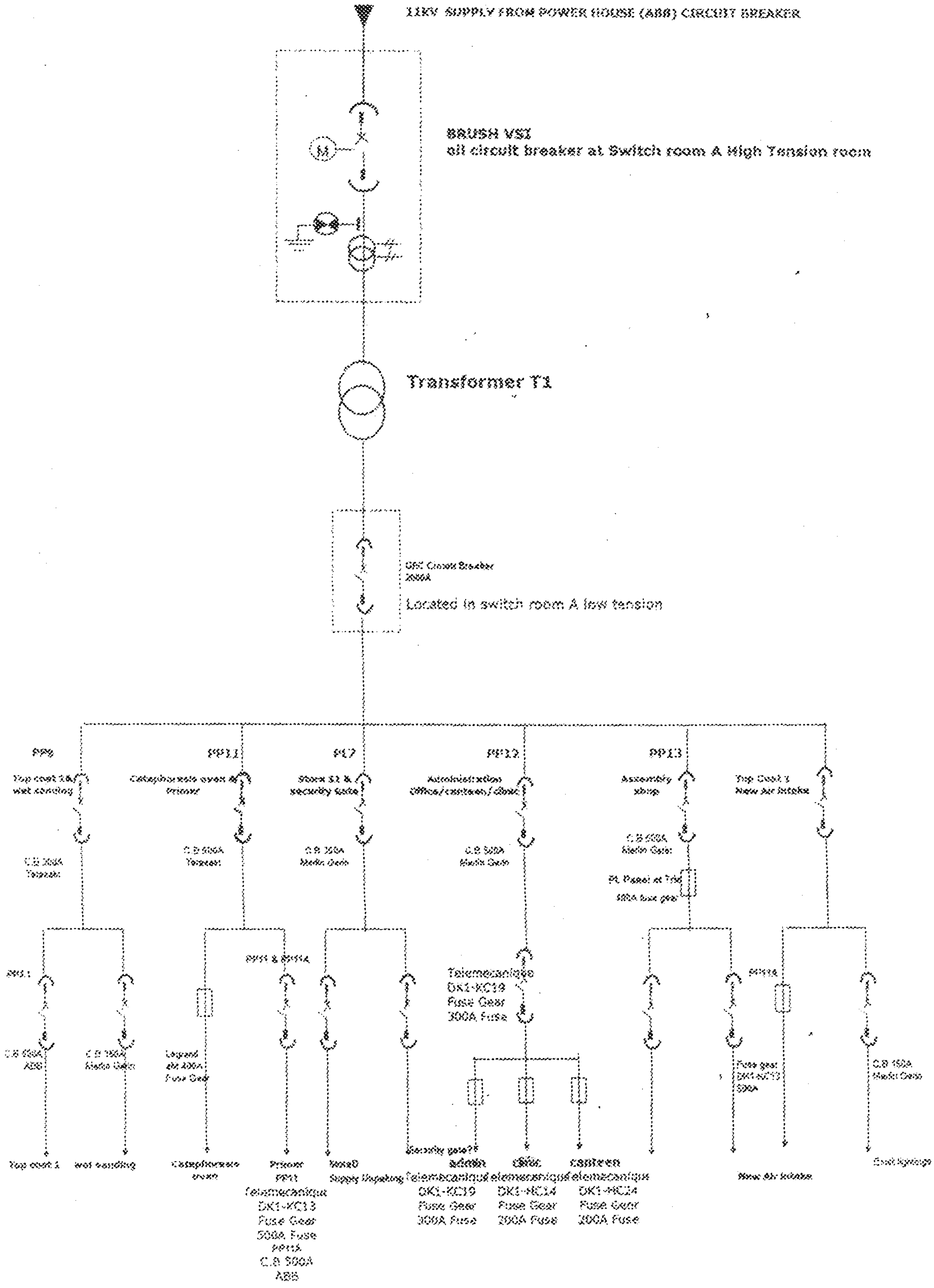


Figure 3.2: Single Line Diagram of Power Distribution through Transformer T1
Of Switch room A

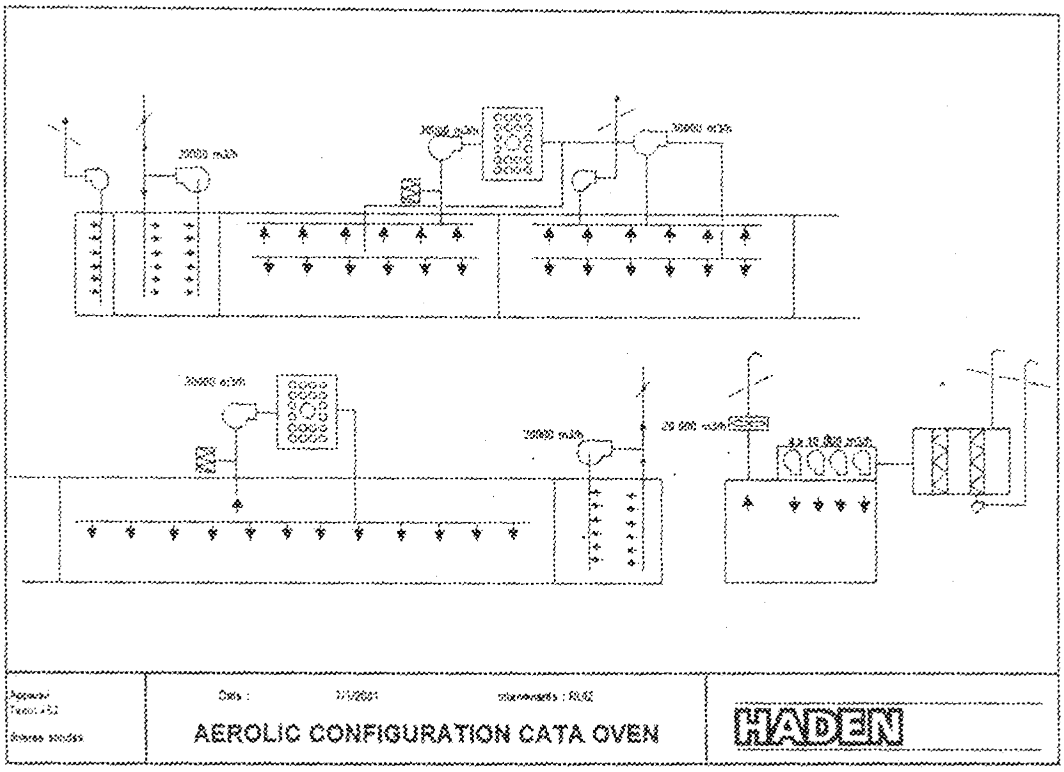


Figure 3.3: Air-flow Installation for Cataphoresis Oven showing fans driven by Electric motors

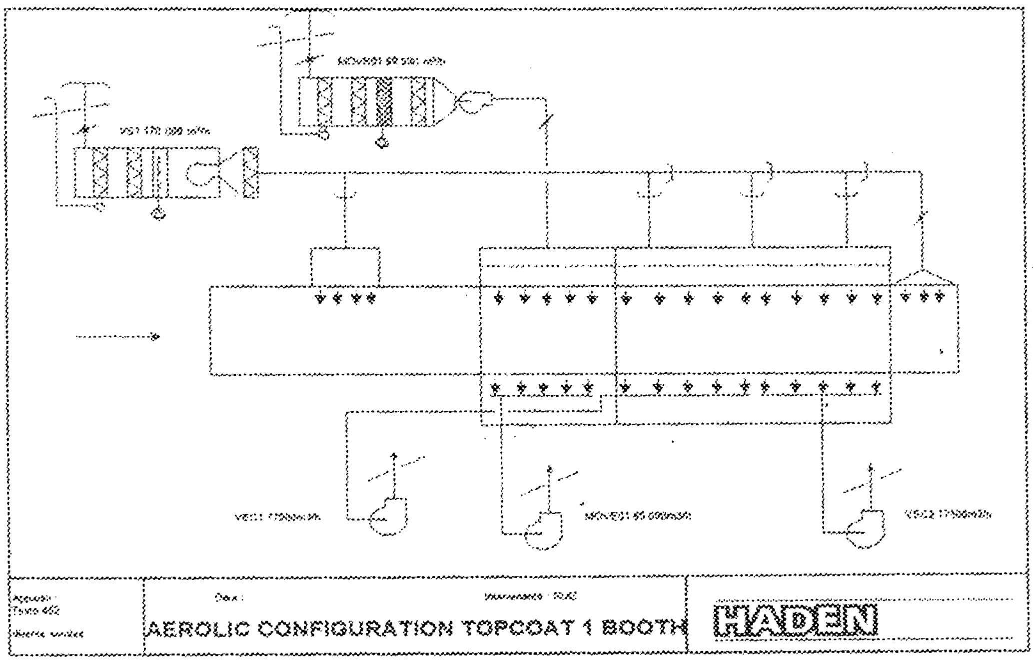


Figure 3.4: Air-flow Installation for Top Coat 1 Booth showing fans driven by Electric motors

3.2 Lighting

Lighting systems are mainly fluorescent fittings which are used throughout production shops and offices. Halogen fittings are also employed in shops to enhance greater illumination. Due to the emphasis on quality of cars produced in the factory, lighting is taken seriously since it allows visibility to every minute space and also enhances quality audits. The tables 3.3 to 3.5 and figures 3.4 to 3.10 below show lighting distribution in the three production shops, that is. Body, Paint, Assembly, Administrative and Training blocks.

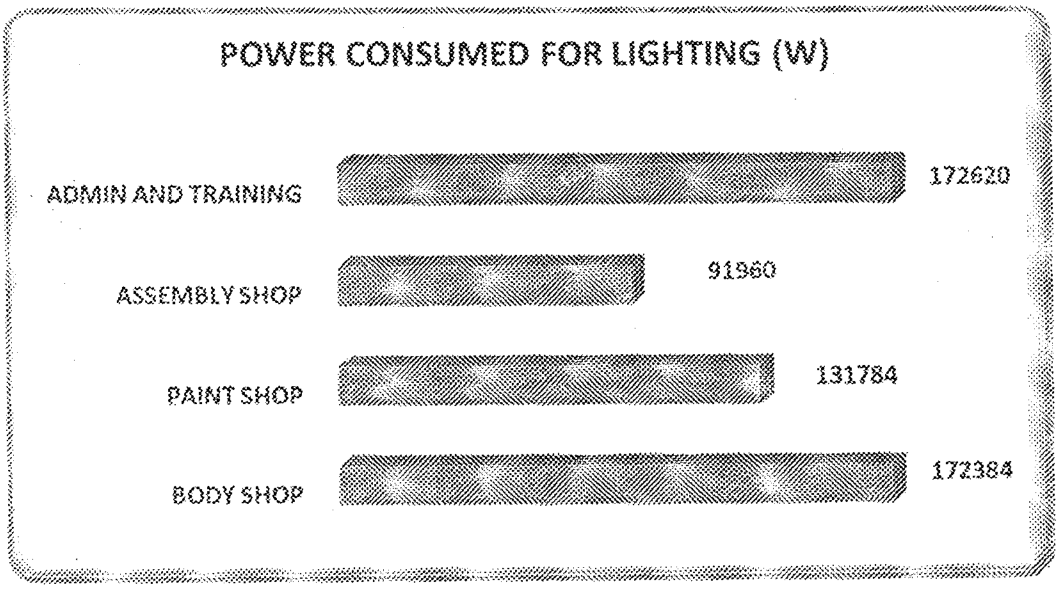


Figure 3.5: Power in watts consumed in the factory

Below are the breakdowns of the power according to the production lines

3.3 BODY SHOP LIGHTING LOAD

Table 3.3: Body Shop Lighting Load

ZONES	TYPES(W) (5Ft)	QUANTITY	POWER(W)
307 main line	56	76	4256
406 main line	56	98	5488
Metal Finish line	56	252	14112
UEP Zone	56	24	1344
Retouch zone	56	16	896
Maintenance zone	56	162	9072
Maintenance office	56	78	4368
Jig shop	56	44	2464
Engine room	56	14	784
Halogen	400	324	129600
		TOTAL	172384

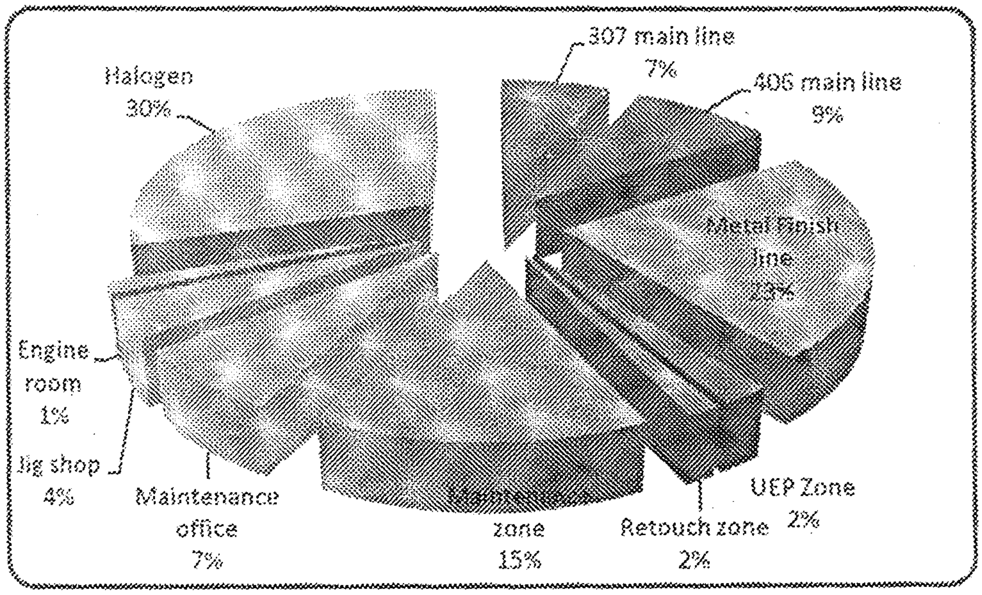


Figure 3.6: Lighting Fittings Percentage distribution

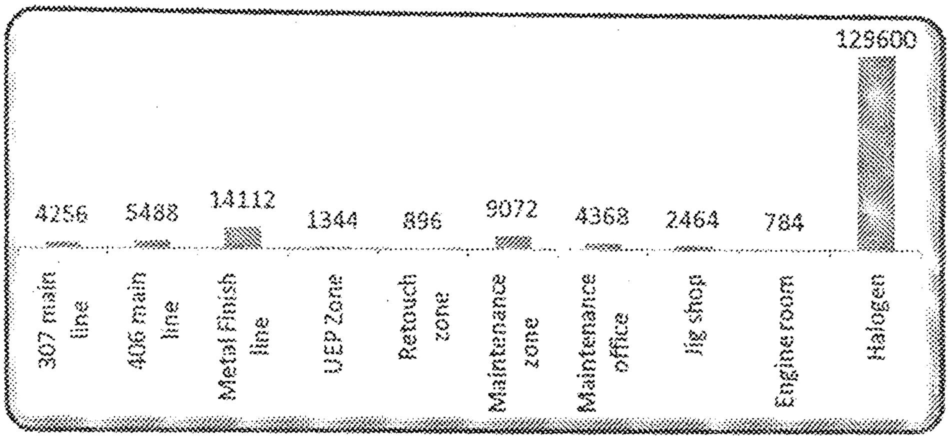


Figure 3.7: Lighting Power Distribution in Body shop

From the figure 3.7 it shows that halogen fittings consume greater power - 129.6KW follows by metal finish line 14.1KW

3.4 PAINT SHOP LIGHTING LOAD

Table 3.4: Paint Shop Lighting Loads

ZONES	TYPES(W) (5Ft)	QUANTITY	POWER(W)
Hanging TTS & Cata	56	57	3192
Mastic	56	66	3696
Antigravel	56	114	6384
Dry Sanding/Primer	56	234	13104
Wet Sanding	56	344	19264
Wet Sanding Retouch	56	20	1120
Top Coat 1	56	582	32592
Top Coat 2	56	204	11424
Top Coat retouch	56	39	2184
Omia Oven	56	69	3864
Rest Zone	56	10	560
Halogen	400	86	34400
		TOTAL	131784

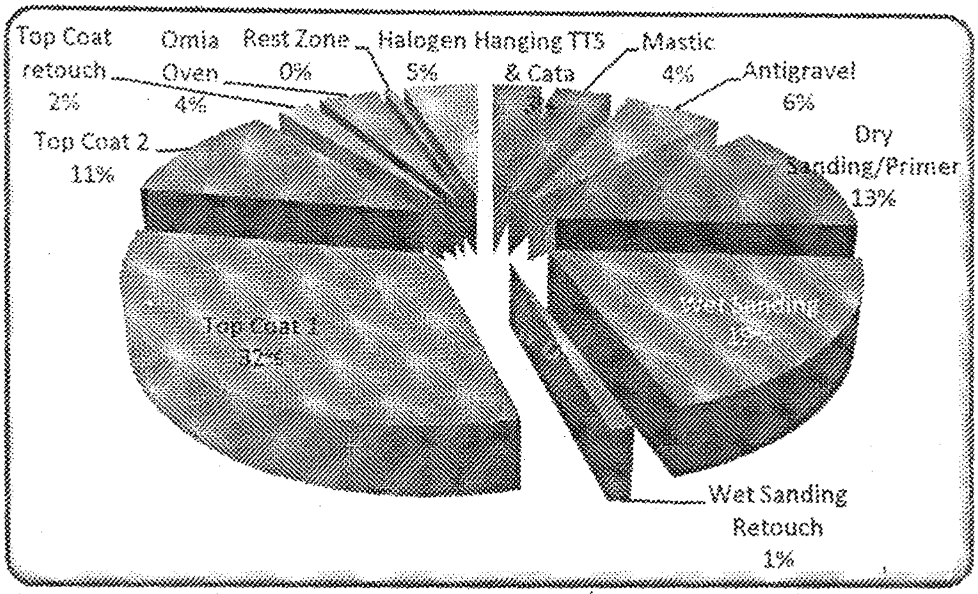


Figure 3.8: Lighting Fittings Percentage Distribution in Paint shop

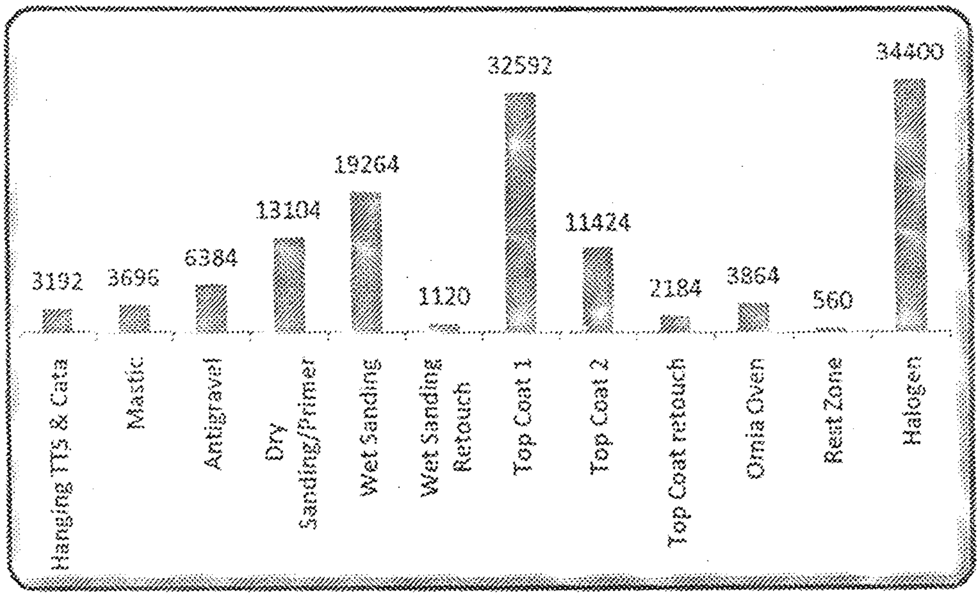


Figure 3.9: Lighting Power Distribution in Paint shop

Figure 3.9 shows that halogen light consume highest power follows by Top coat 1 exit. Top Coat 1 exit consist of massive lighting system that allows good illumination for retouch and quality acceptation process

3.5 ASSEMBLY SHOP LIGHTING LOADS

Table 3.5: Assembly shop lighting loads

Zones	Types(W) (5Ft)	Quantity	Power (W)
Trim line	56	312	17472
Chassis line	56	288	16128
ACOM	56	402	22512
Quality Acceptation	56	24	1344
Wheel Alignment	56	16	896
Industrial office	36	400	14400
UEP Zone	56	73	4088
Halogen	56	270	15120
		TOTAL	91960

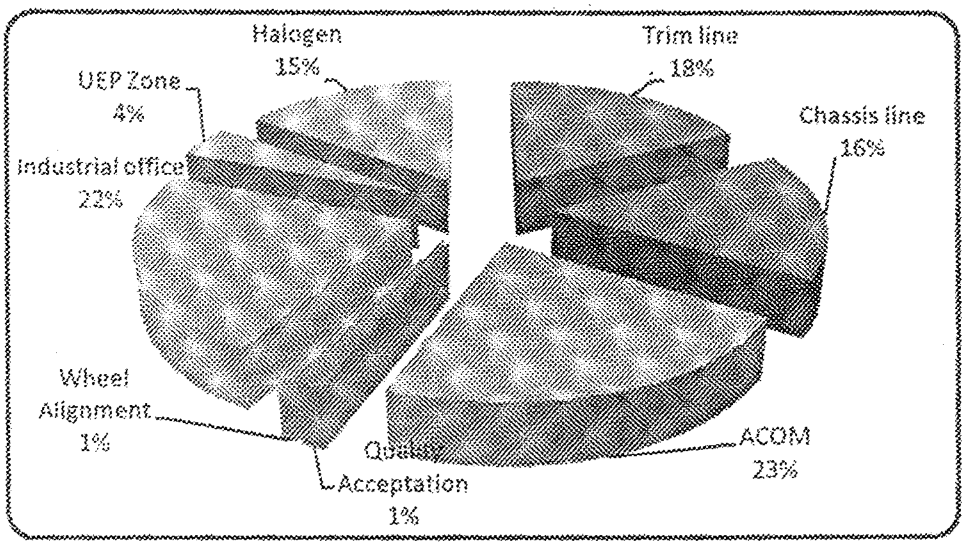


Figure 3.10: Lighting Fittings Percentage Distribution in Assembly

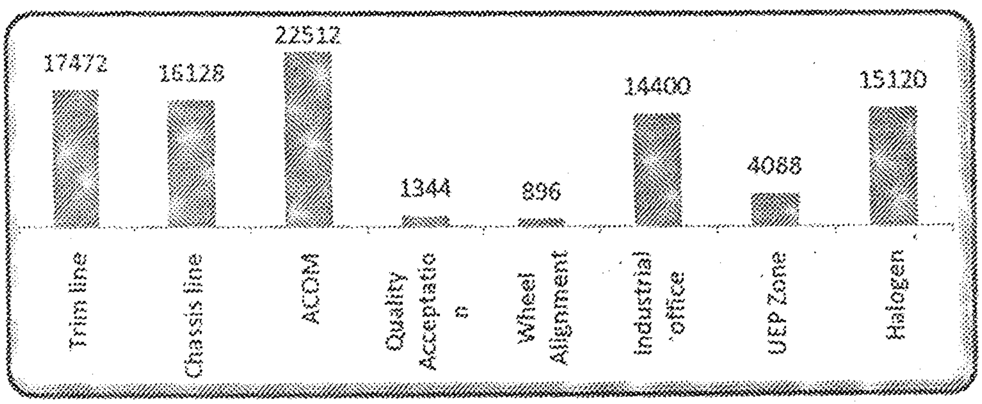


Figure 3.11: Lighting Fittinga Distribution in Assembly

3.6 Air Conditioning

The factory offices comprise 100 units of various types of Air conditioning units. They are majorly of window and split units. Production floors consist of extraction fans for the removal of poisonous gases for the convenience and safety of workers.

3.7 Office Equipment

3.7.1 Personal Computers and Printers

The factory comprising the production shops, administrative offices, and training centre contain about 300 personal computers, 50 printers and 10 photocopiers. They are being managed by information technology department.

3.8 ENERGY CONSERVATION MANAGEMENT

Every manufacturing outfit embarks on energy conservation techniques in order to reduce cost of production so as to have higher profits. Wastes are reduced and productivity enhanced. All these also dovetail into resource conservation and image enhancement.

In order to improve electrical energy consumption, the following ideas can be of help.

1. Provision of separate lighting transformer for control of lighting system.

2. Location of substation near the load centres to minimize energy losses in cables and also improve voltage levels.

3. Installation of capacitors with automatic power factor control panel to maintain a PF of not less than 0.9 for large capacity motors and at the substation for all loads.

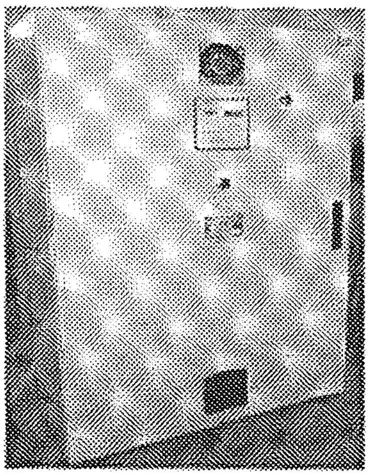


Plate IX: Casing Containing Capacitor Banks

4. Identification of under loaded transformers and redistribute the load to achieve optimum loading conditions.

5. To replace inefficient motors and transformers.

6. Transfer the operation of high capacity loads to lighting loaded shift hours to reduce maximum demand to flatten the load curve and maintain a high load factor.

7. Stagger starting and operation of high capacity motors

8. Balancing of loads on all 3 phases within + or – 1% as voltage imbalance results in higher losses.

9. Optimize the tariff structure with utility supplier.

3.9 Fan and Blowers

1. Usage of smooth well rounded air inlet cones.
2. Avoidance poor flow distribution at the fan inlet.
3. Minimizing fan inlet and outlet obstructions.
4. Cleaning of screens, filters and fan belts.
5. Usage of low slip or flat belts.
6. Checking of belt tensions regularly.
7. Using Variable Speed Drive VSD for large variable fans.
8. Usage of energy efficient motors for continuous or near continuous operation.
9. Elimination of leakages in the duct works.
10. Minimizing bends in duct work.

3.10 Electric Motors

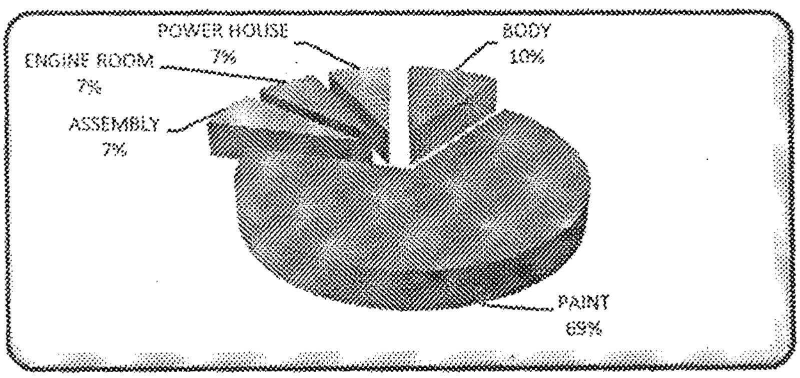


Figure 3.12: Approximate Distribution of Electric motors in Production facilities of PAN

In any automotive industry or manufacturing plant, electric motors are the most common electrical equipment. Paint shop of PAN contains 99 units of electric motors of different capacities. A lot of efficiency can be obtained if the under listed tips are adhered to

1. Voltage supply should near to the value mentioned on the motor rating, maximum tolerance for voltage could be between 3-5%. Voltage fluctuation results reduced efficiency of the motors.
2. Elimination of improper cabling.
3. Ensure that the motor is well aligned.
4. Usage of synchronous motor to improve power factor.
5. Provision of proper ventilation.
6. Maintenance of high power factor as lower power factor reduces the motor efficiency and also reduces the efficiency of electrical distribution. Lower power factor results when motors run below the full load ratings.
7. Having controls which stop motors which are running idle.
8. Replacing motors with new motors before it fails.
9. Procurement of energy efficient motors.
10. Usage of Variable frequency drives (VFDs) whenever possible for varying load like compressors/ blowers and fans.

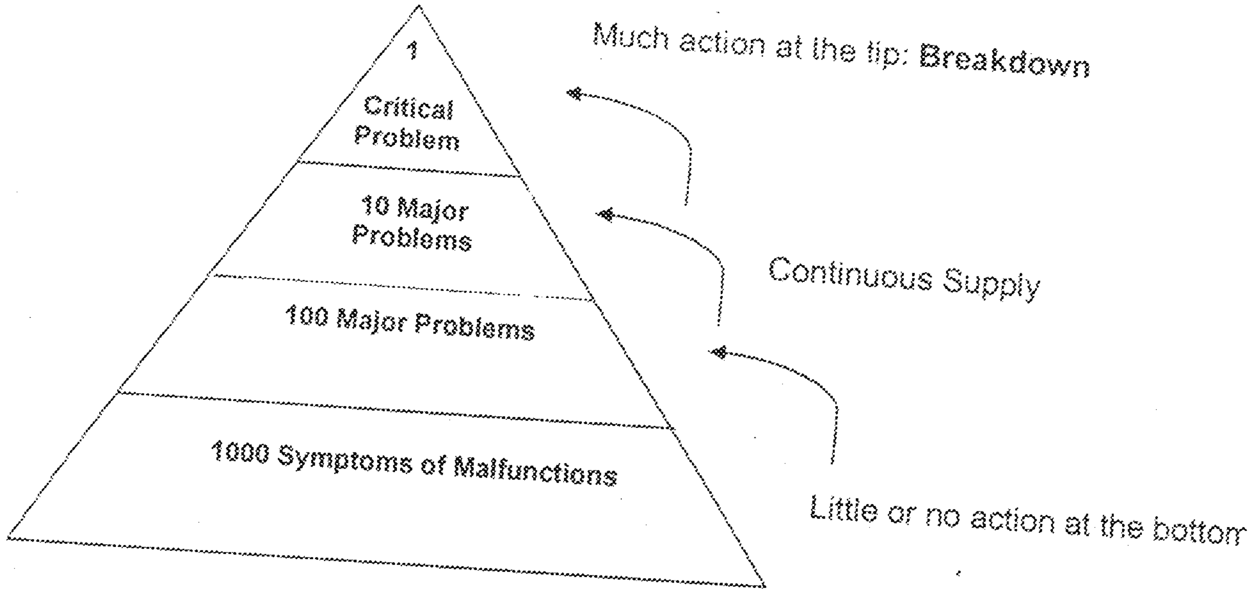
3.11 Cooling Towers

1. Turning off unnecessary cooling tower fans when the loads are reduced.

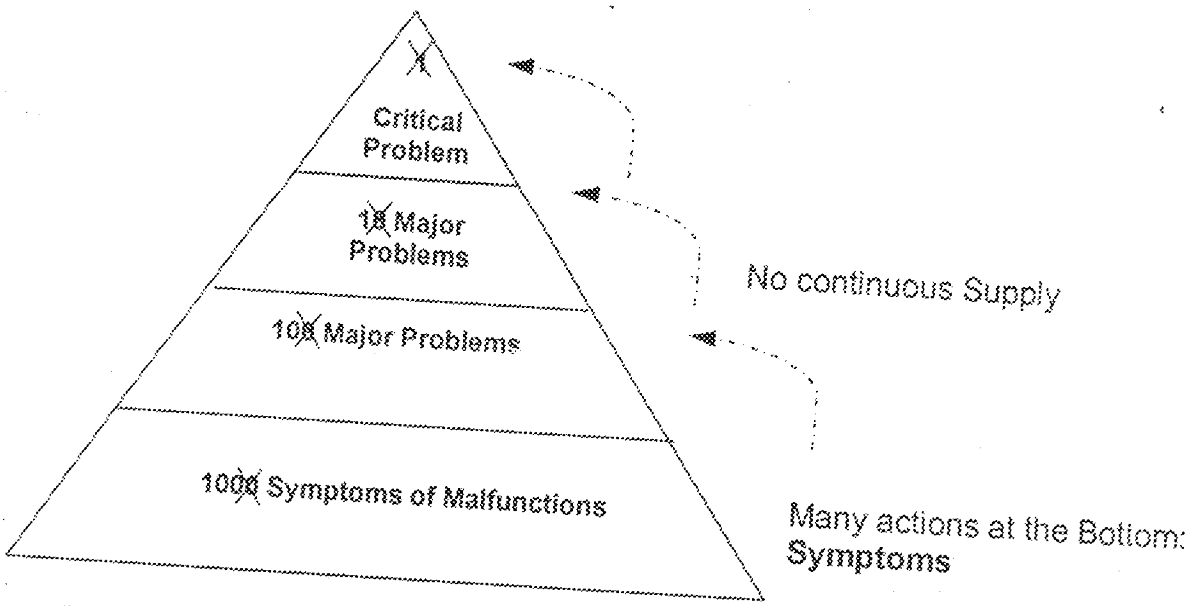
2. Controlling cooling tower fans based on leaving water temperature
3. Periodic cleaning of cooling tower water distribution nozzles.
4. Installation of new nozzles to obtain more uniform water pattern.
5. Optimization cooling tower fan blade angle on a seasonal and on load basis.
6. To check water overflow pipes for proper operating level.
7. Optimization of chemical use.
8. Optimization of blow down rate.

3.12 Total Productive Maintenance (TPM)

Total Productive Maintenance (TPM) can be defined as proactive programme for the improvement of equipment performance through daily involvement of every stakeholder. TPM is a Japanese idea that can be traced back to 1951 when preventive maintenance was introduced into Japan from USA. Nippondenso of Toyota introduced plant wide preventive maintenance in 1960. In preventive maintenance operators produced goods using machines and the maintenance group was dedicated to the work of maintaining the machines. When high level of automation was introduced, maintenance became problem as so many more maintenance personnel are required. So the management decided that the routine maintenance of equipment would now be carried out by the operators themselves-an autonomous maintenance, one of the features of TPM. The maintenance group then focussed on maintenance works of upgrade and equipment modification that would improve its reliability.



(a) Production Facility without TPM



(b) Production Facility with TPM (No critical problem)

Figure 3.13: TPM Pyramid

TPM is active at symptoms level; most of the actions are done at the bottom of the pyramid (Figure 3.13). By so doing, there is no continuous supply of problems; resulting to disappearance of critical problem at the tip of the pyramid. But without TPM, reverse is the case, there is always continuous supply of the problem, little or no activity at symptom level resulting to critical problem(Break down) which lowers the efficiency of the production zone. Maintenance group put many actions at the tip (Breakdown).

The methodology uses Edmund Deming PDCA wheel to achieve its laudable objectives. An action is planned, done, checked for control purpose, if there is a deviation from the reference input (initial plan), further action is put again. Figure 3.14

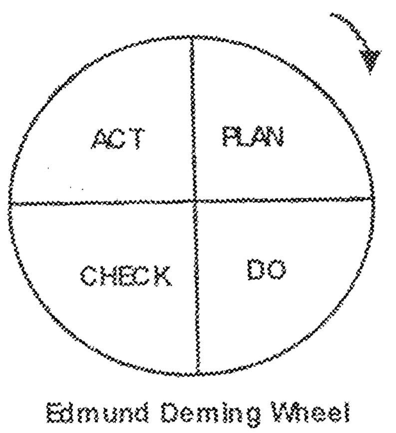


Figure 3.14: Edmund Deming Wheel

3.12.1 TPM Tools

Tools involve production workers in the maintenance of the equipment they use. This is possible because they have real time information about the equipment performance. Common TPM tools are: checklists, logging, self maintenance tool and TPM problem ticket.

3.12.2 Checklists

Checklist is created by TPM team according to the equipment in that work zone. At every production day, in the morning, the worker fills the checklist. For example, he has some items to check while the equipment is idle and some other ones at first cycle of operation. He or she marks G for Good and B for bad. Bad situations are recorded on the progress action list for correction. Once again the problem being referred to are "symptoms of malfunction" it may not disturb operation on the day. A deadline for rectification must be fixed.

3.12.3 Logging:

Some symptoms are not visible in the morning but after series of operations during the day. The logging tool created for that particular workpost is used to capture the problem. This is by putting tally against the problem daily. If those symptoms are noticed, maybe five times, or more depending on the TPM service, it is recorded on the Progress Action List (PAL) and a deadline is set for the rectification of the problems.

3.12.4 Self Maintenance Procedures

The tool allows the worker to solve some little problems on the production line without waiting for maintenance man. But such a worker will be trained adequately for such an activity.

3.12.5 TPM Problem Ticket

A day is fixed by the TPM service when problem tickets are taking to the line. The workers are made to write the problems in their work posts on the ticket. Afterward, those tickets are attached the equipment using thin ropes.. The duplicates copies of the tickets are given to the pilots of the problems, deadlines for the correction are determined while the TPM service follows up the solution. Whenever the problems are solved, the tickets also are detached from the equipment.

3.13 ENERGY EFFICIENCY ANALYSIS

3.13.1 Power Factor Correction

The peak power consumed in each switch room is shown in the table 3.6 below, it is required to raise the power factor from PF_1 to PF_2

Table 3.6: Switch Rooms Peak Loads and Their Power Factors

	SW RM. A			SW RM B	SW RM C
	T1	T2	T3	T4	T5
KW	423	400	423	387	420
PF 1	0.71	0.78	0.8	0.78	0.92
PF2	0.95	0.95	0.95	0.95	0.95

In view of this, the value of KVAr of capacitor banks will be calculated as follows:

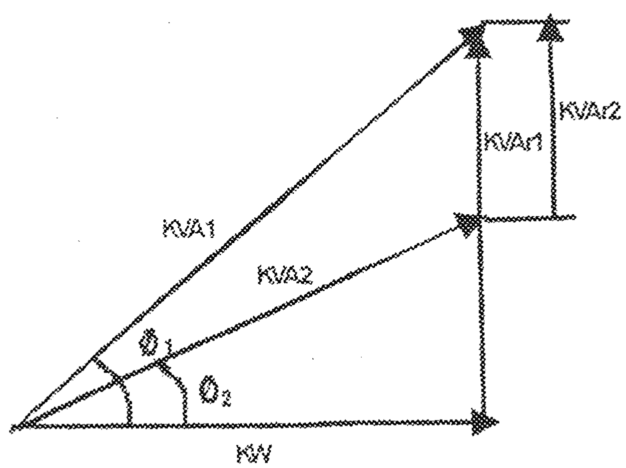


Figure 3.15: Power Triangle

KW = Power consumed by the system

KVA1= Apparent power

KVA2 = Apparent power after correction

KVA r1 = Inductive KVAR

KVAr2 = Capacitive KVAR

$\cos\Phi_1$ = PF before correction

$\cos\Phi_2$ = PF after correction

$$\cos\Phi = KW / KVA \quad (3.1)$$

$$\tan\Phi = KVAr / KW \quad (3.2)$$

$$KVAr = KW \tan\Phi \quad (3.3)$$

So from eqn. 3.3

$$KVAr_2 = KW (\tan\Phi_1 - \tan\Phi_2) \quad (3.4)$$

3.13.2 To Calculate the Required KVAR to Raise PF from 0.71 to 0.95

$\Phi_1 = \cos^{-1} PF_1 = \cos^{-1} 0.71 = 44.76^0$

Also $\Phi_2 = \cos^{-1} PF_2 = \cos^{-1} 0.95 = 18.19^0$

By using (3.12)

$KVAr_2 = 673 (\tan 44.76^0 - \tan 18.19^0)$

$= 673(0.99-0.328)$

$= 673 \times 0.66$

$= 445.12$ KVAR

Therefore 445 KVAR Capacitor bank would raise the PF from 0.71 to 0.95

3.13.3 To Calculate the Required KVAR to Raise PF from 0.78 to 0.95

$\Phi_1 = Cos^{-1} PF_1 = Cos^{-1} 0.78 = 38.74^0$

Also $\Phi_2 = Cos^{-1} PF_2 = Cos^{-1} 0.95 = 18.19^0$

By using (3.12)

$KVAr_2 = 465 (Tan\ 38.74^0 - Tan\ 18.19^0)$

$= 465(0.802 - 0.328)$

$= 465 \times 0.474$

$= 220.54.12$ KVAR

Therefore 221 KVAR Capacitor bank would raise the PF from 0.78 to 0.95

3.13.4 To Calculate the Required KVAR to Raise PF from 0.8 to 0.95

$\Phi_1 = Cos^{-1} PF_1 = Cos^{-1} 0.8 = 36.86^0$

Also $\Phi_2 = Cos^{-1} PF_2 = Cos^{-1} 0.95 = 18.19^0$

By using (3.12)

$KVAr_2 = 649 (Tan\ 36.86^0 - Tan\ 18.19^0)$

$= 649(0.75-0.328)$

$= 649 \times 0.422$

$=273.87$ KVAR

Therefore 274 KVAR Capacitor bank would raise the PF from 0.8 to 0.95

3.13.5 To Calculate the Required KVAR to Raise PF from 0.92 to 0.95

$\Phi_1 = Cos^{-1} PF_1 = Cos^{-1} 0.92 = 23.1^0$

Also $\Phi_2 = Cos^{-1} PF_2 = Cos^{-1} 0.95 = 18.19^0$

By using (3.12)

$KVAr_2 = 64 (Tan 23.1^0 - Tan 18.19^0)$

$= 64(0.43-0.328)$

$= 64 \times 0.102$

$=6.52KVAR$

Therefore 6.52 KVAR Capacitor bank would raise the PF from 0.92 to 0.95

3.13 Energy Efficient Motor Analysis

Figure 3.16 shows factory electric motors distribution according Horse-Power. 58 units fall within the range of one to five Horse-Power while other four units are within 101 to 165 Horse-Power.

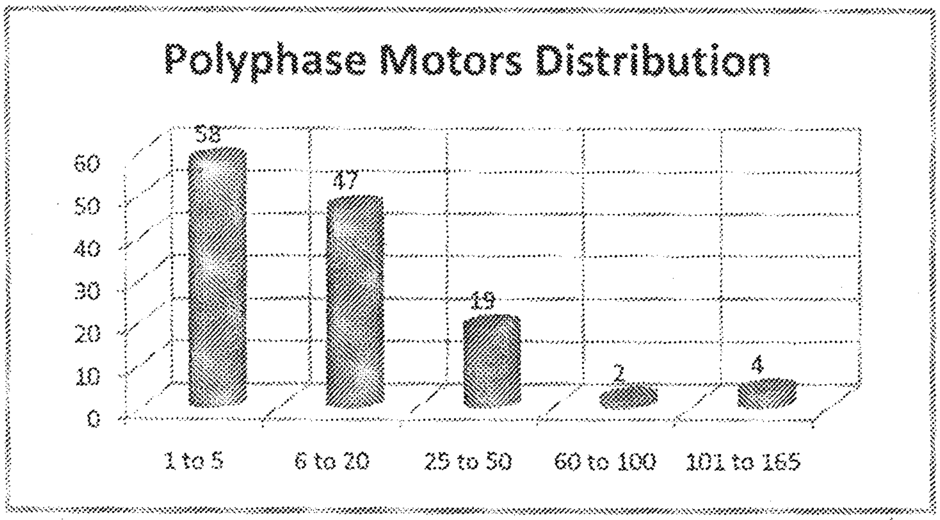


Figure 3.16: Polyphase Motors Distribution in Horse- Power

$Pa = Pn / (\eta \times \cos \varphi)$

That is, KVA Demand = KW / ($\eta \times \cos \varphi$)

It can either be KVA Demand before the correction or KVA Demand after the correction. In the case of KVA before, the PF for the zone before the correction is done and the efficiency of standard motors are used for the calculation. Also, in the same way KVA after is computed by using new anticipated PF after correction with the efficiency of new premium energy efficiency motors. The results for Cataphoresis oven tunnel motors are as tabulated in table 4.1. By using the same method, the bar chart in Figure 4.1 shows the reductions in KVA demands in all other production zones.

3.14.1 To Determine Annual Energy Saving

KW_{saved} $= KW \times L / E_{St} - KW \times L / E_{Pr}$ (1).

$= KW \times L \times (100/ E_{St} - 100/ E_{Pr})$ (2)

Where E_{St}=Efficiency of a standard motor.

E_{Pr}=Efficiency of a premium motor (Appendix A).

L= load factor.

For example, for a 9KW motor, E_{st} =86%, E_{Pr}= 90%, taking L =75%

Using equation 2 above

$= 9 \times 0.75 \times (100/86 - 100/90) = 0.35$ KW.

KWh saving = KW_{saved} × Annual operating hour (3)

= 0.35KW × 1840 Hours

= 641.86 KWh/Year

$Cost_{saved}$ = KWh saving × Energy charge

= 641.86KWh/Yr × N12.9 =N8279.99K

3.15 Energy Efficient Lighting Analysis

It has been recommended that working areas where visual tasks are only occasionally performed be illuminated with Illuminance in the range between 100-150lm/m^2

For example, Toyota, a pacesetter in the automotive industry sets a standard of 100lm/m^2 in the quality check areas. With this, Toyota claims saving of 30% on lighting energy use. Ford, as part of assessment programs, is aiming to reduce energy costs for lighting by eliminating some lights where areas are over lit. Typical 56W fluorescent lampa has luminous efficacy of 66lm/w. This translates to 3696 lumen. Assuming, surface area to be illuminated corresponds to the working height of $2.5\ m^2$.

$$Illuminance = \frac{Luminous\ flux\ (Lumen)}{Surface\ Area\ (m^2)} \qquad (3.5)$$

$$= \frac{3696}{2.5^2} = 591.36 lm/m^2$$

Also, 22W LED fluorescent has luminous efficacy of 40lm/w

Hence, 22W produces 40lm/w x 22 = 880lumen.

In the same way, Illuminance is $= \dfrac{880}{2.5^2} = 141\ lm/m^2$

The resultant value falls within the range recommended for energy efficiency void of waste.

The result is better than that specified by Toyota Production System (TPS).

3.15.1 Calculation on Replacement of 56W Fluorescent fitting with 22W Unit

3.15.2 Mainline (Jigs)

Fluorescent Fitting (56W)

$Power_{76\ units} = 56 \times 76 = 4256W$

Fluorescent Fitting (22W)

$Power_{76\ units} = 22 \times 76 = 1672W$

Energy saved

$$Energy_{saved} = 4256 - 1672 = 2584W$$

Energy saved per day (10hours)

$$Energy_{saved/day} = 2584 \times 10 = 25840Wh = 25.84\ KWh$$

Energy saved per Annum (184 days average)

$$Energy_{saved/Annum} = 25.84 \times 1840 = 4754.56\ KWh$$

Amount saved in Naira per annum (N12.9/KWh)

Amount saved annually = 4754.56 × ₦12.9 = ₦ 61,333.82

Payback = Cost of Energy saving units × Discount / Annual saving

= ₦ 76000 × 0.75/₦ 61,333.82 = 0.93Years, 1 yr Approx.

3.15.3 Development of Energy Saving Calculator

The energy saving calculator automatically calculates the energy saving capabilities of replacements done. This is achieved by changing the variables indicated by the rectangles. The developed calculating aid automatically plots a bar chart for visual appreciation of the acts of changing energy inefficient lighting systems. Figure 3.17 The tool was developed using Excel application software.

ENERGY SAVING CALCULATOR				
No of working days in a month 20		12-Jan-12		
No of working days in a Year 184	1	2	3	4
Power Consumption (W) - Efficient lighting	9	22	22	100
Power Consumption (W) - Inefficient lighting	40	56	56	400
Replaced Quantity (PCS)	3	76	0	2
Saving /Type (W)	93	2584	0	600
Average daily use (hrs)	10	10	10	10
Electricity Cost Naira/KWh		12.9		
Energy Saving/Type/Day (KWh)	0.93	25.84	0.00	6.00
Energy Saving/Type/Month(KWh)	18.60	516.80	0.00	120.00
Energy Saving/Type/Year (KWh)	171.12	4754.56	0.00	1104.00
Total Saving/Year (Naira)	2207.45	61333.82	0.00	14241.60
Cost of Energy Saving Units (Naira)	250.00	2000.00	1200.00	1300.00
Discount (%)	25	25	25	25
Payback (Years)	0.25	0.03	No Replacement	0.14

Figure 3.17: Energy Saving Calculator.

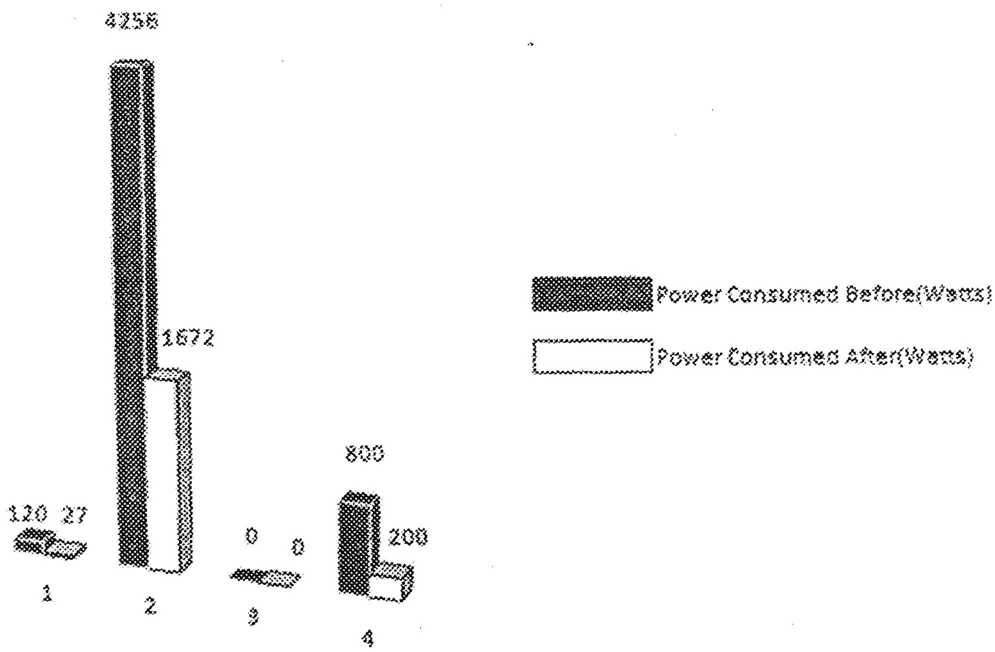


Figure 3.18: Energy Saving Calculator Plots Automatically Power Consumed Before and After Replacement of fittings.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Power Factor Correction

The result in table 4.1 compares KVA demand after correction with the one before. There is a mark reduction in their demands. It shows the processes, their electric motors in relation to their sizes. A total gain of 48.0KVA is recorded.

Table 4.1: A reduction in KVA demand with Premium energy efficient motors and power factor improvement from 0.8 to 0.95 in Cataphoresis Oven tunnel.

PROCESSES	Hp	RPM	RATING (KW)	Avg. Eff. Std.%	Avg. Eff. Prem. %	KVA DEMAND (PF=0.8)	KVA DEMAND AFTER CORRECTION (PF=0.95)
Air intake	50	1800	37	91	93	50.8	41.9
Air intake	12	1800	9	86	89	13.1	10.6
Air intake	5	1800	4.05	83	87	6.1	4.9
Exhaust VE1	15	1800	11	86	90	16.0	12.9
Exhaust VE2	15	1800	11	86	90	16.0	12.9
Exhaust VE3	15	1800	11	86	90	16.0	12.9
Exhaust VE4	15	1800	11	86	90	16.0	12.9
Exhaust VE4	5	1800	3.5	83	87	5.3	4.2
Exhaust VE5	1	1800	1.1	77	83	1.8	1.4
Burner	1	1800	0.76	77	83	1.2	1.0
Burner	15	1800	11	86	90	16.0	12.9
Burner	15	1800	11	86	90	16.0	12.9
Oven seal VRA 1	10	1800	7.5	86	89	10.9	8.9
Burner	1	1800	0.76	77	83	1.2	1.0
Burner	20	1800	15	88	92	21.3	17.2
Cooler unit	22	1800	16.2	89	93	22.8	18.3
Oven seal VRA 2	20	1800	15	88	92	21.3	17.2
					TOTAL	251.7	203.7
						GAIN	48.0

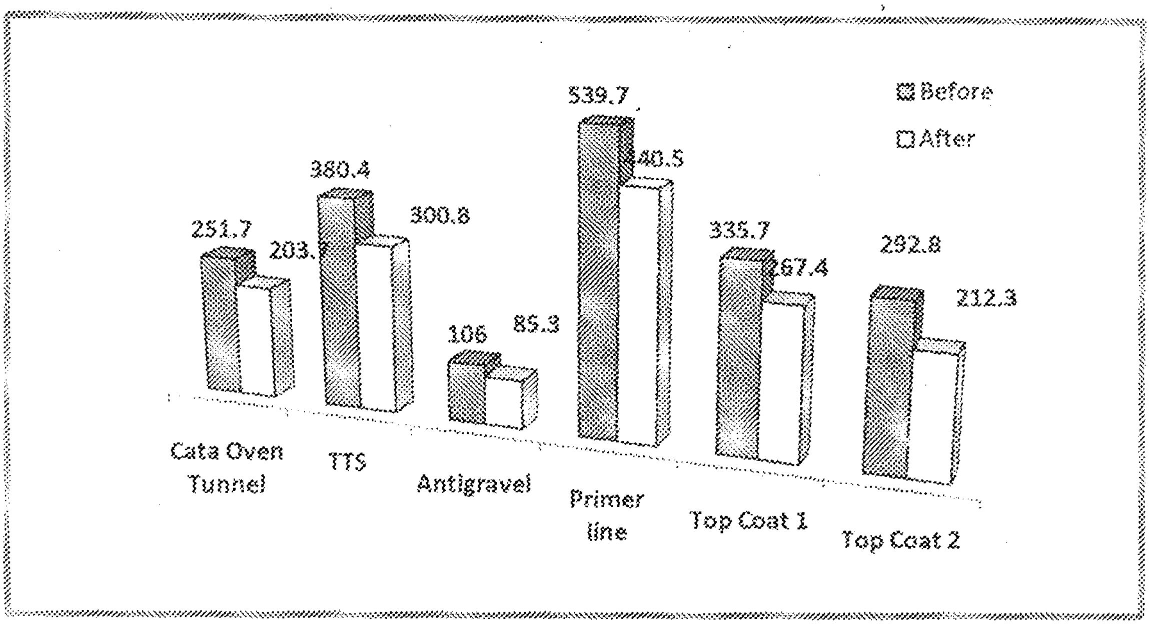


Figure 4.1: KVA Demands Before and After Employing Energy Efficient Motors

The total KVA demand is 1906.3KVA before and 1510KVA after; there is total gain of 396.3KVA. The PHCN tariff schedule for year 2010/2011 which came to effect in 1st July, 2010 shows that Industrial D5 tariff for Demand KVA per month is ₦408.85, Energy KWh per month is ₦ 12.9 while cost for Meter maintenance per month is ₦ 4, 148.00. The cost savings juxtaposed with initial and final KVA demand according to production lines are tabulated in Table 4.2 below.

Table 4.2: Cost Saving by Correcting Power Factor

Production line	Before	Cost	After	Cost
Cata Oven Tunnel	251.70	102907.55	203.7	83282.75
TTS	380.40	155526.54	300.8	122982.08
Antigravel	106.00	43338.10	85.3	34874.91
Primer line	539.70	220656.35	440.5	180098.43
Top Coat 1	335.70	137250.95	267.4	109326.49
Top Coat 2	292.80	119711.28	212.3	86798.86
	TOTAL ₦	779390.76	TOTAL ₦	617363.50

The table 4.3 below shows the calculations of total amount saved per annum in each production line as result of using energy efficient motors.

Table 4.3: Total Amount to be saved Per Annum in Each Production Line as a Result of Using Energy Efficient Motors.

Production line	KW/Yr Saved	Cost Saved (₦)
Cata Oven Tunnel	10848.60	139946.94
TTS	15149.40	195427.26
Antigravel	5205.20	67147.08
Primer line	16008.20	206505.78
Top Coat 1	10795.00	139255.50
Top Coat 2	8532.70	110071.83
	Total ₦	858354.39

4.2 Energy Saved Through Energy Saving Lighting Fittings

Table 4.4 below shows the total analysis of what to be gained by using energy saving fittings by each production zones in Body shop.

Table 4.4: Energy Saved, Cost Saved and Payback by Using Energy Saving Fittings in Body shop

ZONES	TYPES (5Ft) W	QTY	POWER (W)	Power (Energy) 22W	Cost (₦)	KWh saved	KWh Annual	Cost Saving	Payback
307 main line	56	76	4256	1672	76000	25.84	4754.56	61333.82	0.92
406 main line	56	98	5488	2156	98000	33.32	6130.88	79088.35	0.92
Metal Finish line	56	252	14112	5544	252000	85.68	15765.12	203370.04	0.92
UEP Zone	56	24	1344	528	24000	8.16	1501.44	19368.576	0.92
Retouch zone	56	16	896	352	16000	5.44	1000.96	12912.384	0.92
Maintenance zone	56	162	9072	3564	162000	55.08	10134.72	130737.88	0.92
Maintenance office	56	78	4368	1716	78000	26.52	4879.68	62947.872	0.92
Jig shop	56	44	2464	968	44000	14.96	2752.64	35509.056	0.92
Engine room	56	14	784	308	14000	4.76	875.84	11298.336	0.92
Halogen	400	324	129600	32400	324000	972	178848	2307139.2	0.10
		TOTAL	172384	49208	1088000	1231.76	226643.8	2923705.5	8.46

Table 4.5 below shows the total analysis of what to be gained by using energy saving fittings by each production zones in Paint shop.

Table 4.5: Energy Saved, Cost Saved and Payback by Using Energy Saving Fittings in Paint Shop

ZONES	TYPE S(W) (5Ft)	QTY	POWER (W)	Power (Energy) 22W	Cost (₦)	KWh saved	KWh Annual	Cost Saving	Payback
Hanging TTS & Cata	56	57	3192	1254	57000	19.38	3565.92	46000.37	0.92
Mastic	56	66	3696	1452	66000	22.44	4128.96	53263.58	0.92
Antigravel	56	114	6384	2508	114000	38.76	7131.84	92000.74	0.92
Dry Sanding/Primer	56	234	13104	5148	234000	79.56	14639.04	188843.6	0.92
Wet Sanding	56	344	19264	7568	344000	116.96	21520.64	277616.3	0.92
Wet Sanding Retouch	56	20	1120	440	20000	6.8	1251.2	16140.48	0.92
Top Coat 1	56	582	32592	12804	582000	197.88	36409.92	469688	0.92
Top Coat 2	56	204	11424	4488	204000	69.36	12762.24	164632.9	0.92
Top Coat retouch	56	39	2184	858	39000	13.26	2439.84	31473.94	0.92
Omia Oven	56	69	3864	1518	69000	23.46	4316.64	55684.66	0.92
Rest Zone	56	10	560	220	10000	3.4	625.6	8070.24	0.92
Halogen	400	86	34400	8600	8600	258	47472	612388.8	0.01
		TOTAL	131784	46858	1747600	849.26	156263.8	2015804	10.23

Table 4.6 below shows the total analysis of what to be gained by using energy saving fittings by each production zones in Assembly shop.

Table 4.6: Energy Saved, Cost Saved and Payback by Using Energy Saving Fittings in Assembly

ZONES	TYPE S(W) (5Ft)	QTY	POWE R(W)	Power (Energy) 22W	Cost (₦)	KWh saved	KWh Annual	Cost Saving	Payback
Trim line	56	312	17472	6864	312000	106.08	19518.72	251791	0.93
Chassis line	56	288	16128	6336	288000	97.92	18017.28	232422	0.93
ACOM	56	402	22512	8844	402000	136.68	25149.12	324423	0.93
Quality Acceptation	56	24	1344	528	24000	8.16	1501.44	19368.	0.93
Wheel Alignment	56	16	896	352	16000	5.44	1000.96	12912.	0.93
UEP Zone	56	24	1344	528	24000	8.16	1501.44	19368.	0.93
Halogen	400	270	108000	27000	270000	810	149040	192261	0.11
		TOTAL	167696	50452	1336000	1172.44	215729	278290	5.68

4.3 Discussion of Results

The results show that by improving the power factor in Cataphoresis oven tunnel from 0.8 to 0.95 and replacing standard motors with premium energy efficient motors, KVA demand drops from 251.7KVA to 203.7KVA translating to the saving of 48KVA. Also, in TTS, KVA demand drops from 380.4KVA to 300.8KVA. In paint shop, total gain of 396.3KVA is achieved; this results to the saving of ₦162, 027.25.

In the same vein, using energy efficient lighting fittings in Assembly shop, 1172KWh will be saved translating to 215729KWh annually with cost saving of about ₦2.7million. Also, N2 million and ₦2.9million will be saved in Paint shop and Body shop respectively. It is on records that in 2010 alone, PAN spent about ₦90 million on provision of electrical energy for her services. Going by the aforementioned, more savings can be made with attendant increase in annual productiops thus improving national Gross Domestic Product (GDP).

Lower KVA demand means lower current demand and vice versa; reduction in current drawn by equipment, conducted by conductors and handled by switchgears and circuit breakers will undoubtedly translate to reduction in the rate of their breakdowns.

Industries all over the world are established in order to garner profits; this is also attainable if maintenance cost subsides, a situation occasioned by reduction in breakdown of power equipment, without which the aim would be a mirage. Efficient electrical power will reduce downtime, rework duties in the production facilities will be greatly abated; all resulting to increase in production, and hence more energy will be channelled into production of cars.

Industrial electrical energy efficiency do dovetails into reduction of carbon dioxide to be emitted into the atmosphere, this is because the higher the unwanted loads, the greater the activity of prime movers of the generators to meet the demands, also more diesel is consumed. In PAN's case, when a set of 2MVA is on load, in order to meet higher demand, other ones are automatically called upon to shoulder the new demands, thus translating to higher emissions of carbon dioxide, one of the culprits of global warming and climate change. If the proffered solutions are adhered to, the efficiency will be improved while our environment will be saved from pollutions and their resultants.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Investigation of electrical energy saving potential of Peugeot Automobile Nigeria Limited has been carried out in this research work. The results obtained from the study undoubtedly justify the need to install capacitor banks for the improvement of low power factor and replacement of aging standard motors with premium energy efficient motors. Also, replacement of ballast fluorescent fittings with energy saving types has brought about major reduction in energy consumption for lighting. This coupled with implementation of Total Productive Maintenance (TPM) methodology is sine qua non to improved industrial electrical energy efficiency in the industry.

The developed energy saving calculating tool provides a lee-way to energy auditing particularly lighting system. This tool can be used by engineers and consumers alike to calculate energy consumption and gains accruable from energy saving lighting.

It has also been shown that reduction in energy consumed will bring about reduction in cost of producing cars in the factory with concomitant profits. The investment with short period of payback can as well propel the launching of modern cars like Peugeot 408 in one hand and diversification of the factory to production of other Fast Moving Consumer Products thus translating to more gainful employment of teeming unemployed Nigerian youths.

5.2 Recommendations

In order to consolidate the results, it is pertinent to always consider the following recommendations.

1. To make energy efficiency a watchword whenever new equipment is to be acquired.
2. No equipment should be procured without considering its KVA demand.
3. Cablings and electrical equipment should be selected in relation to allowable voltage drops from them.
4. Any unused production line should have their lightings disengaged.
5. Every action should be employed to reduce the number of generators engaged.
6. Maintenance supporting functions should always embrace the tenets of TPM
7. Production of cars must always be juxtaposed with energy efficiency.
8. A periodic energy auditing of the industry should be encouraged. This will reveal the current energy consumption and its costs.

APPENDICES

APPENDIX A

Table A1: Average Efficiencies for Standard and Energy Efficient Motors

1800 RPM Totally Enclosed Fan-Cooled Motors

hp	Average Standard Motor Efficiency, %	Average Energy-Efficient Motor Efficiency, %	Efficiency Improvement, %	Typical Standard TEFC Motor List Price	Typical Energy-Efficient TEFC Motor List Price	List Price Premium
5	83.3 (11)	87.3 (32)	4.6	$344 (8)	$448 (6)	$104
7.5	85.2 (20)	89.5 (22)	4.8	494 (7)	647 (6)	153
10	86.0 (10)	89.4 (30)	3.8	614 (6)	780 (5)	166
15	86.3 (8)	90.4 (27)	4.5	811 (7)	1042 (5)	231
20	88.3 (13)	92.0 (20)	4.0	1025 (8)	1268 (5)	243
25	89.3 (14)	92.5 (18)	3.5	1230 (7)	1542 (5)	312
30	89.5 (9)	92.6 (23)	3.3	1494 (6)	1824 (5)	330
40	90.3 (10)	93.1 (21)	3.0	1932 (7)	2340 (6)	408
50	91.0 (9)	93.4 (22)	2.6	2487 (6)	2881 (4)	394
60	91.7 (11)	94.0 (18)	2.4	3734 (7)	4284 (5)	514
75	91.6 (6)	94.1 (24)	2.7	4773 (7)	5520 (5)	747
100	92.1 (13)	94.7 (17)	2.7	5756 (6)	6775 (4)	1019
125	92.0 (10)	94.7 (16)	2.9	7425 (5)	9531 (8)	2106
150	93.0 (10)	95.0 (18)	2.1	9031 (6)	11123 (6)	2092
200	93.8 (9)	95.4 (14)	1.7	10927 (5)	13369 (4)	2442

Note: Full-load efficiencies are given. The numbers in parenthesis indicate either the number of motors considered or number of motor manufacturers using the identical list price. List prices are extracted from 1990 manufacturers' brochures.

(Source: National Electrical Manufacturers Association)

APPENDIX B

Metric SI Units and Conversion Factors

(A) Multiples and Submultiples

M = Mega (X 1 million)
k = Kilo (X 1000)
m = milli (1 thousandth)
μ = micro (1 millionth)

(B) Length

1in = 25.4mm
1ft = 0.3048m
1yd = 0.9144m
1mm = 0.03937in
1m = 1.09366yd

(C) Area

$1in^2$ = $645.16mm^2$
$1ft^2$ = $0.0929m^2$
$1yd^2$ = $0.836127m^2$
$1mm^2$ = $0.00155in^2$
$1m^2$ = $1.19599yd^2$

(C) Mass

1lb = 0.4536kg

1ton = 1016kg

1kg = 2.205lb

(E) Volume

$1in^3$ = $16387mm^3$
$1ft^3$ = $0.0283m^3$
1UK gal= 3.78541L
$1m^3$ = $35.315ft^3$
1L = 0.22UKgal

(F) Pressure

$1\ lb/in^2$ = $6.895kN/m^2$
1kN/m = $0.145lbf/in^2$

(G) Force

1 lbf = 4.448N
1N = 0.2248 lbf

(H) Temperature

$$^0F = (\frac{9}{5} X\ ^0C) + 32$$

$$^0C = (\frac{5}{9} X (^0F - 32)$$

(E) Energy (work, heat)

1 kWh = 3.6MJ = 3412 Btu
1Btu = 1055J

APPENDIX C

Table A3: Recommended Illumination level according to Activities

Activity	Illumination (*lux, lumen/m²*)
Public areas with dark surroundings	20 - 50
Simple orientation for short visits	50 - 100
Working areas where visual tasks are only occasionally performed	100 – 150
Warehouses, Homes, Theaters, Archives	150
Easy Office Work, Classes	250
Normal Office Work, PC Work, Study Library, Groceries, Show Rooms, Laboratories	500
Supermarkets, Mechanical Workshops, Office Landscapes	750
Normal Drawing Work, Detailed Mechanical Workshops, Operation Theatres	1,000
Detailed Drawing Work, Very Detailed Mechanical Works	1500 – 2000
Performance of visual tasks of low contrast and very small size for prolonged periods of time	2000 – 5000
Performance of very prolonged and exacting visual tasks	5000 – 10000

(Source: www.wikipedia.org)