RAW MATERIAL AND COMPONENT SUPPLY INFRASTRUCTURE IN GHANA TO SUPPORT PROFESSIONAL ENGINEERING DESIGN AND MANUFACTURING

by

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DECLARATION

"I hereby declare that this submission is my own towards an MSc. and that, to the best of my knowledge, it contains neither material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text".

Michael Akpakpavi

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Signature Date

Certified by:

Dr. S.M. Sackey .... ……………………..

(Supervisor) Signature Date

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(Head of Department) Signature Date

DEDICATION

To the Holy Trinity-God the Father, God the Son and God the Holy Spirit.

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First and foremost, I thank the one who knows the end from the beginning. The King of Kings, the Ancient of days, the Almighty God for seeing me through the course and giving me the strength, knowledge, understanding and wisdom to write this essay. Thank you Lord. Secondly, I am deeply grateful for the guidance, patience, love and concern of Dr. S.M. Sackey during the course of my studies. Dr. Sackey is a senior lecturer at the Mechanical Engineering Department, K.N.U.S.T. His constructive criticisms, suggestions, additions and subtractions, and above all, his encouragement offered immense help towards the realization of this study. My thanks also go to all lecturers of the Mechanical and Agricultural Engineering Department, K.N.U.S.T., my course mates, Edem Benson, Seth Daniel Oduro, Boniface Nii Adams who gave me the necessary help and encouragement to complete the programme.

ABSTRACT

The purpose of this thesis work is to assess the supply and availability of raw material and component infrastructure in Ghana to support professional engineering design and manufacturing. The areas covered by the research include: the range of engineering inputs available in the country; the sizes, ratings, as well as the condition of the available inputs; the criteria used by importers of those inputs; technical qualifications of the importers; the amount of engineering inputs produced locally as compared to those imported into the country and the effects of non-availability of the required material inputs on overall manufacturing efficiency and effectiveness.

In the study the availability of engineering inputs are investigated using a questionnaire administered on suppliers/dealers in engineering inputs, local engineering materials producers as well as machinery design and manufacturing firms in the country. In addition, some amount of data was generated through personal observation.

The survey revealed that most of the engineering materials available in the country essentially comprise low and medium carbon steels which come in various forms. Engineering components such as bearings and their mountings, roller chains, washers, pins, retaining rings, ‘O’ rings, induction motors, motor starters, contactors, circuit breakers as well as main switches are readily available and can be obtained as both ‘new’ and ‘used’ components in various sizes. It further revealed that, almost all of these engineering inputs come from outside sources into the country. Again, most of the suppliers/dealers have very low technical qualifications with majority of them having no background at all in relevant technical areas. Also, occasional requests made by customers coupled with importers’ own personal experiences from the import business form the criteria upon which the later order their engineering inputs, but healthier situation will result if qualified people such as graduates from the country’s higher training institutions, particularly the universities and polytechnics, are encouraged to go into the design and manufacture of machinery as well as the supply of engineering inputs. This will ensure availability and correct specification of the inputs.

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LIST OF ABBREVIATIONS

ASTM	-	American Society for Testing and Materials
ISO	-	International Standards Organisation
AA	-	Aluminium Association
AISC	-	American Institute of Steel Construction
AISI	-	American Iron and Steel Institute
UNS	-	United Number Standards Institute
ANSI	-	American National Standards Institute
ASME	-	American Society of Mechanical Engineers
ASM	-	American Society for Metals
AWS	-	American Welding Society
AFBMA	-	Antifriction Bearing Manufacturing Association
SAE	-	Society of Automotive Engineers
IS	-	Indian Standards
G.C.E	-	General Certificate Examination
'O' Levels	-	Ordinary levels
'A' Levels	-	Advanced levels
SSSCE	-	Senior Secondary School Certificate Examinations
BECE	-	Basic Education Certificate Examination

CHAPTER ONE

INTRODUCTION

This chapter gives a brief description of the background to this work. It also presents the statement of the problem, the objectives of the research, the justification of the study and a summary of how the thesis is organised.

1.1 Background of the Research

Developed countries such as the United States of America, Germany, Japan and others have achieved success principally because they are able to add value to bulk of natural raw material and other semi-finished inputs using machinery they design and manufacture. Other countries such as Malaysia, Indonesia and India, that were once regarded as weak economies are now having booming and buoyant economies because their governments have been able to develop engineering capability to support design and manufacturing for large scale processing.

Ghana has since independence tried to industrialize, but to date, has made only modest progress in this direction. It has not been possible for instance, to develop the appropriate machinery infrastructure required to upgrade our traditional methods of processing raw materials and foodstuff for both domestic consumption and export. Several factors account for this, and notable among them is a lack of a well-developed raw material and component supply infrastructure to support professional engineering design and manufacture.

An industrial survey of standard raw material and component parts used in design and manufacturing in Ghana could help bring to light the extent of availability, affordability, quality and state of those inputs. The study will also critically assess the criteria used by the metal raw materials, units and components importers in bringing those materials into the country. Furthermore, the study attempts to determine the qualifications as well as the engineering language literacy level of materials importers as far as it relates to the technical description and presentation of those engineering input. To conclude the study, the work endeavours to make appropriate recommendations to all stakeholders regarding the need to uphold high standards in the supply of engineering materials and components in Ghana to support professional engineering design and manufacturing.

1.2 Statement of the Problem

The primary aim of establishing engineering design and manufacturing industries is to help design and manufacture both simple and complex products that make use of raw material and other inputs by turning them into finished or semi-finished products for both domestic consumption and export. Ghana for example, has been endowed with such raw materials as cocoa, timber, cotton, gold, diamond and so on. To date, Ghana has not been able to locally add value to most of these raw materials because the engineering capital goods design and manufacturing sector is not well developed. These materials are exported mostly in their raw state and thus earn far less foreign exchange than is possible if value were added to them before export.

Currently, in Ghana, a sizeable proportion of the inputs required to support mechanical engineering design and manufacturing are brought from external sources by mostly non-engineering importers, and sometimes by the engineering manufacturing firms themselves. It is thought that large amounts of used inputs are brought into the country because the prices of new materials and components are too expensive. This situation, where many engineering manufacturing firms resort to large scale use of scrap inputs whose properties are generally not tested, tends to undermine the quality of the products produced from these. Not surprisingly, these products often fail to meet international standards.

It is in view of the above challenges facing engineering design and manufacturing in Ghana that this research is conducted. Its goal is to come out with appropriate recommendations to help improve the standard of machinery design and manufacturing in the country.

1.3 Objective of the Research

The primary objective of this project is to investigate the availability of raw material and component supply infrastructure in Ghana to support professional engineering design and manufacturing.

To achieve this, the following specific objectives will be used as sign posts.

1. To find out the range of mechanical engineering units, components and raw materials currently available, as well as those not available in the country for machinery design and manufacturing.
2. To determine the range of sizes, ratings, as well as the state of those inputs available in the country.
3. To investigate the criteria and decision processes used by importers of those inputs.
4. To examine the technical qualifications, the general terminology as well as the engineering language literacy level of importers and dealers.

5. To assess the amount of engineering inputs produced locally as compared to those imported into the country.
6. To verify, finally, the effect of non-availability of required material inputs on overall engineering design and manufacturing efficiency and effectiveness.

1.4 Justification for the Study

The success of any design and manufacturing enterprise hinges on uninterrupted availability of right raw materials and components inputs. This research provides information about a wide range of metal and other raw material and standard parts used generally for design and manufacturing activities. It also provides useful information about the range of sizes as well as the condition of the mechanical units, components and materials available in the country for stated purposes. Based on these, recommendations are made to the appropriate authorities to come up with policies that will help improve on engineering materials and components supply infrastructure. When this is achieved, more design and manufacturing industries will be in a position to function effectively with the result that the efficiency and effectiveness of engineering design and manufacturing in the country will be greatly improved.

1.5 Organisation of Thesis

This thesis is organised into five chapters. The introduction, occupies chapter one, and consists of the subject’s background, statement of the problem, objective of the study, justification of the study and organisation of this report. Chapter two performs a review of concepts in mechanical design and manufacturing, mechanical engineering materials and enumerates the types, sizes, and shapes of the engineering materials, components and units used globally for machinery design and manufacturing. Chapter three discusses the research methodology including the design of a questionnaire and its administration. The presentation and discussion of responses and results from the survey is the subject of chapter four while chapter five summarises the findings, conclusions and recommendations from the work.

CHAPTER TWO

LITERATURE REVIEW

Significant work about the topic does not seem to have been done previously in the literature. However, in relation to the topic in question, this chapter gives general information about mechanical engineering design, codes and standards, the classification and specification of steels, engineering materials and components including procedures and aids to materials selection.

2.1 Mechanical Engineering Design

Mechanical engineering materials and components only become useful when they are developed into machinery and other engineering products to meet human needs. Value addition therefore becomes the first thing to consider when dealing with the supply and availability of those engineering inputs. Generally, mechanical engineering design procedures are used to develop those engineering inputs into usable products. This engineering procedure is therefore discussed briefly:

Mechanical design encompasses the design of things and systems of mechanical nature– machines, products, structures, devices, and instruments. Mechanical design therefore essentially helps to develop simple and complex machinery required to process raw materials into finished as well as semi finished products for local consumption and export [Shigley and Mitchell, 1983].

The general procedure involved in solving an engineering design problem is as shown below. The procedure is actually used globally to develop engineering materials and components into all manner of machinery and other engineering products to meet human needs [Khurmi and Gupta, 1989].

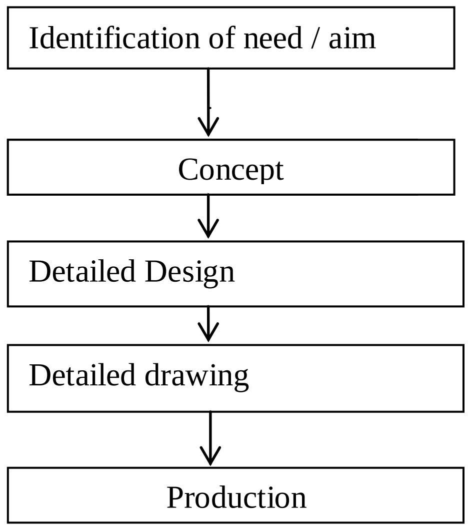

Figure 2.1–General Procedure in Machine Design [Khurmi and Gupta, 1989].

2.2 Engineering Codes and Standards

As soon as a designer has been able to establish a solid definition of the problem at hand, and to formulate a promising solution to it, the next logical step is to begin the collection of available reference materials such as codes and standards [Khurmi and Gupta, 1989]. This is because engineering materials, components and units are principally available in standard sizes, shapes and forms. A brief explanation of standards and codes is therefore given below.

2.2.1 Codes: A code is a set of specification for the analysis, design, manufacture, and construction of something. The purpose of a code is to achieve a specified degree of safety, and performance or quality [Shigley and Mitchell, 1983].

2.2.2 Standards: A standard is a set of specification for parts, materials, or processes intended to achieve uniformity, efficiency and a specified quality. One of the important purposes of a standard is to place a limit on the number of items in the specifications so as to provide a reasonable inventory of tooling, sizes, shapes and varieties [Shigley and Mitchell, 1983].

2.2.3 Differences between Codes and Standards

The fundamental differences between codes and standards are as shown below.

Table 2.1: Differences between Codes and Standards

Codes	Standards
1. This is any set of standards set forth and enforced by a local government for the protection of public safety, health etc.	1. This is defined as something considered by an authority or general consent as a basis of comparison, or an approval model
2. In practical terms, codes tell the user what to do and when and under what circumstances to do it.	2. Standards however, tell the user how to do it.
3. Codes are often legal requirements that are adopted by local jurisdictions that then enforce their provision.	3. Standards are usually regarded as only recommendations that do not have the force of law.

Source: [Shigley and Mitchell, 1983]

2.2.4 Organisations Involved in Establishing Codes and Standards

The various standards of engineering materials and components available are specified by certain organisations. It is important to identify those organisations when dealing with the supply of those inputs. The American Society of Testing and Materials (ASTM) for example, publishes thousands of standards relating to materials and the methods of testing to ensure compliance with the requirements of the standards [Key to Metals, 2005].

Other organisations involved in similar activities include:

1. The International Organisation for Standardisation (ISO)
2. Aluminium Association (AA)
3. American Institute of Steel Construction (AISC)
4. American Iron and Steel Institute (AISI)
5. United Number System (UNS)
6. American National Standards Institute (ANSI)
7. American Society of Mechanical Engineers (ASME)
8. American Society for metals (ASM)
9. American Society of Testing and Materials (ASTM)
10. American Welding Society (AWS)
11. Antifriction Bearing Manufacturing Association (AFBMA)
12. Society of Automotive Engineers (SAE) and
13. Indian Standards (IS)

[Shigley and Mitchell, 1983].

2.2.5 Engineering Materials: A material is that out of which anything is or may be made. Engineering materials comprise a wide range of metals and non-metals which must be worked upon to form the finished product [Shigley and Mischke, 1986].

2.2.5.1 Engineering Materials Classification

Most engineering materials may be classified into one of these basic types.

a) Metals – Ferrous–steels, cast iron, etc

Non-ferrous–Cu, Al, Zn, Sn etc., and their alloys

b) Ceramics

c) Organics

d) Composite materials

a) Metals:

Metals play a major role in the industrial and everyday life of human beings.

Examples of commonly employed metals used largely in machinery design and manufacturing include:

1) Steel – Comprising of low, medium, high and special alloy steels.

2) Cast Iron

3) Non-Ferrous Metals including copper, aluminium, zinc, tin etc. and their alloys.

1) Steel Products

Steel is an alloy of iron and carbon. The carbon composition in weight percent (wt%) of the various steel products used generally in machinery manufacturing are as shown in the table below.

Table 2.2: Various Steels and their Carbon Compositions

Steel Type	Composition
i) Low Carbon Steel	0.05 – 0.15 wt% C
ii) Medium Carbon Steel	0.45 – 0.55 wt% C
iii) High Carbon Steel	0.7 – 1.5 wt% C
iv) Alloy Steels	Contains Various amount of Carbon plus other alloying elements such as chromium, vanadium, nickel etc. Example, stainless steel

Source: [Dowling, 1993]

i) Low and Medium Carbon Steels - These are supplied in the following forms:

- Semis: ingots, slabs, blooms (150 mm x 150 mm to 300 mm x 300 mm), billets (50 mm^2 to 125 mm^2).
- Sections: round tubing, channels, equal angles, unequal angles, ‘W’ shapes, ‘S’ shapes as well as square and rectangular structural steel tubing.

  The details of these shapes are listed in Appendices B10, B11, B12, B13, B14, B15 and B16.
- Rolled Products: hot rolled black bars and bright drawn bars.
- Flat Products: plates, strips, sheets and galvanized sheets.
- Drawn Products: wires, tubes, pipes and squares.
- Truck Material: Fish plate bars, fish plates, light rails, bearing plate bars, crane rails and sleeper bars.
- Others: Tin plates, nails, washers, nuts and bolts and expanded metals [Wiley, 2003].

The material characteristics and typical applications of various plane low-carbon steels are listed in Appendices B1 and B2.

ii) High Carbon Steels - These are available worldwide in forms such as – black strip, spring wire, black rolled bars, short bars and plates [Vlack, 1989].

The typical applications and mechanical property ranges of oil-quenched and tempered high carbon steels are listed in Appendix B3.

iii) Alloy Steel Products - These steels are generally produced and supplied as:

- Forged products
- Rolled products
- Sheet Metal products
- Forged products are supplied in the form of round bars, square bars, flat bars, die blocks and rings.

• Round bars are available in diameter from 30 to 530 mm and 6 m long.
• Square bars are available in sizes from 30 mm to 420 mm and 6 m long.
• Flat bars can be had in width from 30 to 650 mm long and 6 m long.
• Die blocks: Maximum sizes are 600 mm thick, 750 mm wide and 1500 mm long.
• Rings: Available in sizes–outside diameter 150-1250 mm, inside diameter 1200 mm maximum, thickness 13 to 400 mm.

- Rolled products are supplied either as hot rolled round cornered square billets (Diameter from 40 to 195 mm) or as hot rolled rounds (diameter 22 to 125 mm).

- Sheet metal products are supplied either as hot rolled sheets or plates. Thickness range 1.6 to 12 mm and widths 1000 mm up to 5 mm thickness and 1250 mm over 5mm thickness. Standard lengths 2000 mm and 2500 mm or as cold rolled sheets with thickness range 0.8 to 3.25 mm. Standard widths 1000 mm. Standard length 2000 m [Hoyle, 1988].

The typical applications and properties of the various alloy steels are listed in appendices B2, B3 and B4.

2) Cast Iron

This is basically an engineering material containing between 2.14 and 6.70 wt% C [Callister, 2000]. The types of cast irons and their compositions available in the literature are shown in the table below.

Table 2.3: Types of Cast Iron and their Compositions

Cast Iron	**Composition**
i) Gray Cast Iron	a) 2.3-3.8 wt% C b) Contains flakes of graphite in a matrix of ferrite
ii) Malleable Cast Iron	a) 2-3 wt% C b) Contains ferrite or pearlite matrix
iii) Nodular Cast Iron	a) 3.2-4.2 wt% C b) Contains nodules, or spheroids, or rounded graphite particles
iv) White Cast Iron	a) 1.8-3.6 wt% C b) Contains free carbon in a combined form as cementite

Source: [Smith, 1997]

Generally, cast iron is available in the forms including cast plates, pipes, short bars, hollow cylinders, pipe fittings and pots [Smith, 1997].

The designations, minimum mechanical properties, approximate compositions and typical applications of various gray, nodular and malleable cast irons are listed in appendix B5.

3) Non-Ferrous Metals

A wide range of non-ferrous metals and their alloys are also available for machinery design and manufacturing. The compositions, mechanical properties and typical applications of copper, aluminium, magnesium and titanium alloys are listed in appendices B6, B7, B8, and B9.

b) Ceramic Materials

Ceramics usually consist of oxides, nitrides, carbides, silicates or borides of various metals. Examples of ceramic materials are silicon carbide, boron nitride, abrasives and tungsten carbide [Dowling 1993].

c) Organic Materials

Examples of organic materials available in the literature include wood, plastics, adhesives, lubricants and fuels [Wiley, 2003].

d) Composite Materials

A number of composite materials have been engineered that consist of more than one material type. Familiar examples of composite materials used generally include-

1. Polymer-matrix composites: This consists of a polymer resin as the matrix, with fibres as the reinforcement medium. Example is fibre glass which is largely used for making automotive and marine bodies, plastic pipes, storage containers etc.
2. Metal-matrix composites: This essentially consists of a ductile metal matrix. Examples include supper alloys, copper and aluminium alloys which are largely used to manufacture machine parts required to operate in high temperature environments.
3. Ceramic-matrix composites: This largely consists of ceramic materials which are used for making components in automobile and aircraft gas turbine engines.
4. Carbon-carbon composites: In this material, both reinforcement and matrix are carbon. The carbon-carbon composites are employed in rocket motors, as friction materials in air crafts, high-performance automobiles and advanced turbine engines [Callister, 2000].

2.2.5.2 The Classification and Specification of Steels

A chunk of engineering materials and components available comprise of steels. It is important therefore to identify those organisations in charge of the steels and explain briefly how they specify them.

The SAE, AISI, AISE, UNS and so on are responsible for steels as well as other alloys [Khanna, 1987].

a) The 'SAE/ AISI' Steel Numbering System

The 'SAE/AISI' designation for steels is a four-digit number: the first two digits indicate the alloy content; the last two, the carbon content. For plain carbon steels, the first two digits are 1 and 0; alloy steels are designated by other initial two-digit combinations (example, 13, 41, 43). The third and fourth digits represent the weight percent carbon multiplied by 100. For example, 1060 steel is a plain carbon steel containing 0.6 wt% C. [Callister, 2000].

b) The ‘UNS’ System

The Unified Numbering System (UNS) is used for uniformly indexing both ferrous and non-ferrous alloys. Each UNS number consists of a single-letter prefix followed by a five-digit number. The letter is indicative of the family of metals to which an alloy belongs. The UNS designation for these alloys begins with G, followed by the AISI/SAE number; the fifth digit is a zero. Example, G10800 steel is a plain carbon steel containing 0.80 wt% C. [Callister, 2000].

c) The ‘ISO’ Standards

Here in Ghana, the ISO Standards are adopted and used to designate metals. The Ghana Standards Board is the umbrella organisation in charge of these standards and other similar ones such as the British Standards. Specifically, the ISO 6892 is the standard chosen and used by the Ghana Standards Board to index all metallic materials.

2.2.6 Engineering Components and Units

Wide range of engineering components and units are available for machinery design and manufacturing. Some of those inputs are as listed below:

- **Transmission Chains**

A variety of transmission chains are available generally for machinery design and manufacturing. Familiar examples of these chains in the literature are:

a. **Roller chains:** These include the following types of chains –

   i. **Standard roller chains:** These come with pitches of ¼ to 3 inches and are standardised by the American National Standards Institute (ANSI).

   ii. **Non-standard roller chains:** These are chains which are dimensionally different from the standard roller chains.

   iii. **Double roller chains:** These chains have double-pitch in construction.

   iv. **Multiple strand roller chains:** These are available from ¼ to 3 inches and they are constructed of two or more chains joined side by side with link pins extending through the entire width to align the different strands. These chains are used for heavy duty applications [Mary Land Metrices, 2005].

b. **Other chains include:** detachable chains, ladder chains, bead chains, cable chains, pintle chains, offset chains, inverted tooth (silent) chains etc. [Parmley, 1976].

- **Sprockets**

  Basic sprockets types used with precision steel roller chains conform to ANSI standards. Sprockets available include single steel sprockets, double steel sprockets and double cast iron sprockets [Jensen and Helsel, 1985].

  Other sprockets available include heat treated sprockets, rack tooth sprockets, skip tooth sprockets, thinner than standard sprockets, metric sprockets and stamped sprockets [Millwright, 1990].

- **Springs**

  Springs may be classified into three general groups according to their application [Kenneth and Robert, 1991]. We have;

  a. **Controlled action springs:** These have well defined function for each cycle of operation. Examples are valves, dies and switch springs.

  b. **Variable-action springs:** These have a changing range of action because of the variable conditions imposed upon them. Examples are suspension, clutch and cushion springs.

  c. **Static springs:** These exert a comparatively constant pressure or tension between parts. Examples are packing or bearing pressure, anti-rattle and seal springs. The common springs in use include helical springs (compression), helical springs (extension), flat coil springs, torsion springs (bar), leaf springs, Belleville springs, flat springs and Volute springs [Lee Spring Limited, 2005].

- **Spring Clips**

  Basically, spring clips are light-duty fasteners and serve the same function as small bolts. Typical spring clips in use include dart-type spring clips, stud receiver clips, cable clips, wire tube clips, spring molding clips as well asU-shaped, S-shaped and C-shaped clips [Walker, 1985].

- **Gearbox Units**

  Some of the popular types of gearboxes in use are bevel gearboxes, helical gearboxes, planetry gearboxes, sequential gearboxes, spiral bevel gearboxes, worm reduction gearboxes, cycloidal gearboxes, offset gearboxes, shaft mounted gearboxes and crane duty gearboxes [Rino Mechanical Components Incorporated, 2005].

- **Pulleys**

  Different types of pulleys are available and they are essentially used for flat, ribbed and positive-drive belts. Some of the types of pulleys in use include flat belt pulleys, V-belt pulleys, Idler pulleys, timing belt pulleys, magnetic separation pulleys **[**Business.Com, 2005].

- **Couplings**

  Couplings, as the name implies, are used to couple or join shafts. There are two types of couplings: permanent couplings and clutches. Typical permanent couplings in use are roller chain couplings, silent chain couplings, morflex couplings, rubber ball couplings, application couplings, sure-flex couplings and universal couplings (universal joints) [Jensen and Helsel, 1985].

- **Single Components**

  The single components available are as enumerated below:

  a) Washers

  Washers help to make designs simple, quick and inexpensive. The type of washers available for machinery design include cupped washers, Belleville spring washers, dished washers, serrated washers, flat rubber washers, versatile flat washers, plain washers, spring washers etc. [Kenneth and Robert, 1991].

b) Retaining Rings

Retaining rings are used in diverse basic applications and help to simplify design and cut cost. They essentially aid in assembling of parts. Available retaining rings include the versatile retaining rings, the multi-purpose retaining rings and round retaining rings [Millwright, 1990].

c) 'O'–Rings

An 'O' ring is a simple and versatile ring-shaped packing or sealing device with a circular cross section. 'O' rings can perform as protective devices, hole liners, float stops and other key design components. They are normally made from rubber materials and are supplied in various sizes [Buck and Hickman, 1991].

d) Inserts

When a design calls for lightweight materials like aluminium, magnesium and plastics, threaded holes become a problem because of the low shear strength of these materials. Hence, inserts help to solve these problems and other similar ones. Typical inserts available include wire thread inserts, solid self-tapping inserts and solid bushes [Walker, 1985].

e) Pins

Assembled under pressure, pins help to provide powerful gripping action to locate and hold parts together. In the electrical and electronic field, pins work as terminals, connectors, actuators and so on. Types of pins in common use include slotted spring pins, spring pins, split pins, spiral-warped pins, cotter pins, dowel pins, taper pins, Grooved pins and coiled type spring pins [Parmley, 1976].

f) Bushes

A bushing, also known as bush, is an independent plain bearing that is inserted into a housing to provide a bearing surface for rotary applications. They are the simple, inexpensive and often times over looked components. Bushes are made from materials such as steel, brass as well as materials with high wear and friction properties. Types of bushes in common use include flanged bushes, flanged rubber bushes, press-fit bushes and expandable bushes [Millwright, 1990].

- **Bearings**

A bearing is a device to allow constrained relative motion between two or more parts, typically rotation or linear movement [Vlack, 1989]. Bearings are made from materials such as high-carbon chromium steels, martensitic stainless steels, chrome steels etc.

Typical bearings in practical use include deep groove ball bearings, angular-contact ball bearings, self aligning ball bearings, single direction thrust ball bearings, double-direction angular-contact bearings, thrust ball bearings, cylindrical roller bearings, needle roller bearings, tapered roller bearings, spherical roller bearings, cylindrical roller thrust bearings, needle roller thrust bearings, tapered roller thrust bearings and spherical roller thrust bearings [Industrial Bearing Company, 2005].

The various sizes of the available cylindrical roller bearings are prefixed with the following letters: Nu- means bearing performs best when used as free side bearing, Nj and Nf- mean bearing type can carry axial loads in one direction. With angular contact ball bearings, B, C, or no indication after bearing number indicates nominal contact angle of 40^0, 15^0 and 30^0 respectively [Industrial Bearing Company, 2005].

- **Bearing Mountings**

This is the right tool used essentially to ensure proper bearing fitting and shaft cohesion to promote maximum machine life. Common bearing mountings include pillow block and flanged Cartridge [Jensen and Helsel, 1985].

The various types and sizes of the available bearing mountings are prefixed with the following letters for easy identification:

Uk – means type is adapter locking, Uc – means type is set screw locking, Ucx – means type falls within the standard series and set screw locking, p – means pillow, fl and f – mean flanged type and t – means take up type [Jensen and Helsel, 1985].

- **Industrial Motors**

The dimensions of the integral horsepower, general-purpose motors are shown in appendix B17. Practical industrial motors used globally are listed below:

AC and DC Electric Motors: 1 to 35, 000 Horse power including –

a) AC Motors: synchronous motors, induction motors, servo motors and brushless AC servo motors.

b) DC Motors: brushed DC motors and brushless DC motors.

c) Other Motors: stepper motors and linear motors [Whiteson, 1996].

- **Switches**

The most generally accepted switches in the literature include bypass isolation switches, general-use switches, general-use snap switches, isolating switches, motor-circuit switches, transfer switches, mercury switches, three-way switches, four-way switches and photoelectric switches [Greenwood, 1965].

- **Fuses**

A fuse acts as a ‘Safety Valve’ for electrical systems. Ranges of fuses available include plug fuses, fustats fuses, SC or class G fuses, as well as fuses for 250V and 600V circuits. Example is the cartridge fuse [Chapman, 2000].

2.2.7 Procedures for Material Selection

Nearly every engineered item goes through the sequence of activities known as design ⟶ material selection ⟶ fabrication ⟶ evaluation ⟶ and possible redesign or modification. Several methods have been developed for approaching a design and selection problem. Some of these methods are enumerated below:

a) The Case History Method: This method assumes that something has worked successfully before, and that a similar component may be made with the same engineering material and method of manufacture.

b) Cost Centered Method: This method involves modification of an existing product; generally in an effort to essentially reduce cost or to improve quality.

c) Needs Assessment Method: The safest and most thorough material selection approach is to view the task as the development of an entirely new product. The first step in any material selection problem is to define the needs of the product. These needs or requirements fall into three major areas including the shape or geometry considerations, property requirements as well as the service environment [Kalpakjian, 2001].

The typical designation, composition, and applications of the various grades of steels are listed in appendices B1, B2, B3, B4, B5, B6, B7, B8 and B9.

2.2.8 Aids to Material Selection

Material selection procedures require the use of several sources of data. Some of these sources include:

a) Materials Handbook: This is mostly published by ASM International. Other handbooks include Steel Castings Handbook, The Heat Treater's Guide, The ASME Handbook and Tool and Manufacturing Engineers Handbook [Wiley, 2003].

b) Knowledge and Experience of Trained Individuals

Here, experienced personnel assist to reevaluate final materials and manufacturing sequences to assure full compliance with the needs of a product [Kalpakjian, 2001].

2.3 Chapter Summary

This chapter has provided an overview of the basic concepts in mechanical design and manufacturing, engineering codes and standards, organisations involved in establishing codes and standards, as well as engineering components and materials available for machinery design and manufacturing. The key engineering materials, components and units available can be categorised as:

- **Metals:** This can be classified as ferrous and non-ferrous. Examples of commonly employed metals include steel, cast iron, aluminium, copper, zinc, brass, bronze etc.
- **Ceramic materials**: This includes silicon carbide, tungsten carbide, boron nitride, abrasives etc.
- **Organic materials**: This includes wood, plastics, adhesives, lubricants etc.
- **Composite materials**: This essentially includes polymer-matrix composites, metal-matrix composites, ceramic-matrix composites, carbon-carbon composites etc.
- **Engineering components and units**: Examples include chains, sprockets, springs, gearbox units, pulleys, couplings, washers, bearings, industrial motors, fuses, switches, etc.

CHAPTER THREE

RESEARCH METHODOLOGY AND RESULTS

This chapter describes the method used for the study and the results achieved.

3.1 Methodology of Survey

Structured questionnaires were administered at the premises of selected engineering materials and components suppliers (importers), machinery designers and manufacturers as well as engineering material producers in the country. This was to essentially investigate, among other things, the various sizes, shapes and state of the range of engineering materials and components currently available in the country for machinery design and manufacturing.

The personnel in charge of each of these selected firms were met by the researcher to seek rapport and to explain the objectives of the research. The questionnaires were left with the firms and the responses collected later. Apart from questionnaires being the main research instrument used, observations and discussions were also used to some extent in gathering the relevant data. Copies of the questionnaires are provided in appendix A.

3.1.1 Sampling Units

The target group could be divided into several categories such as engineering materials and components dealers and machinery manufacturers. Owing to this, Stratified Random Sampling was used in selecting the sampling units. Stratified Random Sampling is used to select samples in situations where the population is heterogeneous but has definite strata or classes which are homogeneous [Moses and Kalton, 1989].

Regarding the choice of the study places, preference was given to engineering materials and components dealers (importers) and manufacturers in Kumasi, Accra and Tema. However, the local engineering materials producers surveyed were all located in Tema. The survey was confined to these three places because, according to Powell (1995), most industrial activities are concentrated there, and, indeed, this finding is still the same now. Also, the three centres mentioned are all urban areas. Hence, it was taught that the views of the respondents from these centres would adequately represent the whole population. Eight (8), fifteen (15) and ten (10) of the questionnaires were administered to the target groups in Kumasi, Accra and Tema respectively. However, twelve (12), thirteen (13) and nine (9) of separate questionnaires were also administered to the machinery designers and manufacturers at those same locations mentioned respectively.

Three local engineering material producers all located in Tema were also identified and served with separate questionnaires, but only two (2) of them responded. The remainder could not respond to the questionnaire since they were no more producing engineering materials of any sort.

3.2 Results (Responses to Questionnaire)

The responses given by the twenty-five (25) firms in the target group as well as the two (2) engineering materials producers in the country who responded to the questionnaires are described in the remaining part of this chapter.

The tables below show the response rates of the questionnaires by respondents in the various locations.

Table 3.1: Questionnaire Response Rates – Engineering Materials and Components Suppliers/Dealers.

Location	Number Administered	Number Received	Response Rates (%)
Kumasi	8	5	62.5
Accra	15	12	80.0
Tema	10	8	80.0

Table 3.2: Questionnaire Response Rates – Machinery Designers and Manufacturers

Location	Number Administered	Number Received	Response Rates (%)
Kumasi	12	9	75.0
Accra	13	10	76.9
Tema	9	6	66.7

3.2.1 Areas and Level of Technical Training

Question one of the questionnaires for the engineering materials and components dealers as well as the machinery designers and manufacturers sought information about areas and level of formal training. This was to find out about their qualifications and technical competences. Of the twenty-five suppliers/dealers surveyed, only two (8%) responded having technical training in mechanical engineering. Thirteen (52%) indicated having training in Marketing, Six (24%) responded training in Purchasing and Supply, while four (16%) indicated Administration. None indicated having training in such technical areas as Electrical engineering, Materials engineering and Agricultural engineering.

Moreover, fifteen (60%) out of twenty-five of the machinery manufacturers who responded to the questionnaire indicated having training in Mechanical engineering, three (12%) had training in Agricultural Engineering while seven (28%) responded having training in other fields such as Welding and Fabrication and Physics.

The responses given by the suppliers/dealers and machinery designers and manufacturers are as shown in figures 3.1 and 3.2 below.

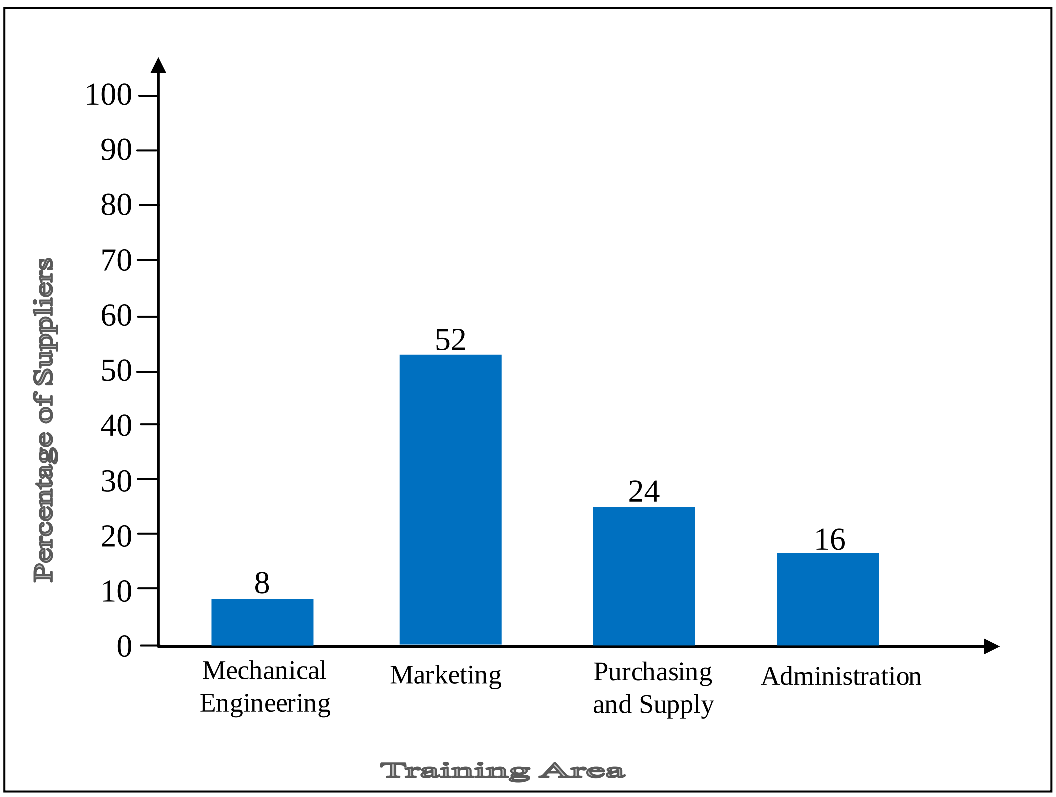

Figure 3.1 Technical Areas of the Suppliers/Dealers

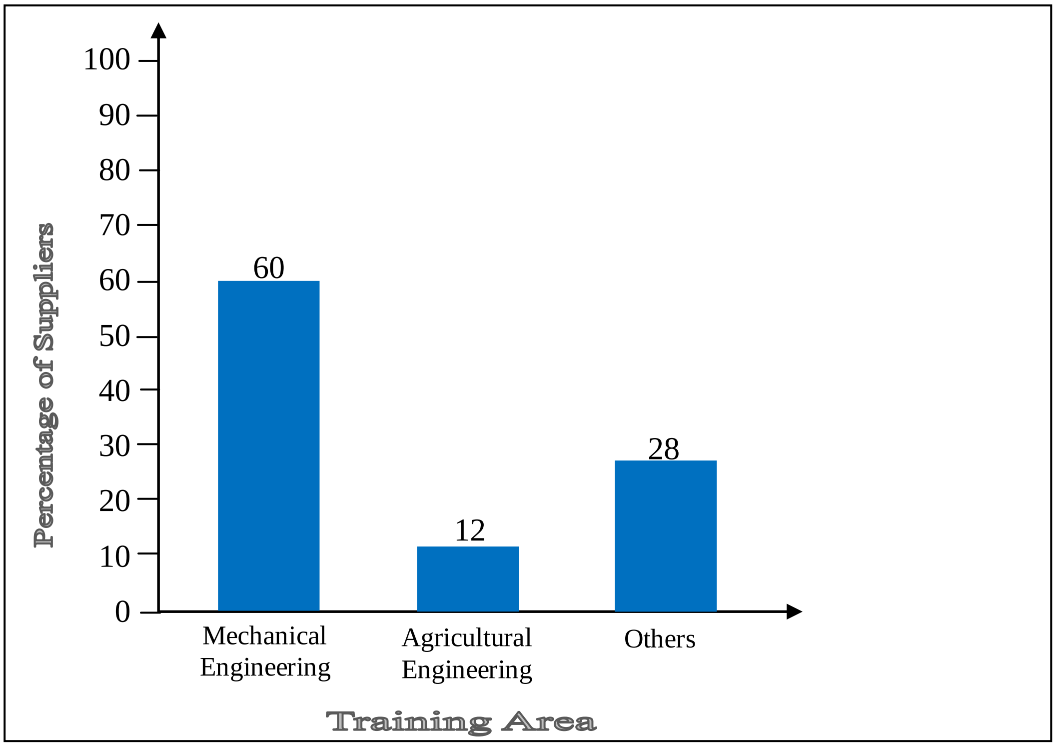

Figure 3.2 Technical Training Areas of Machinery Designers and Manufacturers

With regard to the level of training, three (12%) indicated having university degree, five (20%) respond having diploma, three (12%) indicated having intermediate/advanced certificates whilst fourteen (56%) responded having other qualifications such as G.C.E. 'O' and 'A' levels, SSSCE, BECE and Middle School Leaving Certificates. The responses given by the machinery designers and manufactures on the same issue of level of training also show that four (16%) out of twenty-five responded having university degree, six (24%) indicated diploma, ten (40%) responded having Intermediate/Advanced certificates while five (20%) indicated having other qualifications essentially in the form of apprenticeship.

These are shown in figures 3.3 and 3.4 below.

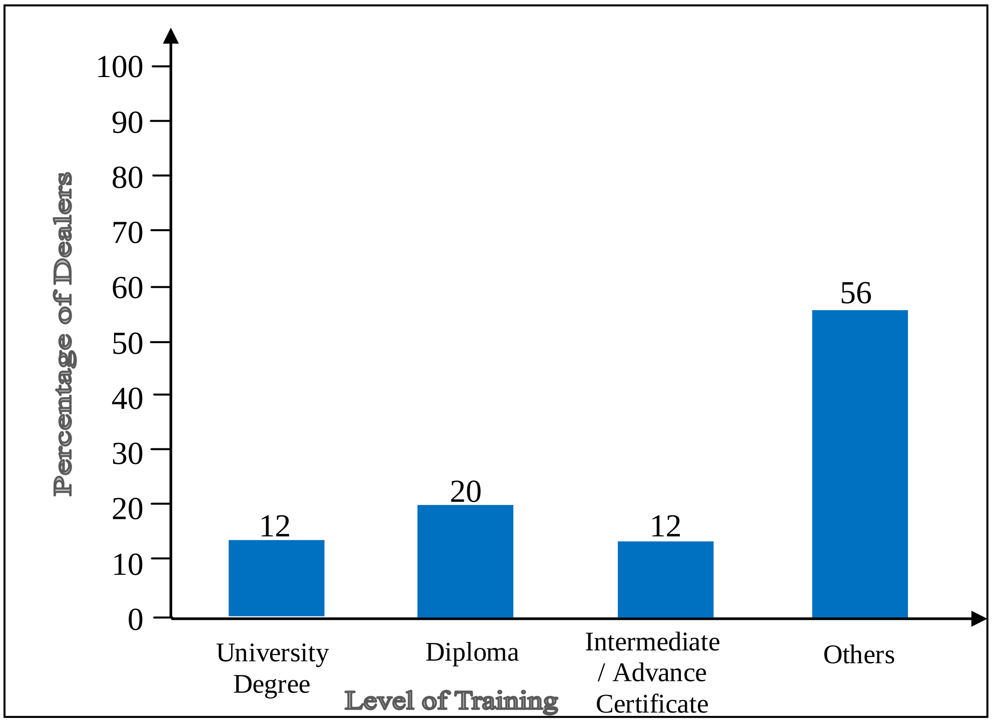

Figure 3.3 The Level of Technical Training Areas of Suppliers/Dealers

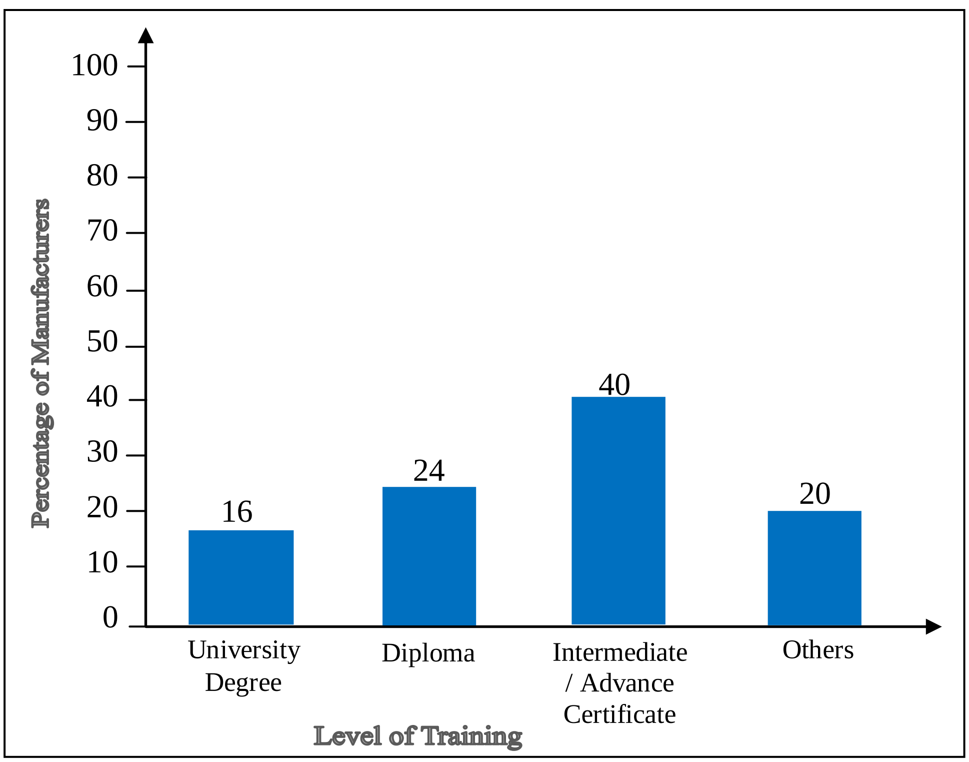

Figure 3.4 Level of Technical Training of Machinery Designers and Manufacturers

3.2.2 Engineering Materials and Components dealt in by Suppliers

Table 3.3 below provides information on the engineering materials and components supplied by dealers to machinery designers and manufacturers.

Table 3.3: Engineering Materials and Components

Material/ Component	Size/Dimension/ Description (mm)	SOURCE: Locally Produced/ Imported	Condition [New/Used]
STEEL SHEETS/PLATES	0.6 x 1219.2 x 2438.4	Imported	New
	0.8 x 1219.2 x 2438.4	-do-	-do-
	1 x 1219.2 x 2438.4	-do-	-do-
	1.25 x 1219.2 x 2438.4	-do-	-do-
	1.25 (BLK) x 1219.2 x 2438.4	-do-	-do-
	1.15 x 1219.2 x 2438.4	-do-	-do-
	1.15 (BLK) x 1219.2 x 2438.4	-do-	-do-
	2 x 1219.2 x 2438.4	-do-	-do-
	2.5 x 1219.2 x 2438.4	-do-	-do-
	3 x 1219.2 x 2438.4	-do-	-do-
	4 x 1219.2 x 2438.4	-do-	-do-
	5 x 1219.2 x 2438.4	-do-	-do-
	6 x 1219.2 x 2438.4	-do-	-do-
	8 x 1219.2 x 2438.4	-do-	-do-

Table 3.3 continued: Engineering Materials and Components

Material/ Component	Size/Dimension/ Description (mm)	SOURCE: Locally Produced/ Imported	Condition [New/Used]
STEEL SHEETS/PLATES	9 x 1219.2 x 2438.4	Imported	New
	10 x 1219.2 x 2438.4	-do-	-do-
	12 x 1219.2 x 2438.4	-do-	-do-
	15 x 1219.2 x 2438.4	-do-	-do-
	16 x 1219.2 x 2438.4	-do-	-do-
	18 x 1219.2 x 2438.4	-do-	-do-
	19 x 1219.2 x 2438.4	-do-	-do-
	20 x 1219.2 x 2438.4	-do-	-do-
	25 x 1219.2 x 2438.4	-do-	-do-
	30 x 1219.2 x 2438.4	-do-	-do-
	40 x 1219.2 x 2438.4	-do-	-do-
	50 x 1219.2 x 2438.4	-do-	-do-
LONG STEEL PLATES	6 x 1524 x 6096	Imported	New
	4 x 1524 x 6096	-do-	-do-
	3 x 1524 x 6096	-do-	-do-
	5 x 1524 x 6096	-do-	do-

Table 3.3 continued: Engineering Materials and Components

Material/ Component	Size/Dimension/ Description (mm)	SOURCE: Locally Produced/ Imported	Condition [New/Used]
STEEL FLAT BARS	20 x 4	Imported	New
	25.4 x 3	-do-	-do-
	25.4 x 5	-do-	-do-
	30 x 3	-do-	-do-
	30 x 4	-do-	-do-
	30 x 5	-do-	-do-
	40 x 4	-do-	-do-
	40 x 6	-do-	-do-
	50 x 4	-do-	-do-
	50 x 5	-do-	-do-
	50 x 8	-do-	-do-
	50 x 10	-do-	-do-
	50 x 12	-do-	-do-
	50 x 8	-do-	-do-
	50 x 10	-do-	-do-
	50 x 12	-do-	-do-
	60 x 6	-do-	-do-
	75 x 6	-do-	-do-

Table 3.3 continued: Engineering Materials and Components

Material/ Component	Size/Dimension/ Description (mm)	SOURCE: Locally Produced/ Imported	Condition [New/Used]
STEEL FLAT BARS	75 x 12	Imported	New
	85 x 10	-do-	-do-
	85 x 12	-do-	-do-
	100 x 6	-do-	-do-
	100 x 10	-do-	-do-
	120 x12	-do-	-do-
	150 x 10	-do-	-do-
	150 x 12	-do-	-do-
STEEL SQUARE PIPES	16 x 16 x 1.5 thick	Imported	New
	20 x 20 x 1.5 thick	-do-	-do-
	25 x 25 x 1.5 thick	-do-	-do-
	30 x 30 x 1.5 thick	-do-	-do-
	35 x 35 x 1.5 thick	-do-	-do-
	40 x 40 x 3 thick	-do-	-do-
	50 x 50 x 1.5 thick	-do-	-do-
	60 x 60 x 3 thick	-do-	-do-
	70 x 70 x 3 thick	-do-	-do-

Table 3.3 continued: Engineering Materials and Components

Material/ Component	Size/Dimension/ Description (mm)	SOURCE: Locally Produced/ Imported	Condition [New/Used]
STEEL SQUARE PIPES	100 x 100 x 4 thick	Imported	New
	100 x 100 x 6 thick	-do-	-do-
STEEL SQUARE BARS	6 x 6	Imported	New
	10 x 10	-do-	-do-
	12 x 12	-do-	-do-
	14 x 14	-do-	-do-
	16 x 16	-do-	-do-
	20 x 20	-do-	-do-
	50 x50	-do-	-do-
STEEL RECTANGULAR PIPES	40 x 20 x 1.5 thick	Imported	New
	50 x 25 x 1.5 thick	-do-	-do-
	60 x 40 x 3 thick	-do-	-do-
	80 x 40 x 3 thick	-do-	-do-
	100 x 50 x 2 thick	-do-	-do-
	100 x 50 x 3 thick	-do-	-do-
	100 x 50 x 5 thick	-do-	-do-

Table 3.3 continued: Engineering Materials and Components

Material/ Component	Size/Dimension/ Description (mm)	SOURCE: Locally Produced/ Imported	Condition [New/Used]
STEEL ROUND PIPES	OD = Outside Diameter 12.7 (OD) x 1.5 thick	Imported	New
	19.1 (OD) x 1.5 thick	-do-	-do-
	25.4 (OD) x 1.5 thick	-do-	-do-
	31.8 (OD) x 1.5 thick	-do-	-do-
	38.1 (OD) x 1.5 thick	-do-	-do-
	50.8 (OD) x 2 thick	-do-	-do-
	76.2 (OD) x 2.5 thick	-do-	-do-
	101.6 (OD) x 3.5 thick	-do-	-do-
	127 (OD) x 5 thick	-do-	-do-
	152.4 (OD) x 5 thick	-do-	-do-
	203.2 (OD) x 6 thick	-do-	-do-
STEEL ROUND BARS	Ø16, Ø20	Imported	New
	Ø25, Ø30	-do-	-do-
	Ø40, Ø50	-do-	-do-
	Ø80, Ø100	-do-	-do-
	Ø120, Ø150	-do-	-do-

Table 3.3 continued: Engineering Materials and Components

Material/ Component	**Size/Dimension/ Description (mm)**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
STEEL ROUND BARS	Ø30, Ø300	Imported	New
	Ø600	-do-	-do-
HEXAGONAL STEEL BARS	40 across flat. This and other sizes are not common lately	Imported	New
STAINLESS STEEL SHEETS/PLATES	0.5 x 1219.2 x 2438.4	Imported	New
	1 x 1219.2 x 2438.4	-do-	-do-
	1.5 x 1219.2 x 2438.4	-do-	-do-
	2 x 1219.2 x 2438.4	-do-	-do-
	3 x 1219.2 x 2438.4	-do-	-do-
STAINLESS STEEL PIPES/BARS	Ø16, Ø20	Imported	New
	Ø30, Ø25	-do-	-do-
	Ø40, Ø50	-do-	-do-

Table 3.3 continued: Engineering Materials and Components

Material/ Component	**Size/Dimension/ Description (mm)**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
SEAMLESS STEEL PIPES	OD = Outside Diameter		
	33.4 (OD) x 3.38 thick	Imported	New
	42.2 (OD) x 3.56 thick	-do-	-do-
	48.3 (OD) x 3.68 thick	-do-	-do-
	6.3 (OD) x 3.91 thick	-do-	-do-
	88.9 (OD) x 5.49 thick	-do-	-do-
	114.3 (OD) x 6.02 thick	-do-	-do-
	168.3 (OD) x 7.11 thick	-do-	-do-
	219.1 (OD) x 8.18 thick	-do-	-do-
	273 (OD) x 9.27 thick	-do-	-do-
	323.8 (OD) x 10.31 thick	-do-	-do-
	355.6 (OD) x 11.19 thick	-do-	-do-
	406.4 (OD) x 12.7 thick	-do-	-do-
	508 (OD) x 15.09 thick	-do-	-do-

Table 3.3 continued: Engineering Materials and Components

Material/ Component	**Size/Dimension/ Description (mm)**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
GALVANISED PLATES	G = Gauge		
	0.6 (G24)	Imported	New
	0.8 (G22)	-do-	-do-
	1.0 (G20)	-do-	-do-
	1.25 (G18)	-do-	-do-
	1.5 (G16)	-do-	-do-
	2.0 (G14)	-do-	-do-
	3.0 (G12)	-do-	-do-
GALVANISED ROUND PIPES			
	12.7 (OD) x 1.5 thick	Imported	New
	19.1 (OD) x 1.5 thick	-do-	-do-
	25.4 (OD) x 1.5 thick	-do-	-do-
	31.8 (OD) x 1.5 thick	-do-	-do-
	38.1 (OD) x 1.5 thick	-do-	-do-
GALVANISED ROUND PIPES	50.8 (OD) x 2 thick	Imported	New
	63.5 (OD) x 2 thick	-do-	-do-

Table 3.3 continued: Engineering Materials and Components

Material/ Component	Size/Dimension/ Description (mm)	SOURCE: Locally Produced/ Imported	Condition [New/Used]
GALVANISED ROUND PIPES	50.8 (OD) x 2 thick	Imported	New
	63.5 (OD) x 2 thick	-do-	-do-
	76.2 (OD) x 2.5 thick	-do-	-do-
	101.6 (OD) x 3.5 thick	-do-	-do-
	152.4 (OD) x 5 thick	-do-	-do-
GALVANISED SQUARE PIPES	12.7 x 12.7 x 1.5 thick	Imported	New
	19.1 x 19.1 x 1.5 thick	-do-	-do-
	25.4 x 25.4 x 1.5 thick	-do-	-do-
STEEL CHEQUERED PLATES	30.0 (thick)	Imported	New
	4.0 (thick)	-do-	-do-
	6.0 (thick)	-do-	-do-
	8.0 (thick)	-do-	-do-

Table 3.3 continued: Engineering Materials and Components

Material/ Component	Size/Dimension/ Description (mm)	SOURCE: Locally Produced/ Imported	Condition [New/Used]
ALUMINIUM CHEQUERED PLATES	2.5 (thick)	Imported	New
	3.5 (thick)	-do-	-do-
STEEL ANGLE BARS	20 x 20 x 3 thick	Imported	New
	25 x 25 x 3 thick	-do-	-do-
	30 x 30 x 3 thick	-do-	-do-
	40 x 40 x 4 thick	-do-	-do-
	45 x 45 x 4 thick	-do-	-do-
	50 x 50 x 5 thick	-do-	-do-
	60 x 60 x 5 thick	-do-	-do-
	60 x 60 x 6 thick	-do-	-do-
	65 x 65 x 6 thick	-do-	-do-
	70 x 70 x 5 thick	-do-	-do-
	70 x 70 x 6 thick	-do-	-do-
	75 x 75 x 6 thick	-do-	-do-
	80 x 80 x 8 thick	-do-	-do-
	90 x 90 x 8 thick	-do-	-do-
	90 x 90 x 12 thick	-do-	-do-

Table 3.3 continued: Engineering Materials and Components

Material/ Component	**Size/Dimension/ Description (mm)**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
STEEL ANGLE BARS	100 x 100 x 8 thick	Imported	New
	100 x 100 x 10 thick	-do-	-do-
	125 x 125 x 10 thick	-do-	-do-
	150 x 150 x 12 thick	-do-	-do-
U-CHANNELS (STEELS)	16 x 16 x 6 thick	Imported	New
	20 x 20 x 6 thick	-do-	-do-
	40 x 20 x 6 thick	-do-	-do-
	40 x 30 x 6 thick	-do-	-do-
	50 x 25 x 6 thick	-do-	-do-
	50 x 40 x 6 thick	-do-	-do-
	60 x 30 x 6 thick	-do-	-do-
	65 x 36 x 6 thick	-do-	-do-
	70 x 40 x 6 thick	-do-	-do-
	80 x 45 x 6 thick	-do-	-do-
	100 x 50 x 8 thick	-do-	-do-
	120 x 55 x 8 thick	-do-	-do-
	127 x 64 x 8 thick	-do-	-do-

Table 3.3 continued: Engineering Materials and Components

Material/ Component	**Size/Dimension/ Description (mm)**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
U-CHANNELS (STEELS)	140 x 60 x 8 thick	Imported	New
	152 x 76 x 10 thick	-do-	-do-
	160 x 75 x 10 thick	-do-	-do-
	200 x 75 x12.7 thick	-do-	-do-
	240 x 100 x 12.7 thick	-do-	-do-
I & H BEAMS (STEELS)	**6000 Long**		
	80 x 40 x 5 thick	Imported	New
	100 x 50 x 6 thick	-do-	-do-
	120 x 60 x 6 thick	-do-	-do-
	140 x 65 x 6 thick	-do-	-do-
	152 x 152 x 8 thick	-do-	-do-
	160 x 85 x 8 thick	-do-	-do-
	200 x 90 x 10 thick	-do-	-do-
	200 x 100 x 10 thick	-do-	-do-
	240 x 110 x 12 thick	-do-	-do-
	300 x 150 x 12 thick	-do-	-do-
	400 x 180 x 16 thick	-do-	-do-

Table 3.3 continued: Engineering Materials and Components

Material/ Component	Size/Dimension/ Description (mm)	SOURCE: Locally Produced/ Imported	Condition [New/Used]
I & H BEAMS (STEELS)	533 x 210 x 16 thick	Imported	New
	12,000 Long	Imported	New
	152 x 89 x 8 thick	-do-	-do-
	160 x 82 x 8 thick	-do-	-do-
	203 x 102 x 8 thick	-do-	-do-
	254 x 146 x 8 thick	-do-	-do-
	305 x 165 x 10 thick	-do-	-do-
	406 x 178 x 10 thick	-do-	-do-
	533 x 210 x 12 thick	-do-	-do-
	152 x 152 x 12 thick	-do-	-do-
	203 x 203 x 12 thick	-do-	-do-
	254 x 254 x 16 thick	-do-	-do-
	305 x 305 x 16 thick	-do-	-do-
	610 x 229 x 16 thick	-do-	-do-
	270 x 127 x 16 thick	-do-	-do-
	356 x 171 x 16 thick	-do-	-do-
	457 x 191 x 16 thick	-do-	-do-

Table 3.3 continued: Engineering Materials and Components

Material/ Component	Size/Dimension/ Description (mm)	SOURCE: Locally Produced/ Imported	Condition [New/Used]
BRASS ROUND SHORT BARS	Ø30, Ø40	Imported	New
	Ø50, Ø60	-do-	-do-
BRONZE ROUND SHORT BARS	Ø20, Ø200	Imported	New
	Ø250 (Not common)	-do-	-do-
BRASS HEXAGONAL BAR	40 across flat (Not common)	Imported	New
COPPER ROUND SHORT BARS	Ø40, Ø20 (Not common)	Imported	New
BEARINGS: **Single row deep-groove ball bearings**	All the sizes are available in the country including:		
	6000, 6204	Imported	New/Used
	6305, 6212	-do-	-do-
	6007, 6322, etc	-do-	-do-

Table: 3.3 continued- Engineering Materials and Components

Engineering Component	**Size/Dimension/ Description (mm)**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
BEARINGS:			
Angular contact ball bearings	All the sizes are available in the country including:		
	7001, 7316	Imported	New/Used
	7404, 7407[B]	-do-	-do-
	7015[C], etc	-do-	-do-
Self-aligning ball bearings	All the sizes are available in the country including:		
	1209, 1320, 2212	Imported	New/Used
	2212,1310, etc	-do-	-do-
Adapter assemblies for self-aligning ball bearing	X-Diameter series, H-Type contains housing. All the sizes are available in the country including:		
	H309X, H2314X, H271X	Imported	New/Used
	4245X, H2320X, etc	-do-	-do-

Table: 3.3 continued- Engineering Materials and Components

Engineering Component	**Size/Dimension/ Description (mm)**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
BEARINGS: **Cylindrical roller bearings**	All the sizes are available in the country including:		
	Nu204, Nj322	Imported	New/Used
	Nf418, Nf210	-do-	-do-
	Nj414, etc	-do-	-do-
Tapered roller bearings	Jr-denotes type with standard contact angle. All the sizes are available in the country including:		
	30202	Imported	New/Used
	33012Jr	-do-	-do-
	30320,etc	-do-	-do-
Spherical roller bearings	All the sizes are available in country including:		
	22205, 21317	Imported	New/Used
	23222, etc	-do-	-do-

Table: 3.3 continued- Engineering Materials and Components

Engineering Component	**Size/Dimension/ Description (mm)**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
BEARINGS:			
Thrust ball bearings	All the sizes are available including:		
	51100, 51318	Imported	New/Used
	51310, etc	-do-	-do-
Spherical thrust roller bearings	All the sizes are available in the country including:		
	29412, 29318	Imported	New/Used
	29434, etc	-do-	-do-
BEARING MOUNTINGS:			
Pillow block type	Ucp209, Ucp210	Imported	New/Used
	Ucp212, Ucp213	-do-	-do-
	Ucp216, Ucp217	-do-	-do-
	Ucxp08, Ucxp09	-do-	-do-

Table: 3.3 continued- Engineering Materials and Components

Engineering Component	Size/Dimension/ Description (mm)	SOURCE: Locally Produced/ Imported	Condition [New/used]
BEARING MOUNTINGS:			
Pillow block type	Ucxp10, Ucxp11	Imported	New/Used
	Ucp309, Ucp310	-do-	-do-
	Ucp311, Ucp312	-do-	-do-
	Ucp215, Ucp219	-do-	-do-
	Ukp209, Ukp209, etc	-do-	-do-
Ball bearing units, rhombic flanged type	fland f-mean flanged type.		
	Ucfl205, Ucfl206	Imported	New/Used
	Ucflx07, Ucfl207	-do-	-do-
	Ucfl307, Ucfl209	-do-	-do-
	Ucflx09, Ucfl215	-do-	-do-
	Ucfl315, etc	-do-	-do-
Ball bearing units, square flanged type	Ucf205, Ucfx05	Imported	New/Used
	Ucf209, Ucfx09	-do-	-do-

Table: 3.3 continued- Engineering Materials and Components

Engineering Component	Size/Dimension/ Description (mm)	SOURCE: Locally Produced/ Imported	Condition [New/Used]
BEARING MOUNTINGS:			
Ball bearing units, square flanged type	Ucf210, Ucfx310	Imported	New/Used
	Ucf308, Ucf311, etc	-do-	-do-
Ball bearing unit, take up type (Uct)	t-means take up type.		
	Uct209, Uctx09	Imported	New/Used
	Uct209, Uctx09	-do-	-do-
	Uct210, Uctx10	-do-	-do-
	Uct310, Uct209	-do-	-do-
	Uct308, Uct208	-do-	-do-
	Uct08, Uct206	-do-	-do-
	Uct306, Uct207	-do-	-do-
	Uct209, Uctx07	-do-	-do-
TRANSMISSION CHAINS:	Pitch (P) x Roller Diameter (D)		

Table: 3.3 continued- Engineering Materials and Components

Engineering Component	**Size/Dimension/ Description (mm)**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
<u>TRANSMISSION CHAINS:</u>	Pitch (P) x Roller Diameter (D)		
1. Single stranded (simplex) roller chains	P (6) x D (4)	Imported	New/Used
	P (8) x D (5)	-do-	-do-
	P (9.525) x D (6.35)	-do-	-do-
	P (12.7) x D (8.51)	-do-	-do-
	P (38.1) x D (25.4)	-do-	-do-
	P (50.8) x D (29.21)	-do-	-do-
	P (63.5) x D (39.37)	-do-	-do-
	P (76.2) x D (48.26)	-do-	-do-
2. Double stranded (Duplex) roller chains	P (8) x D (5)	Imported	New/Used
	P (12.7) x D (8.51)	-do-	-do-
	P (15.875) x D (10.16)	-do-	-do-
	P (25.4) x D (15.88)	-do-	-do-

Table: 3.3 continued- Engineering Materials and Components

Engineering Component	**Size/Dimension/ Description (mm)**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
2. Double stranded (Duplex) roller chains	Pitch (P) x Roller Diameter (D)		
	P (38.1) x D (25.4)	Imported	New/Used
	P (50.8) x D (29.41)	-do-	-do-
	P (63.5) x D (39.37)	-do-	-do-
	P (76.2) x D (48.26)	-do-	-do-
3.Triple stranded (Triplex) roller chains	P (9.525) x D (6.35)	Imported	New/Used
	P (12.7) x D (8.51)	-do-	-do-
	P (15.875) x D (10.16)	-do-	-do-
	P (19.05) x D (12.07)	-do-	-do-
	P (25.4) x D (15.88)	-do-	-do-
	P (31.75) x D (19.05)	-do-	-do-
	P (38.1) x D (25.4)	-do-	-do-
	P (63.5) x D (39.37)	-do-	-do-
	P (50.8) x D 29.21)	-do-	-do-
	P(63.5) x D (39.37)	-do-	-do-
	P (76.2) x D (48.26)	-do-	-do-

Table: 3.3 continued- Engineering Materials and Components

Engineering Component	**Size/Dimension/ Description (mm)**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
SPROCKETS: TYPE A SPROCKETS	**a)** Single strand steel sprockets T = Number of teeth OD = Outside Diameter		
	17 T, OD 145, 25 pitch	Imported	Used
	4O T, OD 420, 30 pitch	-do-	-do-
	4O T, OD 255, 20 pitch	-do-	-do-
	35 T, OD 360, 26 pitch, etc	-do-	-do-
	b) Other type A sprockets		
	-Idler sprocket	Imported	Used
	- Hinge top conveyor chain sprockets	-do-	-do-
	-Thinner than standard sprockets	-do-	-do-
TYPE B SPROCKETS	a) Single strand steel/stainless steel sprockets		
	30 T, OD 160, 16 pitch	Imported	Used
	15 T, OD 135, 27 pitch	-do-	-do-

Table: 3.3 continued- Engineering Materials and Components

Engineering Component	Size/Dimension/ Description (mm)	SOURCE: Locally Produced/ imported	Condition [New/Used]
TYPE B SPROCKETS	19 T, OD 126, 20 pitch	Imported	Used
	10 T, OD 24, 9.5 pitch	-do-	-do-
	b) Double strand steel sprockets. Teeth range: 17 T-95 T. Outside diameter range: Ø56- Ø292	-do-	-do-
	c) Triplex strand steel/ sprockets	Imported	Used
TYPE C SPROCKETS	a) Single stranded steel sprockets	-do-	do
	b) Double stranded steel sprockets	-do-	-do-
	c) Triplex strand steel sprockets	-do-	-do-
	d) Quadruple strand steel sprockets	-do-	-do-

Table: 3.3 continued- Engineering Materials and Components

Engineering Component	**Size/Dimension/ Description (mm)**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
TYPE C SPROCKETS	e) Duplex steel silent sprockets	Imported	Used
	f) Split cast iron sprockets with pitch range 9.5-64. Outside diameter Ø51-Ø1524.	-do-	-do-
PULLEYS:	OD – Outside Diameter		
1. Single V-belt pulleys	OD 38, OD 51, OD 64	Imported	Used
	OD 76, OD 89, OD 102	-do-	-do-
	OD 114, OD 127, OD 140	-do-	-do-
	OD 152, OD 178, OD 203	-do-	-do-
	OD 254, OD 305, OD 320	-do-	-do-
	OD 330, OD 345, OD 335	-do-	-do-
	OD 370, OD 381, OD 610	-do-	-do-

Table: 3.3 continued- Engineering Materials and Components

Material/ Component	**Size/Dimension/ Description (mm)**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
PULLEYS:	OD – Outside Diameter		
2. Double V-belt pulley	OD 38, OD 51, OD 64, etc	Imported	Used
3. Triple V-belt pulley	-do-	Imported	Used
4. Quadruple V-belt pulley	-do-	Imported	Used
5. Multiple V-belt pulley	-do-	Imported	Used
6. Flat belt pulleys	-do-	Imported	Used
COUPLINGS:	For shafts ranging from		
1. Flexible couplings	Ø13 - Ø102	Imported	Used
SPRINGS:	Types available include:		
1. Extension springs (Helical springs)	Machine half loop open	Imported	Used

Table: 3.3 continued- Engineering Materials and Components

Material/ Component	**Size/Dimension/ Description (mm)**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
1. Extension springs (Helical springs)	Short twisted loop open	Imported	Used
	Raised hook	-do-	-do-
	Full twisted loop	-do-	-do-
	Rectangular hook	-do-	-do-
	Full loop at side	-do-	-do-
	Reduced side loop	-do-	-do-
	Double twisted loop	-do-	-do-
	V-hook	-do-	-do-
	Machine cut off	-do-	-do-
	Threaded plug to fit pulleys plain end springs	-do-	-do-
2. Compression springs (Helical springs)	They are available in the following forms as:		
	-Straight springs	Imported	Used
	- coned springs	-do-	-do-
	-Tapered springs	-do-	-do-

Table: 3.3 continued- Engineering Materials and Components

Material/ Component	**Size/Dimension/ Description (mm)**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
2. Compression springs (Helical springs)	**-**A combination of tapered and coned section springs	Imported	Used
3. Torsion springs	Types available:		
	-Special ends	Imported	Used
	-Short hook ends	-do-	-do-
	-Hinge ends	-do-	-do-
	-Straight offset, double torsion end styles	-do-	-do-
4. Leaf springs		Imported	Used
5. Flat coil springs (power spring)		Imported	Used

Table: 3.3 continued- Engineering Materials and Components

Material / Component	Size/Dimension/ Description (mm)	SOURCE: Locally Produced/ Imported	Condition [New/Used]
GEARBOX UNITS: **1. Separate gearbox (Reduction units)**	1. Single reduction units with separate spur, helical or bevel gear arrangements. Gear ratios range from:		
	5:1, 13:1	Imported	Used
	20:1, 25:1	-do-	-do-
	70:1, etc	-do-	-do-
	2. A double reduction unit consisting of a combination of helical and worm wheel gears. Gear ratios range from:		
	20:1-280:1	Imported	Used
	3. A double reduction unit consisting of a worm combined with a separate worm and wheel. Gear ratios range from:		
	25:1 – 4900:1	Imported	Used

Table: 3.3 continued- Engineering Materials and Components

Material/ Component	Size/Dimension/ Description (mm)	SOURCE: Locally Produced/ Imported	Condition [New/Used]
1. Separate gearbox (Reduction units)	4. Single reduction units with helical and Herringbone gears. Speed ratios range from		
	4:1-10:1	Imported	Used
	5. Double reduction units with single helical gears with speed ratios from		
	4:1-10:1	-do-	-do-
<u>WASHERS:</u>	Types available:		
	1. Split-ring type	Imported	New
	2. External type	-do-	-do-
	3. Internal type	-do-	-do-
	4. Internal-external type	-do-	-do-
	5. Countersunk types	-do-	-do-
	6. Heavy duty internal type	-do-	-do-
	7. Dome type	-do-	-do-
	8. Dished type	-do-	-do-

Table: 3.3 continued- Engineering Materials and Components

Engineering Component	**Size/Dimension/ Description (mm)**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
WASHERS:	9. Pyramidal type	Imported	New
	10. Standard flat washers	-do-	-do-
PINS: 1. Cotter pins	a. Standard type	Imported	Used
	b. Humped type	-do-	-do-
	c. Clinch type	-do-	-do-
	d. Hitch type	-do-	-do-
	Size ranges available:		
	Ø1.5 - Ø8		
2. Dowel pins	Types available:		
	a. Shear proof type	Imported	New
	b. Machine key type	-do-	-do-
	c. Knurled type	-do-	-do-
	d. Grooved type	-do-	-do-
	Sizes available range: Ø3- Ø22		

Table: 3.3 continued- Engineering Materials and Components

Engineering Component	Size/Dimension/ Description (mm)	SOURCE: Locally Produced/ Imported	Condition [New/Used]
3. Taper pins	Taper ratio available: 1:48	Imported	New
4. Spring pins	Slotted tubular type. Sizes available ranges from : Ø5 - Ø10	Imported	New
5. Clevis pins	Sizes available range from : Ø5-Ø25	Imported	New
RETAINING RINGS:			
1.Axial assembly rings	a. Basic internal and external rings types	Imported	New
	b. The inverted internal and external types	-do-	-do-
	c. The heavy-duty external rings	-do-	-do-

Table: 3.3 continued- Engineering Materials and Components

Engineering Component	Size/Dimension/ Description (mm)	SOURCE: Locally Produced/ Imported	Condition [New/Used]
2. End play rings	a. Browed internal and external rings	Imported	New
	b. Beveled internal and external rings	-do-	-do-
	c. Locking-prong radial external rings	-do-	-do-
3. Self-locking rings	a. Circular external rings	Imported	New
	b. Circular internal rings	-do-	-do-
	c. Grip external rings	-do-	-do-
	d. Triangular retainer rings	-do-	-do-
4. Radial assembly rings	a. External crescent ring	Imported	New
	b. External E-rings	-do-	-do-
	c. External reinforced E-rings	-do-	-do-
	d. External interlocking rings	-do-	-do-

Table: 3.3 continued- Engineering Materials and Components

Engineering Component	**Size/Dimension/ Description (mm)**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
O-RINGS:	Sizes available range from		
	Ø12.7 - Ø457.2	Imported	New
BUSHES: **1. Press-fit steel bushes**	Length (L) x Outside Diameter (OD)		
	OD 17 x L 55	Imported	Used
	OD 28 x L 80	-do-	-do-
	OD 33 x L 80	-do-	-do-
	OD 41 x L 99	-do-	-do-
	OD 49 x L 110	-do-	-do-
	OD 66 x L 140	-do-	-do-
	OD 65 x L 118.5 etc	-do-	-do-
INDUSTRIAL MOTORS: **1. Induction motors**	Single/ three phases 220 V-380 V 900- 3000 r.p.m		
	0.25 kW	Imported	New/Used
	0.37 kW	-do-	-do-

Table: 3.3 continued- Engineering Materials and Components

Engineering Component	**Type**	**Capacity/Size/ Dimension**	**Source: Locally produced/ imported**	**Condition [New/Used]**
1. Induction motors	Single/three Phases 220V-380V 900-3000 r.p.m	0.55 kW	Imported	New/Used
		0.75 kW	-do-	-do-
		1.1 kW	-do-	-do-
		1.5 kW	-do-	-do-
		2.2 kW	-do-	-do-
		3.0 kW	-do-	-do-
		4.0 kW	-do-	-do-
		5.5 kW	-do-	-do-
		7.5 kW	-do-	-do-
		11.0 kW	-do-	-do-
		15.0 kW	-do-	-do-
		18.50 kW	-do-	-do-
		22.0 kW	-do-	-do-
		30.0 kW	-do-	-do-
		The higher sizes are available as only used ones:		
		37.0 kW	Imported	Used

Table: 3.3 continued- Engineering Materials and Components

Engineering Component	**Type**	**Capacity/Size/ Dimension**	**SOURCE: Locally Produced/ Imported**	**Condition [New/Used]**
1. Induction motors	Single/Three phase 220 V-380 V	45.0 kW	Imported	Used
		55.0 kW etc	-do-	-do-
2. Brake motors	Three phase 220 V-350 V 900-2800r.p.m	2.2 kW	Imported	Used
		4.0 kW	-do-	-do-
		5.5 kW	-do-	-do-
		7.5 kW	-do-	-do-
		30.0 kW	-do-	-do-
		37.0 kW	-do-	-do-
		45.0 kW	-do-	-do-
3. Geared motors	Single/three phase 220 V-380 V 900-2500 r.p.m.	0.55 kW	Imported	Used
		0.75 kW	-do-	-do-
		1.10 kW	-do-	-do-
		1.50 kW	-do-	-do-
		2.20 kW	-do-	-do-

Table: 3.3 continued- Engineering Materials and Components

Engineering Component	Type	Capacity/ Size/ Description	SOURCE: Locally Produced/ Imported	Condition [New/Used]
4. Geared motors with brakes	Three phase 220 V-380 V 700-2000 r.p.m.	0.5 kW	Imported	Used
		0.75 kW	-do-	-do-
		1.1 kW, 2 kW	-do-	-do-
		3 kW and 5.5 kW	-do-	-do-
SWITCHES:		A=Ampere, V=Volts		
1. Motor starters	Single /three phases 50/60 Hz	15 A-63 A 220 V-380 V	Imported	New/Used
2. Contactors	Single/three phases 50/60Hz	0.5 kW 20 A-160 A	Imported	New/Used
3. Circuit breakers	Single/three phases 50/60Hz	32 A-300 A 380 V-660 V	Imported	New

Table: 3.3 continued- Engineering Materials and Components

Engineering component	**Type**	**Capacity/Size Description**	**Source: Locally Produced/ Imported**	**Condition [New/Used]**
4. Main switches	Single/three phase 50/60Hz	32 A-300 A 220 V-380 V	Imported	New
FUSES **1. Plug fuses**	Three-phases	100 A, 500 V	Imported	New
		63 A, 500 V	-do-	-do-
		63 A, 415 V	-do-	-do-
		32 A, 415 V	-do-	-do-
		32 A, 415 V	-do-	-do-
		15 A, 560 V	-do-	-do-

3.2.3 Locally Produced Engineering Materials and Components

The Table 3.4 below essentially shows the engineering products of the two local engineering materials and components producing firms who responded to the questionnaire.

Table 3.4: Engineering Materials and Components Produced Locally

Metal Product	Size/ Dimension (mm)	Quantity/year	Target use/ Intended Purpose
1. Square pipes (by United Steel Co. Ltd., Tema)	16 x 16 20 x 20 30 x 30	186,660 pieces	For gates and other metal fabrication
2. Angle bars (by United Steel Co. Ltd., Tema)	40 x 40 25 x 25 20 x 20	100,284 pieces	For gates and other metal fabrication
3. Flat bars (by United Steel Co. Ltd.,Tema)	15 x 28 20 x 28 25 x 28	100,284 pieces	For gates and other metal fabrications

Table 3.4: Engineering Materials and Components Produced Locally

Metal product	Size/ Dimension (mm)	Quantity/year (Tonnes)	Target use/ Intended Purpose
4. Steel billets (by Tema Steel Works)	100 x 100 80 x 80	30,000	For exports only
5. Iron rods (by Tema Steel Works)	Ø8- Ø32	35,000	For civil works
6. Grinding media balls (by Tema Steel Works)	Ø60 - Ø140	9000	For gold mines, cement mills
7. Special castings	As per customer samples or specifications e.g., cast iron plates, sheets, gear wheels, etc.	400	For all industries

3.2.4. Importation of Supplies upon Request by Customers

Of the twenty five engineering materials and components dealers/suppliers who responded to the questionnaire, eighteen (72%) indicated that they do sometimes import supplies upon request by customers, while the remaining seven (28%) do not. This is shown pictorially in figure 3.5 below.

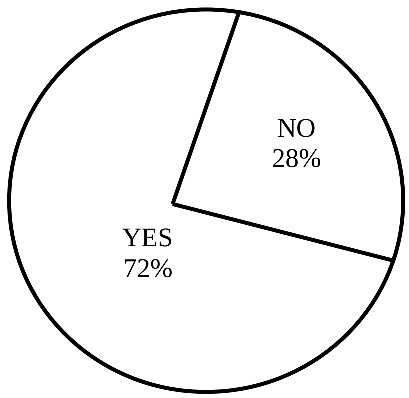

Figure 3.5: Importation of Supplies upon Request by Customers

3.2.5Customers Placing Request Using Full Technical Specifications

Question four of the questionnaire designed for the engineering materials and components suppliers/dealers sought information about how often customers place request using full technical specifications. One (4%) out of twenty five of the suppliers/dealers indicated ‘Frequently’, three (12%) responded ‘Sometimes’, two (8%) ‘Occasionally’ whilst nineteen (76%) said customers ‘Never’ place request using full technical specifications (example, 0.25% carbon steel). Figure 3.6 below depicts this finding in percentage terms.

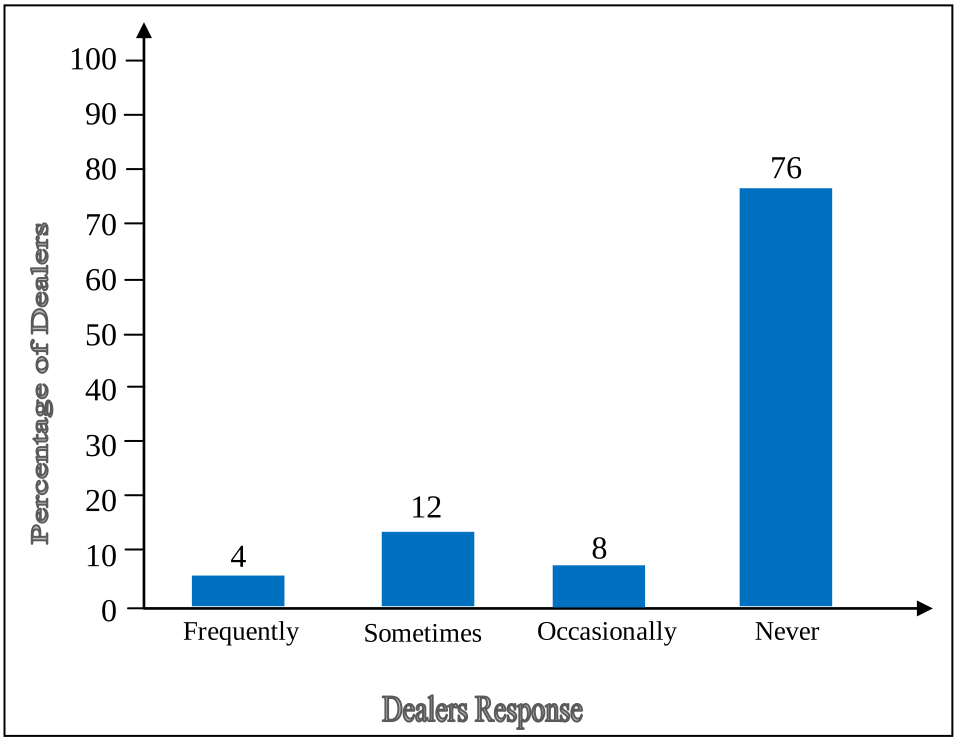

Figure 3.6: Extent of Placing Order Using Full Technical Specifications

3.2.6 Provision of Products Catalogue/ Full Technical Data

On the issue of whether the suppliers offer or provide products catalogue to customers, only two (8%) answered in the affirmative. The remaining twenty three (92%) indicated that they do not offer products catalogue to their customers. Moreover, neither of the two engineering materials producers provides this information to accompany their products. This picture is shown below.

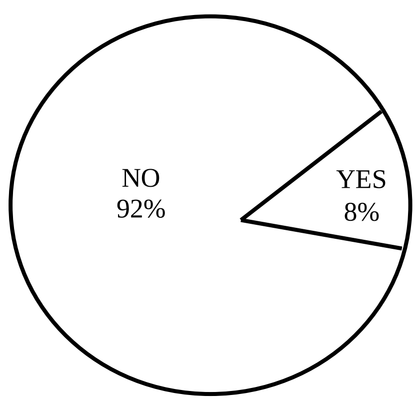

Figure 3.7: Extent of Practice of Providing Product Catalogue to Customers

3.2.7 Interactions with Machinery Manufacturers to know their Needs

In response to the question on how frequently suppliers interact with machinery manufacturers to know the types and sizes of engineering materials required by them, only one (4%) of the suppliers/dears used the word‘often’. Three (12%) responded ‘occasionally’ whilst as many as nineteen (76%) said ‘never’. This information is shown graphically below. On this same question, one of the two engineering materials producers in the country said they never interact with machinery manufacturers whilst the other said they do this only occasionally.

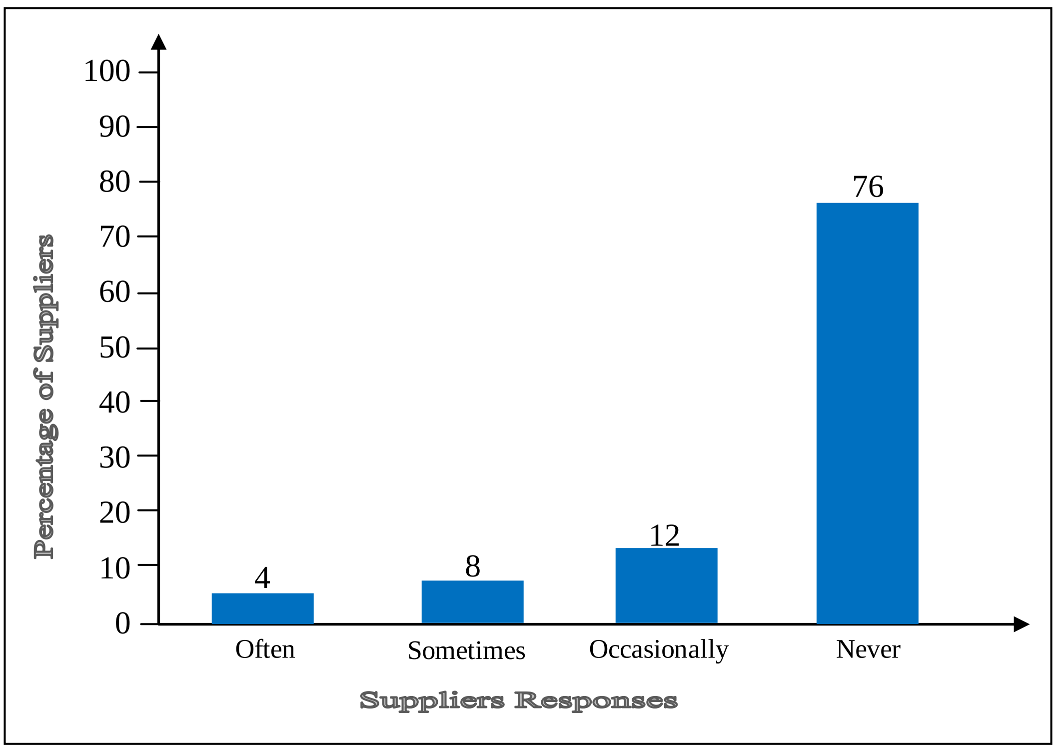

Figure 3.8: Frequency of Interaction of Suppliers with Machinery Manufacturers

3.2.8 Inputs Obtainable on the Local Market for the Design and Manufacture of Machinery and other Engineering Products

Twenty firms (80%) indicated that they are able to obtain all their inputs(actual and substitute) on the local market while the remainder, (20%), said that they are not able to obtain all the inputs they need on the local market and therefore indicated new gearboxes(speed reducers) to be among the scarce items.

The response of machinery manufacturers is shown diagrammatically below.

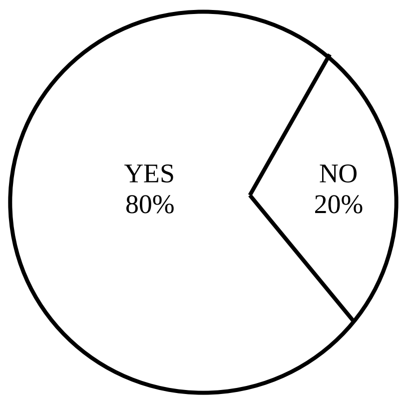

Figure 3.9: Proportions of Firms Able to obtain all their Inputs Locally

3.2.9 Percentage of Inputs Made Up of Substitutes

The response of the twenty five machinery designers and manufacturers on the issue of what percentage of their actual inputs is made up of substitute is as shown in the table below:

Table 3.5: Inputs to Design Made Up of Substitutes

Percentage of inputs made up of substitutes	Percentage of machinery designers using stated substitutes
Under 1%	Three (12%)
1% - 49%	Twenty (80%)
50% -79%	Two (8%)
86% -100%	Zero (0%)

3.2.10 Altering of Design Specifications when Required Inputs are Not Available

Of the twenty five firms surveyed, two (8%) indicated that they often alter specifications, seventeen (68%) responded that they do this sometimes, five (20%) indicated occasionally, whiles only one (4%) responded that they never alter the specifications of designs because of unavailability of engineering inputs. The chart below shows the responses of the machinery manufacturers.

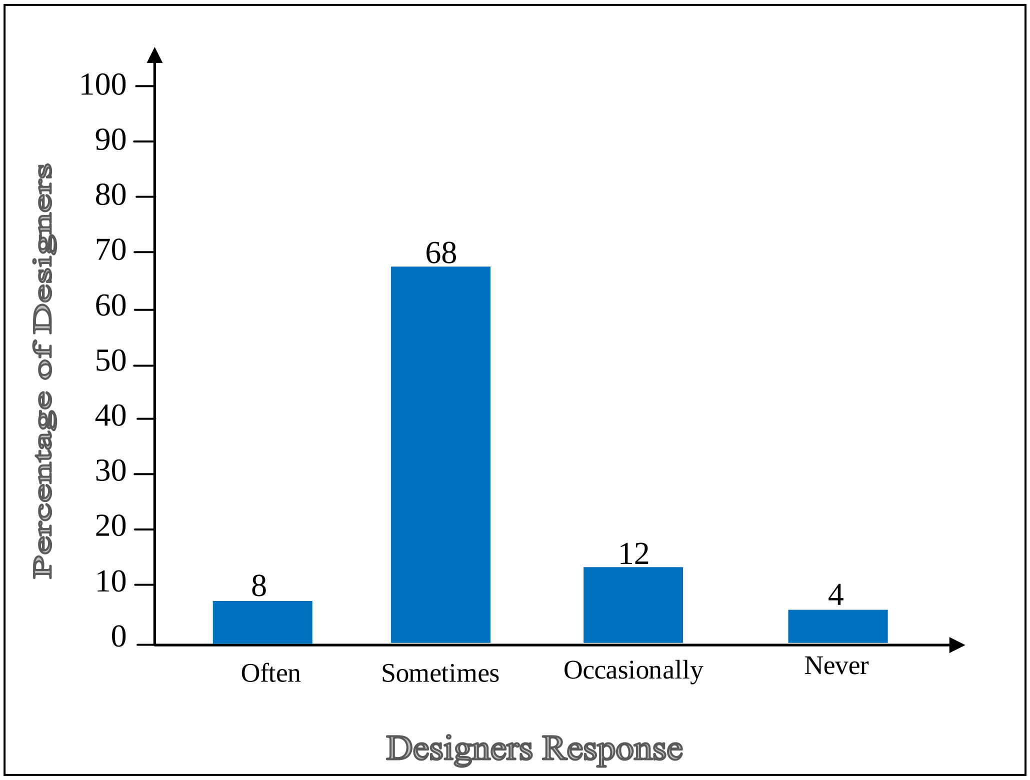

Figure 3.10: Frequency of Alteration of Specifications due to Unavailability of Specified Inputs

3.2.11. Effects of Non-Availability of Required Inputs on Overall Design and Manufacturing Activities

On the above question, the responses are as shown in the table below.

Table 3.6: Machinery Designers Response on the effects of Non-Available Inputs

Effects of non-availability of required inputs	Number (percentage) of manufacturers
'Reduced product functionally', 'Delays in manufacturing operations', 'Higher cost of machinery manufactured', as well as 'other' effects	a) Five (20%)
'Delays in manufacturing operations' and 'Higher cost of machinery manufactured'	b) Sixteen (64%)
'Delays in manufacturing operations' and 'other' effects	c) Four (16%)

However, all twenty five (100%) of the machinery designers and manufacturers who responded to the questionnaire indicated that the non-availability of the required inputs tends to delay their manufacturing activities.

3.3 Chapter Summary

In this chapter the survey methodology and the responses received from twenty-five engineering materials and components suppliers/dealers, machinery designer sand manufacturers as well as engineering materials and components producers have been reported. The questionnaire sought to investigate the availability and supply of engineering materials and components to support professional engineering design and manufacturing.

The suppliers, manufacturers and the materials producing firms surveyed are all located in Accra, Tema and Kumasi. The key responses to the questionnaire can be summarised as:

- Only two (8%) out of the twenty five of the suppliers/dealers surveyed have technical training in mechanical engineering whiles the rest did train in other fields such as Marketing, Purchasing and Supply and Administration.
- Fifteen (60%) of machinery designers and manufacturers have training in mechanical engineering.
- With regard to the level of training, (12%) of suppliers have university degrees with five (20%) of them having diploma.
- Fifteen (60%) of machinery manufacturers have qualifications below diploma levels.
- The range of engineering materials available includes: steel sheets/plates, long steel plates, steel flat bars, steel square pipes/bars, steel rectangular pipes, steel round pipes/bars, hexagonal steel bars, stainless steel sheets/plates/pipes/bars, seamless steel pipes, galvanized plates/round pipes/square pipes, steel chequered plates, aluminium chequered plates, steel angle bars, U-channels, I&H beam steels, brass round short bars, bronze round short bars, brass hexagonal bars, and copper round short bars.
- Apart from the non-ferrous metals, most sizes of ferrous metals (steel) are available and can be obtained as both new and used materials.
- Engineering components available include bearings, bearing mountings, chains, sprockets, pulleys, couplings, springs, gearbox (reduction units), washers, pins, retaining rings, ‘O’ rings, bushes, motors, some types of switches and fuses.

- The range of engineering materials and components available are almost all imported into the country by suppliers/dealers. Often, the composition and quality of these are not known.
- Eighteen (72%) of the engineering materials suppliers surveyed do import supplies upon request by customers.
- Nineteen (76%) of customers never place request using full technical specifications.
- Only 8% of suppliers offer products catalogue to their customers while neither of the two material producing firms provides full technical data to accompany their products.
- Only 4% of suppliers/dealers surveyed often interact with machinery manufacturers to know their needs.
- Twenty (80%) design and manufacturing firms affirm that they are able to obtain all their inputs on the local market.
- Most manufacturers say they use '1%-49%' substitutes.
- Seventeen (68%) of manufacturers indicated that they sometimes alter their design specifications when the required engineering inputs are not available.
- All of the machinery designers and manufacturers surveyed say that the non availability of the required inputs delays their manufacturing activities.

CHAPTER FOUR

DISCUSSION

This chapter presents a discussion of the survey results on the availability of engineering materials and components in the country for machinery design and manufacturing.

4.1 Technical Competence and Level of Training/Qualification

According to Kalpakjian [2001], "experts in the field of engineering deal in engineering materials and publish annual handbooks on them". From section 3.2.1 of this report, 92% of the engineering materials and components suppliers/dealers surveyed have received training in rather non-technical areas such as marketing, purchasing and supply and administration. Moreover, a majority of the machinery manufacturers (88%) indicate that they have some background in mechanical engineering, with a few having training in agricultural engineering.

Also, from the section 3.2.1, a large percentage of the suppliers/dealers have qualifications below diploma such as G.C.E 'O' and 'A' levels, SSSCE, BECE, and Middle School Leaving Certificates. Again, from section 3.2.1, majority of the machinery manufacturers have low qualifications such as the Intermediate/Advanced Certificates and other qualifications in the form of apprenticeship.

Again, from observation, most of the suppliers find it difficult when it comes to identifying the engineering inputs that they deal in by their correct engineering names and terminologies. The dealers have rather developed their own terminologies which they use to describe the various engineering materials and components that they import and supply. For example, bearings are termed by most of the suppliers as “boris”. This means that the engineering language literacy level of most of the dealers/suppliers is rather low.

Furthermore, observation reveals that the jobs of dealing in engineering materials and components have rather been perceived erroneously by most people as jobs reserved for school “drop-outs”. This therefore, does not encourage qualified people such as engineering graduates from tertiary institutions to go into the supply of required engineering inputs to ensure their availability.

Indeed, it is clear that these low qualifications and training contribute to practitioners’ inability to describe material compositions and quality adequately. Most of the machinery manufacturers on the other hand, also have low engineering literacy levels and qualifications and as such may not be capable of communicating effectively with suppliers regarding the technical characteristics of engineering inputs.

4.2 Interactions with Machinery Manufacturers

Effective collaboration and interactions take place between machinery manufacturers and engineering inputs suppliers in most technologically advanced countries and elsewhere to ensure that the required engineering inputs are supplied to the manufacturers [Khurmi and Gupta, 1989]. From section 3.2.6 of this report, 76% of the selected engineering materials and components suppliers/dealers do not interact with machinery manufacturers to know their needs. Also, from the section 3.2.6, the majority of the selected materials producing firms surveyed ‘never’ interact with the machinery manufacturers to enable them meet their demands adequately.

Obviously, lack of effective interaction between the suppliers and machinery manufacturers could lead to a situation where the needed critical engineering materials and components become non-available in the country, since suppliers/dealers may not be aware of any lack regarding these inputs.

4.3 Importation of Engineering Inputs upon Request by Customers

As indicated by the survey, a large number of the engineering materials and components suppliers (72%) do import some of their supplies upon request by customers. Moreover, an informal interaction with the suppliers/dealers reveals that, the requests made sometimes by the customers coupled with the suppliers’ own personal experiences in the import business forms the basis upon which the suppliers import those engineering inputs into the country. A lot of research takes place continually on daily basis to improve the available engineering inputs to match the ever changing and increasing trends in technology in most developing as well as developed countries [Shigley and Mitchell, 1983]. None of the engineering materials and components suppliers/dealers as well as the local engineering material producers surveyed indicates any intentions of introducing new stock of engineering materials and components. Undoubtedly, this means that, significant improvements in engineering inputs supply in the country to match the current technological trends may take a very long time to achieve.

4.4 Customers Using Full Technical Specifications to place Orders

From section 3.2.4, 76% of the selected engineering materials and components suppliers/dealers indicate that customers ‘never’ place orders using full technical specifications (example, 0.25% carbon steel). This could be attributed to the low engineering literacy levels/qualifications of the customers as identified in section 3.2.1.The problem of the suppliers not being able to state the compositions as well as the quality of engineering inputs that they deal in as identified in section 3.2.2 would not have persisted if customers were to be placing orders using full technical specifications. The suppliers would have also been better informed about the required sizes, shapes, compositions and state of those engineering inputs required by customers.

Moreover, an informal discussion with some renowned machinery designers and manufacturers who are highly trained qualified engineers reveals that they are unwilling to use those engineering inputs which are imported into the country by the importers/suppliers. They bemoan the poor quality of those inputs in that whenever they use those materials they tend to receive a lot of criticism from their customers regarding product durability and performance. Consequently, these manufacturers have resolved to import their own engineering materials and components with the required physical and metallurgical properties which they use in their machinery. Obviously, this problem of poor quality engineering inputs being imported into the country can only be identified by the few highly trained technical personnel in the machinery design and manufacturing sector.

4.5 Provision of Products Catalogue/Full Technical Data

As a common practice in most technological advanced countries, almost all engineering products, materials, components etc. are supplied together with catalogues usually containing full technical data. This enables potential buyers and customers to be aware, not only of the prices of those items, but more essentially, the range of sizes, quality, compositions, properties and state of those products.

A large majority (92%) of suppliers/dealers do not offer products catalogue to their customers. Also, from section 3.2.6, none of the engineering material producing firms follows this practice, which is common in most advanced countries. The worst offenders are those that deal in critical engineering components such as pulleys, speed reducers, transmission chains, bushes, sprockets, and some types of motors. A large percentage of these components cannot be obtained in the country as 'new' components and therefore are only available as second-hand inputs in scrap yards. Thus, virtually no technical data accompanies such products. This in turn, makes it difficult for machinery manufacturers to be informed regarding the technical characteristics of those components.

4.6. Inputs Obtainable on the Local Market for the Design and Manufacture of Machinery and other Engineering Products

From the survey, a very large percentage of the machinery designers and manufacturers claim they are able to obtain all their inputs on the local market for their manufacturing activities. According to Kalpakjian [2001], "experienced personnel assist to reevaluate final materials and manufacturing sequences to assure full compliance with the needs of a product". From observation, these machinery manufacturers do not give due consideration to the composition as well as the state of those engineering inputs they use in their machines, a key requirement for acceptable products. Hence, even though most of these manufacturers claim they are able to obtain all their inputs on the local market, they can hardly establish the quality, suitability and acceptability of those engineering inputs.

Indeed, the manufacturers inability to critically assess engineering inputs they use in their machinery manufacturing activities could be attributed essentially to their low engineering literacy level and competence.

On the contrary, a minority (20%) of manufacturers, who seem qualified and highly trained, tend to do proper assessment of the available engineering inputs before using them. They seem to have come to terms with the fact that they are not able to obtain all their engineering inputs from the local market, and, as such, have identified the non-available engineering inputs. These include high carbon steel products, most non-ferrous metals as well as critical components such as new gearboxes, couplings, bushes, some types of motors, etc.

4.7 Percentage of Actual Inputs Made Up of Substitutes

Most renowned machinery manufacturing firms globally aim at producing machines that meet international standards, quality and durability, and, therefore, avoid the use of substitute inputs in their machinery [Shigley and Mitchell, 1983]. From section 3.2.8 of this report, a chunk of the machinery designers and manufacturers surveyed indicate that their actual inputs consist of at least between 1%-49% substitute materials and components. Moreover, majority of machinery manufacturers say they ‘sometimes’ alter their design specifications to available substitute engineering materials and components.

Undoubtedly, the altering of design specifications leading to a massive usage of substitute inputs in the manufacture of machinery may result in reduced machinery functionality and durability. The products may fall short of international standards, and cannot be exported.

4.8 Effects of Non-Availability of Required Inputs

The required types, sizes, quality, state and compositions of most engineering materials and components are readily available and can be obtained in the hardware shops of most advanced countries for machinery design and manufacturing [Jensen and Helsen, 1985]. From section 3.2.10 of this report, all of the machinery designers and manufacturers surveyed, among other things, indicate that they experience a lot of delays, particularly in their manufacturing activities/operations, as a result of the non-availability of the required engineering inputs.

An informal interaction with majority of the manufacturers reveals that, they spend a lot of their time moving from one scrap yard to another in search of the required engineering inputs. Sometimes, those manufacturers located in Kumasi and its environs are forced to travel a long way to Accra and Tema for a number of weeks to enable them obtain the needed engineering inputs. According to them, they sometimes have to wait for months for new consignments of engineering inputs to be brought into the country by importers. Avery disturbing situation was witnessed by the researcher at a manufacturing firm located at 'Ashaiman', a suburb of Accra. The manufacturer was to supply one hundred pieces of 'palm oil expeller' machines as part of a World Bank project, and he was to use gearboxes (speed reducers) and other critical engineering components in the manufacture of those machines. However, he was not able to obtain the required types, sizes as well as the number of speed reducers he needed from any of the renowned engineering hardware shops and scrap yards available in the country to enable him complete his project. This delayed his project and made him lose the confidence of his clients. Thus, it can be seen that the non-availability of required engineering materials and components is having an adverse impact on the efficiency and effectiveness of machinery design and manufacturing in the country.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

This work has sought to survey the supply and availability of engineering materials and components in the country for machinery design and manufacturing. To achieve this, the following objectives were set:

1. to find out the range of mechanical engineering units, components and raw materials use generally for machinery design and manufacturing,
2. to determine the range of sizes, ratings, as well as the state of those inputs available in the country,
3. to investigate the criteria and decision processes used by importers of these inputs,
4. to examine the technical qualifications, the general terminology and the engineering language literacy level of importers and dealers,
5. to assess the amount of engineering inputs produced locally as compared to those imported into the country, and
6. to verify, finally, the effects that non-availability of the required engineering inputs is having on overall manufacturing efficiency and effectiveness.

From the investigation conducted most of the engineering materials available in the country for machinery design and manufacturing essentially comprise low and medium carbon steels which are supplied in various forms. Most of the sizes of these materials are available and they can be obtained in both 'new' and 'used' condition in the country. However, engineering materials comprising of high carbon steels, special steels as well as most non-ferrous metals such as copper alloys, aluminium alloys, aluminium-lithium alloys, magnesium alloys and titanium alloys are hard to come by in the country. Engineering components such as bearings, bearing mountings, roller chains (single, double, and triple), washers, pins, retaining rings, 'O' rings, induction motors, motor starters, contactors, circuit breakers as well as main switches are readily available and can be obtained as both 'new' and 'used' components in many sizes.

Moreover, critical components such as sprockets, pulleys, springs, gearbox units, press-fit bushes, brake motors, gear motors as well as gearbox motors with brakes are not so readily available and can only be obtained as 'used' components in various sizes from scrap yards. On the other hand, required sizes and types of components such as inserts, couplings, spring clips, flanged bushes, expandable bushes, silent chains, other special chains, servo motors, synchronous motors, photoelectric switches, mercury switches and other similar components are almost not available in the country.

Worst still, clearly, all the engineering materials and more particularly components available in the country are rather imported into the country by dealers/suppliers. The compositions, quality as well as the physical and the metallurgical properties of these imported inputs nonetheless are hardly known as they are not normally accompanied by full technical data.

From the survey the following conclusions can be drawn:

1. Majority of the engineering materials and components suppliers/dealers do not regularly interact with the machinery manufacturers to know their needs.

2. Most of the engineering materials and components suppliers/dealers do not have the requisite technical training, as the jobs of dealing in engineering inputs in the country are "perceived" to belong to school "drop-outs".
3. Even though majority of the machinery designers and manufacturers such as Sethi Engineering Limited, Orlando Metal Works and Geco Metal Company Limited seem to have some background in mechanical engineering, they, together with the suppliers/dealers, have low technical qualifications.
4. It emerged from the survey that, 99% of all the engineering materials and components available in the country for machinery design and manufacturing are imported from other countries with their compositions, quality as well as physical and metallurgical properties undetermined as most of these inputs come in as second-hand products.
5. Suppliers/dealers' own personal experiences in the import business coupled with customers' requests guide the former in importing those engineering inputs into the country.
7. Machinery designers and manufacturers as well as other customers do not normally place requests for their inputs using full technical specifications.
8. As high as 92% of the suppliers/dealers surveyed do not offer products catalogues to their customers to enable the latter to be informed regarding the required sizes, types as well as the quality of those engineering inputs available in the country.
9. Machinery manufacturers sometimes alter their design specifications to suit the available engineering inputs.
10. Substitute engineering inputs are often used to some extent by machinery designers and manufacturers in their manufacturing activities.

11. Engineering products manufacturers in the country such as Gratis Foundation, Sis Engineering Limited, Homeku Engineering Limited, Agbemskod Engineering Limited etc. among other things, experience undue delays in their activities as a result of non-availability of the required engineering inputs.

In light of the findings and conclusions deduced from the study, the following recommendations are made:

1. The Ghana Institution of Engineers, and The Ghana Standards Board should organize training and workshops regularly for suppliers/dealers to enable them upgrade and update their technical competencies and engineering literacy levels.
2. Engineering graduates from the country's training institutions, particularly the universities and polytechnics, should be encouraged to go into the design and manufacture of machinery as well as the supply of engineering inputs to ensure availability and correct specification of the inputs.
3. The government, banks as well as other corporate organisations should assist to expand and resource the few existing engineering materials producing firms as well as establish new ones in the country to help produce more of the required engineering inputs locally and by so doing create jobs.
4. There should be constant and regular interactions between machinery manufacturers and suppliers/dealers to enable the suppliers to be informed about the required engineering inputs so they can make them readily available for purchase.
5. Suppliers/dealers should endeavour to provide product catalogues to their customers to enable them to become acquainted with the types, sizes, compositions as well as the physical and the metallurgical properties of those inputs.

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APPENDIX A–Survey Questionnaire

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

MSc. RESEARCH PROJECT

QUESTIONNAIRE TO INVESTIGATE THE SIZES, STATES AND AVAILABILITY OF ENGINEERING MATERIALS, COMPONENTS AND UNITS OFFERED BY SUPPLIERS/DEALERS

1) Please, indicate any formal training you may have had in any of the following technical areas? (Please tick as many as apply)

Technical Training Area	Level of Training
☐ Mechanical Engineering	
☐ Electrical Engineering	☐ University Degree
☐ Materials Engineering	☐ Polytechnic Diploma/Part III
☐ Agricultural Engineering	☐ Intermediate/Advanced Certificates
☐ Others (please specify)………….	☐ Others (please specify)……………...
……………………………………………..	…………………………………………………..
……………………………………………..	…………………………………………………..
……………………………………………..	…………………………………………………..

2) Please, provide the requested information about the engineering raw materials and components you deal in.

Materials/Components	Size/Dimension/ Description	Composition	Condition [New/Used]	Source: [Produced Locally/ Imported]
i. **Materials**				

Materials/components	Size/Dimension/ Dimension	Composition	Condition [New/Used]	Source: [Produced Locally/ Imported]
ii) **Components/Units**				

3) Do you sometimes import some of your supplies upon request by your customers? (Please tick one)

☐ Yes

☐ No

4) How often do customers place request using full technical specifications? (example, 0.25% carbon steel)
(Please tick one)

☐ Frequently

☐ Sometimes

☐ Occasionally

☐ Never

5) Do you offer or provide products catalogue to your customers?
(Please tick one)

☐ Yes

☐ No

6) Please, list the materials and components that you would like to have in stock but are not able to do so……………………………………………………………………….

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7 Please, why would you like to have in stock those products you stated in question 6?

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8) How frequently do you interact with machinery manufacturers to know their needs?

(Please tick one)

☐ Often

☐ Sometimes

☐ Occasionally

☐ Never

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

MSc. RESEARCH PROJECT

QUESTIONNAIRE TO ASSESS AVAILABILITY OF ENGINEERING MATERIALS, COMPONENTS AND UNITS USED BY MACHINE DESIGNERS AND MANUFACTURERS

1. Please, indicate any formal training you may have had in any of the following technical areas? (Please tick as many as apply)

Technical Training Area	Level of Training
☐ Mechanical Engineering	
☐ Electrical Engineering	☐ University Degree
☐ Materials Engineering	☐ Polytechnic Diploma/Part III
☐ Agricultural Engineering	☐ Intermediate/ Advanced Certificates
☐ Others (please specify)………….	☐ Others (please specify)…………….
……………………………………………..	…………………………………………………..
……………………………………………..	…………………………………………………..
……………………………………………..	…………………………………………………..

2) What is the highest qualification of your most experienced designer or manufacturing engineering practitioner? (Please state)

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3. Please, provide the requested information about the engineering materials, components and units you use in manufacturing your products.

Materials/Components/ Electrical Units	Size/Dimension/ Description	Condition: [New/Used]	Original Source: [Locally Produced/ Imported]	Point of Purchase: [Local/ Foreign]
i **Materials**				
1.				
2.				
3.				

Materials/Components/ Electrical Units	Size/Dimension/ Description	Condition: [New/Used]	Original Source: [Locally produced/ Imported]	Point of Purchase: [Local/Foreign]
ii) **Components/Units**				

Materials/Components/ Description	Size/Dimension/ Description	Condition: [New/Used]	Original Source: [Locally produced/ Imported]	Point of Purchase: [Local/Foreign]
iii) **Electrical Units**				

4) Are you normally able to obtain all the inputs you need on the local market?

(Please tick one)

☐ Yes

☐ No

5) List or describe the inputs that you normally find unavailable on the local market.

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6) In your estimation, what percentage of your actual inputs is made up of substitutes?

(Please tick one)

☐ Under 1%

☐ 1% - 49%

☐ 50% - 79%

☐ 80% - 100

7) How frequently do you have to alter the specifications of your design when you realise that the required engineering inputs are not available?

(Please tick one)

☐ Often

☐ Sometimes

☐ Occasionally

☐ Never

8) How does non-availability of the required engineering inputs affect your overall design and manufacturing activities? (Please tick as many as apply)

☐ Reduced product functionality and performance

☐ Higher cost of machinery manufactured

☐ Delays in manufacturing operations

☐ Others (please specify)……………………...

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KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

MSc. RESEARCH PROJECT

QUESTIONNAIRE TO INVESTIGATE THE RANGE OF ENGINEERING MATERIALS ORIGINALLY MANUFACTURED IN THE COUNTRY

1. Please, provide the requested information about the metal products that you produce.

Metal Products	Size/Dimension	Composition	Quantity/ Year	Target use/ Intended Purpose
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				

2) Do you provide full technical data to accompany your products?

(Please tick one)

- [ ] Yes
- [ ] No

3) Are you normally able to meet the demand requirements on your products?
(Please tick one)

- [ ] Yes
- [ ] No

4) How frequently do you interact with machinery or engineering product manufacturers to know the types and sizes of engineering materials required by them? (Please tick one)

- [ ] Often
- [ ] Sometimes
- [ ] Occasionally
- [ ] Never

5) What Form(s) of assistance do you receive from the government in your manufacturing activities? (Please tick as many as apply)

- [ ] Tax reliefs
- [ ] Subsidies
- [ ] Funded training
- [ ] Provision of capital equipment, tools and machines on some terms

☐ Others (Please specify)………………………………………………………

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6) What new engineering materials and components do you plan introducing in the future? (Please specify)……………………………..

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7) Please, why will you like to introduce those products you stated in question 6?

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KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

MSc. RESEARCH PROJECT

QUESTIONNAIRE TO INVESTIGATE MECHANICAL- RELEVANT ELECTRICAL COMPONENTS AVAILABLE LOCALLY

1) Please, indicate any formal training you may have had in any of the following technical areas? (Please tick as many as apply).

Technical Training Area	Level of Training
☐ Mechanical Engineering	
☐ Electrical Engineering	☐ University Degree
☐ Materials Engineering	☐ Polytechnic Diploma/Part III
☐ Agricultural Engineering	☐ Intermediate/ Advanced Certificates
☐ Others (please specify)………….	☐ Others (please specify)…………….
……………………………………………..	……………………………………………..
……………………………………………..	……………………………………………..
……………………………………………..	……………………………………………..

2. Please, provide the requested information about the electrical motors, switches, and fuses that you deal in.

Engineering Components	Type	Capacity/Size/ Description	Source:[Locally Manufactured/ Imported	Condition: New/Used
1. <u>Motors</u>				
1.				
2.				
3.				

Components	Type	Capacity/Size/ Description	Source: [Locally Manufactured/ Imported	Condition: New/Used
ii) **Switches**				

Components	Type	Capacity/Size/ Description	Source:[Locally Manufactured/ Imported	Condition New/Used
iii) **Fuses**				

3) Do you sometimes import some of your supplies upon request by your customers?

(Please tick one)

☐ Yes

☐ No

4) How often do customers place request using full technical specifications? (e.g., an A.C. induction motor with a horse power of 0.5, speed of 930 r.p.m and frame size of C.162KN)

(Please tick one)

☐ Frequently

☐ Sometimes

☐ Occasionally

☐ Never

5) Do you offer or provide products catalogue to your customers?

(Please tick one)

☐ Yes

☐ No

6) Please, list the types of motors, switches and fuses that you would like to have in stock but are not able to do so.

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7) Please, why would you like to have in stock those products you stated in question 6?

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8) How frequently do you interact with machinery manufacturers to know their needs? (Please tick one)

☐ Often

☐ Sometimes

☐ Occasionally

☐ Never

APPENDIX-B1

MATERIAL CHARACTERISTICS OF HOT – ROLLED MATERIAL AND TYPICAL APPLICATIONS FOR VARIOUS PLAIN LOW – CARBON AND HIGH – STRENGTH, LOW – ALLOY STEELS

AISI/SAE or ASTM Number	Tensile Strength [MPa(ksi)]	Yield Strength [MPa(ksi)]	Ductility 1% EL in 50 mm (2in) J	Typical Applications
PLAIN LOW – CARBON STEELS				
1010	325(47)	180(26)	28	Automotive panels, nails, and wire.
1020	380(55)	205(30)	25	Pipe, structural and sheet steel.
A36	400(58)	220(32)	23	Structural (bridges and buildings.
A516 Grade 70	485(70)	260(38)	21	Low – temperature pressure vessels.
HIGH – STRENGTH, LOW – ALLOY STEELS				
A440	435(63)	290(42)	21	Structures that are bolted or riveted.
A633 Grade E	520(75)	380(55)	23	Structures used at low ambient temperatures.
A656 Grade 1	655(95)	552(80)	15	Truck frames and railway cars.

Source: [Callister, 2000]

APPENDIX-B2

TYPICAL APPLICATIONS AND MECHANICAL PROPERTY RANGES FOR OIL – QUENCHED AND TEMPERED PLAIN CARBON AND ALLOY STEELS

(CLASSIFIED AS HIGH – CARBON STEELS)

AISI Number	UNS Number	Tensile Strength [Mpa(Ksi)]	Yield Strength [Mpa(Ksi)]	Ductility/% EL in 50 mm (2m)J.	Typical Applications
PLAN LOW – CARBON STEELS					
1040	G10400	605 – 780 (88 – 113)	430 – 385 (62 – 85)	33 – 19	Crankshafts, bolts
1080[a]	G10800	800 – 1310 (116 – 190)	480 – 980 (70 – 142)	24 – 13	Chisels, hammers
1095[a]	G10950	760 -1280) (110 – 186)	510 – 830 (74 – 120)	26 – 10	knives, hacksaw blades
ALLOY STEELS					
4063	G40630	786 – 2380 (114 – 345)	710 – 1770 (103 – 257)	24 – 4	Springs, hand tools
340	G43400	980 – 1960 (42 – 284)	895 – 1570 (130 – 228)	21 – 11	bushings, aircraft tubing
6150	G61500	815 – 2170 (118 – 315)	745 – 1570 (108 – 170)	22 – 7	Shafts, pistons, gears

Source: [Callister, 2000]

APPENDIX-B3

DESIGNATIONS, COMPOSITIONS, AND APPLICATIONS FOR SIX TOOL STEELS

AISI Number	UNS Number	Composition (wt%)[a]						Typical Applications
		C	Cr	Ni	Mo	W	V	
M1	T11301	0.85	3.75	0.3max	8.70	1.75	1.2	Drills, saws, lathe and planner tools
A2	T30102	1.00	5.15	0.3max	1.15	–	0.35	Punches, embossing dies.
D2	T30402	1.50	12	0.3max	0.95	–	1.10max	Cutlery, drawing dies.
O1	T31501	0.95	0.5	0.3max	–	0.50	0.3max	Sheer blades, cutting tools.
SI	T41901	0.50	1.40	0.3max	0.5max	2.25	0.25	Pipe cutters, concrete drills.
W1	T72301	1.10	0.15 max	0.2max	0.1max	0.15 max	0.1max	Necksmith tools, wood – working tools.

Source: [Callister, 2000]

APPENDIX-B4

DESIGNATIONS, COMPOSITIONS, MECHANICAL PROPERTIES AND TYPICAL APPLICATIONS FOR VARIOUS STAINLESS STEELS

				MECHANICAL PROPERTIES			
AISI Num ber	UNS Number	Compos-ition (Wt%)[a]	Condition	Tensile strength [MPa(Ksi)]	Yield Strength [MPa(Ksi)]	Ductility /% EL in 50 mm	Typical Application
FERRITIC							
409	S40900	0.08C.11.0Cr 0.1Mn 0.5 Ni0.75Ti	Annealed	380 (55)	205(30)	20	Automotive exhaust components, tanks for agricultural spray.
446	44600	0.2C.25Cr 1.5Mn	Annealed	515 (75)	275(40)	20	Values (High temperature), glass molds, combustion chambers
AUSTENITIC							
304	S30400	0.08C.19Cr 9Ni2.0Mn	Annealed	515 (75)	205(30)	40	Chemical and food processing equipment , cryogenic vessels.
316L	S31603	0.03C.17Cr 12Ni2.5Mo, 2.0mN	Annealed	485 (70)	[70(25)	40	Welding construction
MARTENSITIC							
410	S41000	0.15c12.5Cr 1.0Mn	Annealed Q&T	485 (70)- 825 (120)	275(40) 620(90)	20 12	Rifle barrels cutlery, jet engine parts
440A	S44002	0.7C.17Cr 0.75 Mo, 1.0Mn	Annealed Q&T	725 (105) 1790(250)	415(60) 1650(240)	20 5	Cutlery, bearings, surgical tools
PRECIPITATION HARDENABLE							
17 – 7PH	S17700	0.09C.17Cr 7Ni1.0AL, 1.0Mn	Precipitation hardened	1450(210)	1310(90)	1 6	Springs, knives, pressure vessels

Source: [Callister, 2000]

APPENDIX-B5

DESIGNATIONS, MINIMUM MECHANICAL PROPERTIES, APPROXIMATE COMPOSITIONS AND TYPICAL APPLICATIONS FOR VARIOUS GRAY, NODULAR, AND MALLEABLE CAST IRONS

				MECHANICAL PROPERTIES			
Grade	UNS Number	Composition (Wt%)[a]	Matrix Structure	Tensile strength [MPa(Ksi)]	Yield Strength [MPa(Ksi)]	Ductility /% EL in 50 mm	Typical Applicat-ions
GRAY IRON							
SAE G1800	F10004	3.4 – 3.7C, 2.55Si, 0.7Mn	Ferrite + Pearlite	124(18)	–	–	Miscellaneous soft iron castings in which strength is not a primary consideration.
SAE G2500	F10005	3.2 – 3.5C, 2.2Si, 0.8Mn	Ferrite + Pearlite	173(25)	–	–	Small cylinder blocks, cylinder heads, pistons, clutch plates, transmission cases.
SAE G4000	F10008	3 – 3.3C, 2Si, 0.8Mn	Pearlite	276(40)	–	–	Diesel engine castings, linears, cylinders and pistons.
DUCTILE (NODULAR) IRON							
ASTM A536 60-40-18	F32800	3.5 – 3.8C, 2 – 2.8 Si	Ferrite	44(60)	276(40)	18	Pressure-containing parts such as valve and pump bodies.
100-70-03	F34800	0.05Mg, < 0.2Ni	Pearlite	689(100)	483(70)	3	High – strength gears and machine components.
120-90-02	F36200	< 0.2Ni, < 0.1Mo	Tempered martensite	827(120)	6121(90)	2	Pinions, gears, rollers, slides.

APPENDIX-B5: CONTINUED

DESIGNATIONS, MINIMUM MECHANICAL PROPERTIES, APPROXIMATE COMPOSITIONS AND TYPICAL APPLICATIONS FOR VARIOUS GRAY, NODULAR, AND MALLEABLE CAST IRONS

				MECHANICAL PROPERTIES			
Grade	UNS Number	Compo-sition (Wt%)[a]	Matrix Structure	Tensile strength [MPa(Ksi)]	Yield Strength [MPa(Ksi)]	Ductility /%EL in 50 mm	Typical Applicat-ions
MALLEABLE IRON							
32510	F22200	2.3-2.7C, 1-1.75Si, < 0.55 Mn	Ferrite	345(50)	224(32)	10	General engineering service at normal and elevated temperatures.
MALLEABLE IRON							
32510	F22200	2.3-2.7C, 1-1.75Si, < 0.55 Mn	Ferrite	345(50)	224(32)	10	General engineering service at normal and elevated temperatures.

Source: [Callister, 2000]

APPENDIX-B6

COMPOSITIONS, MECHANICAL PROPERTIES, AND TYPICAL APPLICATIONS FOR EIGHT COPPER ALLOYS

				MECHANICAL PROPERTIES			
Alloy Name	UNS Number	Composition (Wt%)[a]	Condition	Tensile strength [MPa(Ksi)]	Yield Strength [MPa Ksi)]	Ductility /%EL in 50 mm	Typical Applications
WROUGHT ALLOYS							
Electrolytic tough pitch	C11000	0.040	Annealed	220(32)	69(10)	45	Electrical wire, rivets, screening gaskets, pans, nails, roofing.
Beryllium copper	C17200	1.9Be, 0.2Co	Precipitation hardened	1140-1310 (165-190)	690-860 (100-125)	4-10	Springs, bellows, firing pins, bushings, valves, diaphragms.
Cartridge Brass	C26000	302n	Annealed Cold-war ked (HO4 Hard)	300(44) 525(76)	75(11) 435)03)	68 8	Automotive radiator cores, ammunition components, lamp fixtures, flashlight shells, kickplates.
Phosphor bronze 5% A	C51000	dSn,0.2P	Annealed cold-worked (HO4 Hard)	325(47) 560(81)	130(19) 515(75)	64 10	Bellows, clutch disks, diaphragms, fuse clips, springs, welding rods.
Copper nickel, 30%	C71500	30Ni	Annealed cold-worked (HO_2 Hard)	300 (55) 515(75)	125 (18) 485 (70)	36 15	Condenser and heat-exchanger components, salt-water piping.

Source: [Callister, 2000]

APPENEDIX-B6: CONTINUED

COMPOSITIONS, MECHANICAL PROPERTIES, AND TYPICAL APPLICATIONS FOR EIGHT COPPER ALLOYS

				MECHANICAL PROPERTIES			
Alloy Name	UNS Number	Composition (Wt%)[a]	Condition	Tensile strength [MPa(Ksi)]	Yield Strength [MPa(Ksi)]	Ductility /% EL in 50 mm	Typical Applicat-ions
CAST ALLOYS							
Leaded yellow brass	C85400	29Zn,3Pb, 1Sn	As cast	234 (34)	83 (12)	35	Furniture Hardware, radiator fittings, light fixtures, battery clamps.
Tin bronze	C90500	1OSn, 22m	As cast	310 (45)	152 (22)	25	Bearings, bushings, piston rings, steam fittings gears.
Aluminium Bronze	C95400	4Fe, 11 Al	As cast	586 (85)	241 (35)	18	Bearings, gears, worms, bushings, valve seats and guards, pickling hooks.

Source: [Callister, 2000]

APPENDIX-B7

COMPOSITIONS, MECHANICAL PROPERTIES, AND TYPICAL APPLICATIONS OF SEVERAL COMMON ALUMINIUM ALLOYS

				MECHANICAL PROPERTIES			
Aluminium Association Number	UNS Number	Composition (Wt%)[a]	Condition Temper Designation	Tensile strength [MPa(Ksi)]	Yield Strength [MPa(Ksi)]	Ductility /%EL in 50 mm	Typical Applications Characteristics
WROUGHT NON HEAT – TREATABLE ALLOYS							
1100	A91100	0.12Cu	Annealed (0)	90 (13)	35 (5)	35– 45	Food/chemical handling and storage equipment, heat exchangers, light reflectors.
3003	A93003	0.12Cu,1.2Mn 0.12n	Annealed (0)	110 (16)	40 (6)	30– 40	Cooking utensils, pressure vessels and piping.
5052	A95052	2.5Mg, 0.25 Cr	Strain hardened (H32)	230 (33)	195 (28)	12– 18	Aircraft fuel and oil lines, fuel tanks, appliances, rivets, and wire.
WROUGHT, HEAT – TREATABLE ALLOYS							
2024		4.4Cu,1.5Mg 0.6Mn	Heat treated (T4)	470 (68)	325 (47)	20	Aircraft structures, rivets, truck wheels, screw machine products.
6061	A96061	10.Mg, 0.6Si, 0.3Cu, 0.Cr	Heat treated (T4)	240 (35)	145 (21)	22– 25	Trucks, canoes, railroads, cars, furniture, pipelines.
7075	A97075	5.6 Zn, 2.5Mg, 1.6Cu, 0.23 Cr	Heat treated (T6)	570 (83)	505 (73)	11	Aircraft structural parts and other highly stressed applications.

Source: [Callister, 2000]

APPENDIX-B7: CONTINUED

COMPOSITIONS, MECHANICAL PROPERTIES, AND TYPICAL APPLICATIONS OF SEVERAL COMMON ALUMINIUM ALLOYS

				MECHANICAL PROPERTIES			
Allumium Association Number	UNS Number	Composition (Wt%)[a]	Condition Temper Designation	Tensile strength [MPa(Ksi)]	Yield Strength [MPa(Ksi)]	Ductility /%EL in 50 mm	Typical Applicat-ions Characteristics
CAST HEAT – TREATABLE ALLOYS							
2950	A02950	4.5Cu, 1.1 Si	Heat treated (T4)	221 (32)	110 (16)	8.5	Flywheel rear-axle housings, bus and aircraft wheels, crankcases.
3650	A03560	7.0Si, 0.3 Mg	Heat treated (T6)	228 (33)	164 (24)	3.5	Aircraft pump parts automotive transmission cases, water cooled cylinder blocks.
ALLUMINIUM – LITHIUM ALLOYS							
2090	–	2.7Cu, 0.25 Mg, 2.25Li, 0.125Zr	Heat treated cold worked (T83)	455 (66)	455 (66)	5	Aircrafts structures and cryogenic tankage structures.
8090	_	1.3Cu, 0.95Mg, 2Li, 0.1Zr	Treated cold worked (T651)	465 (67)	360 (52)	–	Aircraft structures that must be highly damage tolerant.

Source: [Callister, 2000]

APPENDIX-B8

COMPOSITIONS, MECHANICAL PROPERTIES, AND TYPICAL APPLICATIONS OF SIX MAGNESIUM ALLOYS

				MECHANICAL PROPERTIES			
ASTM Number	UNS Number	Composition (Wt%)[a]	Condition	Tensile strength [MPa(Ksi)]	Yield Strength [MPa(Ksi)]	Ductility /%EL in 50 mm	Typical Applicat-ions
WROUGHT ALLOYS							
A231B	M11311	3.0AL, 1.0Zn, 0.2Mn	As extruded	262(38)	200(29)	15	Structures and tubing, cathodic protection.
HK31A	M13310	3Th, 0.6 Zr	Strain hardened partially annealed	255(37)	200(29)	9	High strength to 315^0C
2K60A	M16600	5.5Zn, 0.45 Zr	Artificial aged	350(51)	285(41)	11	Forgings of maximum strength for aircraft.
CAST ALLOYS							
AZ91D	M11916	9AL, 0.15Mn, 0.7Zn	As cast	230(33)	150(22)	3	Die – cast parts for automobiles, luggage and electronic devices.
Am60A	M10600	6.0sl, 0.13Mn	As cast	220(32)	130(19)	6	Automotive wheels
AS41a	M10410	4.3AL, 1.0Si, 0.35Mn	As cast	210(31)	140(20)	6	Die castings requiring good creep resistance.

Source: [Callister, 2000]

APPENDIX-B COMPOSITIONS, MECHANICAL PROPERTIES, AND TYPICAL APPLICATIONS OF SEVERAL COMMON TITANIUM ALLOYS

				MECHANICAL PROPERTIES			
Alloy Type	Common Name UNS Number	Composition (Wt%)[a]	Condition	Tensile strength [MPa(Ksi)]	Yield Strength [MPa(Ksi)]	Ductility /%EL in 50 mm	Typical Applications
WROUGHT ALLOYS							
Commercially pure	Unalloyed (R50500)	99.1 Ti	Annealed	484 (70)	414 (60)	25	Jet engine shrouds, cases and airframe skins, corrosion-resistant equipment for marine and chemical processing industries.
α	Ti-5AL-2.5 Sn (R545.20)	5AL, 2.5Sn, balance Ti		826 (120)	784 (114)	16	Gas turbine engine casings and rings, chemical processing equipment requiring strength to temperatures of 480^0C.
Near α	Ti-8AL-1 Mo-Iυ (R54810)	8AL, 1Mo, Iv, balance Ti	Annealed (duplex)	950 (135)	890 (129)	15	Forgings for jet engine components (compressor disks, plates and hubs).
α - β	Ti –6Al-4V (R56400)	6Sal, 4V, balance Ti	Annealed	947 (137)	877 (127)		High-strength prosthetic implants, chemical-processing equipment, air-frame structural components.

Source: [Callister, 2000]

APPENDIX-B9: CONTINUED

COMPOSITIONS, MECHANICAL PROPERTIES, AND TYPICAL APPLICATIONS OF SEVERAL COMMON TITANIUM ALLOYS

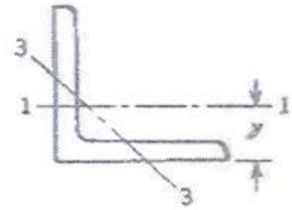
				MECHANICAL PROPERTIES			
Alloy Type	Common Name UNS Number	Composition (Wt%)[a]	condition	Tensile strength [MPa(Ksi)]	Yield Strength [MPa(Ksi)]	Ductility /%EL in 50 mm	Typical Applications
WROUGHT ALLOYS							
α – β	Ti-6Al-6V-2Sn (R56620)	6Al, 2Sn, 6V, 0.75Cu, balance Ti	Annealed	1050 (153)	985 (143)	14	Rocket engine case airframe applications and high – strength airframe structures.
B	Ti-10V-2Fe – 3Al	10V, 2Fe, 3Al, Balance Ti	Solution + Aging	1223 (178)	1150 (167)	10	Best combination of high strength and toughness of any commercial titanium alloy, used for applications requiring uniformity of tensile properties at surface and center locations, high-strength airframe components.

Source: [Callister, 2000]

APPENDIX-B10

PROPERTIES OF STURCTURAL SHAPES – EQUAL ANGLES (L)

w_a = weight per foot of aluminum sections, lb
w_s = weight per foot of steel sections, lb
A = area, in^2
I = moment of inertia, in^4
k = radius of gyration, in
y = centroidal distance, in
Z = section modulus, in^3



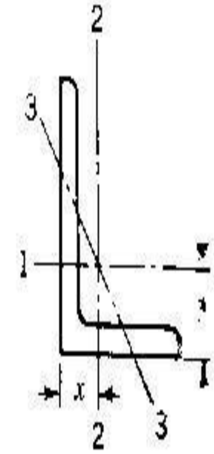
Size	w_a	w_s	A	I_{1-1}	k_{1-1}	Z_{1-1}	y	I_{3-3}	k_{3-3}
$1 \times 1 \times \frac{1}{8}$	0.28	0.80	0.23	0.02	0.30	0.03	0.30	0.008	0.19
$1 \times 1 \times \frac{1}{4}$	0.53	1.49	0.44	0.04	0.29	0.05	0.34	0.016	0.19
$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{8}$	0.44	1.23	0.36	0.07	0.45	0.07	0.41	0.031	0.29
$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$	0.83	2.34	0.69	0.14	0.44	0.13	0.46	0.057	0.29
$2 \times 2 \times \frac{1}{8}$	0.59	1.65	0.49	0.18	0.61	0.13	0.53	0.08	0.40
$2 \times 2 \times \frac{1}{4}$	1.14	3.19	0.94	0.34	0.60	0.24	0.58	0.14	0.39
$2 \times 2 \times \frac{3}{8}$	1.65	4.70	1.37	0.47	0.59	0.35	0.63	0.20	0.39
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	1.45	4.1	1.19	0.69	0.76	0.39	0.71	0.29	0.49
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	2.11	5.9	1.74	0.98	0.75	0.56	0.76	0.41	0.48
$3 \times 3 \times \frac{1}{4}$	1.73	4.9	1.43	1.18	0.91	0.54	0.82	0.49	0.58
$3 \times 3 \times \frac{3}{8}$	2.55	7.2	2.10	1.70	0.90	0.80	0.87	0.70	0.58
$3 \times 3 \times \frac{1}{2}$	3.32	9.4	2.74	2.16	0.89	1.04	0.92	0.91	0.58
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{4}$	2.05	4.9	1.69	1.93	1.07	0.76	0.94	0.80	0.69
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{8}$	3.01	7.2	2.49	2.79	1.06	1.11	1.00	1.15	0.68
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$	3.94	11.1	3.25	3.56	1.05	1.45	1.05	1.49	0.68
$4 \times 4 \times \frac{1}{4}$	2.35	6.6	1.94	2.94	1.23	1.00	1.07	1.21	0.79
$4 \times 4 \times \frac{3}{8}$	3.46	9.8	2.86	4.26	1.22	1.48	1.12	1.75	0.78
$4 \times 4 \times \frac{1}{2}$	4.54	12.8	3.75	5.46	1.21	1.93	1.17	2.26	0.78
$4 \times 4 \times \frac{5}{8}$	5.58	15.7	4.61	6.56	1.19	2.36	1.22	2.76	0.77
$6 \times 6 \times \frac{3}{8}$	5.27	14.9	4.35	14.85	1.85	3.38	1.60	6.07	1.18
$6 \times 6 \times \frac{1}{2}$	6.95	19.6	5.74	19.38	1.84	4.46	1.66	7.92	1.17
$6 \times 6 \times \frac{5}{8}$	8.59	24.2	7.10	23.64	1.82	5.51	1.71	9.70	1.17
$6 \times 6 \times \frac{3}{4}$	10.20	28.7	8.43	27.64	1.81	6.52	1.76	11.43	1.16

Source: [Shigley and Mitchell, 1983]

APPENDIX-B11

PROPERTIES OF STURCTURAL SHAPES – UNEQUAL ANGLES (L)

w_a = weight per foot of aluminum sections, lb
w_s = weight per foot of steel sections, lb
A = area, in^2
I = moment of inertia, in^4
k = radius of gyration, in
x and y = respective centroidal distances, in
Z = section modulus, in^3



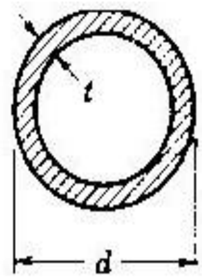
Size	w_a	w_s	A	I_{1-1}	k_{1-1}	Z_{1-1}	y	I_{2-2}	k_{2-2}	Z_{2-2}	x	I_{3-3}	k_{3-3}
$2 \times 1\frac{1}{2} \times \frac{1}{8}$	0.51	1.44	0.42	0.17	0.63	0.12	0.60	0.08	0.44	0.07	0.36	0.04	[illegible]
$2 \times 1\frac{1}{2} \times \frac{1}{4}$	0.98	2.77	0.81	0.31	0.62	0.23	0.66	0.15	0.43	0.14	0.41	0.08	[illegible]
$3 \times 2 \times \frac{3}{16}$	1.10	3.07	0.91	0.82	0.95	0.40	0.94	0.29	0.56	0.19	0.46	0.17	[illegible]
$3 \times 2\frac{1}{2} \times \frac{1}{4}$	1.58	4.5	1.31	1.12	0.92	0.53	0.89	0.70	0.73	0.38	0.64	0.35	[illegible]
$3 \times 2\frac{1}{2} \times \frac{3}{8}$	2.32	6.6	1.92	1.60	0.91	0.78	0.94	1.00	0.72	0.55	0.69	0.51	[illegible]
$3 \times 2\frac{1}{2} \times \frac{1}{2}$	3.02	9.4	2.49	2.03	0.90	1.01	0.99	1.26	0.71	0.72	0.74	0.65	[illegible]
$4 \times 3 \times \frac{1}{4}$	2.05	5.8	1.69	2.68	1.26	0.96	1.21	1.29	0.87	0.56	0.72	0.70	[illegible]
$4 \times 3 \times \frac{1}{2}$	3.95	11.1	3.25	4.96	1.24	1.85	1.31	2.36	0.85	1.08	0.82	1.30	[illegible]
$6 \times 4 \times \frac{3}{8}$	4.36	12.3	3.60	13.02	1.90	3.17	1.90	4.63	1.13	1.50	0.91	2.67	[illegible]
$6 \times 4 \times \frac{1}{2}$	5.74	16.2	4.74	16.95	1.89	4.19	1.96	6.01	1.13	1.98	0.97	3.47	[illegible]

Source: [Shigley and Mitchell,1983]

APPENDIX-B12

PROPERTIES OF ROUND TUBING

w_a = weight per foot of aluminum tubing, lb/ft
w_s = weight per foot of steel tubing, lb/ft
A = area, in^2
I = moment of inertia, in^4
k = radius of gyration, in
Z = section modulus, in^3

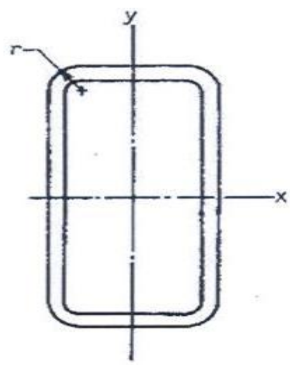


Size	w_a	w_s	A	I	k	Z
$1 \times \frac{1}{8}$	0.416	1.128	0.344	0.034	0.313	0.067
$1 \times \frac{1}{4}$	0.713	2.003	0.589	0.046	0.280	0.092
$1\frac{1}{2} \times \frac{1}{8}$	0.653	1.769	0.540	0.129	0.488	0.172
$1\frac{1}{2} \times \frac{1}{4}$	1.188	3.338	0.982	0.199	0.451	0.266
$2 \times \frac{1}{8}$	0.891	2.670	0.736	0.325	0.664	0.325
$2 \times \frac{1}{4}$	1.663	4.673	1.374	0.537	0.625	0.537
$2\frac{1}{2} \times \frac{1}{8}$	1.129	3.050	0.933	0.660	0.841	0.528
$2\frac{1}{2} \times \frac{1}{4}$	2.138	6.008	1.767	1.132	0.800	0.906
$3 \times \frac{1}{4}$	2.614	7.343	2.160	2.059	0.976	1.373
$3 \times \frac{3}{8}$	3.742	10.51	3.093	2.718	0.938	1.812
$4 \times \frac{3}{16}$	2.717	7.654	2.246	4.090	1.350	2.045
$4 \times \frac{3}{8}$	5.167	14.52	4.271	7.090	1.289	3.544

Source:[Shigley and Mitchell, 1983]

APPENDIX-B13

PROPERTIES OF SQUARE AND RECTANGULAR STRUCTURAL STEEL TUBING

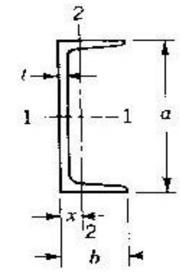


Size, in	Weight, lb/ft	Area A, in^2	Radius‡ r, in	I_x, in^4	I_y, in
2 × 2 × 3/16	4.32	1.27	3/8	0.668	
1/4	5.41	1.59	1/2	0.766	
3 × 2 × 3/16	5.59	1.64	3/8	1.24	0.977
1/4	7.11	2.09	1/2	2.21	1.15
3 × 3 × 3/16	6.87	2.02	3/8	2.60	
1/4	8.81	2.59	1/2	3.16	
5/16	10.58	3.11	5/8	3.58	
4 × 2 × 3/16	6.87	2.02	3/8	3.87	1.29
1/4	8.81	2.59	1/2	4.69	1.54
5/16	10.58	3.11	5/8	5.32	1.71
4 × 3 × 3/16	8.15	2.39	3/8	5.23	3.34
1/4	10.51	3.09	1/2	6.45	4.10
5/16	12.70	3.73	5/8	7.45	4.71
4 × 4 × 3/16	9.42	2.77	3/8	6.59	
1/4	12.21	3.59	1/2	8.22	
5/16	14.83	4.36	5/8	9.58	
3/8	17.27	5.08	3/4	10.7	
1/2	21.63	6.36		12.3	
5 × [illegible] × 1/4	12.21	3.59	1/2	11.3	5.05
5/16	14.83	4.36	5/8	13.2	5.85
3/8	17.27	5.08	3/4	14.7	6.48
1/2	21.63	6.36	1	16.9	7.33
5 × 4 × 1/4	13.91	4.09	1/2	14.1	9.98
5/16	16.96	4.98	5/8	16.6	11.7
3/8	19.82	5.83	3/4	18.7	13.2

Source: [Shigley and Mischke, 1986]

APPENDIX-B14

PROPERTIES OF STRUCTURAL SHAPES – CHANNELS (C)



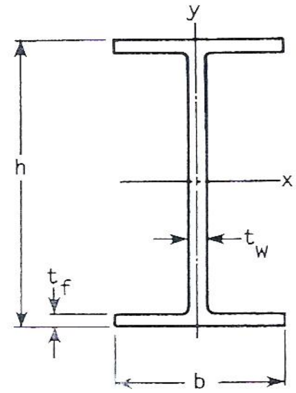
w_a = weight per foot of aluminum sections, lb
w_s = weight per foot of steel sections, lb
A = area, in^2
I = moment of inertia, in^4
k = radius of gyration, in
x = centroidal distance, in
Z = section modulus, in^3

a	b	t	A	w_a	w_s	I_{1-1}	k_{1-1}	Z_{1-1}	I_{2-2}	k_{2-2}	Z_{2-2}	x
3	1.410	0.170	1.21	1.46	4.1	1.66	1.17	1.10	0.20	0.40	0.20	0.44
3	1.498	0.258	1.47	1.78	5.0	1.85	1.12	1.24	0.25	0.41	0.23	0.44
3	1.596	0.356	1.76	2.13	6.0	2.07	1.08	1.38	0.31	0.42	0.27	0.46
4	1.580	0.180	1.57	1.90	5.4	3.83	1.56	1.92	0.32	0.45	0.28	0.46
4	1.720	0.320	2.13	2.58	7.25	4.58	1.47	2.29	0.43	0.45	0.34	0.46
5	1.750	0.190	1.97	2.38	6.7	7.49	1.95	3.00	0.48	0.49	0.38	0.48
5	1.885	0.325	2.64	3.20	9.0	8.90	1.83	3.56	0.63	0.49	0.45	0.48
6	1.920	0.200	2.40	2.91	8.2	13.12	2.34	4.37	0.69	0.54	0.49	0.51
6	2.034	0.314	3.09	3.73	10.5	15.18	2.22	5.06	0.87	0.53	0.56	0.50
6	2.157	0.437	3.82	4.63	13.0	17.39	2.13	5.80	1.05	0.52	0.64	0.51
7	2.090	0.210	2.87	3.47	9.8	21.27	2.72	6.08	0.97	0.58	0.63	0.54
7	2.194	0.314	3.60	4.36	12.25	24.24	2.60	6.93	1.17	0.57	0.70	0.52
7	2.299	0.419	4.33	5.24	14.75	27.24	2.51	7.78	1.38	0.56	0.78	0.53
8	2.260	0.220	3.36	4.10	11.5	32.30	3.10	8.10	1.30	0.63	0.79	0.58
8	2.343	0.303	4.04	4.89	13.75	36.11	2.99	9.03	1.53	0.61	0.85	0.55
8	2.527	0.487	5.51	6.67	18.75	43.96	2.82	10.99	1.98	0.60	1.01	0.57
9	2.430	0.230	3.91	4.74	13.4	47.68	3.49	10.60	1.75	0.67	0.96	0.60
9	2.485	0.285	4.41	5.34	15.0	51.02	3.40	11.34	1.93	0.66	1.01	0.59
9	2.648	0.448	5.88	7.11	20.0	60.92	3.22	13.54	2.42	0.64	1.17	0.58
10	2.600	0.240	4.49	5.43	15.3	67.37	3.87	13.47	2.28	0.71	1.16	0.63
10	2.739	0.379	5.88	7.11	20.0	78.95	3.66	15.79	2.81	0.69	1.32	0.61
10	2.886	0.526	7.35	8.89	25.0	91.20	3.52	18.24	3.36	0.68	1.48	0.62
10	3.033	0.673	8.82	10.67	30.0	103.45	3.43	20.69	3.95	0.67	1.66	0.65
12	3.047	0.387	7.35	8.89	25.0	144.37	4.43	24.06	4.47	0.78	1.89	0.67
12	3.170	0.510	8.82	10.67	30.0	162.08	4.29	27.01	5.14	0.76	2.06	0.67

Source:[Shigley and Mischke, 1986]

APPENDIX-B15

PROPERTIES OF STRUCTURAL SHAPES – ‘W’ SHAPES



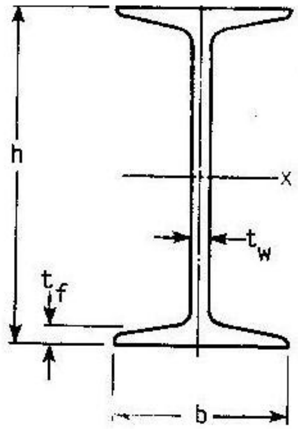
Properties of W Shapes†

Designation	Area A, in^2	h, in	t_w, in	b, in	t_f, in	I_x, in^4	I_y, in^4
W 4 × 13	3.83	4.16	0.280	4.060	0.345	11.3	3.86
W 5 × 16	4.68	5.01	0.240	5.000	0.360	21.3	7.51
5 × 19	5.54	5.15	0.270	5.030	0.430	26.2	9.13
W 6 × 9	2.68	5.90	0.170	3.940	0.215	16.4	2.19
6 × 12	3.55	6.03	0.230	4.000	0.280	22.1	2.99
6 × 16	4.74	6.28	0.260	4.030	0.405	32.1	4.43
6 × 15	4.43	5.99	[illegible]	5.990	0.260	29.1	9.32
6 × 20	5.87	6.20	[illegible]	6.020	0.365	41.4	13.3
6 × 25	7.34	6.38	[illegible]	6.080	0.455	53.4	17.1
W 8 × 10	2.96	7.89	0.170	3.940	0.205	30.8	2.09
8 × 13	3.84	7.99	0.230	4.000	0.255	39.6	2.73
8 × 15	4.44	8.11	0.245	4.015	[illegible]	48.0	3.41
8 × 18	[illegible]	8.14	0.230	5.25	[illegible]	61.9	7.97
8 × 21	[illegible]	8.28	0.250	5.27	[illegible]	75.3	9.77
8 × 24	[illegible]	7.93	0.245	6.495	0.400	82.8	18.3
8 × 28	8.25	8.06	0.285	6.535	0.465	98.0	21.7
8 × 31	9.13	8.00	0.285	7.995	0.435	110	37.1
8 × 35	10.3	8.12	0.310	8.020	0.495	127	42.6
8 × 40	11.7	8.25	[illegible]	8.070	0.560	146	49.1
8 × 48	14.1	8.50	[illegible]	8.110	0.685	184	60.9
8 × 58	17.1	8.75	[illegible]	8.220	0.810	228	75.1
8 × 67	19.7	9.00	0.570	8.280	0.935	272	88.6
W 10 × 12	3.54	9.87	0.190	3.960	[illegible]	53.8	2.18
10 × 15	[illegible]	9.99	0.230	4.000	[illegible]	68.9	2.89
10 × 17	[illegible]	10.11	0.240	4.010	[illegible]	81.9	3.56
10 × 19	5.62	10.24	0.250	4.020	0.395	96.3	4.29
W 10 × 22	6.49	10.17	0.240	5.75	0.360	118	11.4
10 × 26	7.61	10.33	0.260	5.770	0.440	144	14.1
10 × 30	8.84	10.47	0.300	5.810	0.510	170	16.7
W 10 × 33	9.71	9.73	0.290	7.960	0.435	170	36.6
10 × 39	11.5	9.92	0.315	7.985	0.530	209	45.0
10 × 45	13.3	10.10	0.350	8.020	0.620	248	53.4

Source: [Shigley and Mischke,1986]

APPENDIX-B16

PROPERTIES OF STRUCTURAL SHAPES – ‘S’ SHAPES



Properties of S Shapes†

	Designation	Area A, in²	h, in	t_w, in	b, in	t_f, in	D, in	I_x, in⁴	I_y, in⁴
S	3 × 5.7	1.67	3.00	0.170	2.330	0.260	. . .	2.52	0.455
	3 × 7.5	2.21	3.00	0.349	2.509	0.260	. . .	2.93	0.586
S	4 × 7.7	2.26	4.00	0.193	2.663	0.293	. . .	6.08	0.764
	4 × 9.5	2.79	4.00	0.326	2.796	0.293	. . .	6.79	0.903
S	5 × 10	2.94	5.00	0.214	3.004	0.326	. . .	12.3	1.22
	5 × 14.75	4.34	5.00	0.494	3.284	0.326	. . .	15.2	1.67
S	6 × 12.5	3.67	6.00	0.232	3.332	0.359	. . .	22.1	1.82
	6 × 17.25	5.07	6.00	0.465	3.565	0.359	$\frac{5}{8}$	26.3	2.31
S	7 × 15.3	4.50	7.00	0.252	3.662	0.392	$\frac{5}{8}$	36.7	2.64
	7 × 20	5.88	7.00	0.450	3.860	0.392	$\frac{5}{8}$	42.4	3.17

Source: [Shigley and Mischke,1986]

APPENDIX-B16: CONTINUED

Properties of S Shapes† (*Continued*)

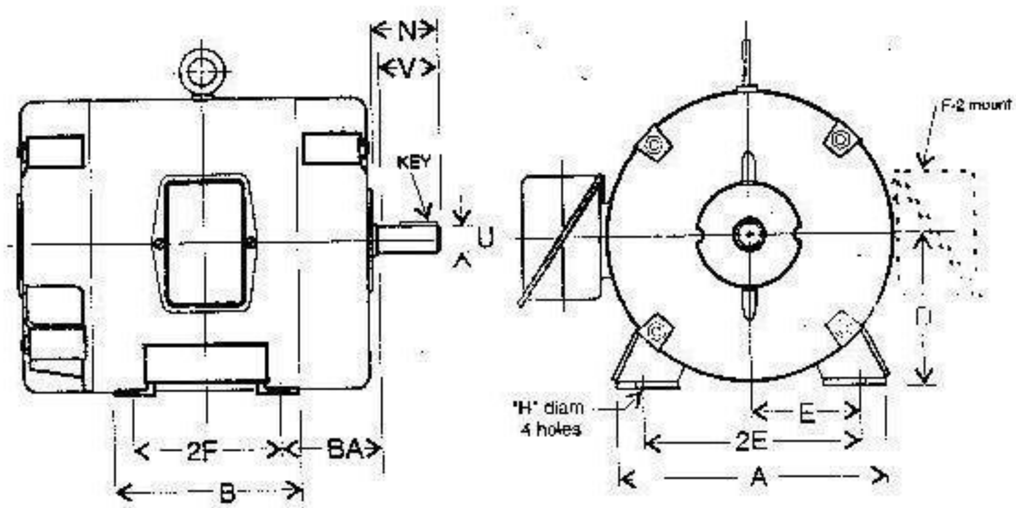
Designation	Area A, in^2	h, in	t_w, in	b, in	t_f, in	D, in	I_x, in^4	I_y, in^4
S 8 × 18.4	5.41	8.00	0.271	4.001	0.426	$\frac{3}{4}$	57.6	3.73
8 × 23	6.77	8.00	0.441	4.171	0.426	$\frac{3}{4}$	64.9	4.31
S 10 × 25.4	7.46	10.00	0.311	4.661	0.491	$\frac{3}{4}$	124	6.79
10 × 35	10.3	10.00	0.594	4.944	0.491	$\frac{3}{4}$	147	8.36
S 12 × 31.8	9.35	12.00	0.350	5.000	0.544	$\frac{3}{4}$	218	9.36
12 × 35	10.3	12.00	0.428	5.078	0.544	$\frac{3}{4}$	229	9.87
S 12 × 40.8	12.0	12.00	0.462	5.252	0.659	$\frac{3}{4}$	272	13.6
12 × 50	14.7	12.00	0.687	5.477	0.659	$\frac{3}{4}$	305	15.7
S 15 × 42.9	12.6	15.00	0.411	5.501	0.[illegible]22	$\frac{3}{4}$	447	14.4
15 × 50	14.7	15.00	0.550	5.640	0.622	$\frac{3}{4}$	486	15.7
S 18 × 54.7	16.1	18.00	0.461	6.001	0.691	$\frac{7}{8}$	804	20.8
18 × 70	20.6	18.00	0.711	6.251	0.691	$\frac{7}{8}$	926	24.1
S 20 × 66	19.4	20.00	0.505	6.255	0.795	$\frac{7}{8}$	1190	27.7
20 × 75	22.0	20.00	0.635	6.385	0.795	$\frac{7}{8}$	1280	29.8
S 20 × 86	25.3	20.30	0.660	7.060	0.920	1	1580	46.8
20 × 96	28.2	20.30	0.800	7.200	0.920	1	1670	50.2
S 24 × 80	23.5	24.00	0.500	7.000	0.870	1	2100	42.2
24 × 90	26.5	24.00	0.625	7.125	0.870	1	2250	44.9
24 × 100	29.3	24.00	0.745	7.245	0.870	1	2390	47.4

Source: [Shigley and Mischke, 1986]

APPENDIX-B17

Dimensions of Integral Horse power, general – purpose motors

Single – and Three-Phase: Characteristics and types available include: rigid base, drip-proof, TFC, explosion proof, from 143T and larger frames.



Approximate dimensions in inches; see chart on opposite page

Source: [Whiteson, 1996]

APPENDIX-B17: CONTINUED

Frame	A (Max)	B (Max)	D	2E	2F	H	N	U	V	BA
143T	7.00	6.50	3.50	5.50	4.00	.340	2.31	.87	2.25	2.25
145T	7.00	6.50	3.50	5.50	5.00	.34	2.31	.87	2.25	2.25
182T	8.75	5.62	4.50	7.50	4.50	.41	2.78	1.12	2.62	2.75
184T	8.75	6.62	4.50	7.50	5.50	.410	2.78	1.12	2.62	2.75
213T	10.38	7.00	5.25	8.50	5.50	.41	3.56	1.38	3.25	3.50
215T	10.38	8.50	5.25	8.50	7.00	.41	3.56	1.38	3.25	3.50
254T	12.00	10.25	6.25	10.00	8.25	.53	4.15	1.62	3.88	4.25
256T	12.00	12.00	6.25	10.00	10.00	.53	4.15	1.62	3.88	4.25
284T	12.75	11.50	7.00	11.00	[illegible]	.53	4.81	1.88	[illegible]	4.75
284TS	12.75	11.50	7.00	11.00	9.50	.53	3.44	1.62	3.12	4.75
286T	12.75	13.00	7.00	11.00	11.00	.53	4.81	1.88	4.50	4.75
286TS	12.75	13.00	7.00	11.00	11.00	.53	3.44	1.62	3.12	4.75
324T	14.50	12.25	8.00	12.50	10.50	.66	5.50	2.12	5.12	5.25
324TS	14.50	12.25	8.00	12.50	10.50	.66	4.00	1.88	3.62	5.25
326T	14.50	13.75	8.00	12.50	12.00	.66	5.50	2.12	5.12	5.25
326TS	14.50	13.75	8.00	12.50	12.00	.66	4.00	1.88	3.62	5.25
364T	17.75	13.25	9.00	14.00	11.25	.66	[illegible]	2.38	5.62	5.88
364TS	17.75	13.25	9.00	14.00	11.25	.66	4.00	1.88	3.50	5.88
365T	17.75	14.25	9.00	14.00	12.25	.66	6.12	2.38	5.62	5.88
365TS	17.75	13.25	9.00	14.00	12.25	.66	4.00	1.88	3.50	5.88
404T	19.75	15.00	10.00	16.00	12.25	.81	7.50	2.88	7.00	6.62
404TS	19.75	15.00	10.00	16.00	12.25	.81	4.50	2.12	4.00	6.62
405T	19.75	16.50	10.00	16.00	13.75	.81	7.50	2.88	7.00	6.62
405TS	19.75	15.00	10.00	16.00	13.75	.81	4.50	2.12	4.00	6.62
444T	21.75	17.00	11.00	18.00	[illegible]	.81	8.75	3.38	8.25	7.50
444TS	21.75	17.00	11.00	18.00	14.50	.81	5.00	2.38	[illegible]	7.50
445T	21.75	19.00	11.00	18.00	16.50	.81	8.75	3.38	8.25	7.50
445TS	21.75	17.00	11.00	18.00	16.50	.81	5.00	2.38	4.50	7.50
505U	25.00	20.50	12.50	20.00	18.00	.94	10.38	3.88	9.88	8.50
505US	25.00	20.50	12.50	20.00	18.00	.94	5.00	2.38	4.50	8.50
508U	25.00	27.50	12.50	20.00	25.00	.94	11.88	4.12	11.38	8.50
508US	25.00	27.50	12.50	20.00	25.00	.94	7.00	3.38	6.50	8.50
510US	25.00	34.50	12.50	20.00	32.00	.94	7.00	3.38	6.50	8.50
447T	21.75	22.50	11.00	18.00	20.00	.81	8.75	3.38	8.25	7.50
447TS	21.75	22.50	11.00	18.00	20.00	.81	5.00	2.38	4.50	7.50
449T	21.50	28.25	11.00	18.00	25.00	.81	8.75	3.38	8.25	7.50
449TS	21.50	28.25	11.00	18.00	25.00	.81	5.00	2.38	4.50	7.50