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PROJECT REPORT

Topic: MATCHING OF TRUCKS TO LOADERS FOR THE HAULAGE SYSTEM AT BILLITON BOGOSU GOLD LIMITED

PROJECT REPORT SUBMITTED IN PARTIAL

FULFILMENT OF THE REQUIREMENTS FOR THE

POSTGRADUATE (PROFESSIONAL) DIPLOMA DEGREE IN MINING ENGINEERING

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ABSTRACT

Every Open Pit mine is planned towards the achievement of maximum productivity. Loading and hauling are two among other main operations, that affect the productivity of an open pit mine. It is therefore very important to match well loaders and hauling units to achieve this goal.

This thesis work presents methods of investigating how the haulage trucks match the Backhoe excavator being used at the Chujah Pit of Billiton Bogosu Gold Limited. Analysis of the data obtained from field studies established that, for minimum or no queuing of trucks, 3 trucks (for waste haulage) and 5 trucks (for ore haulage) were needed for the Backhoe loader to give maximum haulage efficiency. Professor Rjevcki's Method for estimating the number of trucks to match a given loader for a known haulage distance also gave 3 trucks for waste haulage and 5 for ore haulage respectively, for the same Backhoe loader.

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CHAPTER 1

INTRODUCTION

1.1 Problem Definition

Modern trends in organisation of technological operation in mining is towards the maximisation of production. Loading and hauling operations are so tied to each other such that their organisation can only be sequential. As such, to obtain maximum productivity the loading and hauling machinery must be well matched. The hauling units must correspond well with the loader in capacity. Any mismatch in the load-haul machinery combination will reduce operational efficiency and increase cost of operation.

1.2 Objectives

(i) To study the shovel-truck operations at Billiton Bogosu Gold Limited

(ii) To determine (from the haulage distance) the number of trucks that should be allocated to the loader for efficient haulage operations.

1.3 Scope of work

The work was restricted to time and motion studies in the Chujah Pit, using the continuous method. The data collected was used to estimate the number of trucks. Professor Rjevcki's Method of estimating the number of trucks, using haulage distances was also applied.

CHAPTER 2

RELEVANT INFORMATION ABOUT THE MINE

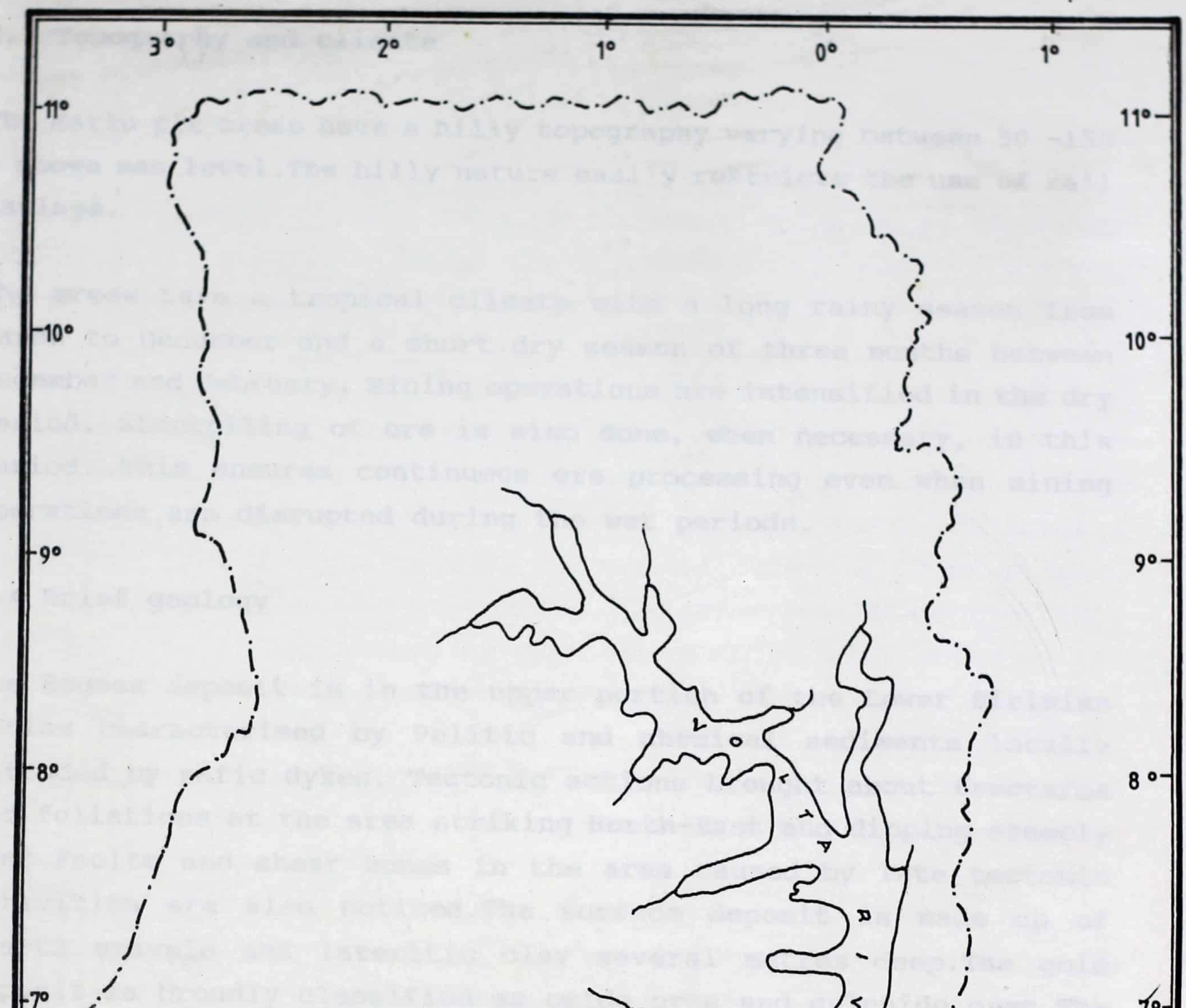
2.1 Location

Bogosu township is located in the Western Region of Ghana approximately 125 km by road North of Takoradi. The Billiton Bogosu Gold Limited (B.B.G.) concession, previously the Canadian Bogosu Resources, occupies an area of 150 km^2. It forms part of the Akanko-Prestea-Bogosu-Obuasi-Konongo-Agogo major shear zone which stretches 250 km from the coast near Axim to Agogo.
Fig. 2.1 is the map of Ghana showing the location of the B.B.G concession (not to scale).

2.2 Mining history

Mining started in the Bogosu area on a small scale as far back as 1930.In the early 1930's, several low-grade deposits were recognised and developed as open pits by the then Marlu Gold Mining Areas Limited.The mine closed down due to the declining of ore grade and mineable reserves accompanied by recovery and labour problems that characterise the period just before Ghana gained its independence.

It was in 1986 that Denison Mining Company Limited acquired the concession. In that same year Denison went into joint venture with Sikaman Gold Resources Limited of Canada to evaluate and develop the concession to be known as the Canadian Bogosu Resources Limited. As shares of the company changed hands, the name also was changed to the current one. The current shareholders of B.B.G. are : Billiton-74%, International Finance Company-16% and Ghana Government-10%.



▨ B. B. G. Concession

Fig.2.1 MAP OF GHANA SHOWING LOCATION OF BOGOSO AND B. B. G. CONCESSION

2.3 Topography and climate

The Marlu pit areas have a hilly topography varying between 50 -150 m above sea level.The hilly nature easily restricts the use of rail haulage.

The areas have a tropical climate with a long rainy season from March to December and a short dry season of three months between December and February. Mining operations are intensified in the dry period. Stockpiling of ore is also done, when necessary, in this period. This ensures continuous ore processing even when mining operations are disrupted during the wet periods.

2.4 Brief geology

The Bogosu deposit is in the upper portion of the Lower Birimian Series characterised by Pelitic and chemical sediments locally intruded by mafic dykes. Tectonic actions brought about fractures and foliations at the area striking North-East and dipping steeply West.Faults and shear zones in the area caused by late tectonic activities are also noticed.The surface deposit is made up of quartz gravels and lateritic clay several metres deep.The gold deposit is broadly classified as oxide ores and sulphide ores.The oxide ores were concentrated by chemical and mechanical weathering of gold bearing reef. The occurrence of gold in the oxide ore is in the form of fines. Gold in the sulphide ores are disseminated throughout rocks of igneous or volcanic origin, that are rich in sulphide minerals and can be separated by roasting and cyanidation. Mineralization is generally contained in the crushed zone and the gold is associated with arsenopyrites. Other minerals include carbonates, sericites and graphites occuring as fine to medium grain masses.

2.5 MINING OPERATIONS

2.5.1 Methods of mining

Active mining of ore and waste is currently going on in two pits, namely Marlu and Chujah.There are five pits in all - Marlu, Chujah, Bogosu-North, Dumassie-East and Dumassie-West.

Drilling and blasting are the main methods employed to fragment the in-situ rock. Blastholes are drilled square in pattern and 3 m deep. Burden and spacing are fixed at 2 m x 2 m. Subdrilling to a depth of 0.5 m is employed. Explosives used are ANFO, 80% special Gelatine, safety fuse, cordtex detonating cord and 17 ms delays. Drilled chips are used for stemming charged holes. After blasting, the ore zone is delineated by previous sampling of blastholes and rip lines (when the ground is weathered).

Excavation of unconsolidated and medium hard rock is done either Direct with backhoe excavator or Indirect using Dozer-Front end loader (FEL) combination.

Direct excavation, by means of backhoe excavator is done as follows: the excavator forces its bucket into the material by means of hydraulic cylinders, lifts the excavated material and dumps it into the waiting truck.

Indirect excavation involving a Dozer and FEL is as follows: the dozer pushes the material to the FEL which in turn loads the waiting trucks. The material is loosened with rippers attached to the rear of the Dozer before pushing to the FEL.

2.6 Mining equipment

Most of the mining equipment of B.B.G use diesel engines as their prime mover and are hydraulically operated. Table 2.6. gives a list of the major mining equipment and their uses.

Table 2.6 Mining equipment used at B.B.G.

EQUIPMENT	MODEL	CAPACITY (cubic metre)	MOUNTING	USES
Rear dump truck	CAT 773B	26	Rubber-tyre	Material haulage
Front End Loader	CAT 988B	4.6	Rubber-tyre	Loading
Dozer	CAT D9N CAT D7H	- -	Crawler	Preparing of roads, moving of material, ripping
Grader	CAT 14G CAT 16G	- -	Rubber-tyre	Cleaning of haul road surface
Drill Rig	DHA 600S	-	Crawler	Drilling of blastholes and exploration holes
Backhoe Excavator	CAT 245B	3.3	Crawler	Moving and digging of material

2.7 Loading

Loading of blasted rock is done with 245B backhoe excavators and 988b FEL into 773B haul trucks. The frontal working face system of mining is used in all the pits and as a consequence the single backup loading method is adopted for convenience (Fig. 2.7).

The 245B excavators load the 773B dump trucks with an average of 8 passes for blasted and 7 passes for unconsolidated materials. However according to Pfleider, 1968, as a rule of thumb, relative excavator and haulage unit capacities should be established so that on short- or medium length hauls under one mile (one way), not less than 3, and not more than 5 passes would be required to load the vehicles. On hauls over one mile (one way), the loading time becomes less significant and, as a result, a greater number of passes could be permitted with a minimum effect on the total haul cycle time and resulting productivity. Also, if loaders and trucks are well matched, an average loading passes between 4 to 6 is the most economical in open pit operations.

The FEL loads the dump trucks with an average of 5 passes. However most of the loading work on the mine is done with the 245B Backhoe excavator. The FEL is used when the 245B excavators are fully occupied and extra loading activity is required, or when they are out of order.

2.8 Hauling

Hauling of ore and waste on the mine is done by the CAT 773 dump trucks,with an average capacity of 26 m^3. They are driven by 682 HP diesel engines. The maximum travel speed of the trucks when empty or loaded is 65 km/hr.

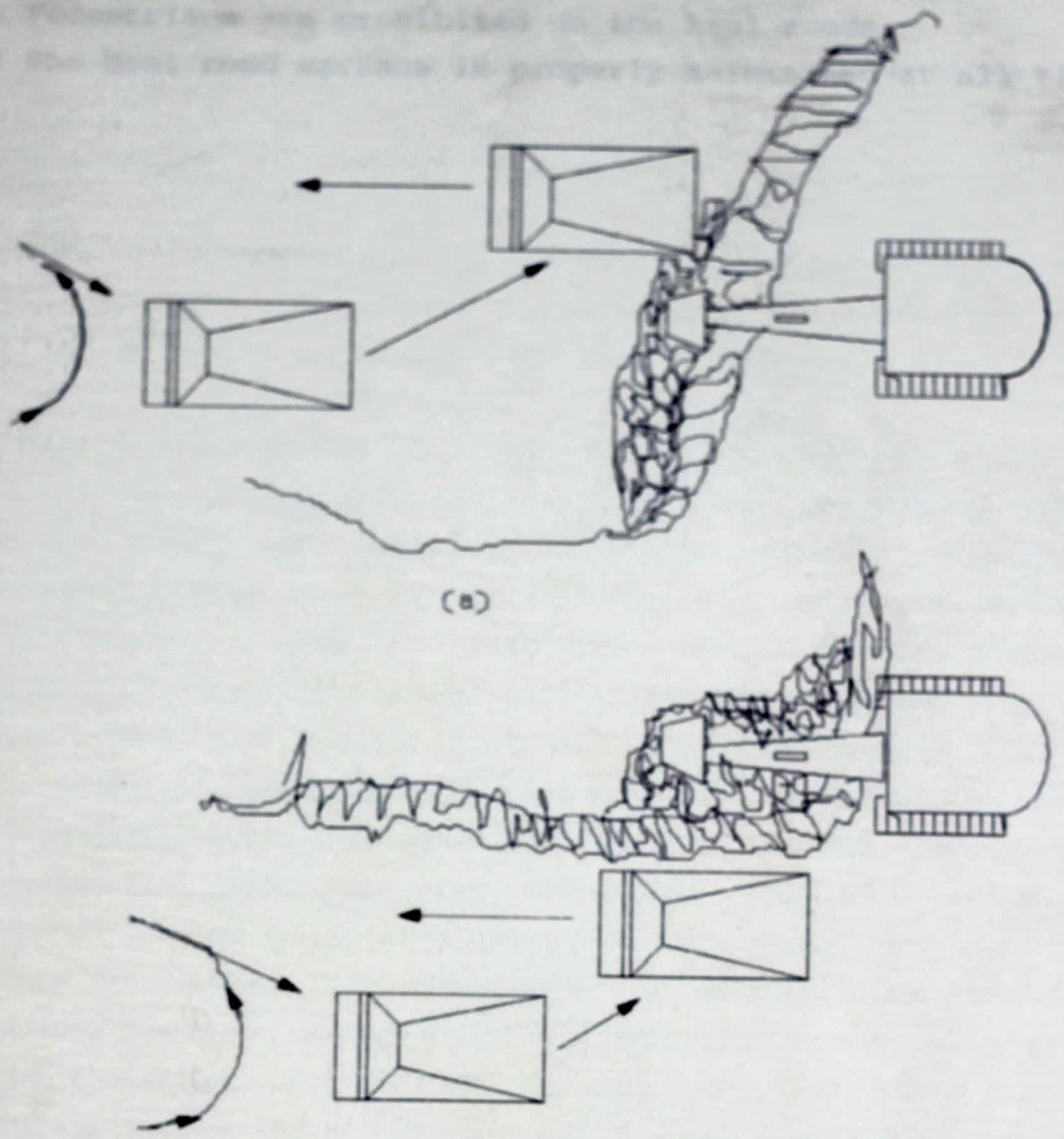
During haulage, the speed is reduced to 15 km/hr and sometimes 10 km/hr, depending on the operator, condition of the haul road and on the ramps. Ramps are constructed with a grade of 10%.

The width of the haul road is 16 m. Movement of dump trucks is allowed in both directions.

To ensure efficient haulage operations the following road safety measures have been instituted:

(i) The maximum speed of dump trucks is limited to 65 km/hr

(ii) Dust generated on the haul road is reduced by watering the



(a)

(b)

(a) Trucks spotted at lower level, with loader at an upper level

(b) Trucks spotted on the same level as loader

Fig. 2.7 The Single Back-up Operation at B.B.G.

road periodically

(iii) Pedestrians are prohibited on the haul roads

(iv) The haul road surface is properly maintained at all times

CHAPTER 3

SHOVEL-TRUCK COMBINATION FOR BULK MATERIAL HAULAGE

3.1 The shovel-truck haulage system

In modern mechanised mining ,material handling is equipment centred. The unit operations involved are characterised by and identified with the equipment that performs them.

For open pit mining, the choice of loading equipment is basically among six types of unit: power shovels, hydraulic backhoe excavators, front end loaders, bucket wheel excavators, draglines and scrapers (Windfried Peters, 1984). For underground mining, front end loaders, load-haul-dump units and continuous miners are prevalent.In underground mines with large openings and sufficient headroom, open pit mining equipment such as - dozers,shovels, trucks, front end loaders and drills, modified to meet safety and operating conditions, are more and more being used. Each category and individual machine has operating characteristics that distinguish it and help to earmark it for selection. But some of them have the unique feature of performing the joint function of loading and hauling. Examples of a loading equipment that perform substantial haulage are rubber-tyre scrapers, roapdrawn scrapers, and load-haul-dump units. Most loaders are required to operate in three working zones, with variety of operating constraints.These zones are digging, maneuvering - transporting and dumping. Some of these constraints are haul distance and gradeability.
The hourly capacities of material handling equipment in open pit mining is growing ever larger. Upper size limits have risen to 300 Tons for trucks 170 m^3 for draglines, 140 m^3 for power shovels and 8400 m^3 per hour for bucket wheel excavators.

Shovels, draglines, and wheel excavators are boom-type machines employed for strip, ore and coal mining.

The reasons for the growing capacities of open pit mining equipment is to reduce the unit cost of production and through that maximise profit.

The shovel-truck haulage system of handling bulk material has loading and hauling as the two principal operations. Hoisting is a third but optional when the need arises to cover very steep vertical distances.

3.2 PRINCIPLES OF EXCAVATION AND LOADING

Excavation and loading are two unsynonimous terms, but are used almost interchangeably. Excavation implies the action of extracting from solid or loosened ground, but loading suggest elevating material into a haulage equipment. In practice, the term loading is used commonly in underground mining and excavation in surface mining.

Extraction and elevating of bulk materials, either loosened or in place is termed excavation or loading (Hartman, 1987).If the material is soil or very soft rock, it can probably be dug in place.If it is rock or very unusually well-consolidated soil, it might require blasting or mechanical breaking prior to excavation. In non-coal mining, 20% of the material has to be blasted (Martens, 1982). A classification of mine excavating-loading equipment is presented in table 3.2. The bases for the classification is the type of mining (open pit or underground) and the continuity of operation (cyclic or continuous).

Table 3.2 Classification of excavating-loading methods and equipment

TYPE OF MINE	MODE OF EQUIPMENT OPERATION	EQUIPMENT
Open pit	Cyclic	Shovels (Power shovels, FEL, backhoe excavators) Draglines (Crawler, Walking) Dozers (Rubber tyre, Crawler) Scrapers (Rubber tyre, Crawler)
	Continuous	Mechanical excavators (Bucket wheel, cutting-head) Continuous miners (Auger, Highwall miner) Hydraulicking equipment (Monitor or Giant) Dredgers (Bucket ladder)
Underground	Cyclic	Loaders (Overhead, Gathering arm, Shovel, FEL) Shaft mucker (Clamshell, Orange peel, Cactus grab) Self loading transport (Load-Haul-Dump) Slusher (Rope-drawn slusher, scraper)
	Continuous	Breaking and loading machines (Milling type, Drum, Ripper, Borer, Auger, Plow-shearer) Boring machine (Tunnel-boring machine, Raise borer, Shaft borer).

3.3 SHOVELLING EQUIPMENT

Shovels are most suitable in medium to hard rock mining. The following shovels being the most applicable in such rock conditions: Power shovels, Front End Loaders and Backhoe excavators.

3.3.1 Power shovels

Three categories of power shovels are generally available for rock excavation .These are identified as universal shovels for constructional work, open pit mining and stripping shovels.

The universal shovels for constructional work have buckets that range from 0.5 to 2 m^3 in size. They are crawler mounted with either diesel or engines that are both diesel and electric. Normally they are used on sand, soft, and fragmented rock in open pits that produce about 0.5 to 2 million m^3 of rock mass yearly. Another area where the use of such shovels is desired is in selective mining of thin ores in large pits. Loading is done above grade.

The second category of power shovels are the quarry-mine shovels. Such shovels are crawler mounted. They are suitable for excavating soft rock and fragmented rock of any hardness. Their bucket sizes range from 2 to 20 m^3. They can be operated on pits of any capacity. For loading above grade , shovels with extended boom are manufactured. With equal bucket sizes the normal shovels are 20 to 40% higher in productivity than those with extended boom used for loading above grade. The travelling speed of crawler mounted power shovels ranges from 0.9 to 3.7 km/hr. Shovels of weight up to 100 Tons can travel on gradients up to 12° and those weighing above 100 Tons are limited to 7° gradient. The pressure which the shovels exert on the ground at the time of filling the bucket, swinging and dumping should not be above the load bearing capacity of the base ground.

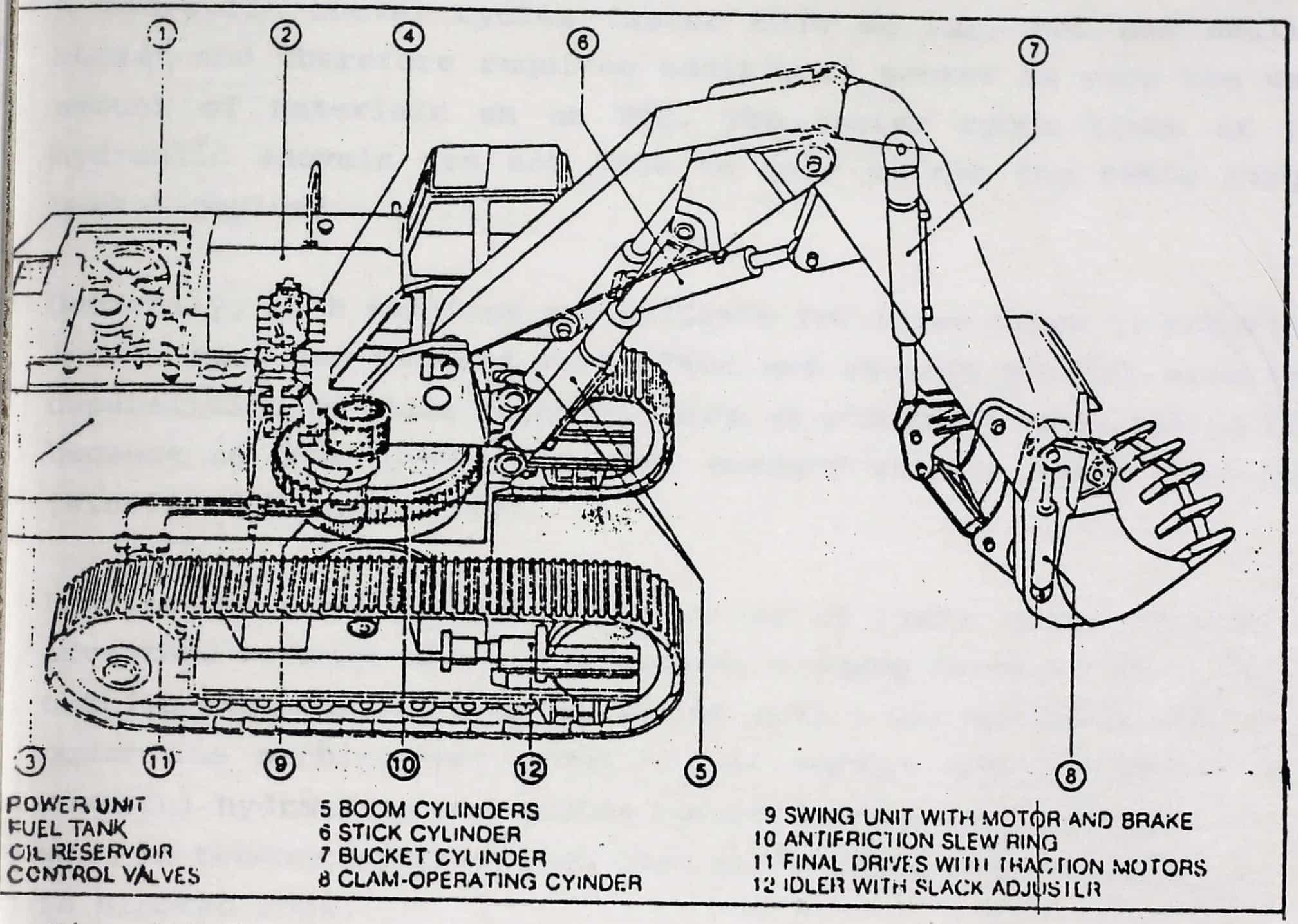


Fig. 3.3.1 The main features of a Hydraulic Shovel Excavator.

3.3.2 Front End Loaders (FEL)

Backhoe shovels used to be a better choice in tough material digging to FEL's. However, advancement in weight and hydraulic power of large loaders has permitted FEL's to match and even outproduce shovels in tough digging.

A hydraulic shovel cycles faster than an FEL, but has smaller bucket and therefore requires additional passes to move the same amount of materials as an FEL. The faster cycle times of the hydraulic shovels are not able to make up for the FEL's larger bucket payload.

Generally, both machines are suitable for three types of material; loose, bank and blasted rock. FELs and shovels provide excellent capabilities in loose materials such as stockpile work, but an FEL, because of its production edge emerges with a lower unit cost (Windfried Peters, 1984).

Loading in consolidated earth or solid banks gives shovels an advantage because they exert greater digging force at the bucket's cutting edge. An FEL's wider bucket puts a limitation on the total power the machine can exert on the bucket edge. However, more powerful hydraulics and better bucket designs have allowed FELs to work in tougher applications than before.This can be observed well in Blasted rock.

FELs fitted with 13 m^3 buckets have operating capacity of 23 Tons. The bucket breakout force is 61235 Kg. Bucket dump height and reach at 45° angle are 5.5 and 2.4 m respectively. Rubber tyre FELs are capable of travelling at 19 Km/hr.This high mobility is one of the key advantages of rubber tyre FELs.They are easily moved from and to the pit before and after blasting. Crawler mounted shovels require more time to walk away from the pit prior to blasting and that much time to return after blasting.

It is reported (Windfried Peters, 1984) that in the US rubber tyre FELs with capacities from 0.4 to 3.1 m³ and power range of 28 to 138 KW are in operation. Those with 3.1 m³ buckets have operating weight of 18 Tons and a breakout force of 12.6 Tons. Their maximum dumping height is 2.9 m straight tipping load is 15.8 Tons. They are powered by diesel engine that are capable of developing a maximum travelling speed of 34 Km/hr, forward or reverse.
Fig. 3.3.2 a and b show required F.E.L. dimensions and load motions.

3.3.3 Backhoe excavator

These machines were first equipped with small-size buckets and their use was limited to small earth moving projects.Modern backhoe excavators are equipped with shorter sticks and bigger buckets, and are capable of moving larger quantities of earth. This mass excavation concept offers an excellent truck loading option in many situations.

Backhoe excavators are able to work in poor underfoot conditions and also dig in tough materials. The mining industries have developed working systems that take advantage of the machine's high penetration and breakout force in tough materials, fast cycling hydraulics, ability to work in poor underfoot conditions and high mobility as compared with the dragline. In tough overburden they are able to dig without pre-blasting.

To maximise truck loading capability of backhoes, it is important to have a proper job layout and trained operators to correctly spot their trucks in the loading area.

Optimization of the loading capability of backhoe is done by varying the stick length and bucket size. By so doing caterpillar has achieved between 33% to 87% increase in production for their no ref to text..!!

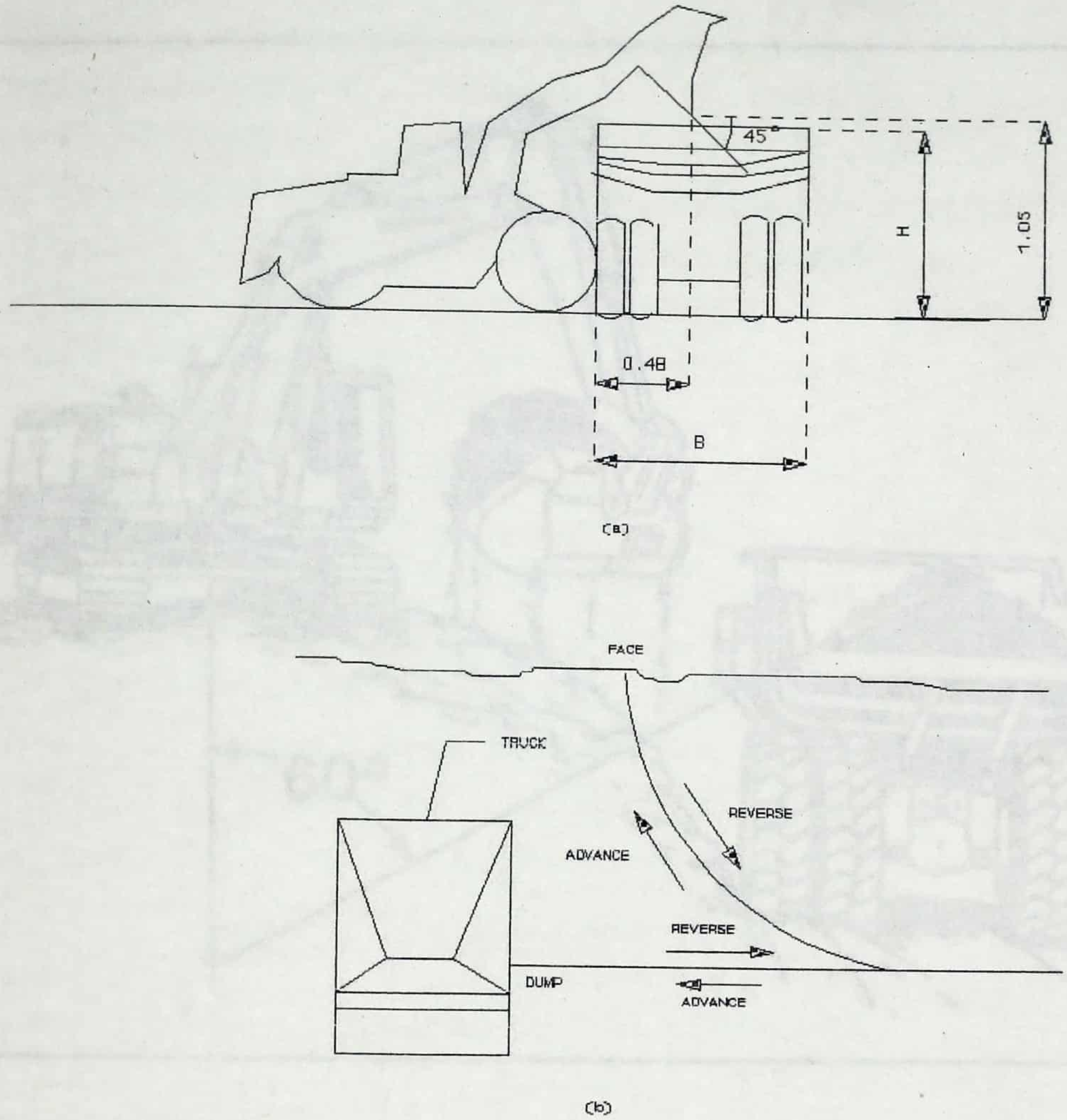


Fig. 3.3.2

(a) Required Front End Loader dimensions to load a truck without restrictions

(b) Load motions of a Front End Loader

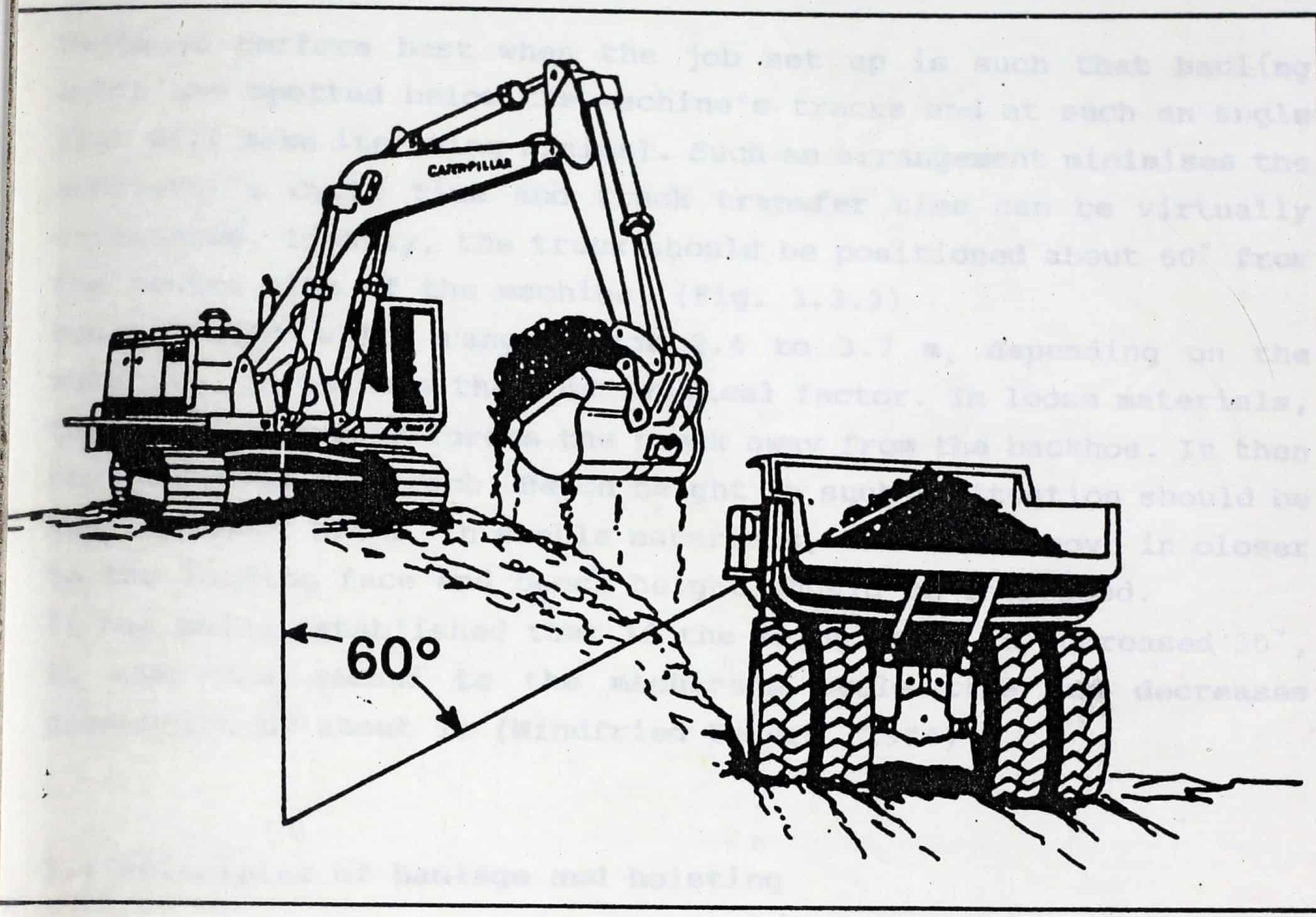


Fig. 3.3.3 Truck positioned to minimise swing angle.

shorter tip radius for more digging force resulting in easier penetration, shorter fill time, and consequently faster cycles. Also the combination of high penetration force and high breakout force has extended the range of economic application of the machines to cover even tougher materials where blasting or ripping are a prerequisite to backhoe excavation.

Backhoes perform best when the job set up is such that hauling units are spotted below the machine's tracks and at such an angle that will make its swing minimal. Such an arrangement minimises the excavator's cycle time and truck transfer time can be virtually eliminated. Ideally, the truck should be positioned about 60° from the centre line of the machine, (Fig. 3.3.3)..
Bench height which ranges from 2.4 to 3.7 m, depending on the material, is perhaps the most critical factor. In loose materials, the angle of repose forces the truck away from the backhoe. It then has to extend its reach. Bench height in such a situation should be kept at about 2.4 m. In stable materials, trucks can move in closer to the loading face and bench height should be increased.
It has being established that if the swing angle is increased 30°, it adds one second to the machine's cycle time and decreases production by about 7% (Windfried Peters, 1984)

3.4 Principles of haulage and hoisting

Bulk materials in mining are transported by haulage (primarily horizontal movement) and hoisting (primarily vertical). Machines to accomplish these functions are identified in table 3.4. The primary function of these equipment is haulage, although some (FEL, Rubber tyre scrapers, LHD) are self loading.

Though there exists a large variety of equipment, certain machines predominate. In open pit mines with multiple benches trucks team up with shovels under favorable conditions. Haulage trucks operate in four cycles: loading, travelling loaded, dumping and travelling empty. To assess the performance a haulage equipment, its operational cycles must be carefully analysed.

Table 3.4 Haulage and hoisting types and equipment

HAULAGE-HOISTING TYPE	HAUL DISTANCE RANGE	GRADEABILITY (degrees)	
		Average	Maximum
Rail (Train)	Unlimited	2	3
Truck, trailer	0.3 to 8 Km	8	12
Scraper (Rubber tyre)	150 to 1500 m	12	15
Front End Loader	Less than 300 m	8	12
Dozer	Less than 150 m	15	20
Skip	less than 2400 m (Vertical)	Unlimited	
Aerial tramway	0.8 to 8 Km	5	20
Conveyor belt	0.3 to 16 Km	17	20
Conveyor (Chain)	0.3 to 8 Km	17	20
Slusher	30 to 90 m	25	30

Source : Hartman, 1987.

3.5 Technological assessment of truck haulage

Truck haulage used to be effective only in pits that produce up to 15 million Tons per year of rock mass. Where production was in excess of this, it was supplemented with other kinds of haulage. With the manufacture of high capacity trucks, 180 Tons and above, trucks are now effective in pits that produce 70 million Tons per year and above. Some of the reasons why truck haulage is preferred in excess of this, it was supplemented with other kinds of haulage. With the manufacture of high capacity trucks, 180 Tons and above, trucks are now effective in pits that produce 70 million Tons per year and above. Some of the reasons why truck haulage is preferred to other haulage equipment include the following:

- They are independent on outside sources of energy;
- High flexibility, maneuverability and independent on each other;
- Haulage road constructions are easier and cheaper which normally shortens the constructional period of the pit;
- Productivity of excavators goes up about 20% to 25% as compared to rail haulage; and
- High rate of mining is achieved.

Truck haulage is very effective in the following mining cases:

- Construction of pits of any capacity;
- Mining of complex ore bodies;
- When the topography of the area is complex; and
- When selective mining is practiced.

Other reasons why truck haulage may not be considered for bulk material handling include:

- The economic effect of truck haulage is realised only when haulage distances are short (around 2 to 3 Km for trucks less than 27 Ton capacity).
- A large number of trucks and operators required;
- High cost of fuel and lubricants;
- Tear and wear of parts and engine is fast when haulage road is not gravelled and gradients are high;
- High capacity trucks are costly and expensive to maintain;
- Highly dependent on climate and road conditions;
- The pit environment could be rendered gaseous if fleet is large or movement is intensive.

Fig. 3.5 shows the views of a typical Rear Dump truck

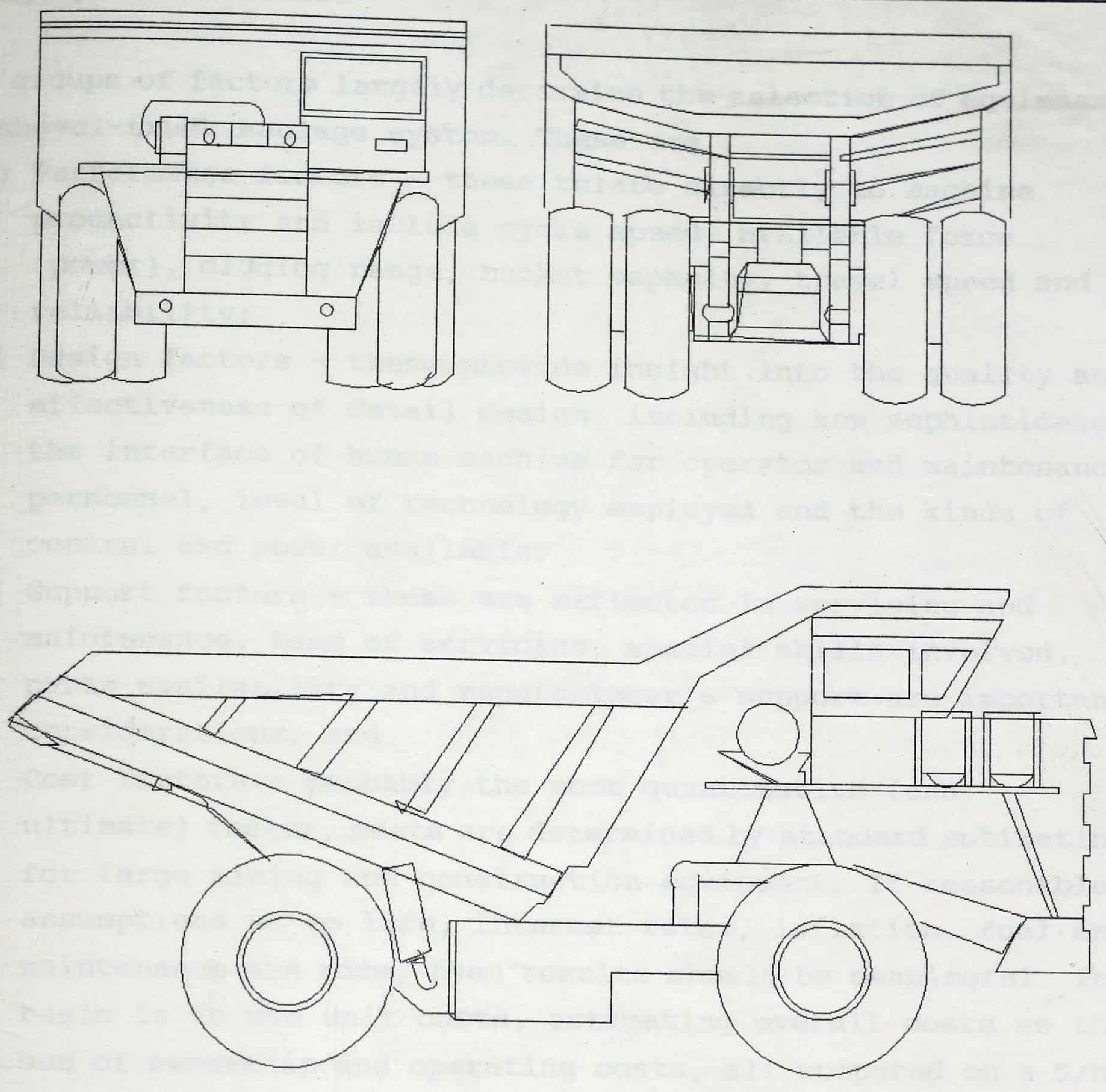


Fig 3.5 The views of a typical rear dump truck

Not refered to in text

.6 Equipment selection

'our groups of factors largely determine the selection of equipment 'or shovel-truck haulage system. These are :

(i) Performance factors - these relate directly to machine productivity and include cycle speed, available force (power), digging range, bucket capacity, travel speed and reliability;

(ii) Design factors - these provide insight into the quality and effectiveness of detail design, including how sophisticated the interface of human-machine for operator and maintenance personnel, level of technology employed and the kinds of control and power available;

iii) Support factors - these are reflected in servicing and maintenance. Ease of servicing, special skills involved, parts availability and manufacturer's support are important considerations; and

(iv) Cost factors - probably the most quantitative (and ultimate) factor, costs are determined by standard estimating for large mining and construction equipment. If reasonable assumptions as to life, interest rates, inflation, fuel and maintenance are made, then results should be meaningful. The basis is to use unit costs, estimating overall costs as the sum of ownership and operating costs, all computed on a \$/hr basis and converted to \$/Ton or \$/m³.

The selection of equipment is preceded by the determination of the ıature of the deposit. Conditions and factors considered include:

(i) The size of the orebody and grade distribution. The size of the equipment is rigidly tied to the size of the orebody but to a lesser extent dependent on grade distribution except in selective mining;

(ii) The nature and thickness of the overburden to be removed. Some materials may require prior ripping to loosen before excavation;

(iii) The character and significance of geologic structures (fractures, faults, shearzones, etc) associated with occurrence;

(iv) The chemical and physical properties of material to be mined which when combined with anticipated climatic conditions, may render certain equipment useless during unfavorable seasons;

(v) The life and expected production rate of the operation;

(vi) The distance and capacity of each disposal area; and

(vii) The future use of the equipment. It is economically desirable to use the same equipment for both overburden removal and mining.

It is generally preferred that when considering the selection of both shovels and trucks to match, we begin with shovels and choose haulage trucks to suit. This is because the truck performance is more influenced by the choice of shovel than vice versa, which must also be suited to the geophysical properties of the orebody and the parameters of the working face, (Crawford and Hustrulid, 1979). But above all, the shovel is more expensive than the truck.

3.7 Selection of loading units

Choosing the right loading unit depends on careful planning of the loading operations based on a thorough analysis of the following:

(i) Geologic conditions;
(ii) Nature of overburden;
(iii) Nature of ore;
(iv) Whether or not blasting will be required;
(v) Amount of overburden and ore to be handled;
(vi) Haulage means and distance;
(vii) Method of mining; and
(viii) Environmental regulations.

The loading unit chosen will also be influenced by the user's attitude towards investment and machine life expectancy, the ability of customer's own service personnel to maintain a given machine, and the anticipated long or short term machine availability related to output requirement.

For any given loading unit, production rate depends on the cycle time, digging characteristics and machine availability. Cycle time is a function of pit layout and machine design. Perhaps the most important factor in choosing a loader is the desired flexibility. If the ore grade is extremely variable throughout the orebody, management may want to be able to mine from more faces simultaneously. In this case the number of loading units will go up and the capacity of each will go down. If ore, grade and ratios are constant throughout, large but fewer machines could be used that will reduce cost. Once the sizes are chosen, the number of loading and hauling units can be determined.

3.8 Selection of trucks

Besides operating cost and productivity, it is necessary to consider haul road grade, haulage distance, tyre limitations, and machine characteristics, before selecting a haulage truck.

The mining engineer must make a haulage study to determine not only the most suitable method of hauling material,but also the most effective and economical type of equipment to use for his prevailing conditions.

The selection of haulage equipment could be based on the following general criteria:

(i) The ability to make maximum use of the equipment on whatever variety of applications may be required;

(ii) The degree of compatibility between hauling or loading equipment and the recommended new units;

whatever variety of applications may be required;

(ii) The degree of compatibility between hauling or loading equipment and the recommended new units;

(iii) Possible restrictions on maneuvering space or side and overhead clearances;

(iv) Possible restrictions on bridge or haul road widths; and

(v) The effect of extreme grades, either favorable or adverse, particularly on the loaded haul.

3.9 Matching of loading units and trucks

The loading units must correspond and combine well with the trucks in capacity, since any mismatch can cause overutilisation or underutilisation of equipment and affect productivity.

The maximum truck size per rated loader production capacity is an effective objective although adverse grades, equipment availability and cumulative bucket capacities also contribute to the final selection.

The matching of loading units to trucks, according to Professor V. V. Rjevcki, 1985, can be done by calculating the volume capacity of truck, V, to suit the bucket capacity of the loader, E. For haulage distances, L between 1 to 1.5 Km, the optimal values of V to E ratio ranges from 4 to 6. When the haulage distance increases to 7 - 8 Km, optimal values of V : E are from 8 to 12 (lower values are obtained for higher capacity equipment). This explains why it is adviceable to minimise queuing times for high capacity trucks. Table 3.9a shows V : E values estimated for E at different L. Appendices 1 to 10 show truck payloads and number of trucks for a given E at different L. Fig. 3.9a and Fig. 3.9b show graphs of truck payload against haulage distance obtained for various loader bucket sizes. Fig. 3.9c and Fig. 3.9d also show graphs of the number of trucks against the haulage distance obtained for various loader bucket sizes.

Rjevcki's method of matching trucks to excavators or loaders (power bulk material over 1 Km compares favorably with that of the rail transport.

The procedure for matching loading units and trucks to handle bulk material in a pit using their capacity ratios is as follows:

(i) Choose a loading unit by considering bench height, ore type, angle of dip, method of mining and equipment cost;

(ii) Choose the truck based on the capacity of loader and haulage distance. Professor Rjevcki has proposed a formula given as

$$V=3.63E-4.38L-0.039E^2+0.545L^2+9.39$$

where V - nominal truck capacity, m^3.
E - nominal bucket capacity of loader, m^3.
L - haulage distance, Km.

Truck capacity, q, in tonnes is

$$q=\frac{\gamma}{K}*V$$

where γ - weight per unit volume of material;
K - swell factor.

Knowing the capacity required, the type of truck is then chosen, using information provided by manufacturers to suit prevailing climatic and topographic conditions.

(iii) The number of trucks required is calculated based on the haulage distance. The number of trucks, N, required for a given loader, is given by Professor Rjevcki as:

$$N=10.56-1.13*\frac{V}{E}+1.08L$$

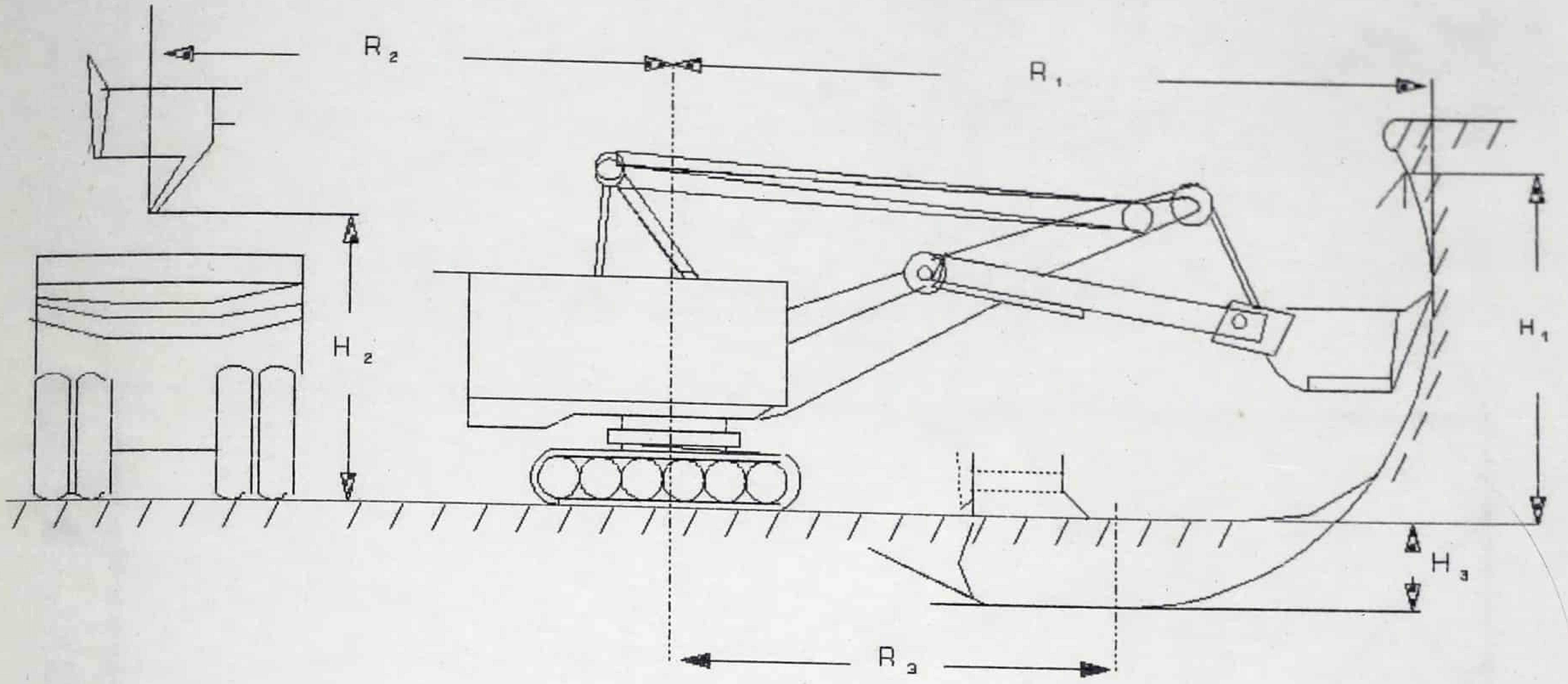
(iv) The number of trucks can also be determined using the truck cycle time and the truck loading time. The number of trucks, N, is given as :

$$N = \text{Truck cycle time / truck loading time.}$$

These cycle and loading times of trucks can be obtained through time and motion studies, using the Continuous or the Snapback methods.

Table 3.9a Capacities ratio of truck to loader at varying haulage distances ( )

E (m^3)	L_1 1-2 Km	L_2 3-4 Km	L_3 5-6 Km	L_4 7-8 Km
	V/E	V/E	V/E	V/E
3.2	5.5	6.4	8.0	10.0
4.0	5.5	6.4	8.0	10.0
5.0	5.2	6.2	7.6	9.6
6.3	5.2	6.2	7.6	9.6
8.0	4.7	5.7	7.3	9.3
10.0	4.7	5.7	7.3	9.3
12.5	4.3	5.3	6.8	8.7
16.0	4.3	5.3	6.8	8.7
20.0	4.0	5.0	6.5	8.0
25.0	4.0	5.0	6.5	8.0



R_1 - Maximum Cutting Radius

R_2 - Maximum Dumping Radius

R_3 - Floor Level Radius

H_1 - Maximum Cutting Height

H_2 - Maximum Dumping Height

H_3 - Maximum Digging Depth Below Ground Level

Fig. 3.9e Shovel Working Dimensions

Fig. 3.9a Graph of V vrs L

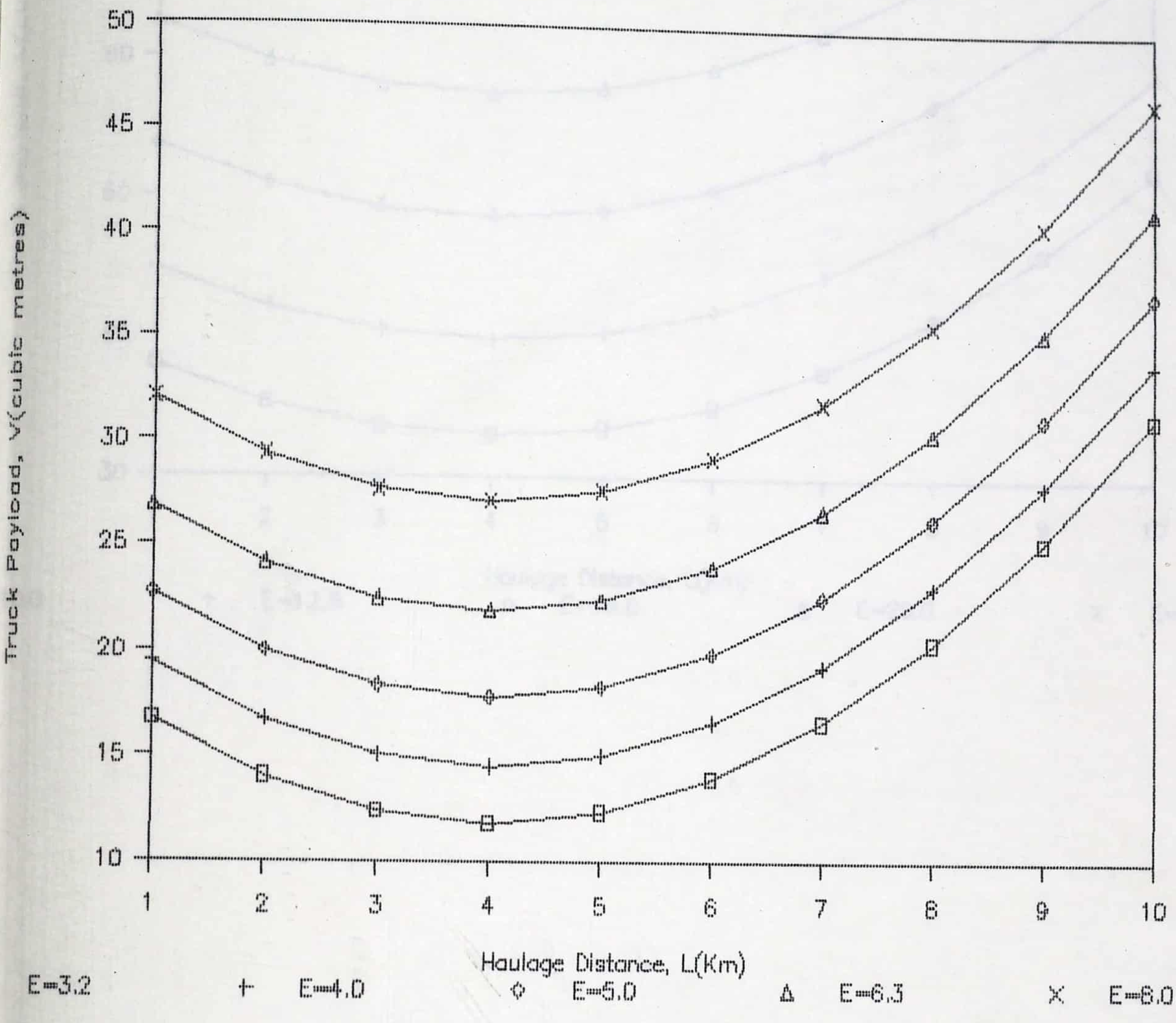


Fig. 3.9b Graph of V vrs L

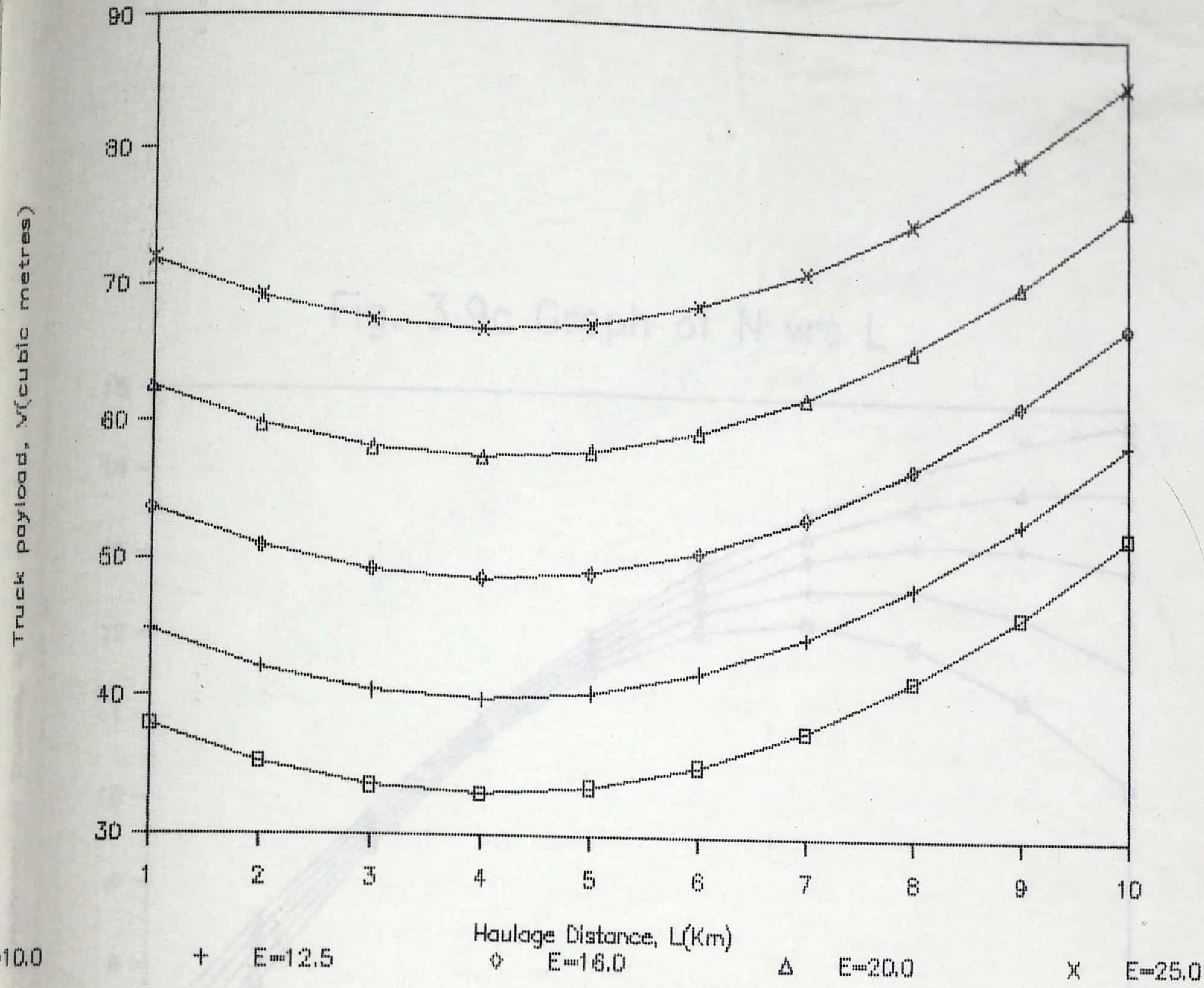


Fig. 3.9c Graph of N vrs L

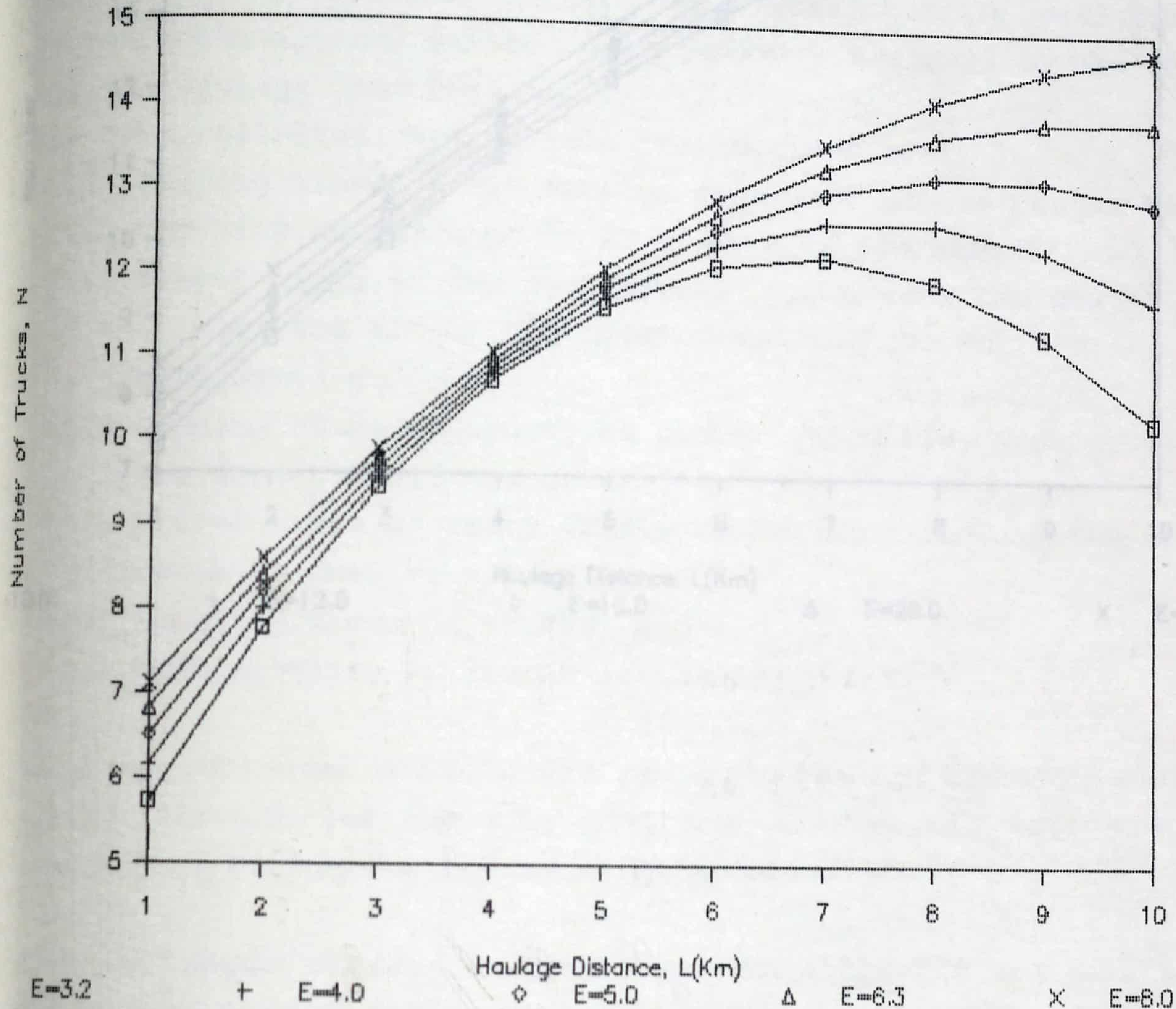
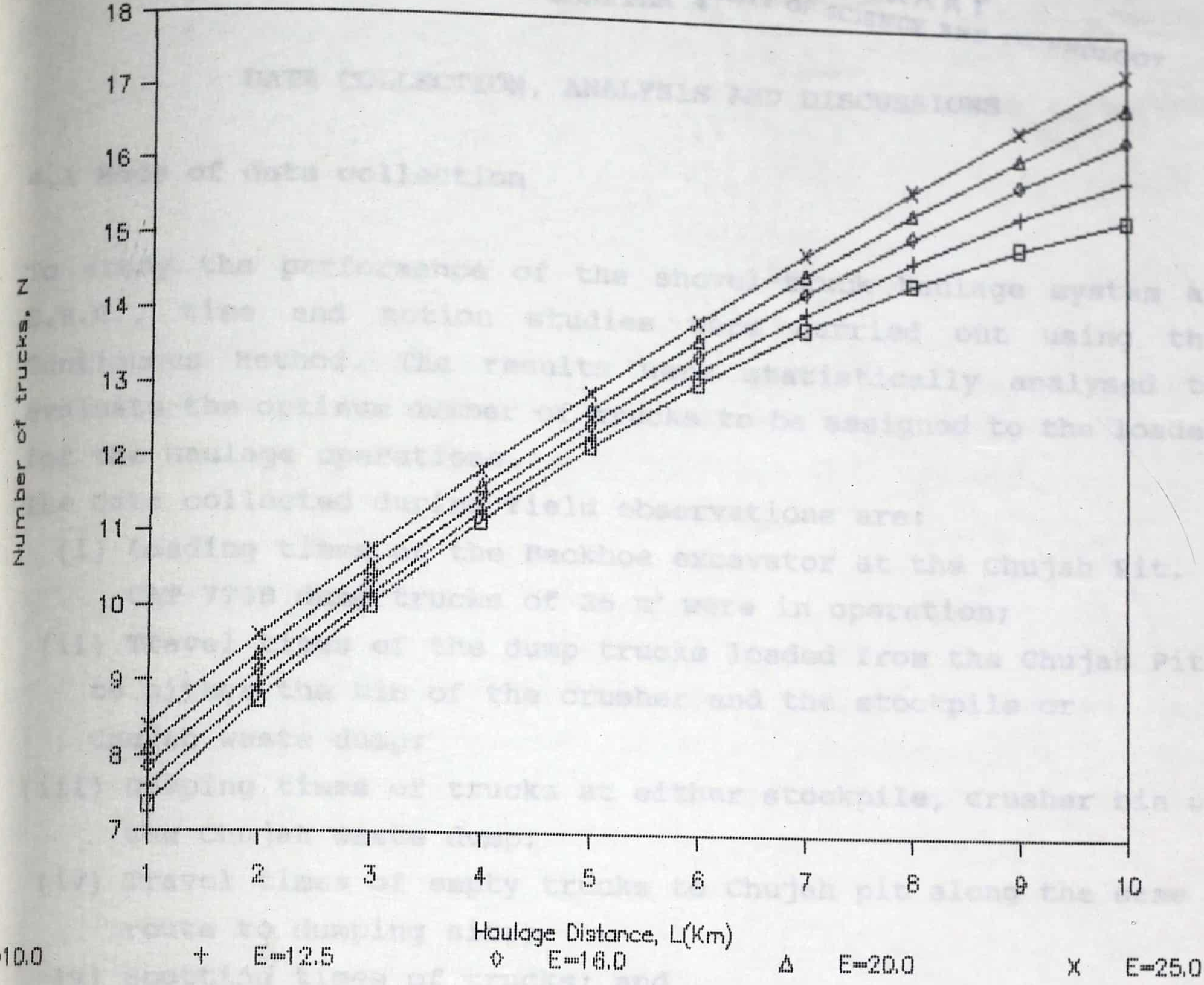


Fig. 3.9d Graph of N vrs L



CHAPTER 4

DATA COLLECTION, ANALYSIS AND DISCUSSIONS

4.1 Mode of data collection

To study the performance of the shovel-truck haulage system at B.B.G., time and motion studies were carried out using the Continuous Method. The results were statistically analysed to evaluate the optimum number of trucks to be assigned to the loader for the haulage operations.

The data collected during field observations are:

(i) Loading times of the Backhoe excavator at the Chujah Pit. CAT 773B dump trucks of 26 m^3 were in operation;

(ii) Travel times of the dump trucks loaded from the Chujah Pit to either the bin of the crusher and the stockpile or Chujah waste dump;

(iii) Dumping times of trucks at either stockpile, crusher bin or the Chujah waste dump;

(iv) Travel times of empty trucks to Chujah pit along the same route to dumping site;

(v) Spotting times of trucks; and

(vi) Queuing times of trucks at loading point.

Data was collected both for ore and waste haulage operations at the Chujah pit. It was the only pit, out of five, in active mining operations during the period of data collection.

The TAG Heuer Microsplit 230S type of stopwatch was the basic instrument used in taking time measurements. Readings were recorded to the nearest second. The stopwatch indicated the time recorded in minutes, seconds and 1/100 of a second.

The data collected was processed using the IBM PC at the U.S.T. School of Mines computer center.

4.1.1 Loading time

Loading time measurements started at the time a dump truck was spotted and when it was fully loaded and just about to leave the spot.

4.1.2 Hauling time

The hauling time measurements started when the dump truck just left the loading spot. Hauling time measurements ended when the loaded truck arrived at the dump site after travelling nonstop.

4.1.3 Dumping time

Recording of dumping time started when the truck arrived at dump site. Spotting of the trucks including maneuvers done in the process up to when the load was emptied, all were recorded as dumping time.

4.1.4 Truck return time

The time taken by a haulage truck to travel back to the loading point was recorded. Return time recording started when truck was leaving the dump site and stopped when it arrived at the loading site either for queuing or spotting.

4.1.5 Queuing time

This is the time elapsed when the truck arrived at the pit and has no access to the loader and when it is signalled to maneuver to the loading spot.

4.1.6 Spotting time

The time taken for the trucks to maneuver to the loading spots to be loaded after it was signalled to do so.

4.2 Data analysis

Data collected from ore and waste haulage operations was analysed using classical statistics. Fig. 4.2a to Fig. 4.2F show histograms drawn from the data set. Each set of data consists of 500 values and these are indicated by the histograms. All the histograms depict normal distribution and these are confirmed by the probability plots, Appendices 11 to 22. The softwares used for these analyses are Lotus 123 and Geo-Eas. The mean of each set of data was found.

4.2.1 Determination of truck cycle time

The mean times for loading, hauling, dumping, return travel, spotting and queuing as calculated from the data are presented below:

Waste haulage

Operation		Time (min)
Loading	- LTw	5.76
Hauling	- HTw	4.01
Dumping	- DTw	0.42
Returning	- RTw	3.12
Spotting	- STw	0.64

$$\text{Mean cycle time, } Tw = LTw + HTw + DTw + RTw + STw$$
$$= 5.76 + 4.01 + 0.42 + 3.12 + 0.64$$
$$= 13.95 \text{ minutes}$$

Queuing time, QTw = 1.947 minutes

Ore haulage

Operation		Time (min)
Loading	- LTo	5.81
Hauling	- HTo	6.82
Dumping	- DTo	0.53
Returning	- RTo	5.70
Spotting	- STo	0.62

Mean cycle time, To = LTo + HTo + DTo + RTo + STo

= 5.81 + 6.82 + 0.53 + 5.70 + 0.62

= 19.48 minutes

Queuing time, QTo = 2.55 minutes

4.2.2 Determination of number of trucks to match loader

The number of trucks, N, required to match a loading equipment is estimated from the equation

$$N = \frac{Truck\ cycle\ time}{Truck\ loading\ time}$$

Applying this formula to the waste haulage operations at Chujah Pit, the number of trucks, Nw, that are to be assigned to the loader is estimated as:

Nw = Tw/LTw

= 13.95/5.76

≈ 2

For the ore haulage operations at the pit, the number of trucks, No, required to match the loader is estimated as;

No = To/LTo

= 19.48/5.81

≈ 3

The cycle and loading times used in the estimation of number of trucks to a loader in the waste and ore haulage operations incoperate queuing times. For very efficient haulage operations, queuing times must be eliminated or reduced to the bearest minimum. Therefore, maximum efficiency of haulage operations at the Chujah pit, can be obtained when queuing times are reduced to zero or there about.

For the waste haulage with zero queuing time, the cycle time, Tw′, becomes:

$$\begin{aligned} Tw' &= Tw - WTw \\ &= 13.95 - 1.947 \\ &= 12.003 \text{ minutes} \end{aligned}$$

Loading time, LTw′, without truck having to queue becomes:

$$\begin{aligned} LTw' &= LTw - QTw \\ &= 5.76 - 1.947 \\ &= 3.813 \text{ minutes} \end{aligned}$$

Therefore, the required number of trucks, Nw′, to match the loader for maximum efficiency in waste haulage operations at the pit is:

$$\begin{aligned} Nw' &= Tw'/LTw' \\ &= 12.003/3.813 \\ &\approx 3 \end{aligned}$$

For ore haulage operations, when queuing time is zero, truck cycle time, To′, and loading time, LTo′ are estimated as:

$$\begin{aligned} To' &= To - QTo \\ &= 19.481 - 2.55 \\ &= 16.931 \text{ minutes} \\ LTo' &= 5.81 - 2.55 \\ &= 3.261 \text{ minutes} \end{aligned}$$

The required number of trucks, No′, to match the loader for maximum efficiency is:

$$\begin{aligned} No' &= To'/LTo' \\ &= 16.931/3.261 \\ &\approx 5 \end{aligned}$$

Professor Rjevcki's formula for estimating the number of trucks, N, required to match a given loader reads:

$$N = 10.56 - 1.13 \cdot \frac{V}{E} + 1.08L$$

where V - the nominal capacity of the truck, m^3.
E - the nominal bucket capacity of the loader, m^3.
L - haulage distance, Km.

For the haulage operations at Chujah pit,

$V = 26\ m^3$

$E = 3.3\ m^3$

$L = 1.5$ Km for waste haulage.

$L = 3.43$ Km for ore haulage.

The number of trucks, Nw, required for waste haulage operations is estimated from the formula as:

$$Nw = 10.56 - 1.13\ (\ 26/3.3\ ) + 1.08 \times 1.5$$
$$\approx 3$$

Also, the number of trucks, No, required for ore haulage operations, according to the formula is:

$$No = 10.56 - 1.13\ (\ 26/3.3\ ) + 1.08 \times 3.43$$
$$\approx 5$$

4.3 DISCUSSION

It is observed that the number of trucks to be assigned to a loader, calculated from Professor Rjevcki's formula (which are 3 for waste haulage and 5 for ore haulage) and those estimated from truck cycle times with zero queuing times (which are 3 and 5 for waste and ore haulages respectively) are the same. For waste and ore haulage operations at Chujah Pit, 3 and 4 trucks are used respectively. Though these values are less than those obtained from the field study evaluation, and Rjevcki's method above, truck queuing exists. This, by observation is the result of, high number of loader passes due to poor rock fragmentation, large swing angle and frequent loader breakdowns.

B.B.G. operates five pits that have different haulage distances both for waste and ore haulages. The trucks used have a constant payload of 26 m^3, and the loaders have bucket sizes of 3.3 m^3 (for Backhoe excavator) and 4.6 m^3 (front end loader). Fig. 4.3 is a graph estimated for the number of trucks, N, for various haulage distances which could be used to estimate the number of trucks to be assigned to each loader, for efficient haulage.

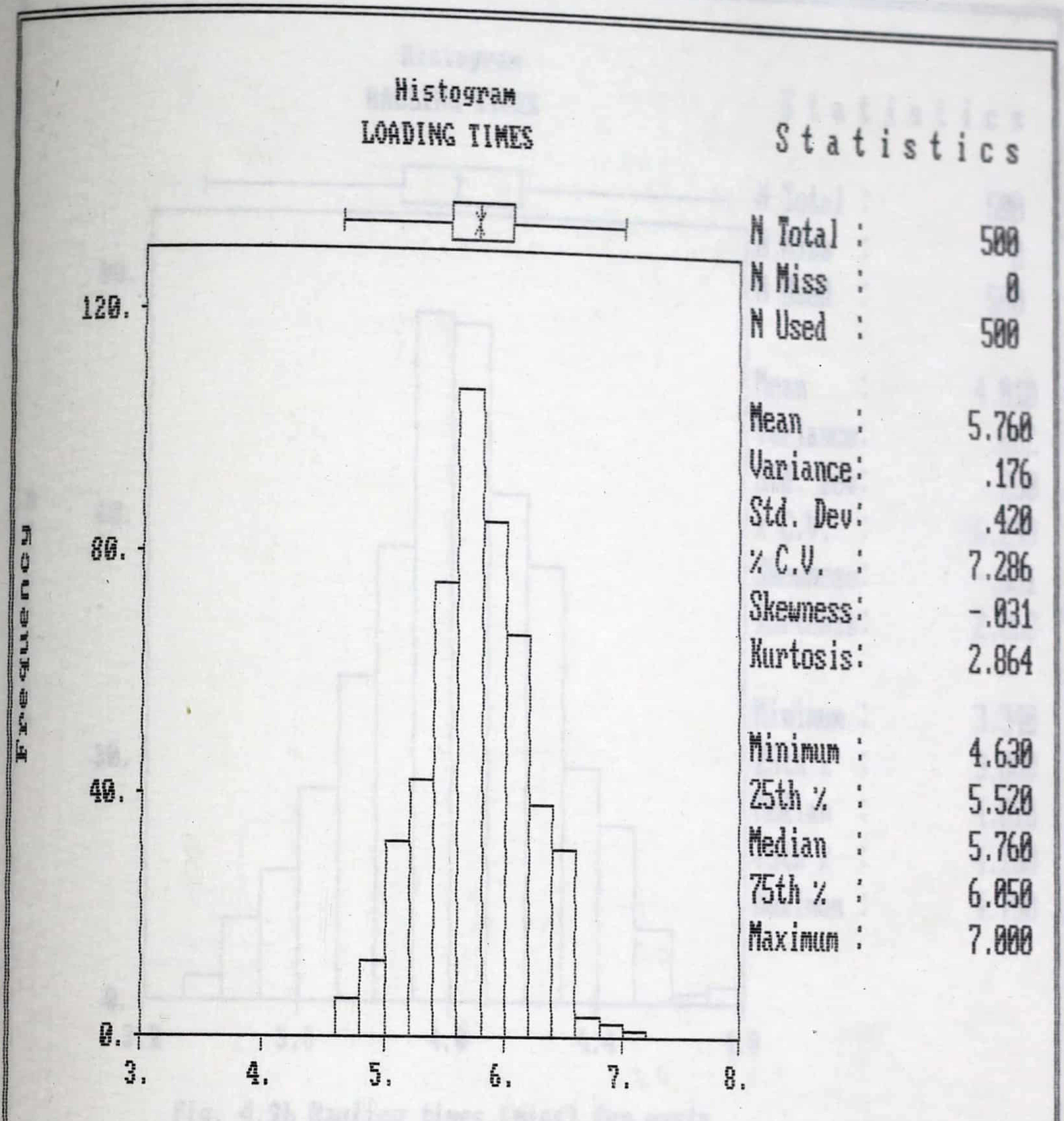


Fig. 4.2a Loading times (mins) for waste

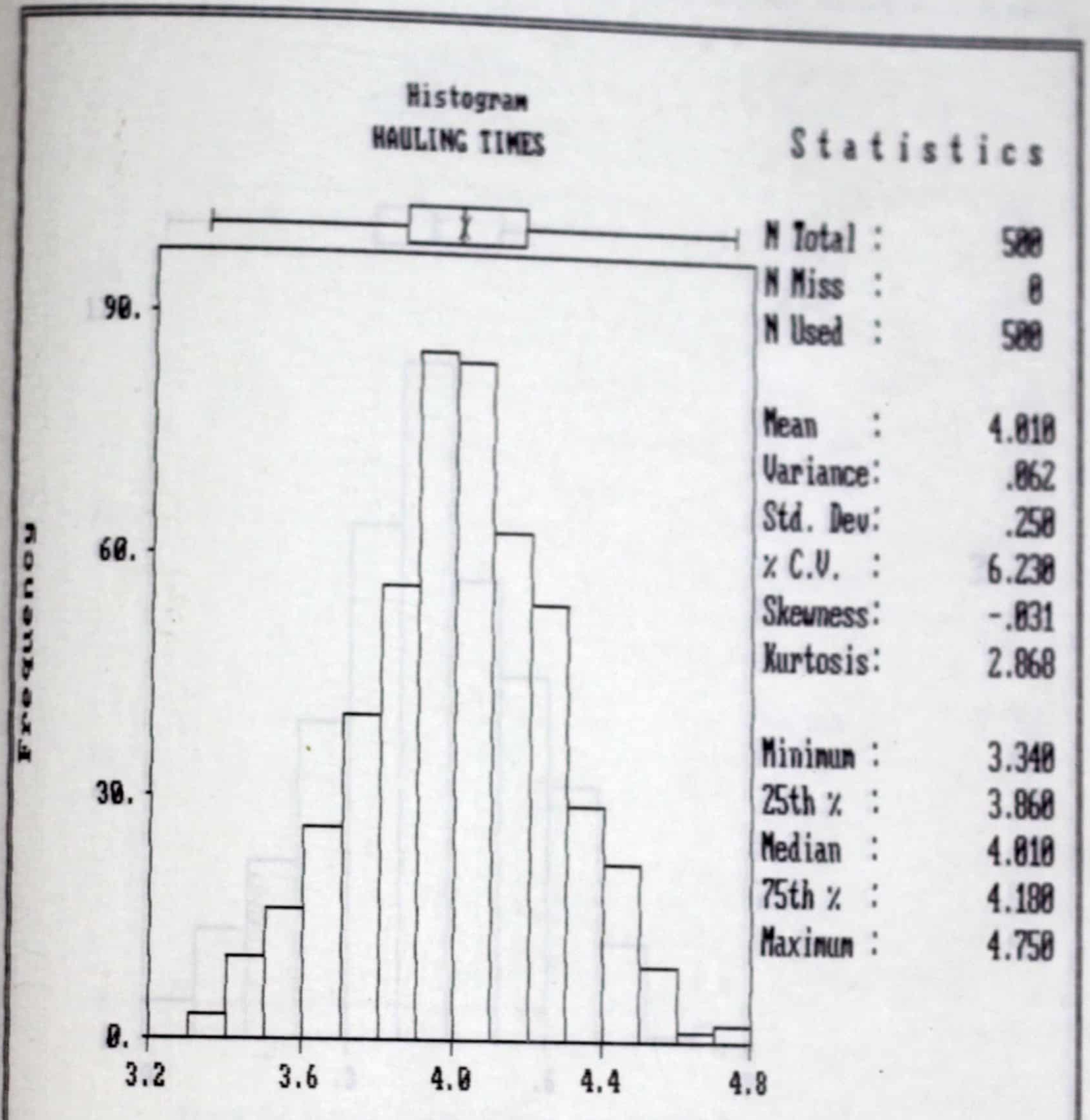
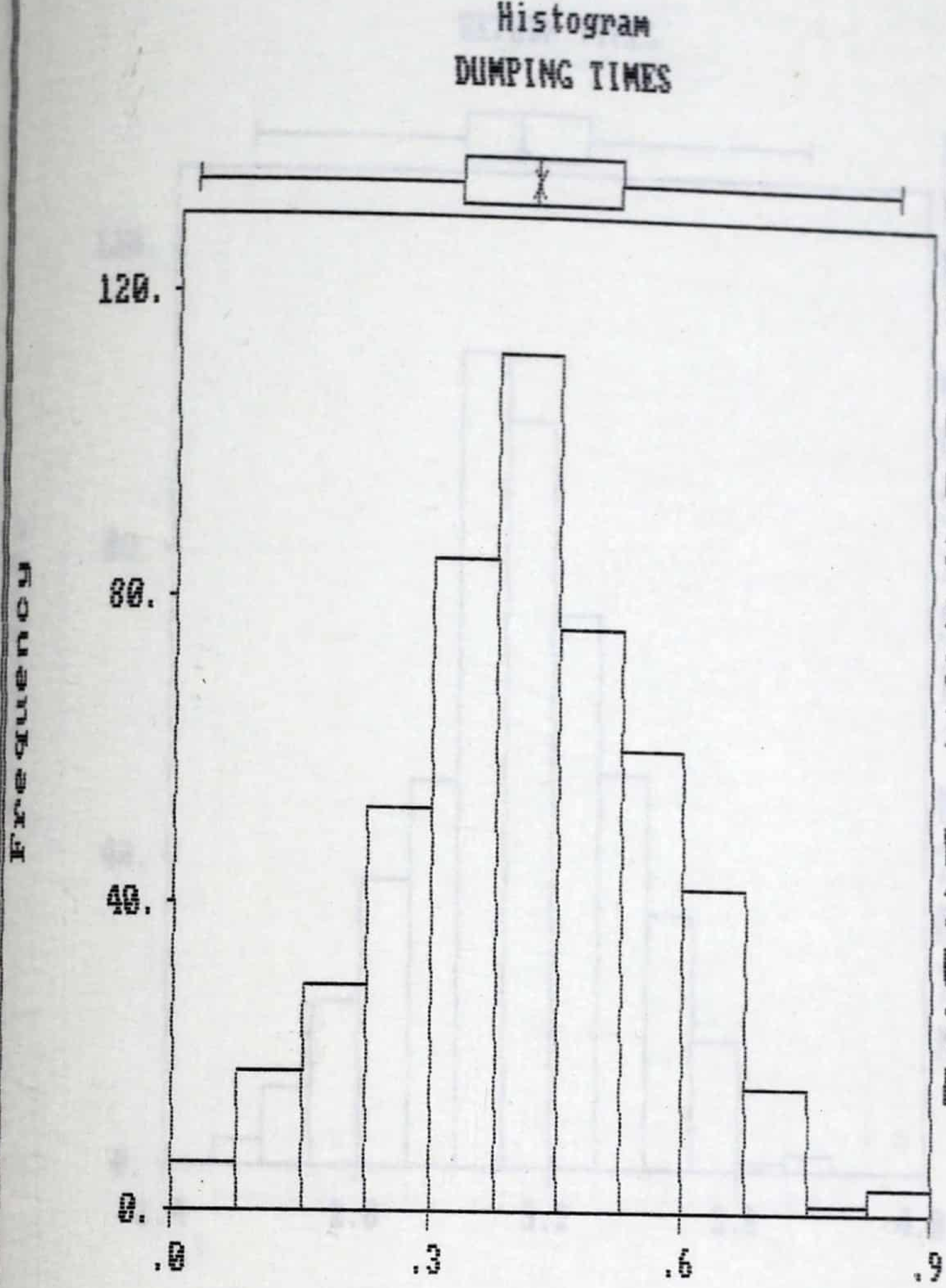


Fig. 4.2b Hauling times (mins) for waste



Statistics

N Total :	500
N Miss :	0
N Used :	500
Mean :	.420
Variance:	.023
Std. Dev:	.150
% C.V. :	35.723
Skewness:	-.031
Kurtosis:	2.859
Minimum :	.020
25th % :	.330
Median :	.420
75th % :	.520
Maximum :	.860

Fig 4.3c Dumping times (mins) of waste

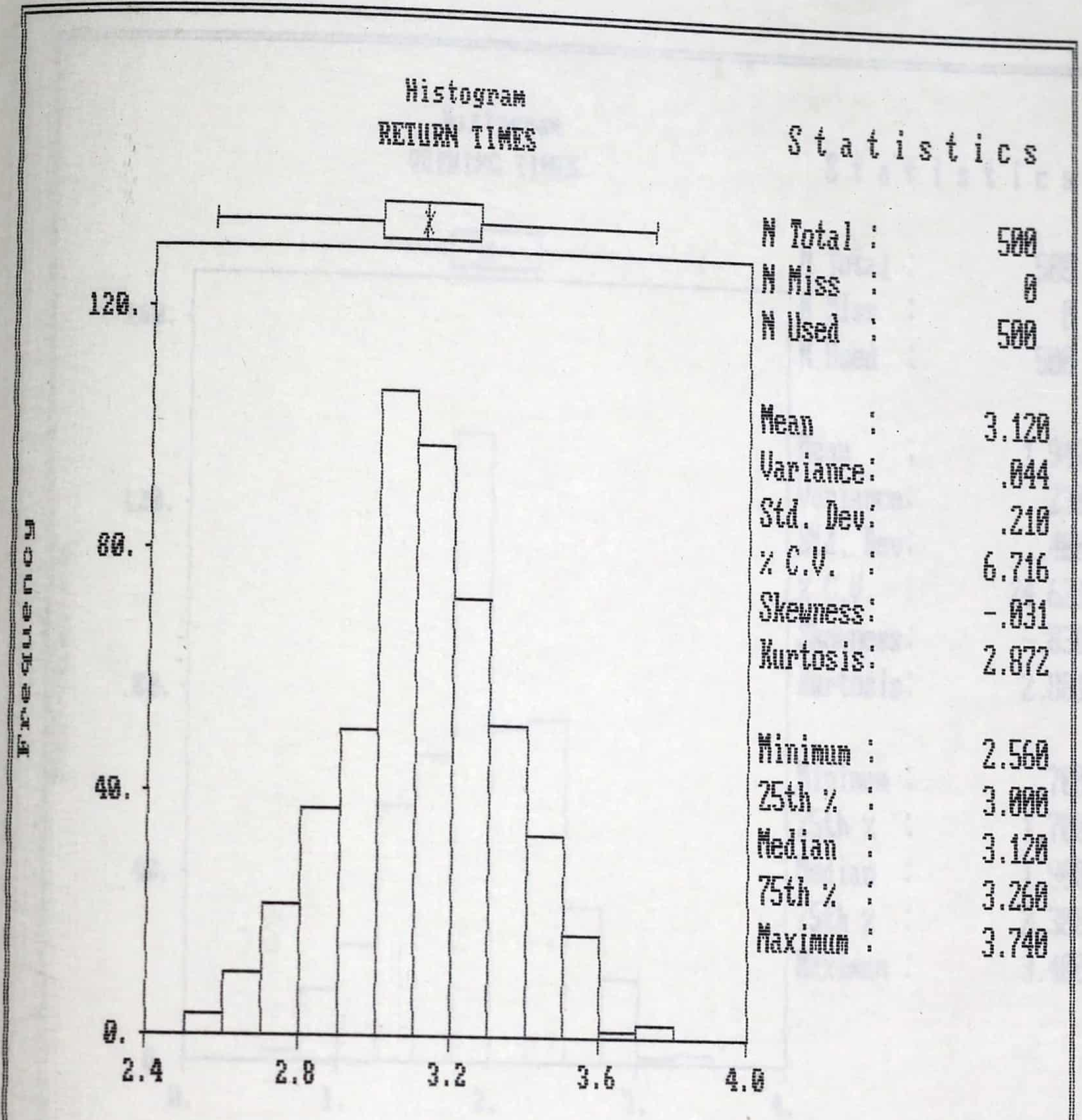


Fig 4.2d Return times (mins) for waste

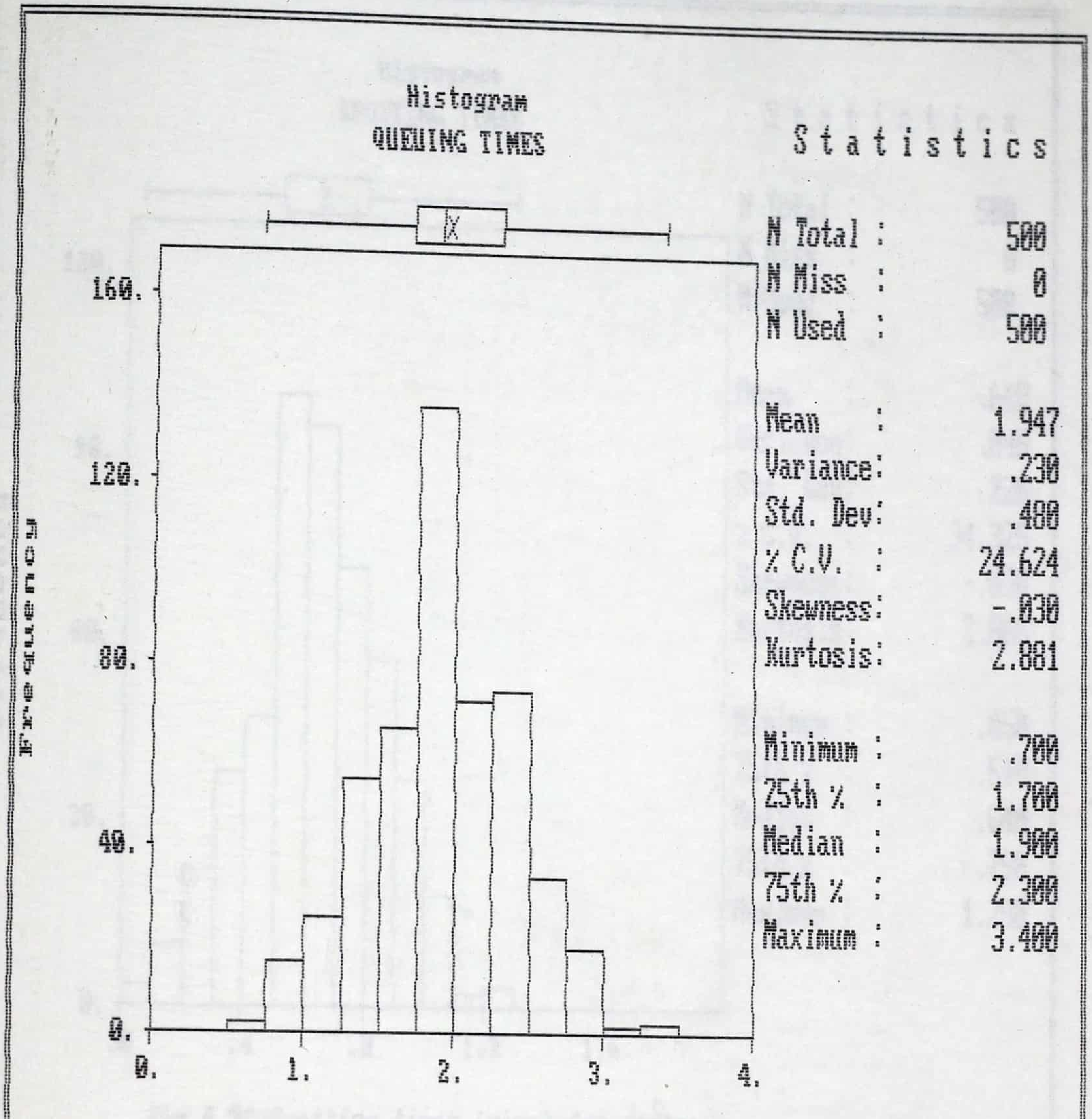


Fig 4.2e Queuing times (mins) for waste

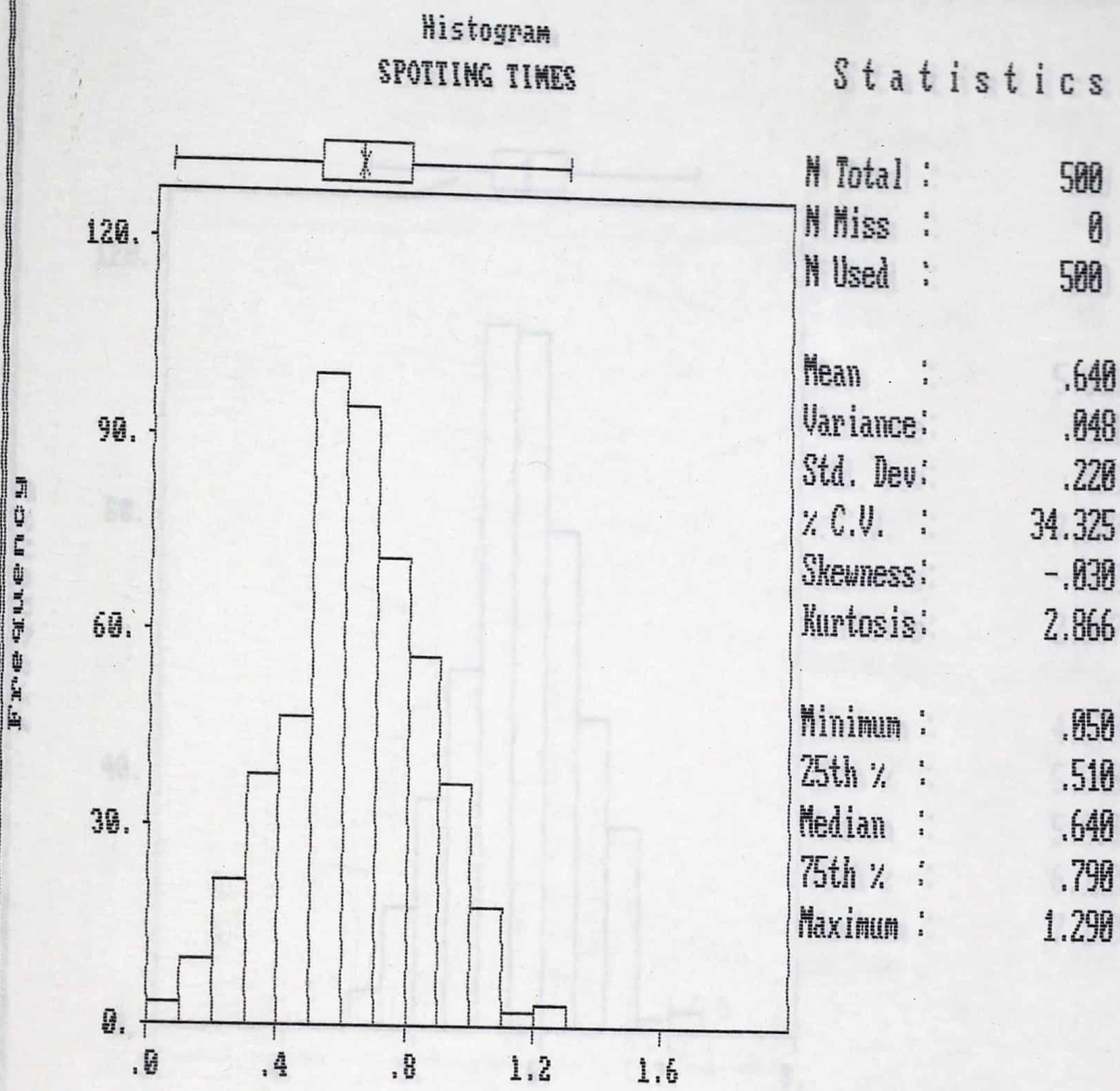


Fig 4.2f Spotting times (mins) for waste

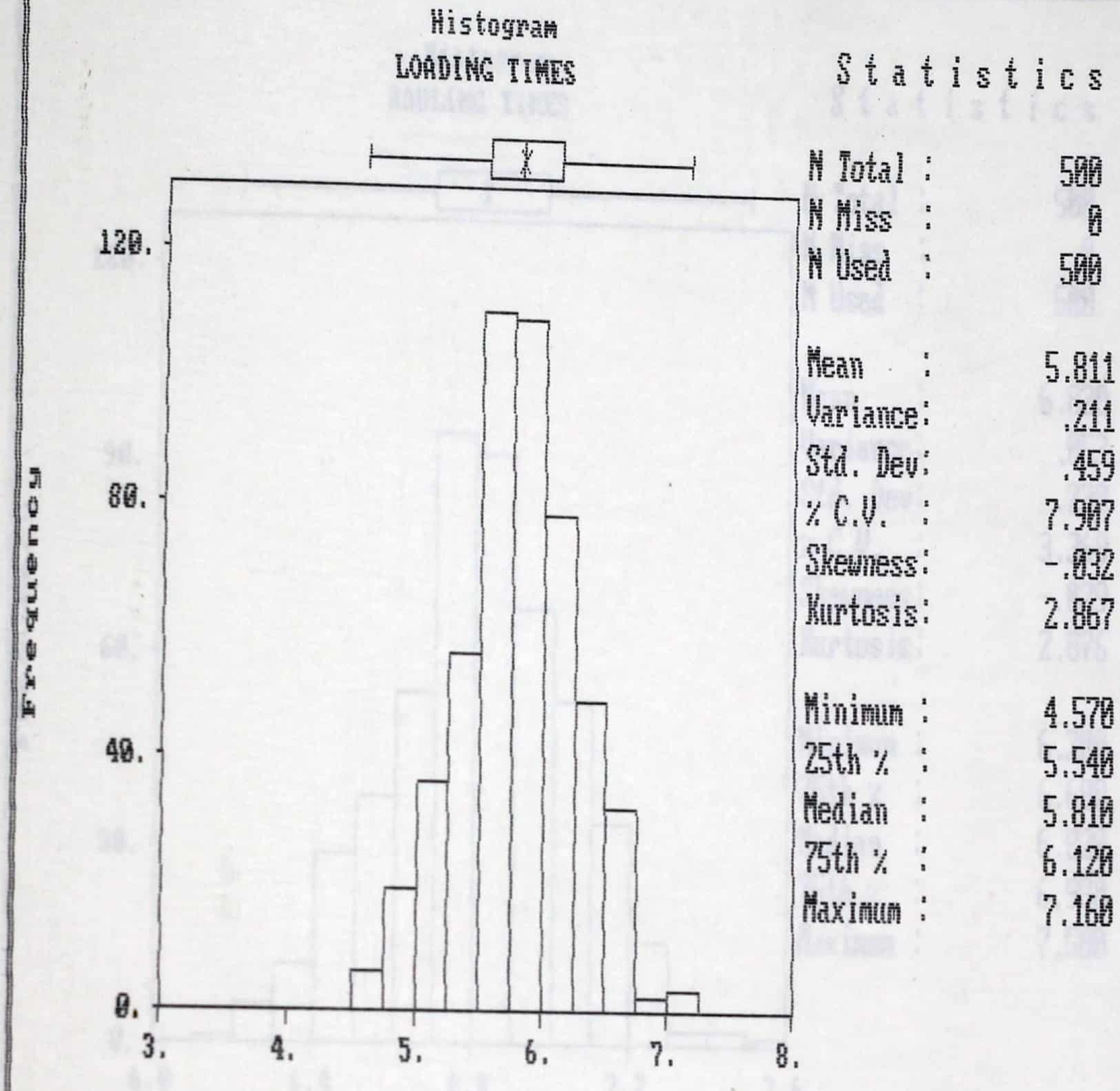
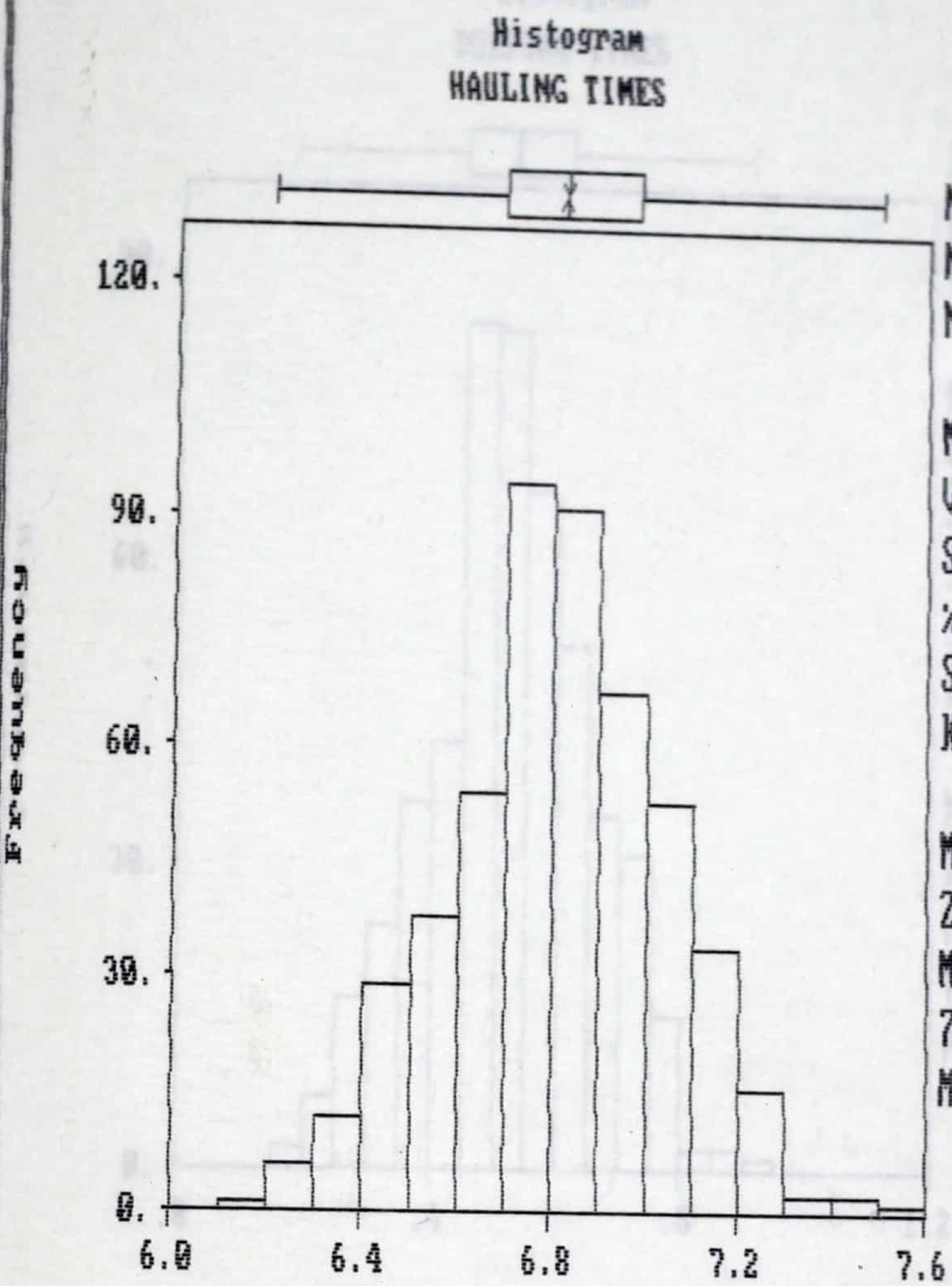


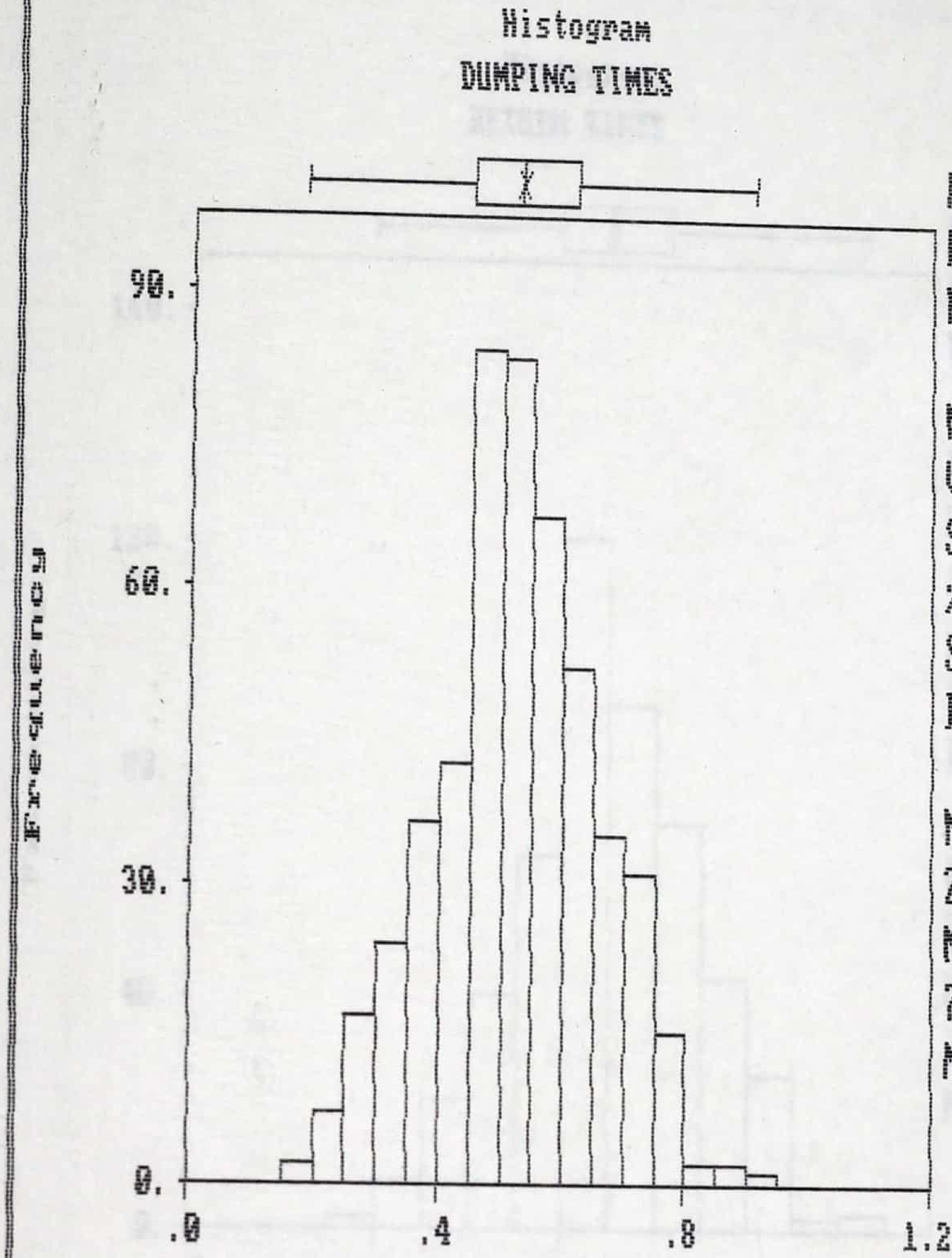
Fig 4.2A Loading times (mins) for ore



Statistics

N Total	:	500
N Miss	:	0
N Used	:	500
Mean	:	6.820
Variance	:	.053
Std. Dev	:	.230
% C.V.	:	3.369
Skewness	:	-.029
Kurtosis	:	2.876
Minimum	:	6.200
25th %	:	6.690
Median	:	6.820
75th %	:	6.980
Maximum	:	7.500

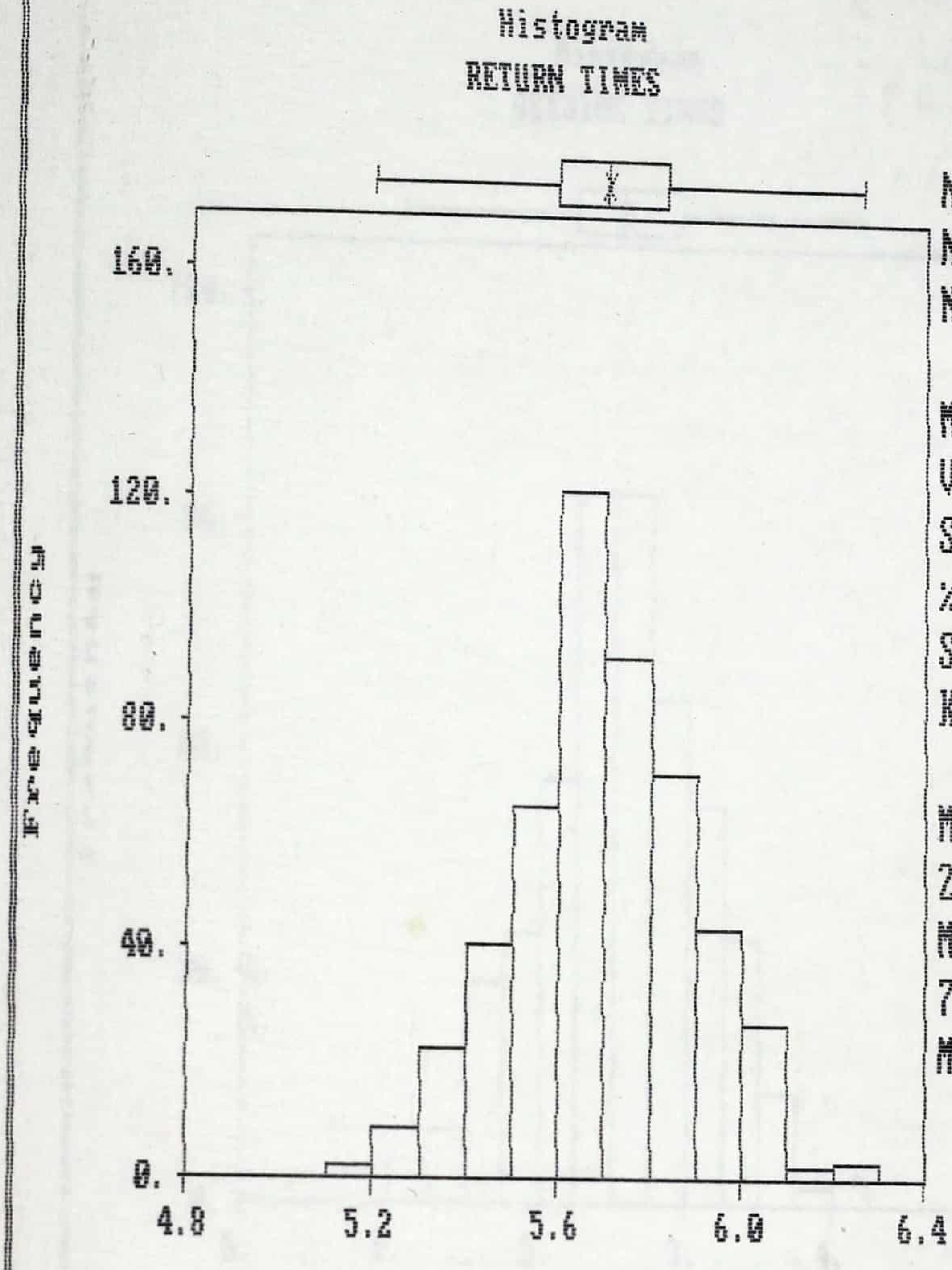
Fig 4.2B Hauling times (mins) for ore



Statistics

N Total	:	500
N Miss	:	0
N Used	:	500
Mean	:	.530
Variance	:	.017
Std. Dev	:	.130
% C.V.	:	24.532
Skewness	:	-.026
Kurtosis	:	2.873
Minimum	:	.180
25th %	:	.450
Median	:	.530
75th %	:	.620
Maximum	:	.910

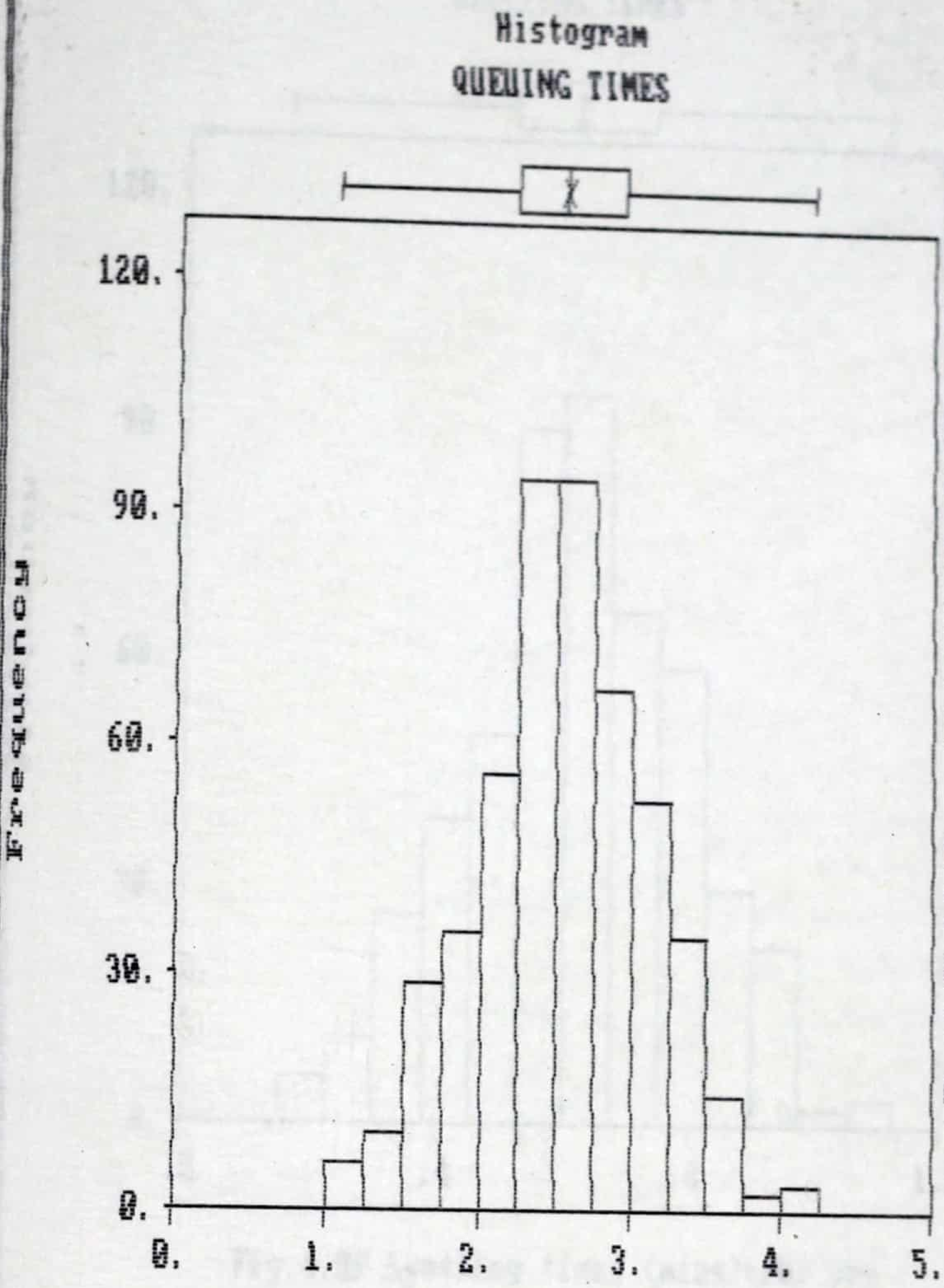
Fig 4.2C Dumping times (mins) for ore



Statistics

N Total :	500
N Miss :	0
N Used :	500
Mean :	5.700
Variance:	.036
Std. Dev:	.190
% C.V. :	3.328
Skewness:	-.032
Kurtosis:	2.867
Minimum :	5.190
25th % :	5.590
Median :	5.700
75th % :	5.830
Maximum :	6.260

Fig 4.2D Return times (mins) for ore



Statistics

N Total :	500
N Miss :	0
N Used :	500
Mean :	2.550
Variance:	.313
Std. Dev:	.559
% C.V. :	21.936
Skewness:	-.030
Kurtosis:	2.868
Minimum :	1.040
25th % :	2.220
Median :	2.545
75th % :	2.930
Maximum :	4.200

Fig 4.2E Queuing times (mins) for ore

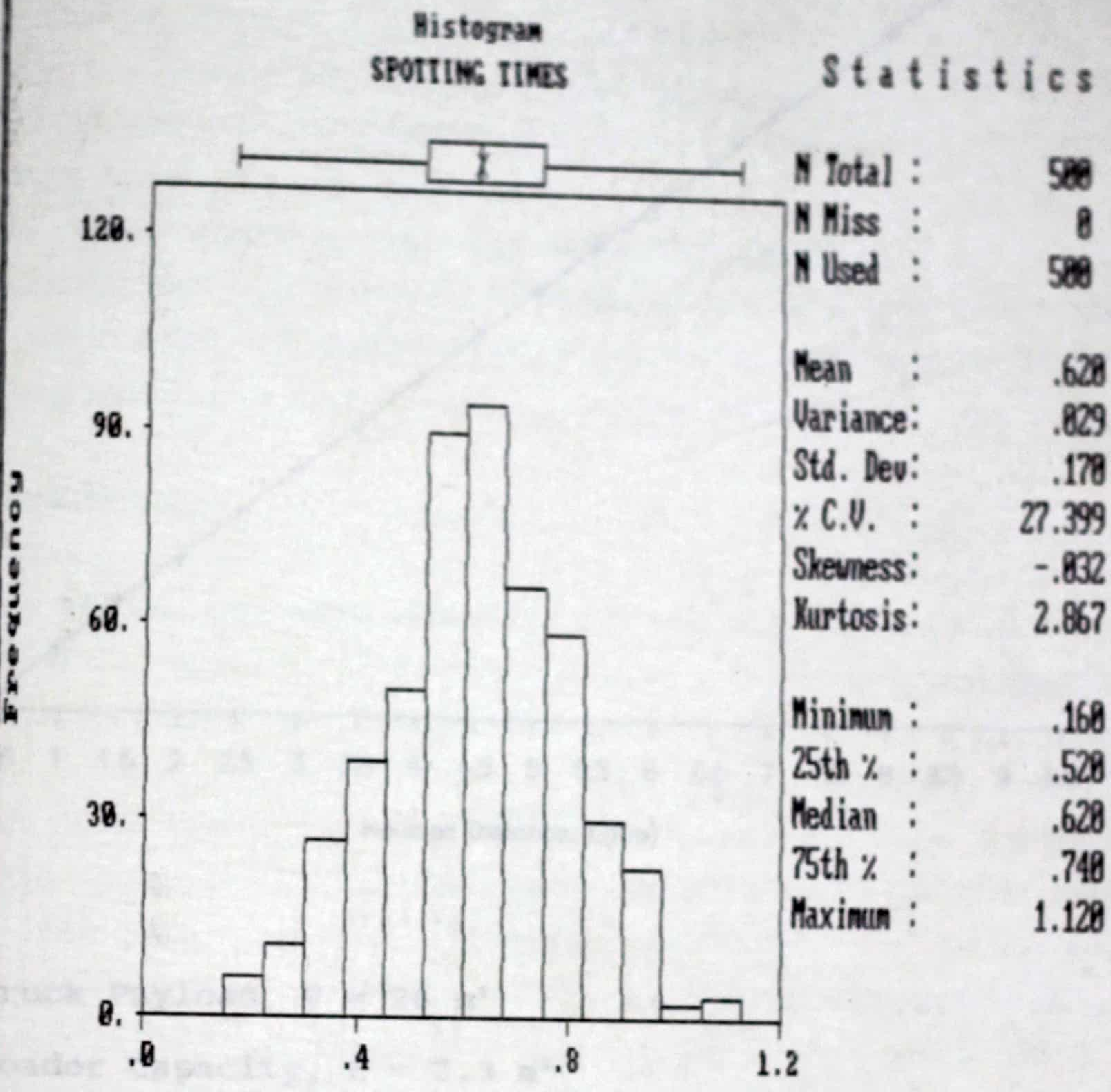
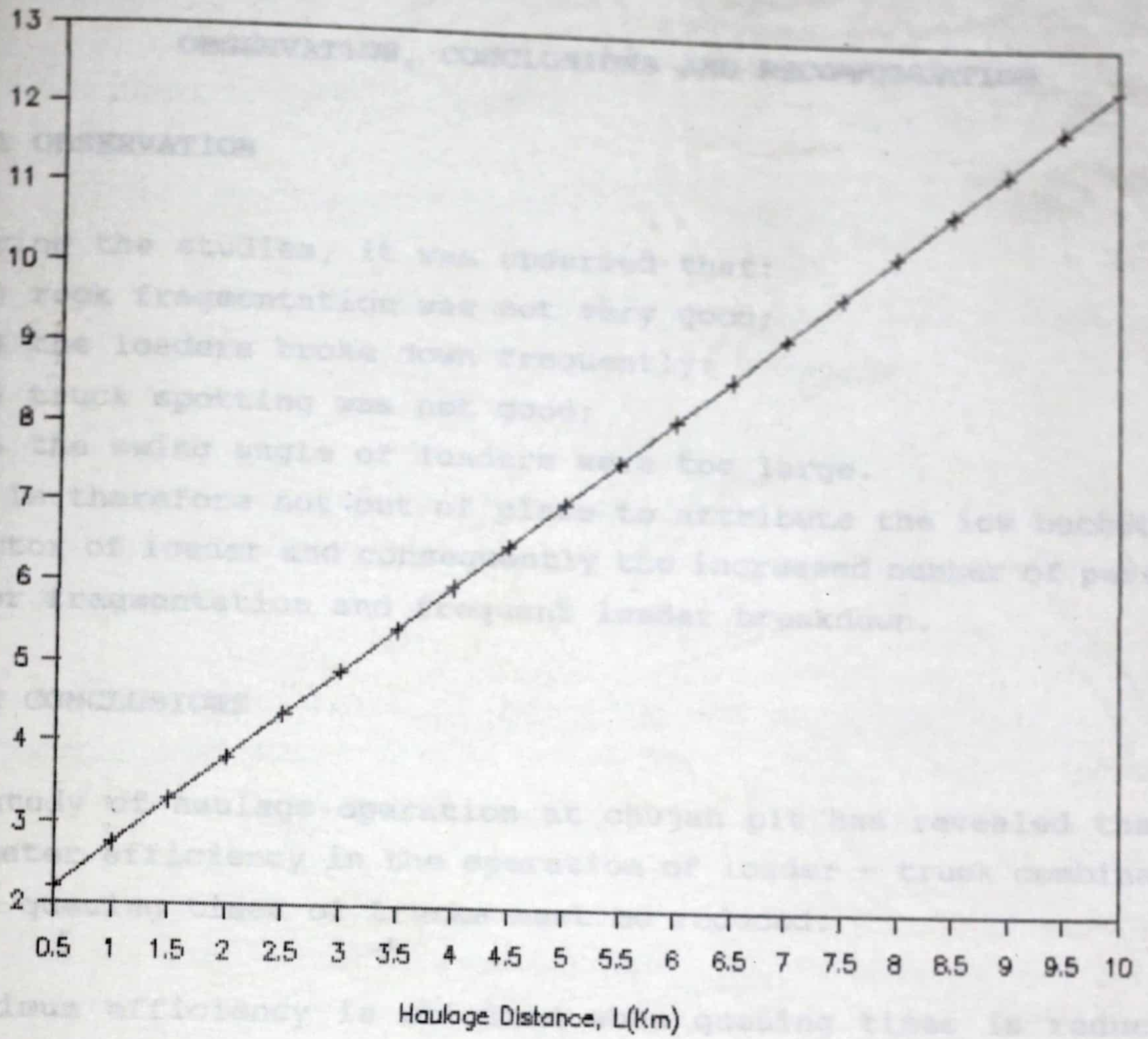


Fig 4.9F Spotting times (mins) for ore

Fig. 4.3 Graph of N vrs L



Truck Payload, V = 26 m^3

Loader Capacity, E = 3.3 m^3

CHAPTER 5

OBSERVATION, CONCLUSIONS AND RECOMMENDATION

5.1 OBSERVATION

During the studies, it was observed that:

(a) rock fragmentation was not very good;

(b) the loaders broke down frequently;

(c) truck spotting was not good;

(d) the swing angle of loaders were too large.

It is therefore not out of place to attribute the low bucket fill factor of loader and consequently the increased number of passes to poor fragmentation and frequent loader breakdown.

5.2 CONCLUSIONS

A study of haulage operation at chujah pit has revealed that for greater efficiency in the operation of loader - truck combination, the queuing times of trucks must be reduced.

Maximum efficiency is obtained when queuing times is reduced to zero. For waste haulage, the number of trucks to be assigned to the loader for maximum efficiency is estimated to be 3 for waste haulage, and 5 for ore haulage. By Professor Rjevcki's method, the number of trucks to match the loader were also estimated to be 3 for waste haulage and 5 for ore haulage respectively. Both methods of estimation therefore gave the same results. For waste and ore haulage at Chujah Pit, B.B.G. allocates 3 and 4 trucks respectively to the loader. It is therefore expected that, though no queuing of trucks should occur for these matchings, it exists. This is the result of the problems enumerated in the observations above.

For the four other pits of B.B.G. with different haulage distances, the number of trucks required to match the loader for efficient operation could be estimated using the proposed formula by Professor Rjevcki.

5.3 RECOMMENDATIONS

It is hereby recommended that:

(a) The blasting design at B.B.G. be improved to ensure good fragmentation, increased bucket fill factor of loader to reduce loading time;

(b) A better maintenance programme that will further reduce the rate of equipment breakdown is necessary to enhance shovel-truck operation;

Driver training experience!

(c) Loading spots must be properly set and truck operators must correctly spot their trucks below the backhoe loader's tracks, to minimise swing angle. The parking when perfectly done will provide excellent eye-to-eye contacts between the operators. According to Windfred, 1984, if swing angle is increased 30°, it adds about one second to the loader's time and cuts production by 7%. Operator training can surely bring about reduction in swing angle. There is room for improvement if B.B.G. reduces queuing and for that matter idle times of trucks.

(d) The graph plotted at Fig. 4.3 be used to estimate the number of trucks to a loader when work resumes on the four other Pits for efficient haulage.

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Appendix 1

Truck Payload and Number of trucks for Loader bucket size, E=3.2m³ at different Haulage Distances.

Haulage Distance L (Km)	Truck Payload V (m³)	Number of Trucks N
1	16.77	6
2	14.03	8
3	12.37	9
4	11.81	11
5	12.33	12
6	13.95	12
7	16.65	12
8	20.45	12
9	25.33	11
10	31.31	10

Appendix 2

Truck Payload and Number of trucks for Loader bucket size, E=4.0 m³ at different Haulage Distances.

Haulage Distance L (Km)	Truck Payload V (m³)	Number of trucks N
1	19.45	6
2	16.71	8
3	15.05	10
4	14.49	11
5	15.01	12
6	16.63	12
7	19.33	13
8	23.13	13
9	28.01	12
10	33.99	12

Appendix 3

Truck Payload and Number of trucks for Loader bucket size, $E= 5.0\ m^3$ at different Haulage Distances.

Haulage Distance L (Km)	Truck Payload V (m^3)	Number of trucks N
1	22.73	7
2	19.99	8
3	18.33	10
4	17.77	11
5	18.29	12
6	19.91	13
7	22.61	13
8	26.41	13
9	31.29	13
10	37.27	13

Appendix 4

Truck Payload and Number of trucks for Loader bucket size, $E=6.3\ m^3$ at different Haulage Distances.

Haulage Distance L (Km)	Truck Payload V (m^3)	Number of trucks N
1	26.88	7
2	24.13	8
3	22.48	10
4	21.91	11
5	22.44	12
6	24.05	13
7	26.76	13
8	30.55	14
9	35.44	14
10	41.41	14

Appendix 5

Truck Payload and Number of trucks for Loader bucket size, $E=8.0m^3$ at different Haulage Distances.

Haulage Distance L (Km)	Truck Payload V (m^3)	Number of trucks N
1	32.10	7
2	29.35	9
3	27.70	10
4	27.13	11
5	27.66	12
6	29.27	13
7	31.98	14
8	35.77	14
9	40.66	15
10	46.63	15

Appendix 6

Truck Payload and Number of trucks for Loader bucket size, $E=10.0m^3$ at different Haulage Distances.

Haulage Distance L (Km)	Truck Payload V (m^3)	Number of trucks N
1	37.96	7
2	35.21	9
3	33.56	10
4	32.99	11
5	33.52	12
6	35.13	13
7	37.84	14
8	41.63	14
9	46.52	15
10	52.49	15

Appendix 7

Truck Payload and Number of trucks for Loader bucket size, E = 12.5 m^3 at different Haulage Distances.

Haulage Distance L (Km)	Truck Payload V (m^3)	Number of trucks N
1	44.84	8
2	42.09	9
3	40.44	10
4	39.87	11
5	40.40	12
6	42.01	13
7	44.72	14
8	48.51	15
9	43.40	15
10	59.37	16

Appendix 8

Truck Payload and Number of trucks for Loader bucket size, E=3.2m^3 at different Haulage Distances.

Haulage Ditance L (Km)	Truck Payload V (m^3)	Number of trucks N
1	53.65	8
2	50.91	9
3	49.25	10
4	48.69	11
5	49.21	12
6	50.83	13
7	53.53	14
8	57.33	15
9	62.21	16
10	68.19	17

Appendix 9

Truck Payload and Number of trucks for Loader bucket size, E=20.0 m^3 at different Haulage Distances.

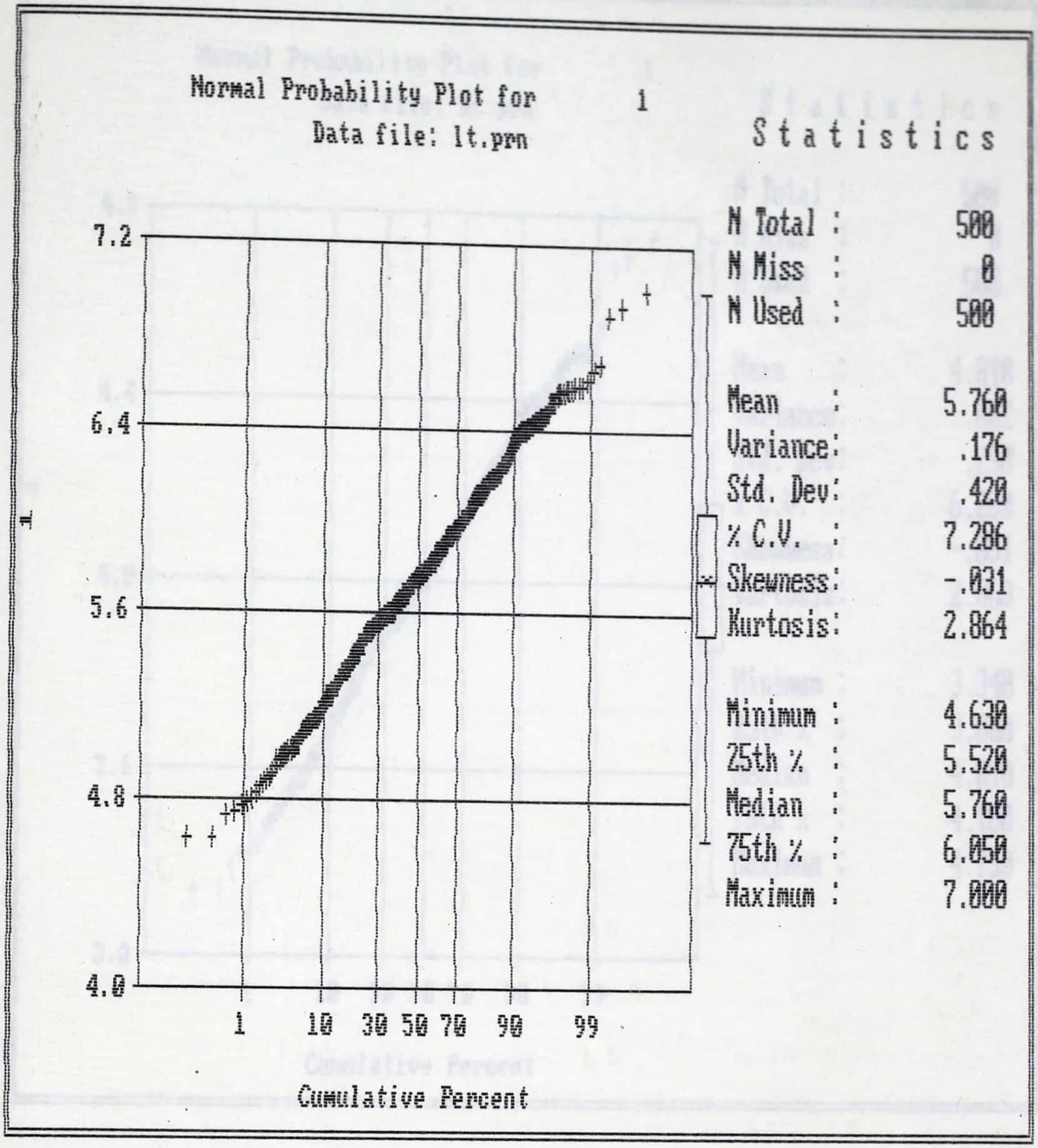
Haulage Distance L (Km)	Truck Payload V (m^3)	Number of trucks N
1	62.56	8
2	59.81	9
3	58.16	11
4	57.59	12
5	58.12	13
6	59.93	14
7	62.44	15
8	66.23	15
9	71.12	16
10	77.09	17

Appendix 10

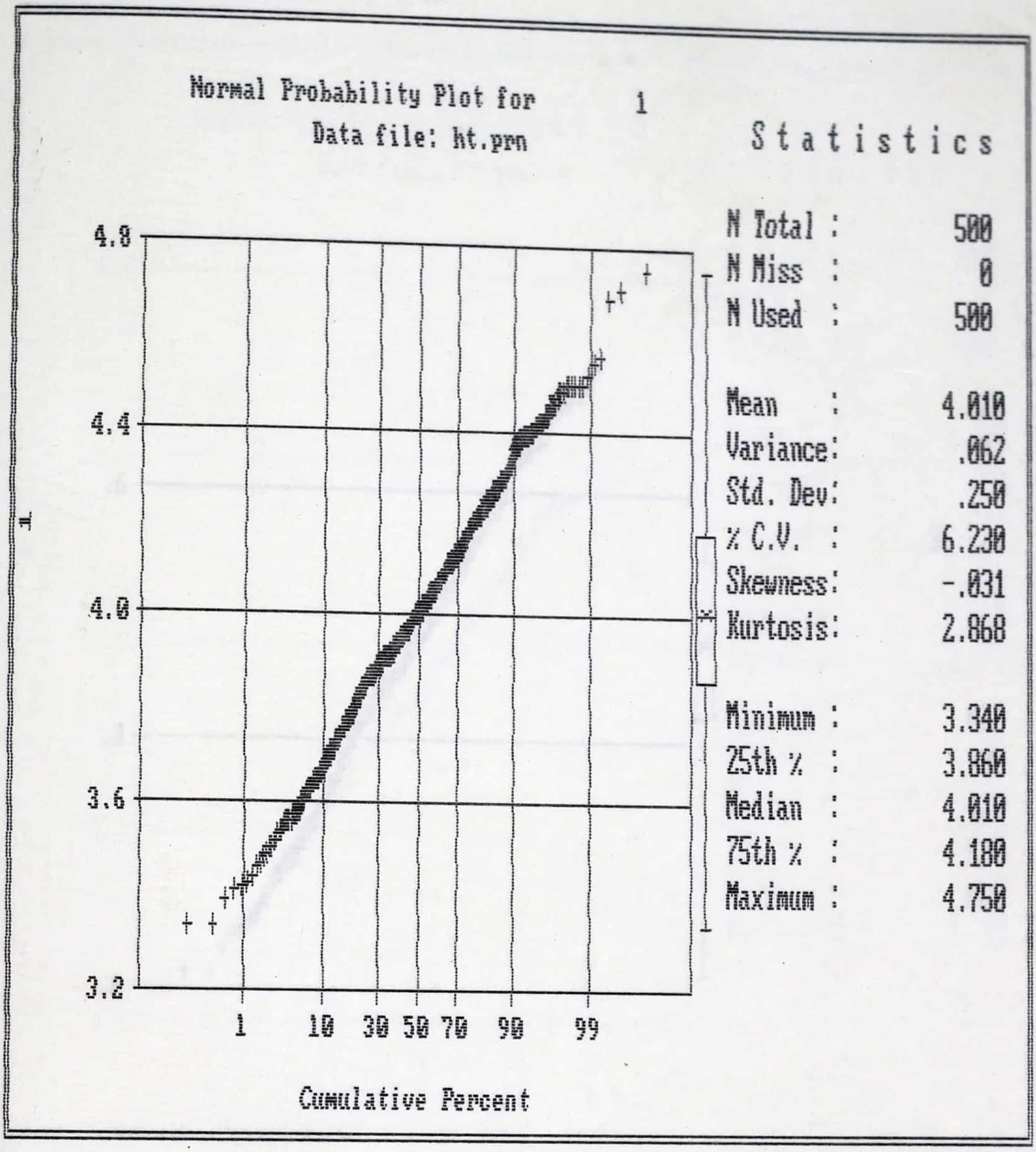
Truck Payload and Number of trucks for Loader bucket size, E=25.0m^3 at different Haulage Distances.

Haulage Distance L (Km)	Truck Payload V (m^3)	Number of trucks N
1	71.93	8
2	69.19	10
3	67.53	11
4	66.97	12
5	67.49	13
6	69.11	14
7	71.81	15
8	75.61	16
9	80.49	17
10	86.47	17

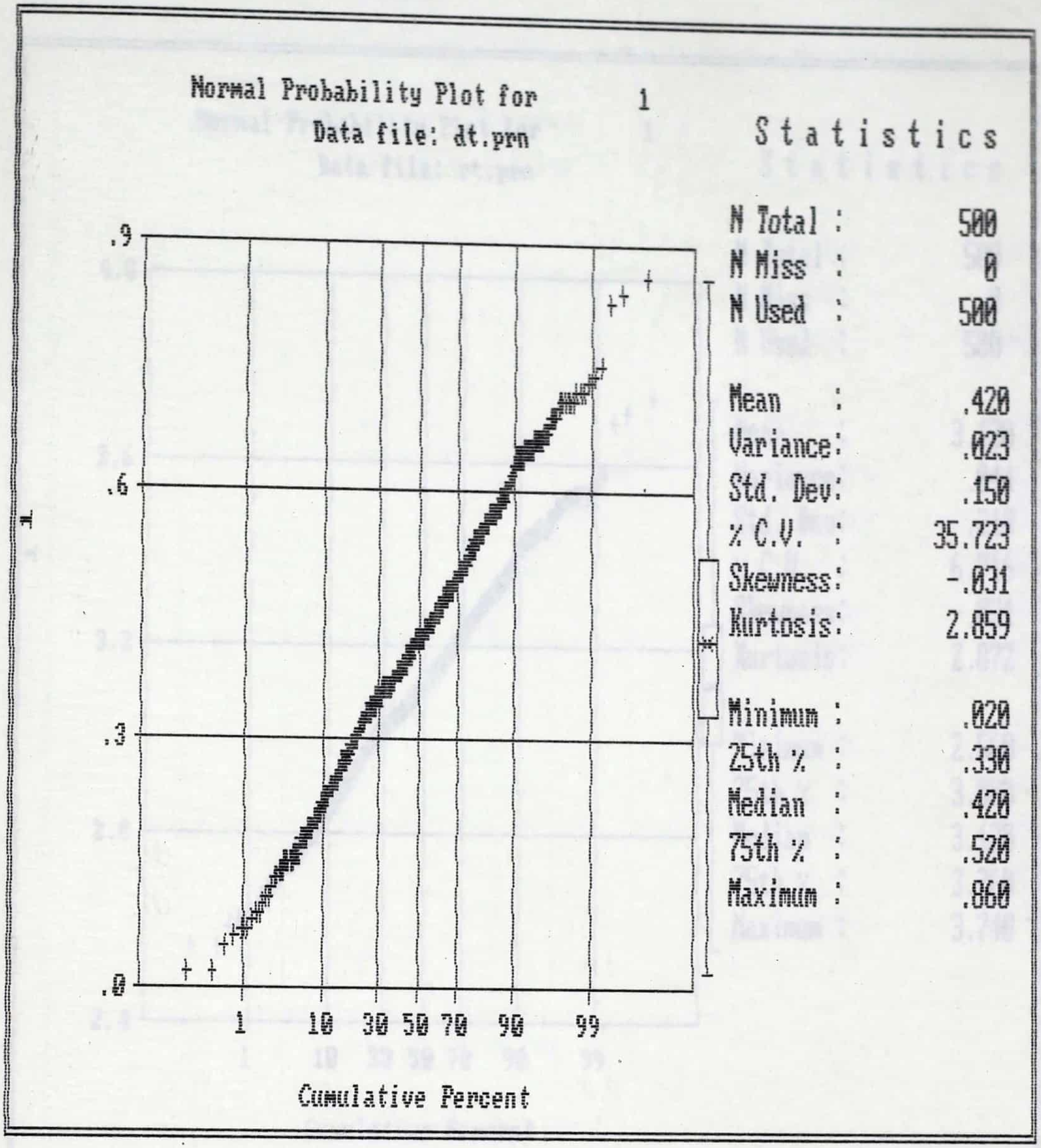
Appendix 11
Loading times for waste



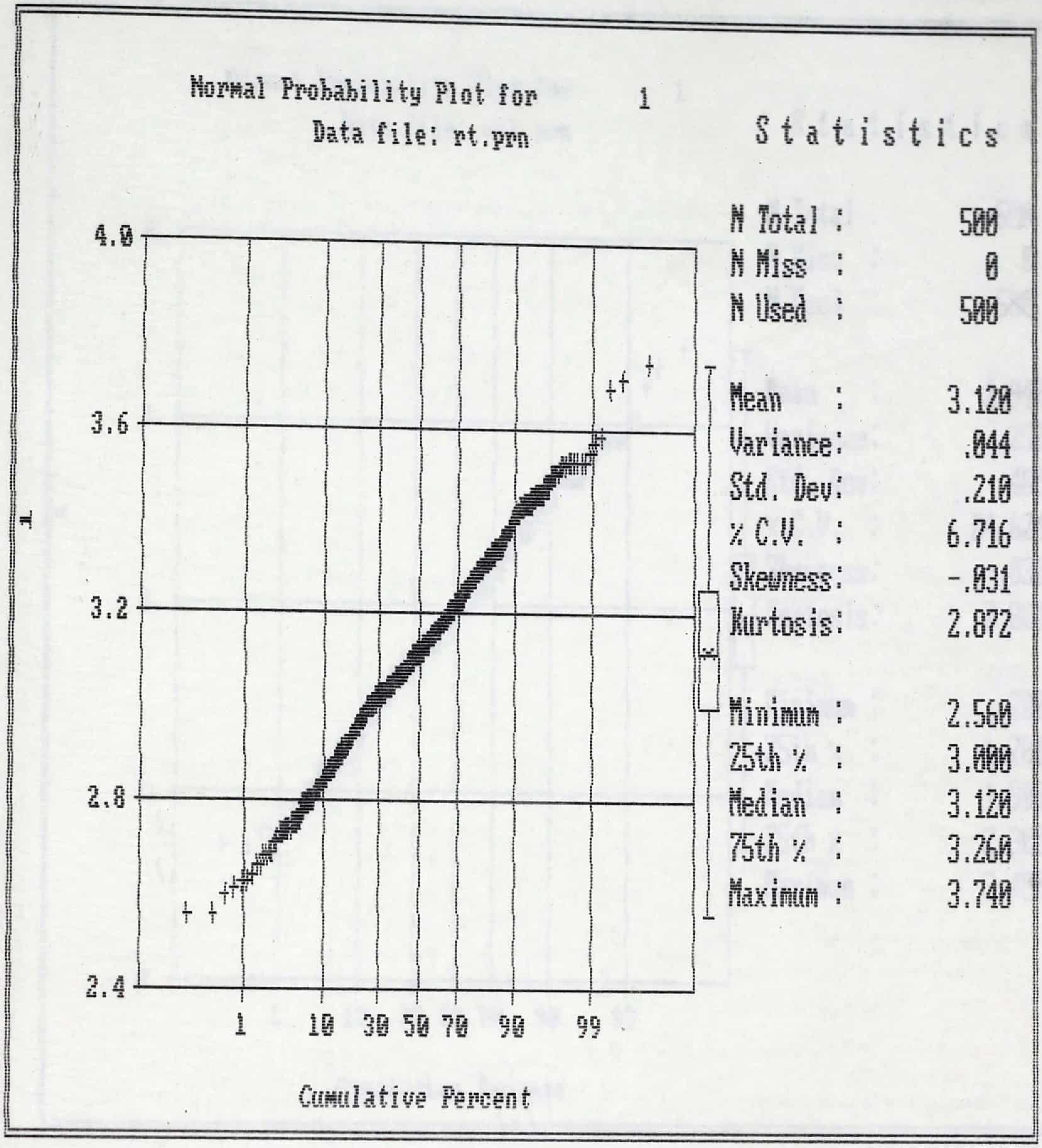
Appendix 12
Hauling times for waste



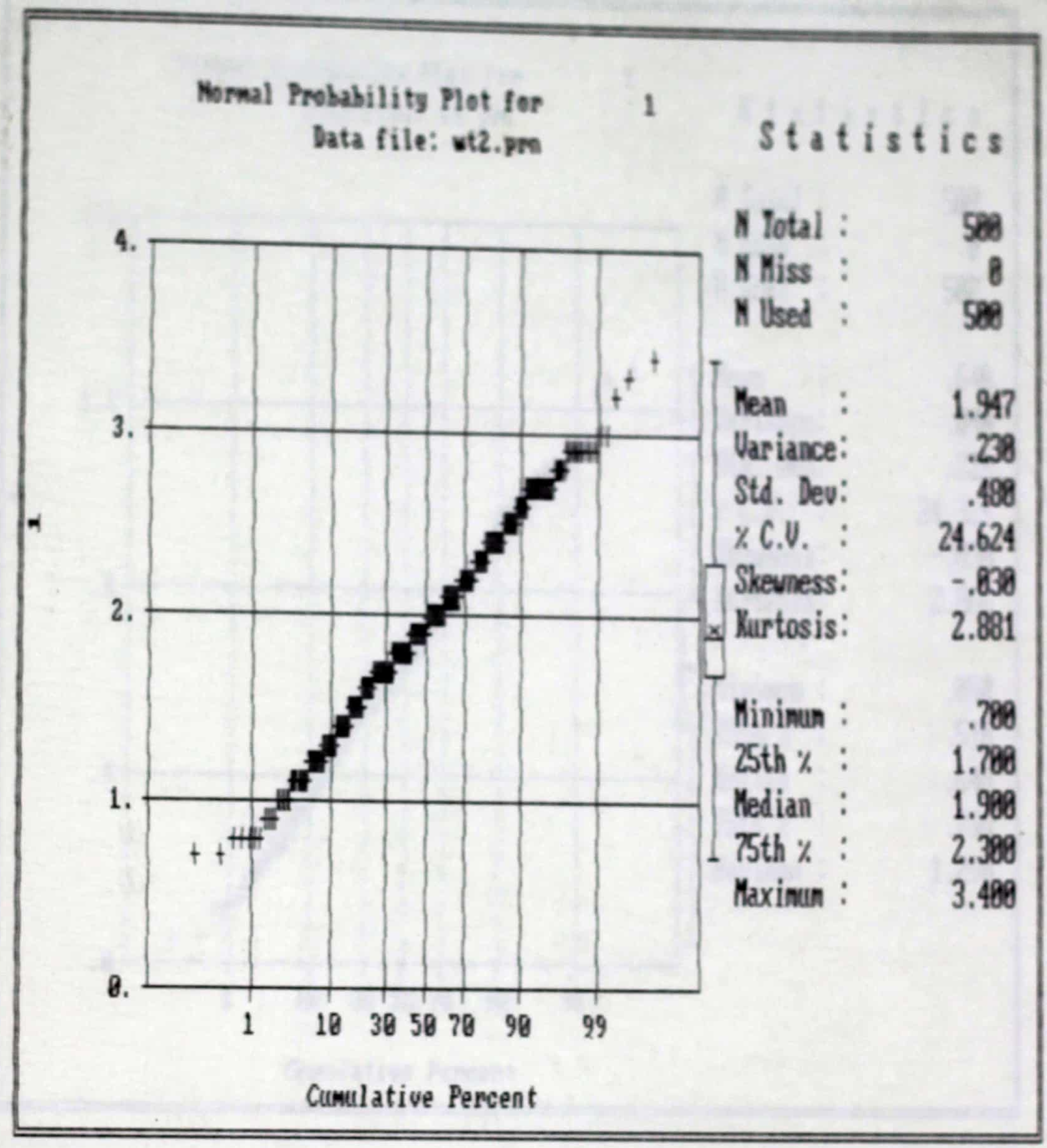
Appendix 13
Dumping times for waste



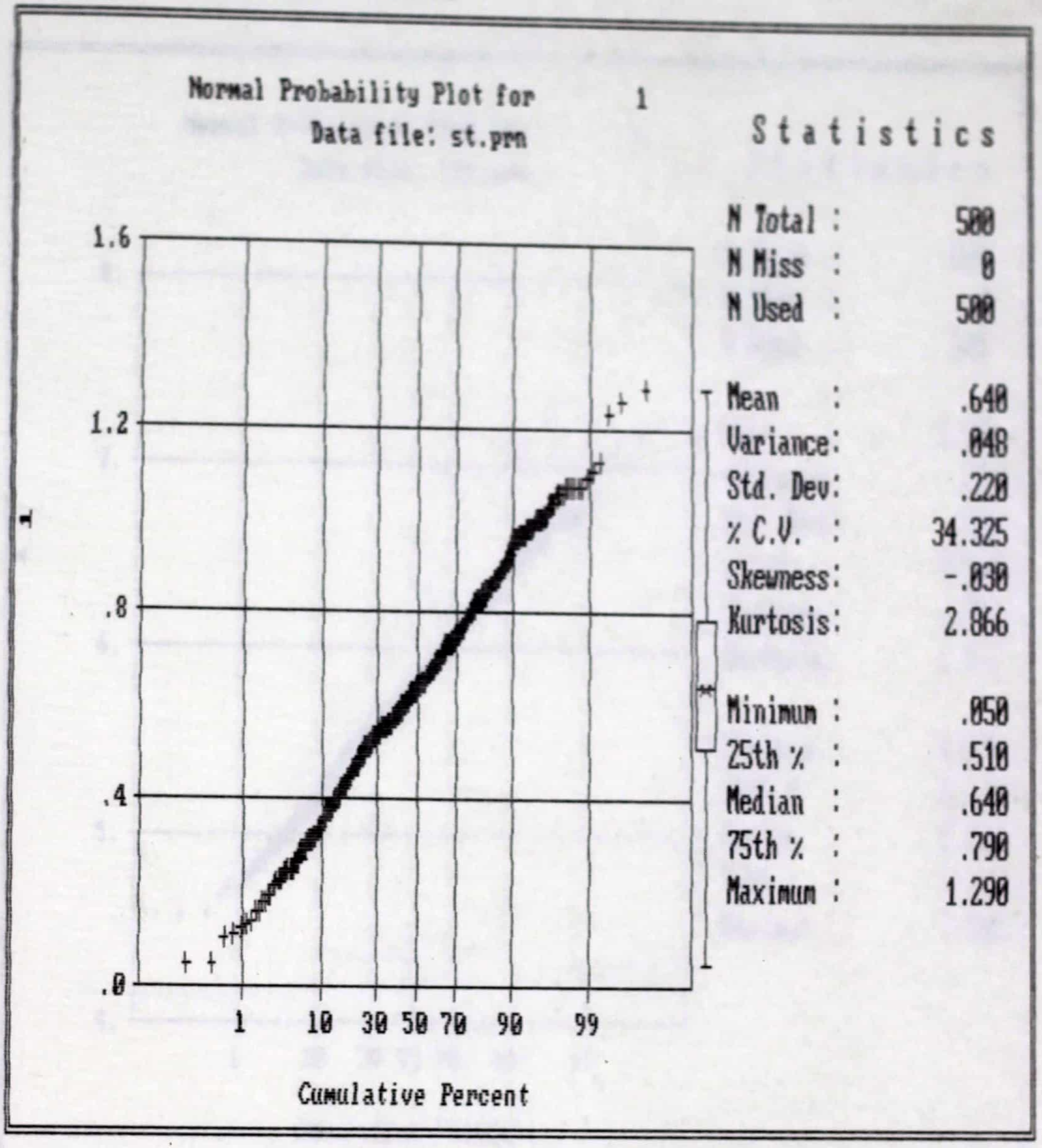
Appendix 14
Return times for waste



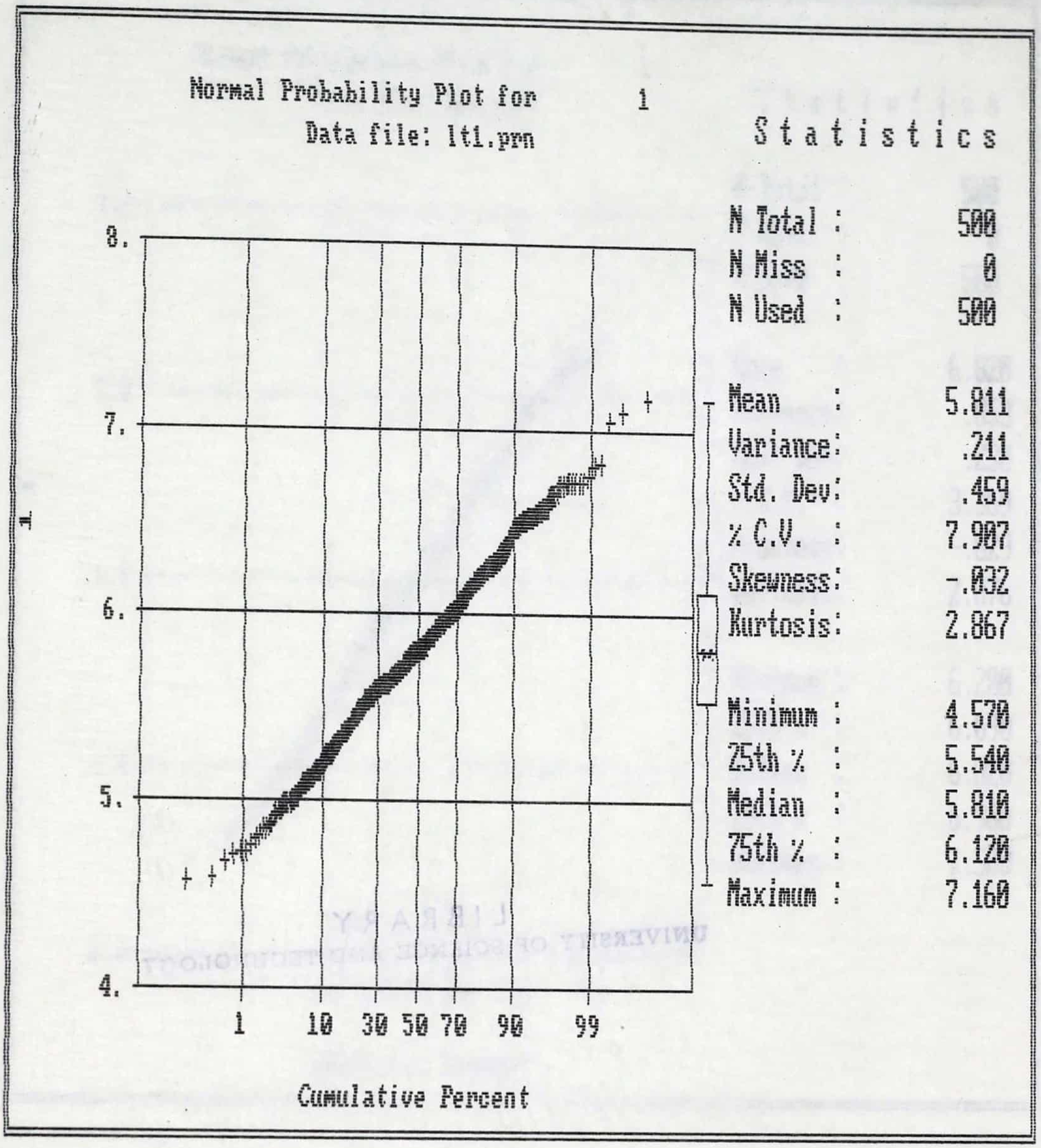
Appendix 15
Queuing times for waste



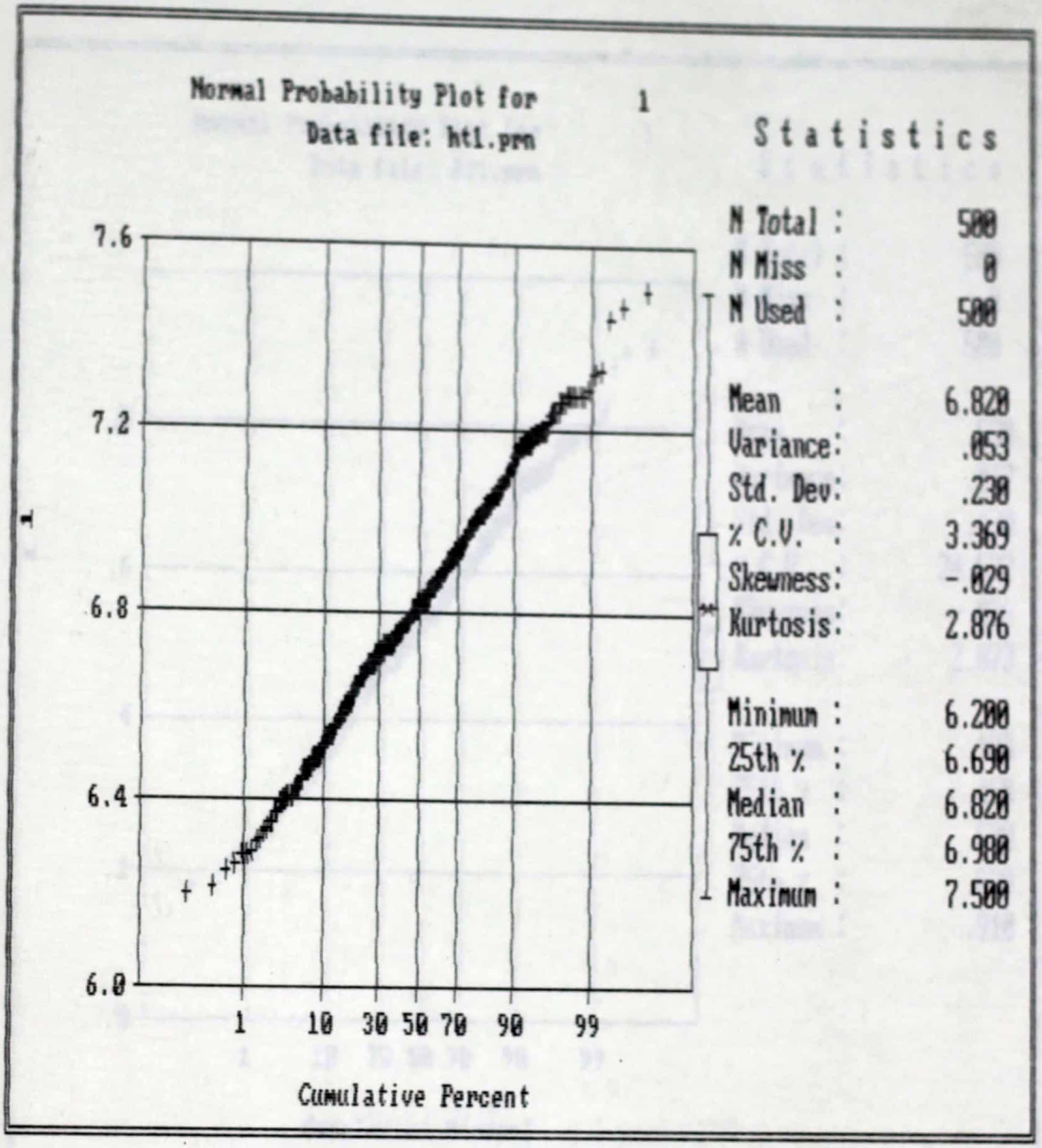
Appendix 16
Spotting times for waste



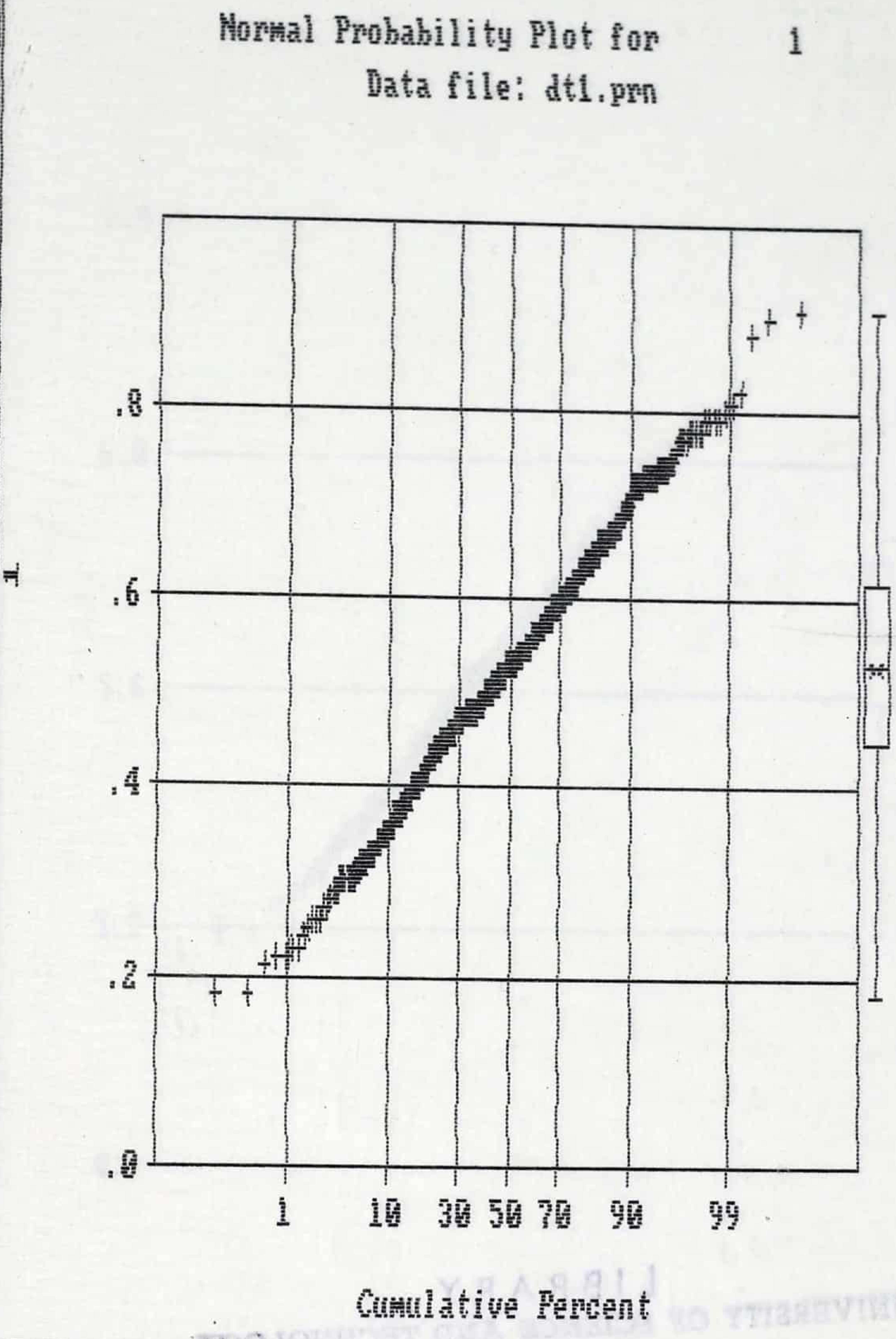
Appendix 17
Loading times for ore



Appendix 18
Hauling times for ore



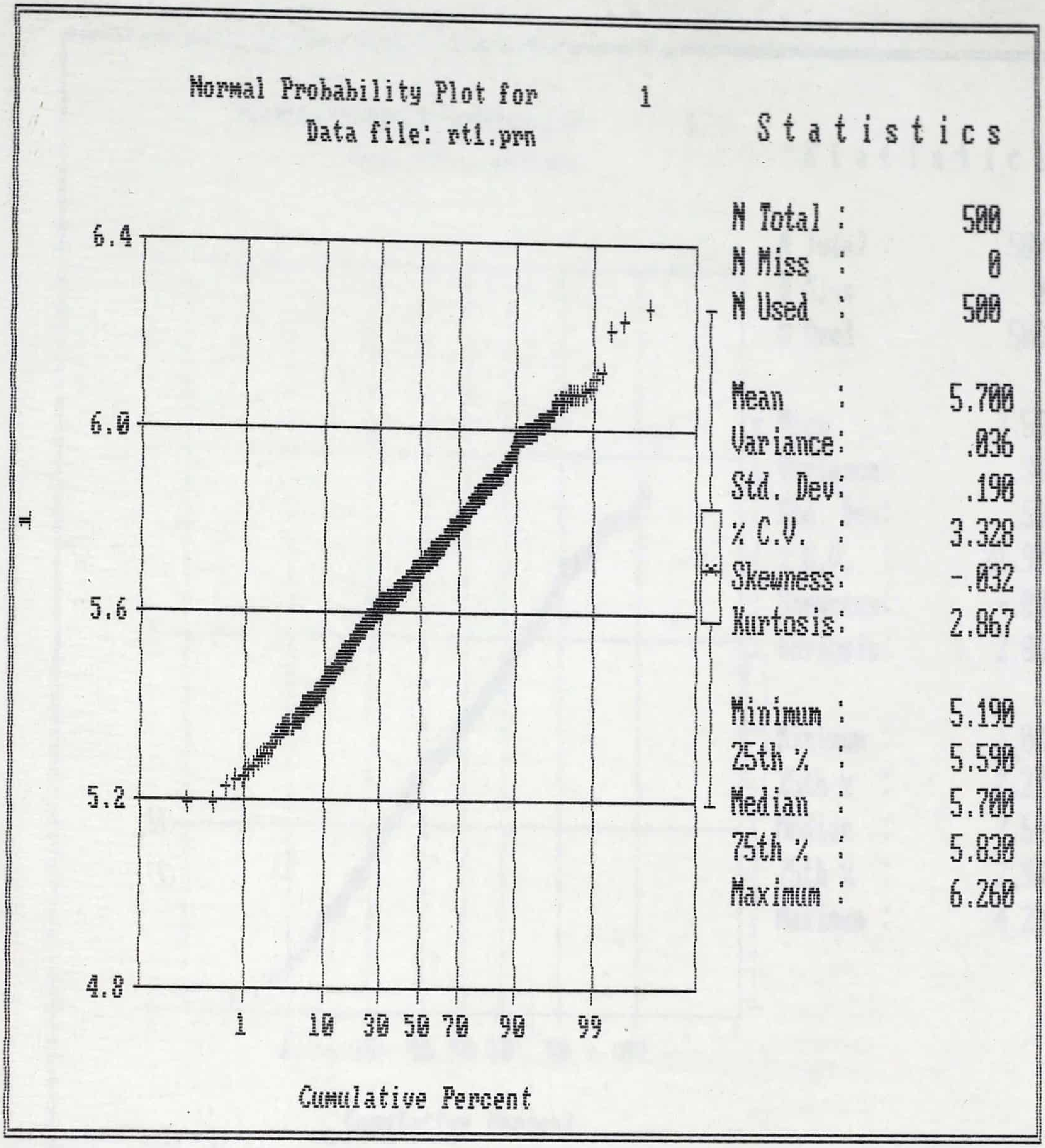
Appendix 19
Dumping times for ore



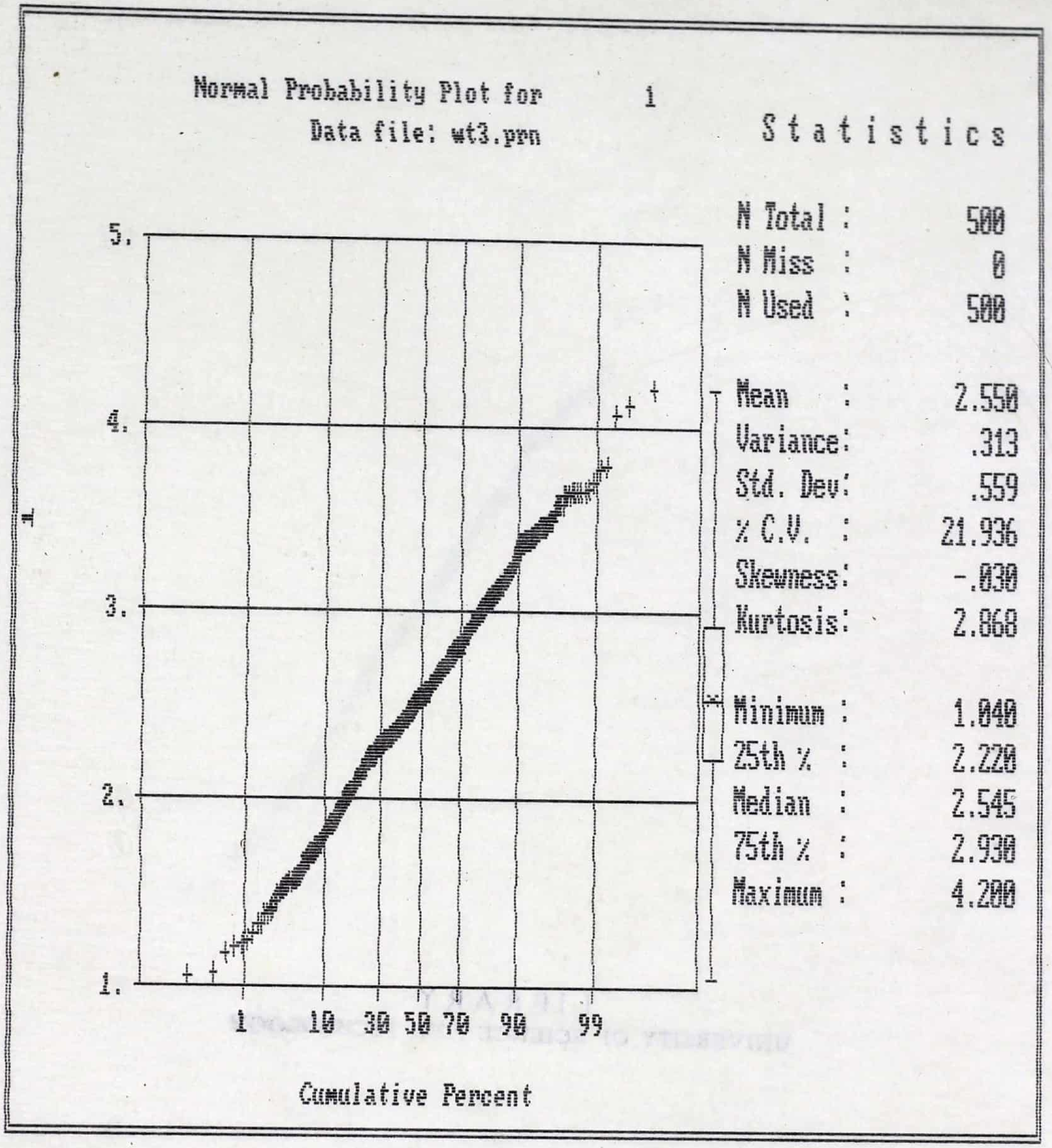
Statistics

N Total :	500
N Miss :	0
N Used :	500
Mean :	.530
Variance:	.017
Std. Dev:	.130
% C.V. :	24.532
Skewness:	-.026
Kurtosis:	2.873
Minimum :	.180
25th % :	.450
Median :	.530
75th % :	.620
Maximum :	.910

Appendix 20
Return times for ore



Appendix 21
Queuing times for ore



Appendix 22
Spotting times for ore