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GUIDELINE MANUAL FOR FRONT-END LOADER LOAD-AND-CARRY APPLICATIONS

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MARTIN CONSULTANTS, INC.

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FORWARD

This report was prepared by Martin Consultants, Inc. under USBM Contract number J0205045. The contract was initiated under the Bureau of Mines Mineral Resource Technology -- Surface Mining Program. It was administered under the technical direction of the Spokane Research Center with Mr. Samuel F. Pangerl acting as Technical Project Officer. Mr. Larry L. Rock was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period of July 7, 1980 to May 5, 1981. This report was submitted by the authors on May 6, 1981.

The authors would like to gratefully acknowledge the assistance given by mine operators and equipment manufacturers in the course of preparing this manual. Without this help and encouragement, much of the data contained herein would have been unavailable.

This report was prepared by Martin Consultants, Inc. with James W. Martin acting as project leader. Contributions to this study were also made by Donald W. Gentry, Professor, Colorado School of Mines; Matthew J. Hrebar, Associate Professor, Colorado School of Mines; and Karl R. Nelson, Assistant Professor, Colorado School of Mines.

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SECTION I

INTRODUCTION

PURPOSE AND SCOPE OF MANUAL

This manual presents data relating to the applications, selection and utilization of front-end loaders (FEL) in load-and-carry mining operations. Further, it contains a method of consolidating and arranging pertinent information so that this approach can be evaluated.

To date, front-end loaders used in mining have been applied primarily to truck loading, stockpile and general utility work. Increasing concern for fuel consumption, combined with the ever present need for mining flexibility, introduces the question of loader use in short haul situations. Increasing use of belt conveyors fed by hoppers or hopper/crushers located close to the digging face and at the same elevation is directed towards reducing the costs associated with material transport up grades to the pit perimeters. Mobile or portable hopper and conveyor units permit periodic advancing along with the digging face and result in the need for an excavating, short haul machine -- such as the rubber tired loader to complement the system.

It is assumed that users of this manual have a general familiarity with heavy equipment operation and mine requirements. The role that the loader can play in mine planning is reviewed along with operating techniques and equipment selection. Production and cost estimating procedures are provided for evaluation of the FEL load-and-carry system.

No attempt has been made to provide comparative cost data for alternative production systems. The number of alternative equipment combinations is almost infinite and beyond the scope of this manual. Similarly, detailed requirements for matching units in the overall haulage plan, such as hoppers and conveyors, are not considered in depth.

While aspects of the sizing and selection of a front-end loader are discussed and specifications included of available commerical units, recommendations are not made for the selection of any specific manufacturer's models. It is assumed that at this stage of evaluation the planner will solicit quotations from suppliers of interest based on previous association, proximity, or information provided in inquiries. Machine pricing and delivery information is constantly changing because of technology and economic conditions which can only be effectively introduced at the time final action on procurement is anticipated. While much of the information included is expected to be applicable for many years, it should be recognized that evolving technology will affect FEL specifications and the relative attractiveness of the outlined system may be significantly impacted by new competitive equipment and/or other components in the total haulage system.

A manual type format is utilized rather than that of a study report, to provide a more concise, summary type treatment of the various subjects. Emphasis is placed on those areas which are believed to be significant to application evaluation. Where there was a broad range of experience and philosophies, an attempt was made to consolidate these views into what appeared to be the best approach based on current information.

The information contained in this manual has been assembled from discussions with operating personnel at mines and equipment manufacturers, plus an extensive review of published literature. Mines utilizing load-and-carry techniques were visited; brief time studies were made at these sites to supplement existing available information.

HOW TO USE MANUAL

The manual is arranged to present the subject material in the normal sequence of evaluation for considering the use of front-end loaders in a load-and-carry operation. In brief, this procedure can be summarized as follows:

- When should a front-end loader be considered in a load-and-carry operation? (Sections II and III)
- What mine planning factors must be considered? (Section IV)
- What site conditions are involved in the application and influence system performance? (Section IV)
- What should be considered in selecting a specific loader for an application? (Section V and VI)
- How to estimate production capability of the FEL? (Section VII)
- How to estimate ownership and operating costs? (Section VIII)
- What operating and safety practices are common in these types of operations? (Section IX, X and XI)
- What are the specifications and characteristics of commercially available loaders? (Appendices A, B, and C)

The table of contents provides a detailed subject break-down, permitting direct reference to individual sections for on-going operations.

The overall process of mine system planning and equipment selection generally involves initially establishing the production targets and site constraints. Based on these, a number of equipment options and alternatives are considered which would fulfill the requirements under the stated conditions and meet acceptaable cost levels. By progressive refinement, the equipment specifications and detailed operational plans are finalized. A series of worksheets and checklists have been provided for each phase of the evaluation to indicate the type of information that is needed in this process.

- General Considerations Worksheet (Form 1)
- Geologic Information Checklist (Form 2)
- Site and Operating Conditions Checklist (Form 3)
- Machine Selection Checklist (Form 4)
- Production Estimate Worksheet (Form 5)
- Ownership & Operating Cost Worksheet (Form 6)

The text's discussion addresses the reasons and background for the selection and use of specific data. The worksheets obviously can be modified to suit any special situation. They are aimed primarily at encouraging a comprehensive and systematic analytical approach to the evaluation procedure, and provide a means of documenting the analysis to support the final conclusions.

Appropriate support data, when practical, has been included in the text as required. This includes a variety of data such as material weights, bucket fill factors, tire work factor, capability factors, etc. In addition, other more extensive input data have been included in the appendices.

- Loader Manufacturers
- Loader Specifications
- Tire Manufacturers and Models

Following through the discussion and analysis proposed in this manual should provide essential information for selection and installation of a load-and-carry operation. If site requirements are such that alternate methods and equipment could be effectively utilized, a similar evaluation of these systems would have to be performed and final selection made based on the relative economics. In comparative analyses of this type, care must be exercised to make certain that all <u>system</u> costs such as haul road maintenance, power distribution, maintenance and facilities and manpower, auxiliary components, etc., are included.

Finally, there are miscellaneous formulae and tables, plus a short list of selected references in the appendices, categorized by subject area for the user who desires additional information.

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SECTION II

ALTERNATIVE MATERIAL HANDLING SYSTEMS

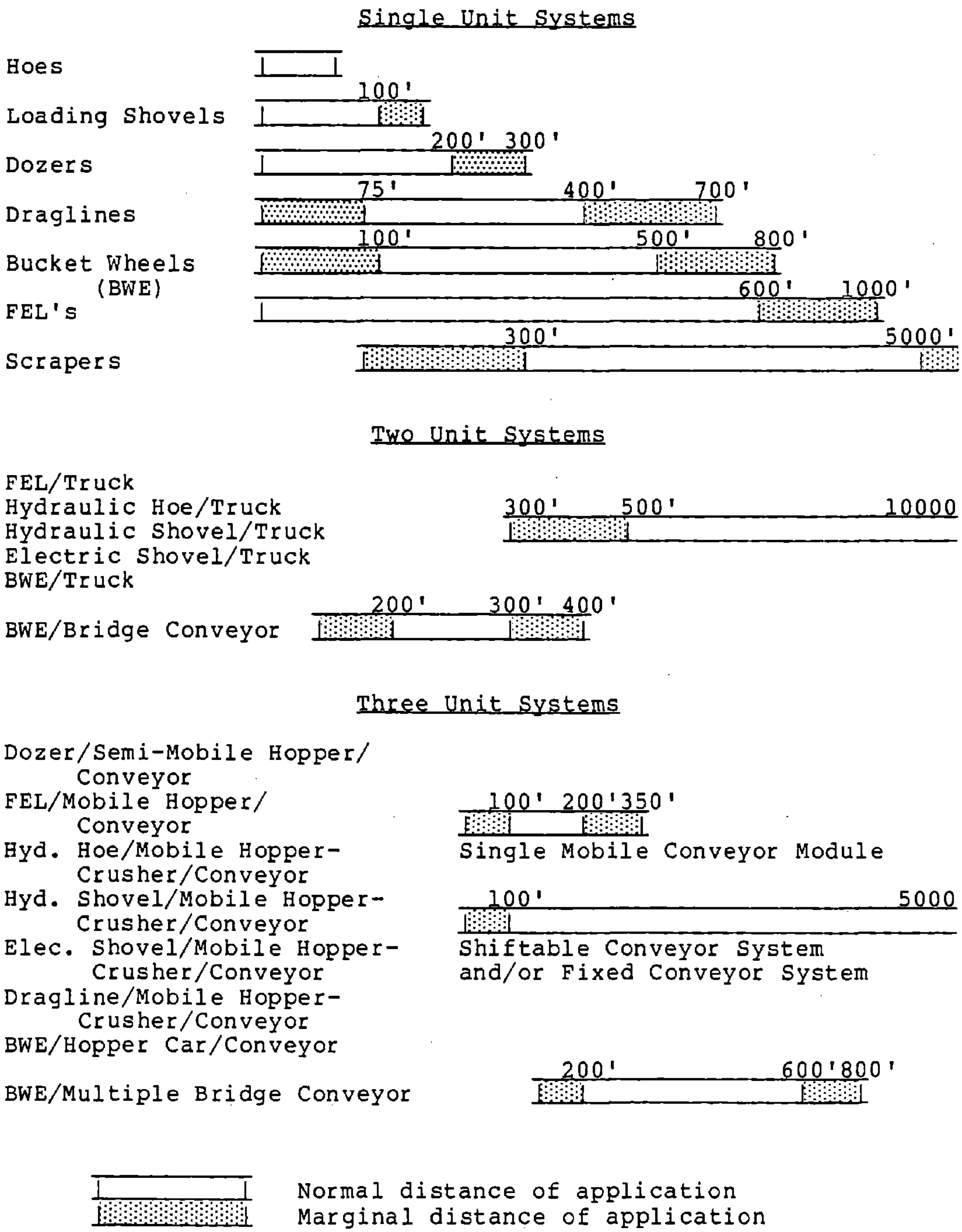
Numerous material handling systems are available for material movement, including excavation and haulage, as indicated in Table II - 1. This table concentrates on mobile units used in the pit and omits reference to systems incorporating rail or slurry pipeline. Pit rail systems are seldom considered in current mine planning except where very large daily capacities are planned. Slurry systems, with questionable economics at the distances involved, have not been employed in-pit to date.

The systems vary in complexity as well as range of typical haulage distance. The imposed distance limitations may be either physical or economic. For example, a long boom dragline would be limited to movement of material a total of 600 ft. because of physical limitations and design of the machine. Material movement over greater distance would require costly rehandling. Conversely, a FEL has the physical capability to move material over long distances but is limited by economics since alternative systems would provide a more economic means of transportation at greater distances. In general, the simple single unit systems are restricted to relatively short distances while the more complex excavator/truck or excavator/conveyor systems can be applied to either short or long hauls. The requirement for size reduction in the system, which is a function of geology or material fragmentation will also contribute to system complexity. When the transportation link requires a maximum topsize, a sizing device such as a breaker or crusher is required in the system to control oversize.

In primary mining production activities, the material handling system can be viewed as consisting of three components -excavation, face haulage and main haulage. Equipment can be selected to perform each of these activities or combinations of these activities. For example, a loading shovel may perform the excavation and trucks may perform face haulage and a conveyor may perform the main haulage to a processing facility. As an alternative, the trucks may be used to haul directly from the excavation area to the processing area, combining the face and main haulage activities.

Table II - 1

MINING SYSTEMS VS. TRANSPORT DISTANCE



Typical primary and auxiliary mining functions can be grouped by haul distance as follows:

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Short Haul	Typical Distances	Characteristics
excavating face to stockpile excavating face to hopper excavating face to spoil	150-1000 ft.	variable as mining face advances
Short Haul - Auxiliary		
stockpile to stockpile stockpile to hopper	50-500 ft.	fixed distances set by plant design
Long Haul		
excavating area to stockpile excavating area to spoil excavating area to processing	more than 1000 ft.	minor variation as mining face advances

The materials handling systems deserve a significant amount of attention because of their high level of energy consumption and associated operating costs. Haulage with mobile diesel equipment, particularly over long distances and steep grades, is a heavy energy consumer and a heavy consumer of high cost petroleum related products such as tires.

As a prime alternative, belt haulage with electric drives is more energy efficient and provides lower operating costs. In order to incorporate belt haulage into the mine material handling system and take full advantage of the economics, excavated material must be transferred to the belt as soon as practical. The hopper/conveyor interface can be provided with units initially located near the excavating face and periodically relocated when the haul distance is considered uneconomical, or with a fully mobile hopper and shiftable/extensible conveyor, which progresses intermittently with the excavator within its disposal range.

Feeding a belt conveyor with a central hopper/crusher located on the bench or pit bottom permits a simple system, a variety of options and excellent mine planning flexibility. This approach requires evaluation of the excavating and short haul equipment alternatives available to feed the hopper and, in turn, the main haulage system. The available alternatives are shown in Table II - 2. The "dump" or disposal possiblities are indicated as they vary with the system.

Table II - 2

SHORT HAUL TRANSPORT
CONFIGURATIONS
(Excavation and Face Haulage)
(0 to 1000 feet)

Excavate		Transport	Dump
FEL Hydraulic excavator Electric shovel Wheel excavator	→	truck →	spoil over bank stockpile hopper/conveyor
Hydraulic excavator Electric shovel	portable hopper semi-portable hopper mobile hopper	belt conveyor	spoil over bank stockpile main conveyor
Wheel excavator	→	belt conveyor	spoil over bank stockpile main conveyor
Scraper	→	→	spoil in lifts stockpile hopper/conveyor
FEL	→	→	spoil over bank stockpile hopper/conveyor

Figure II - 1
LeTourneau L-600 (10 yd^3)

In making the selection of the excavation and face haulage unit(s), general characteristics and limitations of both the excavator (Table II - 3) and the transport unit (Table II - 4) must be considered as they relate to the specific site conditions. Once combinations of excavators and haulage units have been selected which are technologically feasible, a comparative economic study including operating and ownership costs will aid in the selection. In addition to economics, other factors may also be considered in making the decision - capability to meet blending requirements, meet varying production rates, etc.

Table II - 3

GENERAL EXCAVATOR SELECTION CONSIDERATIONS*

	FEL	Hydraulic Shovel	Electric Shovel	Diesel BWE
Sizes available yd^3 (3000 lb/LCY material)	to 24	to 24	to 50	to 3000 yd^3/hr
hard digging capability	limited	medium	excellent	marginal (no boulders)
maximum face height	low	medium	high	medium
dump height	medium	good	good	good
mobility	excellent	good	poor	poor
floor conditions	critical	not critical	not critical	not critical
reliability	medium	medium	high	low
service life	short	medium	long	medium
auxilliary equipment	none	none	dozer required	dozer required
ownership cost	low	medium	high	high
operating cost	............(site specific)....................			
delivery time	short	medium	long	long

*Classifications are relative to other units

Table II - 4

GENERAL TRANSPORT SELECTION CONSIDERATIONS**
(Short Distances)

	FEL	Truck	Conveyor*	Hopper-Crusher-Conveyor*
Tonnages (T/hr) (single unit)	200-2000	750-3500	to 5000	to 2000
Distances (ft)	to 1000	300 & up	70 & up	70 & up
Grades (%)	to 15	to 10	to 27	to 27
Maximum average speeds (mph)	10	15	10.5 (900 fpm)	10.5 (900 fpm)
Haul road requirements	prepared by loader	graded	none	none
Flexibility for: length change	excellent	excellent	good	good
route change	excellent	excellent	good	poor
production change	good (adjust fleet or schedule)	good (adjust fleet or schedule)	limited to scheduling	limited to scheduling
Wet weather constraints	reduced production or shut down	reduced production or shut down	none	none
Reliability	medium	medium	high	medium
Lost time (excluding service & repair)	road maintenance work	-	relocation	relocation
Auxiliary equipment	none	road maintenance equipment	for moves only	for moves only
Ownership cost	medium	high	medium	high
Operating cost	high	high	low	medium

*Shiftable conveyors and/or a series of mobile modules (72 inch and smaller).
**Classifications are relative to other units.

However, given that the limitations and attributes of a hopper/crusher/conveyor system are acceptable as a main haulage system, the FEL provides an effective alternative for face haulage and excavation. Referring again to Table II - 2, the FEL and scraper are the only single unit systems that span the short haul range. Both operate in the load-and-carry mode.

The scraper is limited in most mining applications because of its fairly lengthy loading and dumping area requirements, inability to handle large oversize and requirement for a large and complex transfer unit to a main haulage system. Conversely, the FEL is considerably more attractive for general mining applications for the following reasons:

- ability to excavate and transport large pieces and blocky materials,
- ability to handle and operate on sharp abrasive materials,
- flexibility for blending with multiface operations,
- lesser reduction in productivity under wet conditions when compared with a scraper,
- ability to operate without auxiliary equipment,
- ability to work in a confined area,
- operations are compatible with other commonly employed practices and equipment,
- units provide back up for other loading operations,
- units provide broad general utility support,
- fleet operations require minimal control and scheduling.

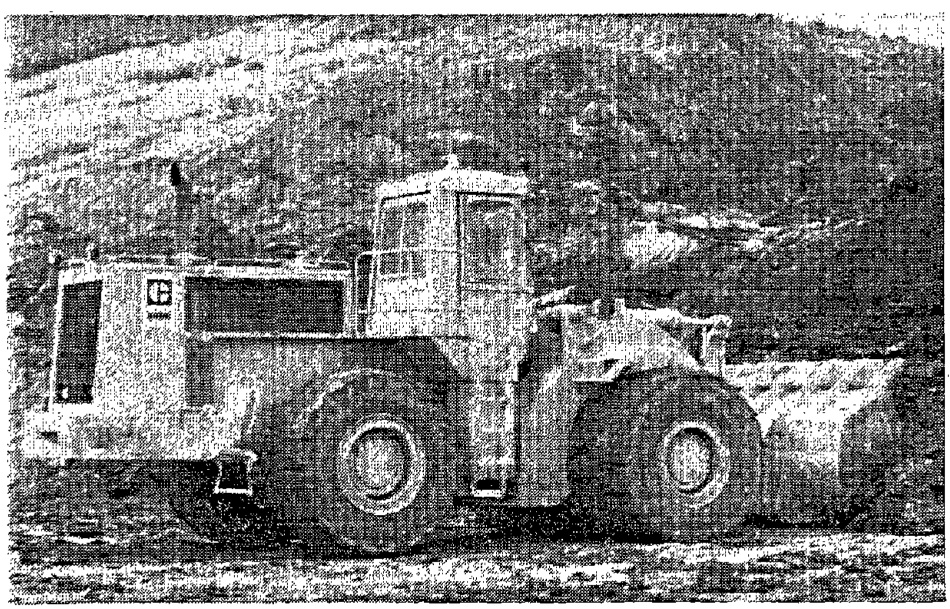

Figure II - 2
Cat 988B (7 yd^3)

Figure II - 3
IHC 580 (22 yd^3)

Eliminating the scraper, the remainder of the excavation and face haulage options involve more complex systems and possess particular short comings. The excavator/truck systems are limited at the low end of the short haul range because of inefficiences in the spot, dump, acceleration and braking components of the truck cycle. These components are a high percentage of time on short hauls and lead to system inefficiences. In addition, a large hopper or hopper/crusher is required to accept the large unit loads of a truck which significantly increases capital costs where conveyors are used for main haulage.

Cyclic, crawler mounted excavators used in conjunction with hopper/conveyor systems offer possibilities in haulage economics but require fairly continuous movement of the hopper which increases its cost and complexity. A major shortcoming appears when blending is a requirement from multiple faces. This is accomplished generally with multiple units which significantly raises capital requirements.

The final option is the wheel excavator/conveyor system. While the system offers continuous excavation and haulage with attendant operating economies, these excavators are limited to a window of application from a materials standpoint. They require homogeneous material without oversize or boulders. As in the prior combination, blending reqirements may increase the capital requirements with the need for multiple units.

It is evident that system selection is complex and site specific, involves judgement, and requires considerable attention to comparative economics. The FEL in load-and-carry should be given consideration where excavation and limited face haulage are required because of its simplicity (single piece of equipment), and superior flexibility.

SECTION III

FRONT-END LOADERS IN LOAD-AND-CARRY SERVICE

The front-end loader (FEL) is used in many applications in the surface mining industry. An important application involves its use in the load-and-carry mode where the machine is employed to perform both the excavation and face haulage functions. The haul distances traversed span the short haul spectrum ranging to a maximum of 1000 ft.

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Figure III - 1
FEL Hauling to Mobile Crushing Plant

CURRENT FEL/LOAD & CARRY APPLICATIONS

The FEL used to load-and-carry is employed to perform the functions of excavation and face haulage. The typical system involves an FEL (or multiple FEL's) excavating from a bank and hauling the material to a hopper or hopper/crusher for placement of material on a conveyor system. The equipment configuration between load-and-carry and conveyor is a function of material characteristics. Haul distances typically range in the 100 to 600 ft. range with an upper limit to 1000 ft.

In terms of numbers of machines, the most common application of the machine in the load-and-carry mode is probably in stockpiling with the following variations:

- crusher feeding: material fed from stockpile to crusher by FEL to provide constant rate of feed or to eliminate queues at the crusher in a truck haulage system

- stockpile rehandling: material removed from stockpile (e.g., typical in sizing plant operations)

- reject handling: reject removed from stockpile

- conveyance loading: product is loaded from stockpile into trucks or railroad cars.

Quarries ranging from sand and gravel to limestone frequently utilize a front-end loader to load-and-carry to a hopper/conveyor when the travel distances are short. Crushers are generally not involved so that the hopper can be simple and often constructed on the site. There is a knowledge and familiarity with conveyors resulting from their broad use in the processing and sorting operations.

Although not common in non-coal mining, the FEL can be used for direct spoiling of overburden or parting material. In coal stripping, the FEL is commonly used in this load-and-carry application in block-contour and occasionally in block area mining methods. Because of the block-by-block extraction process, haul distances can be kept in the 300 to 600 ft. range.

In addition to these major applications, load-and-carry is used for numerous utility applications: snow removal, road construction, road maintenance, facility clean-up, road watering, spoiling plant reject, product loadout, segregating oversize, etc.

PRODUCTION CAPABILITIES

The majority of current FEL load-and-carry operations entail a medium size (6 to 15 yd^3) loader feeding a conveyor haulage system. The smaller systems produce from 2,000 to 3,900 tons per day on a single shift basis. The variation in production is a function of haul distance and bank conditions. A number of larger FEL load-and-carry operations produce from 4,800 to 12,000 tons per day by utilizing combinations of multiple shifts, multiple machines and/or larger machines.

There are apparent limitations on the production capabilities of the FEL load-and-carry operations. The bottom limit is set by efficient utilization of manpower and equipment and by related economic considerations. Front-end loaders in the small size range have limited capabilities in excavating material from a bank, particularly where blocky material is encountered. Small pit conveyors, less than 24 in. wide, are not commonly utilized because of questionable economics. The upper limit on production involves consideraion of deposit geometry, pit geometry, allowable complexity in pit layout and individual FEL production capability. There is no problem in obtaining high capacity main haulage systems. For example, a single 72 in. main belt has the capacity to transport 20,000 to 36,000 tons/shift depending on belt speed. A system of hoppers and cross belts can be designed to feed such a main haulage system if adequate area is available for the multiple faces and if the system can be integrated into the necessary pit geometry. The number of cross belts would be a function of FEL productivity and, in turn, FEL size and bucket capacity. At this juncture, economic application of large FEL's in load-and-carry has not been broadly demonstrated and could place an upper limit on the system.

FEL's are currently operating in bank conditions ranging from unconsolidated sand deposits to limestone where heavy blasting is required. The FEL in conjunction with a belt system is usually selected as an alternative to an excavator/truck system. The FEL system can be cost competitive in these situations. The major exception appears to be in cases where bank and/or floor conditions cause excessive tire wear which decreases tire life and markedly increases tire costs. Considering medium size loaders as an example, load-and-carry operating costs would increase 50% as tire life decreases from 4,000 to 1,000 hours. This increase would be independent of any increases in repair, maintenance and supply costs and corresponding decreases in productivity, which parallel tire cost increases in many pit conditions. It woud appear that the FEL system has economic limitations on production capability in the more rugged pit conditions.

RELIABILITY

Front-end loaders do not generally have a reputation as a high reliability excavator in mining applications. However, when operated on a single shift basis, with most service and maintenance performed off-shift, reliability is quite high. On a one shift/day basis, on shift availabilities of plus 85% are common. The key to this performance lies in the low number of scheduled shifts/day (generally one) which allows adequate time for maintenance activities off-shift. Reliability of the FEL's is satisfactory on this basis. In larger and multiple shift operations, standby FEL capacity is usually maintained. In many cases, this standby equipment is a loader of lesser capacity which is used for intermittent utility functions.

OPERATING FLEXIBILITY

The FEL is unique in its ability to rapidly relocate from digging face to digging face. This ability allows an operator to blend ore grades or quality from multiple areas with a minimum loss of time. This blending can be accomplished over a short period of time if economics permit. In the extreme situation, blending can be done on a bucket load by bucket load basis. This capability is unique to the FEL and would require multiple machines, significant move time or costly blending facilities with other types of excavators.

The same mobility allows haul road distance averaging where material is being hauled to a central location. During high demand periods, short haul faces may be utilized to increase FEL output, long haul faces may be utilized during periods of slack demand.

Such blending and multiple face operation is limited by production or economic constraints. As blending is required over greater areas, unit production will drop making the practice impractical.

Figure III - 2
FEL Hauling

MANAGEMENT ACCEPTANCE

Mine and quarry management currently using the FEL/conveyor systems appear satisfied in terms of production and cost. These managements are not pursuing changes to other material handling systems. However, specific problems such as inadquate crusher capacity or other system bottlenecks, etc., do occur. Most such problems can be alleviated with proper initial or redesign of the system.

The FEL/conveyor systems are generally selected in lieu of an excavator/truck or excavator/truck/conveyor system. The FEL/conveyor system teams the low capital cost/yd^3 of capacity of the loader with the high reliability and low operating cost of a conveyor system. Although a similar approach can be taken with excavator/truck systems for face haulage, the latter system requires significantly larger transfer system (hopper, feeder) to accept the larger loads of the trucks. The transfer system is thus more costly and generally much larger and less mobile. This application appears limited in practice to large, multiple bench operations. In addition, the excavator/truck system usually requires additional auxiliary equipment, particularly in areas of road and bench clean-up and maintenance.

ADVANTAGES AND DISADVANTAGES

A summary of general considerations regarding the FEL in load-and-carry service is presented as follows in the form of a list of advantages and disadvantages.

Advantages

- low capital cost/yd^3 of excavator capacity
- high productivity with small number of operating personnel
- flexibility in blending material within production and pit geometry limits
- when combined with belt system, provides low cost face and main haulage system
- allows simple hopper/feeder system for transfer of material to belt haulage
- can be used for numerous other utility functions
- system reliability high when moderately utilized
- simple system with minimum mobile equipment in face haulage system
- proven technology
- minimum auxiliary equipment
- moderate degree of operator training required

Disadvantages

- operating costs sensitive to floor and haul road conditions and grades, reflected in high tire and repair maintenance and supply costs in adverse conditions
- production sensitive to geologic conditions, reflected in lower productivity in adverse conditions
- system dependent on the mechanical availability of the loader (limited experience with larger models) and the crusher if required
- system limited by ability to reduce material to size acceptable by belt
- system most suitable to high concentrations from local area.
- production is lost during periods when hopper unit and conveyors are relocated
- system production is limited by hopper/crusher and/or conveyor capacities

SECTION IV

EVALUATING APPLICATIONS

This section of the manual covers the general and site specific considerations for evaluating the front-end loader in load-and-carry service. The pit layout discussion focuses on use of the FEL for excavation and face haulage and assumes a belt system is used for main haulage. The remainder of the sections are more general in nature and are broadly applicable to load-and-carry applications. This section follows a point by point procedure for conceptualizing a mine plan and then gathering the site specific data required for a detailed analysis of the mine plan in terms of FEL production, equipment requirements, operating and owning costs, operating procedures, etc.

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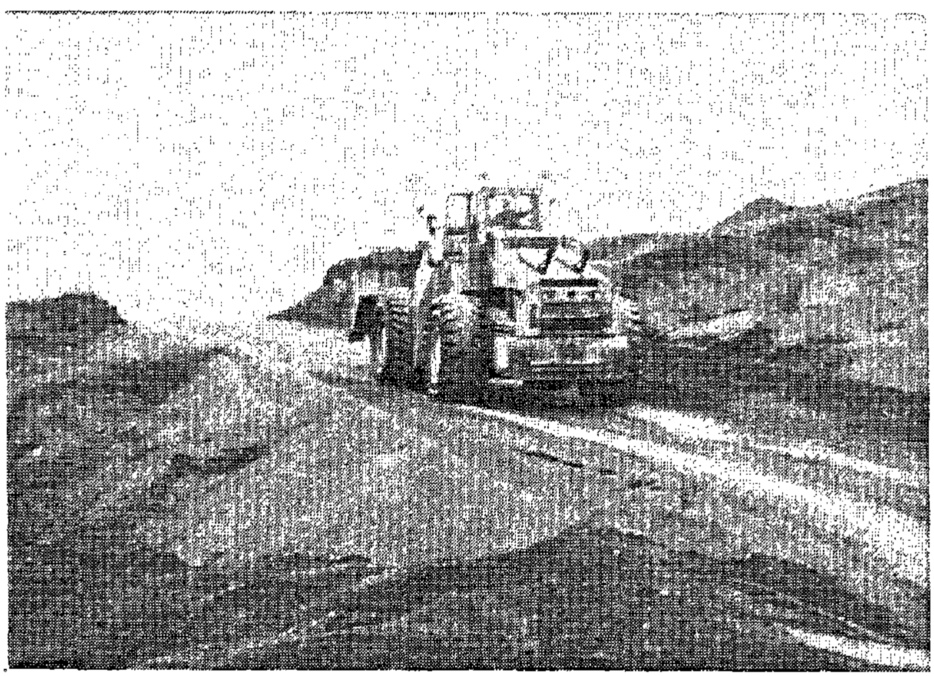


Figure IV - 1
Carrying Load up Ramp

GENERAL CONSIDERATIONS

The following are the major points which should be given consideration in conceptualizing an FEL load-and-carry mine plan. A General Consideration Worksheet has been provided which contains these major points; this worksheet can be used as an aid in planning.

PRODUCTION REQUIRMENTS

It is assumed that an annual production requirement and an approximate mine life considering reserve or market constraints are known. Based on the required annual production, a first approximation of the total FEL bucket requirement can be made by using a production index of 500/tons/shift/cubic yard of bucket capacity and considering scheduled shifts/year. The following equation can be used to approximate total capacity.

$$\text{total yd}^3 \text{ FEL capacity} = \frac{\text{annual production requirement (tons)}}{500 \text{ T/yd}^3 \text{ bucket capacity/shift} \times \text{scheduled shift/yr}}$$

While the actual production index for a specific property will be a function of FEL size, bank conditions, average haul distance, etc., the above approximation will serve as a starting point for conceptual planning. (Detailed production calculations are presented in Section V.)

NUMBER AND CAPACITY OF LOADERS

There are a number of approaches which might be taken to arrive at the approximate number and capacity of FEL's required to meet the total FEL capacity calculated above. Determinants will include blending considerations, minimum or maximum loader size and minimum number of loaders.

In the situation where blending is not called for in the mine plan, a minimum or maximum loader size can be specified and the number of loaders calculated. As a minimum, the operator must select a machine size large enough to ensure it will have the digging forces sufficient to excavate material from the bank efficiently. As a maximum, the operator should consider the largest machine size considered practical for load-and-carry applications. Current practice indicates that the range of loader size utilized in these applications is 6 to 15 yd^3. A range of the number of loaders can be calculated using the following equation.

$$\text{number of loaders} = \frac{\text{total yd}^3 \text{ FEL capacity}}{\text{minimum or maximum loader size}}$$

Other considerations might include preferred loader size or minimum number of loaders. The operator may wish to specify the loader size based on past performance, fleet standardization, etc. A minimum number of loaders may be desired for sustaining minimum production levels during periods when a portion of the loader fleet is not operating for mechanical reasons.

In a blending situation, consideration must be given to the minimum number of faces required to meet product specifications. In addition, the rate of blending and the horizontal and vertical locations of those faces must be considered. If, for example, blending is required on a load-by-load basis from faces 2000 ft. distant, the situation would dictate two faces with a machine per face to minimize non-productive travel time. In the case of blending, the minimum size of loaders can be calculated using the following equation.

$$\text{minimum loader size} = \frac{\text{total yd}^3\text{ FEL capacity}}{\text{number of required operating faces}}$$

The above number must be compared with the minimum and maximum loader sizes as was done in the non-blending situation. Results here may indicate that blending from stockpiles of ore at the processing or sizing facility may be more attractive. Such a determination is beyond the scope of this manual.

For conceptual planning purposes, a decision must be made regarding the number of loaders, working faces and size of loaders. Ultimately, the optimal combination of these will probably be determined by performing an engineering economy study of the various alternatives.

DEPOSIT GEOMETRY

The FEL/conveyor system is commonly installed in homogeneous deposits which are large in areal extent and tabular or bedded in nature. The deposits usually have a low angle of dip and thicknesses of 15 to 100 ft. Plan dimensions of the ultimate pit are often dictated by property or lease boundary constraints.

While these characteristics are not requisites for the system, planning and layout of the pit are simplified because of the loader's limited capabilities on moderate and steeply dipping floors and the straight-line nature of belt main haulage. While the loader belt systems can be employed in more complex geology, a more complex layout, main and face haulage system is usually required. For example, steeply dipping seams would call for multiple near-horizontal benches and deposits with internal waste would probably require multiple belt systems or other systems for ore and waste.

GENERAL CONSIDERATIONS WORKSHEET
(CONCEPTUAL PIT PLANNING)

FRONT-END-LOADER
LOAD-AND-CARRY

Date:______________
Prepared by:________________
No:______________

Location :____
Application :____

PRODUCTION REQUIREMENT

Annual Production Requirement (tons/year):_____________[APR]

Operating Schedule (shifts/year):__________________[OS]

FEL-L&C Production Index $\frac{\text{(tons/yd}^3\text{ bucket capacity)}}{\text{(scheduled shift)}}$*=______[PI]

*use 500 if site specific information is not available

Total yd^3 FEL Capacity = $\frac{[APR]}{[OS] \times [PI]}$ = ______________ yd^3

NUMBER AND CAPACITY OF LOADERS

Non-blending:

Number of Loaders = $\frac{\text{total yd}^3\text{ FEL capacity}}{\text{minimum or maximum loader size (yd}^3\text{)}}$

= $\frac{\_\_\_\_\_\_\_\_\_\_ yd^3}{yd^3}$ = ______

Blending:

Minimum Loader Size = $\frac{\text{total yd}^3\text{ FEL capacity}}{\text{number of required operating faces}}$

= $\frac{\_\_\_\_\_\_\_\_\_\_ yd^3}{\text{no.}}$ = ______

First Approximation:
- Number of Working Faces ____________________
- Number of Loaders _____________________
- Loader Size ________________

DEPOSIT GEOMETRY

Plan and Cross Sectional Sketches of Deposit Geometry

Include: property boundary, deposit boundaries, length, width and thickness of deposit, strike, angle and degree of dip, main haulage dump location, other features

---

PIT LAYOUT

Sketch of Pit Layout Superimposed on Plan and Cross-Sectional Sketches Developed in Deposit Geometry

Include: pit exit arrangements, main belt location, active face widths, production ramp locations, highwall angles, bench height and width, haulage distances and grades, direction of belt and face advance, etc.

Sketch should be provided for or reflect initial years and final years of mining.

FREQUENCY OF MOVES (hopper/conveyor)

$$\text{Production Requirement/Shift} = \frac{\text{annual production requirement (tons/yr)}}{\text{operating shifts scheduled/year}}$$

$$= \frac{\_\_\_\_\_\_\_\_\text{ton/yr}}{\text{shift/yr}}$$

$$= \_\_\_\_\_\_\_\_\text{tons/shift}$$

$$\text{Shifts between Moves} = \frac{\text{pit width (ft) x move distance (ft)* x formation thickness(ft)}}{\text{tonnage factor (ft}^3\text{/ton) x production requirement/shift(T/shift)}}$$

$$= \frac{\_\_\_\_\text{ft x }\_\_\_\_\text{ft x }\_\_\_\_\text{ft}}{\text{ft}^3\text{/ton x }\quad\text{ton/shift}}$$

$$= \_\_\_\_\_\_\_\_\text{shift}$$

*Move distance of approximately 400 ft. corresponds to production index of 500 tons/yd^3 bucket capacity/shift

---

SKETCH OF HOPPER/CRUSHER ARRANGEMENT

Include: hopper type, flow control, size reduction method, ramp number, elevation, width and layout

PIT LAYOUTS

Deposit geometry will largely determine the pit layout utilized on a specific site. Following are a number of possible alternatives and guidelines on haul road distances and grades needed within the pit. Frequency of layout change is discussed in the final section.

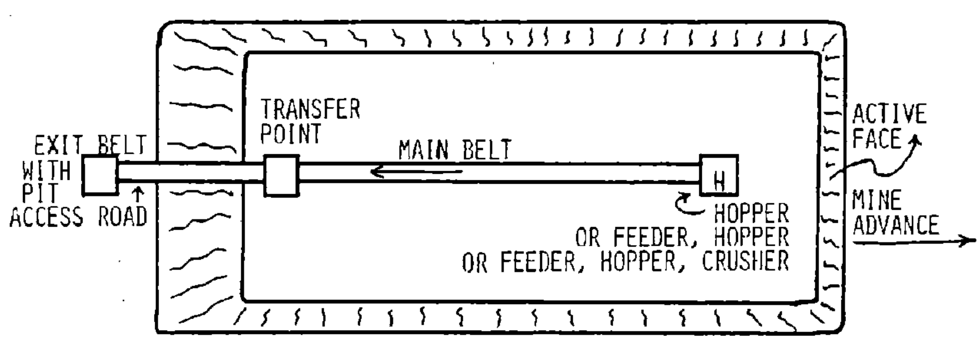
Alternate Arrangements

In addition to pit geometry, production rate, etc., the major variables associated with pit layout involve formation thickness, pit width, and direction of mining. Formation thickness in conjunction with maximum allowable bench height determines the number of operating benches. Pit width in conjunction with plan dimensions of the ore zone and economic haul distance will be used to determine hopper/conveyor set-up and the possible need for cross-belts. An adequate number of working benches, sufficient width or combination of these must be provided to allow the minimum number of working faces. Direction of mining relative to the belt terminus will determine if the advance or retreat mode will be employed.

The most common pit layout employed involves a single bench with a hopper feeding a main belt or transfer conveyor(s) feeding the main belt conveying material away from the active face in a direction opposite the direction of mine advance as shown in the following Figure IV - 2. As the active face advances, the main belt, located on the pit floor, is advanced by adding belt modules or extending the main belt. Haul distances from the hopper to extreme corners of the pit are usually kept to maximum distances allowing the required production rate to be sustained.

Figure IV - 2

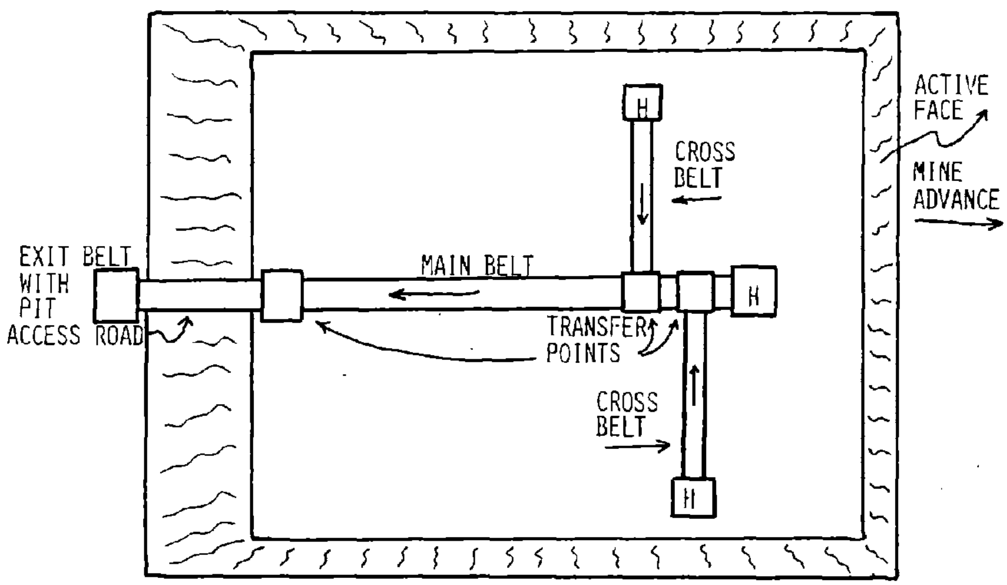
PIT LAYOUT - Single Bench, Narrow Pit



In cases where a wider pit is utilized because of width of formation, property boundaries, or production requirements, a series of cross belts can be added to the system as shown in Figure IV - 3. The cross belts are used to reduce haul distance from the active face to the hopper and are employed when the width of the pit exceeds approximately 1000 ft., dictating maximum one-way hauls of over 500 ft. if only a main belt is employed. As in the prior case, main and cross belts are carried at the pit bottom elevation and advanced incrementally as the active face advances. In each case, a pit exit belt is used to lift the material out of the pit to reach the belt terminus.

Figure IV - 3

PIT LAYOUT - Single Bench, Cross Belts, Wide Pit



Although not common in the current state of the art, a retreat type of system can be employed when facility layout dictates. In this case, the active face moves toward the belt terminus and belt sections are removed as the active face advances as shown in Figure IV - 4. As seen there, one alternative is to use the FEL to lift the material via a ramp to the belt at the elevation of the top of the ore. As the pit width increases, multiple ramps (Figure IV - 5) or ramps and cross belts (Figure IV - 6) can be added depending on economic considerations. These economic consideraions would include a comparison of FEL haulage costs with belt capital and operating costs.

Figure IV - 4

PIT LAYOUT - Single Bench, Narrow Pit, Retreat

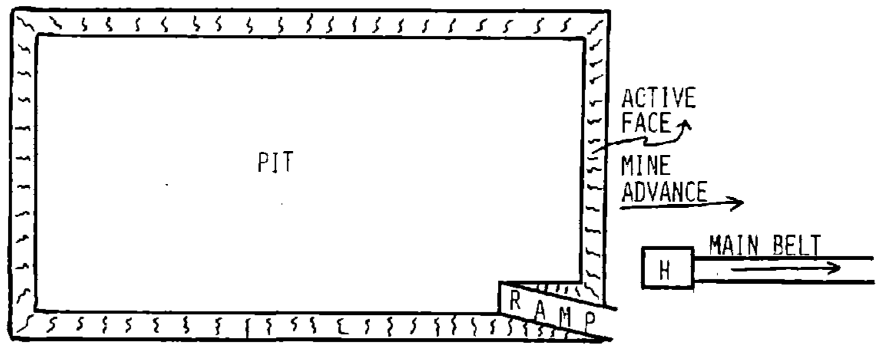


Figure IV - 5

PIT LAYOUT - Single Bench, Wide Pit, Retreat

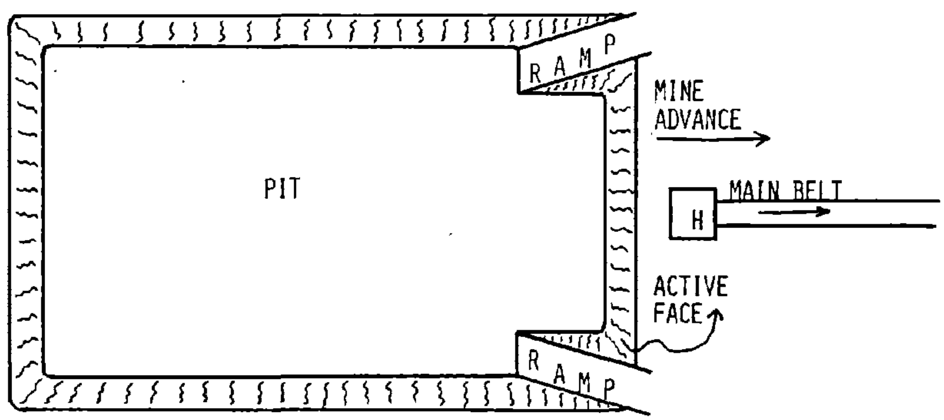
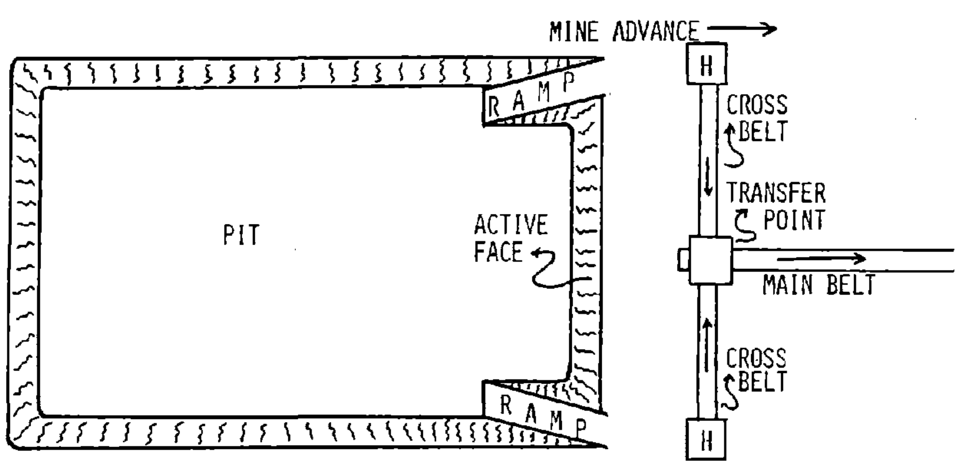


Figure IV - 6

PIT LAYOUT - Single Bench, Wide Pit, Cross Belts, Retreat



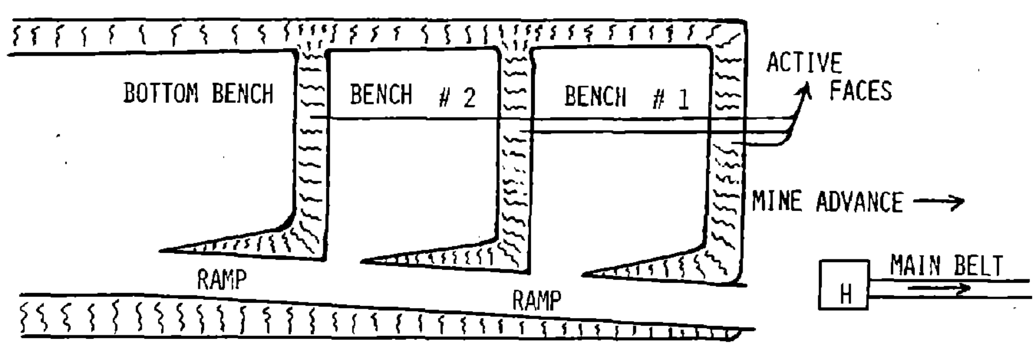
In general, a retreat system will require acquisition and installation of the entire main belt system and would, therefore, require the major capital expenditure early in the life of the project. Advancing systems allow capital expenditure over the life of the mine as the mine face moves away from the belt terminus. A second problem with retreat systems involves the means employed to lift material from the pit. In the sketches, the FEL was employed. The alternative is to run belts down to the pit bottom. In the retreat case, this may cause operational problems as the belt ramps and belts are moved as the mine face advances. Again, an economic trade-off is involved with a comparison of FEL haulage costs compared with belt capital and operating costs which would include production scheduling problems that may arise during the ramp/belt moves.

In cases where formation thickness, blending or production requirements dictate, multiple benches can be included in the pit layout. Such applications are not common in current practice. A major consideration in multiple bench operations is selection of the belt elevation which may range from top of ore to bottom of pit. A consensus on optimal location has not been established in the field.

One operation using a retreat system located the hopper on top of the ore as indicated in Figure IV - 7. The FEL is used to lift the material from the various benches using a ramp system which exits the pit near the hopper at the top of the ore. While numerous combinations have been tried, this layout was finally selected because of ease of operation, although an economic comparison may indicate a more optimal arrangement.

Figure IV - 7

PIT LAYOUT - Multiple Bench, Retreat



When considering the multiple bench situation and the more common advancing system, it is apparent that numerous possible alternatives are available. For example, the belt could be located on the pit bottom and material from upper benches could be ramped down to the hopper as indicated in Figure IV - 8. The hopper could be located on an intermediate bench (Figure IV - 9) using the FEL to lift material to the intermediate bench level. In Figure IV - 10, a belt is installed for each bench, allowing level haul by eliminating all FEL ramp operation.

Figure IV - 8

PIT LAYOUT - Multiple Bench, Bottom Level Belt, Advance

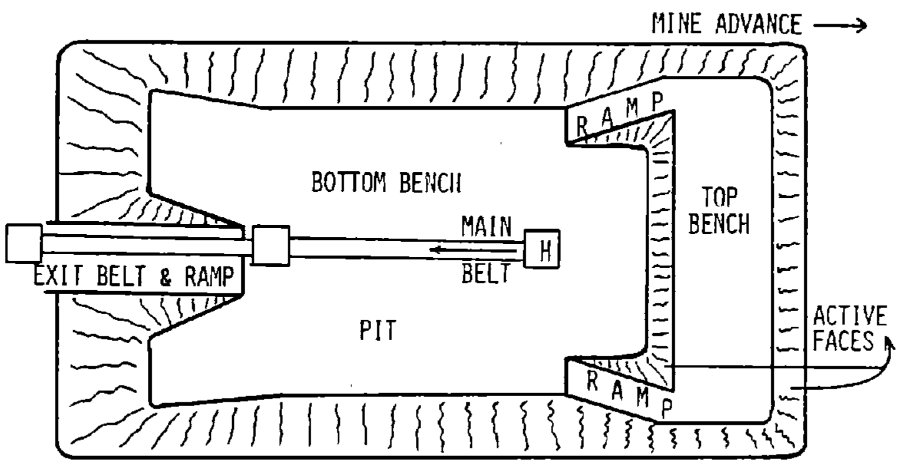


Figure IV - 9

PIT LAYOUT - Multiple Bench, Intermediate Level Belt, Advance

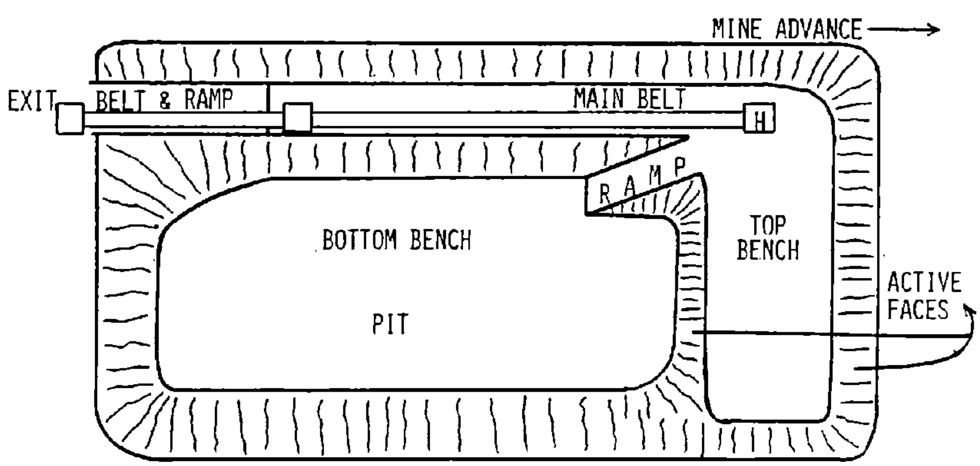
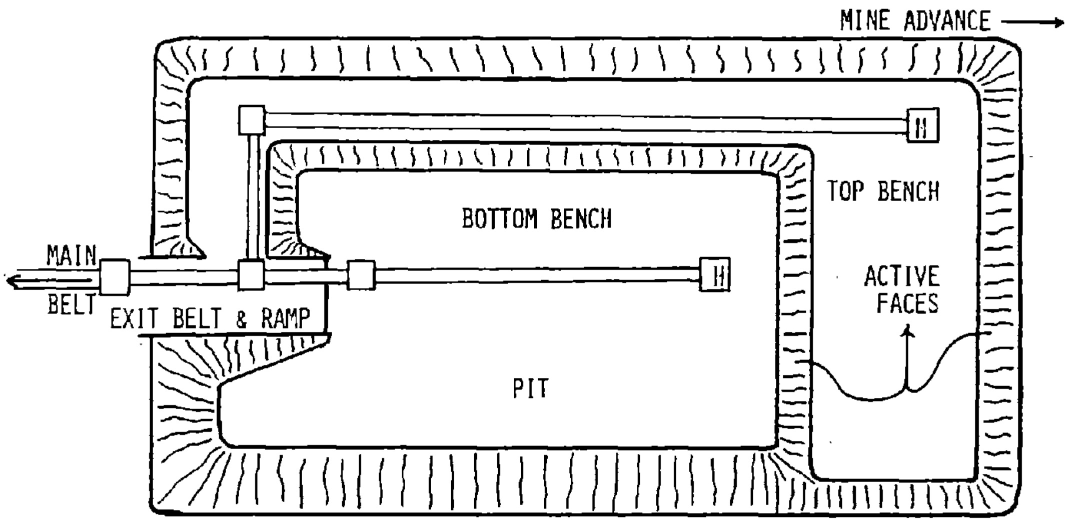


Figure IV - 10

PIT LAYOUT - Multiple Bench, Multiple Belt, Advance



In the elementary case illustrated above, it can be seen that numerous alternatives are available and the possible combinations increase as pit width, number of benches and production rates increase. It is not possible to generalize a solution for specific situations without consideration of the site specific parameters. Again, comparative economics must be generated to arrive at the best solution for each specific case.

Haul Road Distances and Grades

The majority of current load-and-carry operations are operating with haul distances of 100 to 600 ft. from face to crusher with only moderate grades (to 3%) in the greatest portion of the haul profile. Included in this distance are ramps ranging from 50 ft. @ 5% to 75 ft. @ 14%, utilized to access the hopper. The maximum haul distances are nearly 1,000 ft., which is an uncommon situation for most operations. Maximum sustained grades in practice are approximately 450ft. @ 12%, in a situation where benching is utilized in the mine plan and the feeder breaker is maintained on top of the ore. In general, only moderate haul road grades and lengths are utilized in the mine plans with the exception of hopper access ramps. Manufacturers' literature generally suggests haul distances up to 500 - 1,000 ft. are economical with the distances increasing with machine size.

Frequency of Layout Change

In many of the current FEL/conveyor operations, hopper/belt advance is dictated by events other than the pure economics of FEL haulage costs versus hopper move and belt advance costs. Two common reasons for moves are those made to meet production requirements and those made to overlap other external downtimes. When the loaders fail to maintain required daily production as face advances, the moves are made to shorten the haul distance and thereby increase production. The moves can also be conveniently made when another part of the process is scheduled down for repair, thus allowing moves to be performed in the pit (e.g., relining a cement kiln).

Where economic haul distance is considered or where production constraints dictate maximum haul distance, the frequency of layout change will be a function of production rate and pit geometry (pit width and formation thickness). While most current operators are not performing rigorous engineering economy studies, some general guidelines on layout change are available based on their current practices. Hoppers are being moved and conveyors being extended every 2 to 3 months with move lengths of 400 to 600 ft. Extremes are 9 months and 900 ft. The moves are expected to require 2 to 3 days, with a maximum of 7 days and 42 manshifts. The loaders are generally utilized in the equipment relocation.

For conceptual planning purposes, the time between moves can be approximated using the following equations.

$$\text{shifts between moves} = \frac{\text{pit width} \times \text{move distance} \times \text{formation thickness}}{\text{tonnage factor} \times \text{production requirement/shift}}$$

$$\text{production requirement/shift} = \frac{\text{annual production requirement (tons)}}{\text{operating shifts scheduled/year}}$$

In the above equations, pit dimensions are in feet, tonnage factor is in cu.ft./ton and the production requirement is in tons/shift. If other information has not been developed to this point, the move distance can be assumed to be approximately 400 ft. This distance corresponds with the previously stated production index of 500 tons/cu.yd. of bucket capacity.

It should be apparent that an engineering economic study based on more detailed information will provide guidance regarding optimum frequency for a given pit configuration.

MATERIAL CONSIDERATIONS AND BANK PREPARATION

Front-end loaders are currently operating in a broad spectrum of materials ranging from unconsolidated sand formations to blasted, poorly fragmented abrasive and angular muck piles. Bank preparation ranges from none to ripping and dozing to drilling and blasting.

When an FEL/conveyor system is used, material must be sized prior to placement on the belt. This preparation ranges from none, to Stamler-type breakers, to jaw crushers. The need for preparation prior to placement of material on the belt is an important consideration in system selection. The ability to size material efficiently, using a combination of bank preparation and size reduction techniques, is a limitation on the applicability of the system on some sites. The FEL can be used to set aside oversize for secondary breakage although, as the percentage oversize increases, system viability becomes less attractive.

HOPPER/CRUSHER COMBINATIONS

The transfer arrangement from FEL to conveyor is a function of material type and dimensions of system components. Sufficient elevation must be gained to allow adequate dump height for the FEL because the belt line is commonly carried at the pit bottom or bench bottom elevation. Common practice involves utilization of a ramp made from materials available in the pit to gain the required elevation. Significant ramps are usually not required when a low profile feeder/breaker, such as a Stamler, is employed. A minimal ramp is required when free-flowing is dumped over a tunnel arrangement. Ramp elevation is maximum when adequate elevation is required to provide crusher head-room.

An alternate arrangement, which is not currently common practice in pit layout, involves sinking the belt below bench elevation to reduce or eliminate the hopper elevation. Such a practice may eliminate time lost by the FEL in negotiating the ramp.

General hopper configurations are illustrated in Figure IV - 11, and general combinations are summarized in Table IV - 1.

Multiple ramps can be constructed to facilitate efficient FEL utilization. Dumping from two or even three sides can reduce FEL haul distance and increase machine productivity.

The hopper/crusher arrangement can be chosen to possess the degree of permanence and mobility required for the specific application. The mobility required will be a function of the frequency of moves as previously discussed. The arrangment and equipment selected will be the one which best balances move time and cost, equipment cost and reliability.

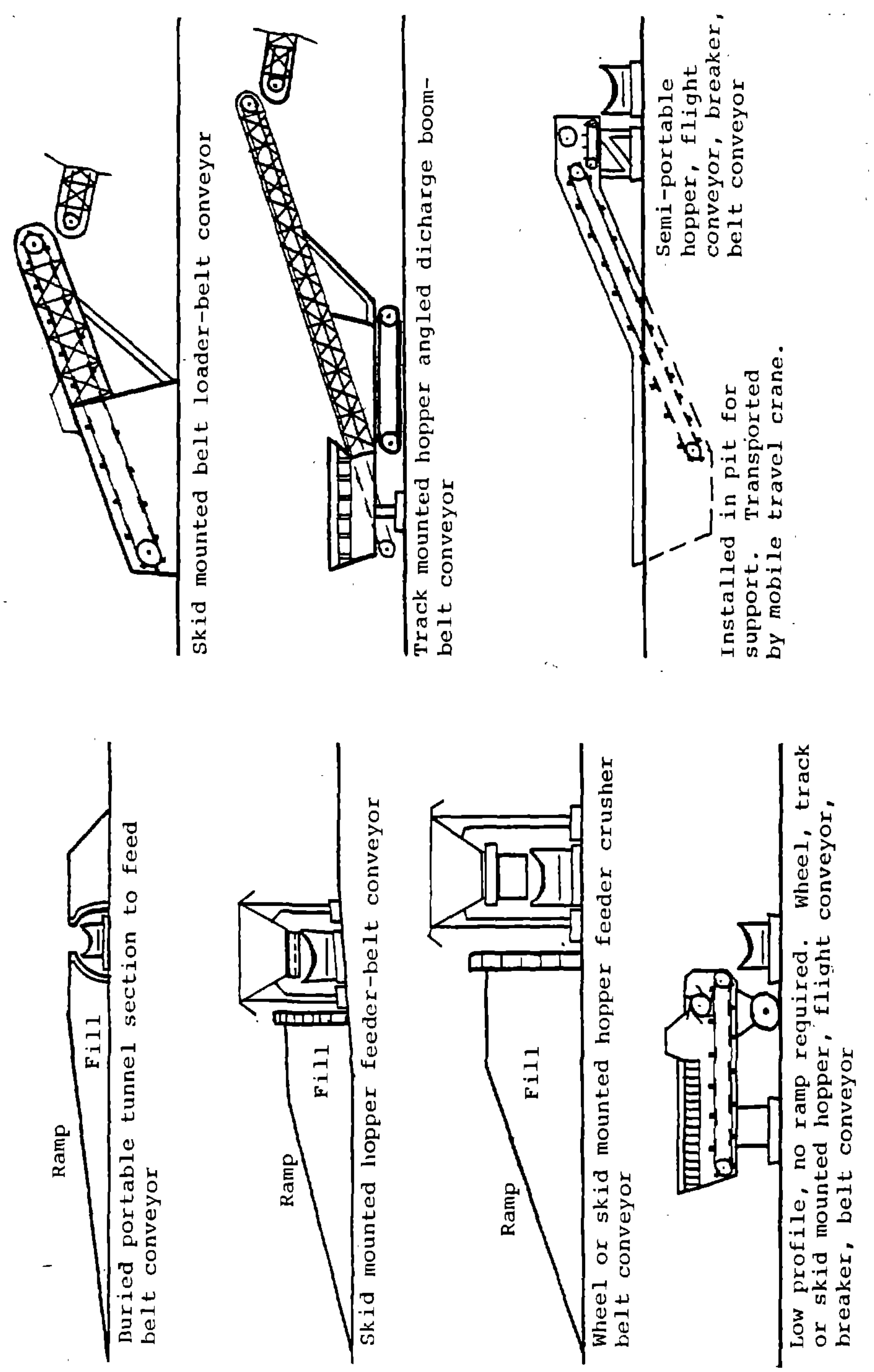
Table IV - 1

BELT LOADING STATION COMBINATIONS

Elevation	Transfer to Belt	Flow Control	Material	Size Reduction
ramp - moderate	portable hopper	door	free-flowing	none
ramp - low	material	door/ tunnel	free-flowing	none
ramp - moderate	portable hopper	feeder	minimum oversize	none
none	mobile hopper	feeder	blocky	Stamler breaker
ramp - high	portable hopper	feeder	blocky	jaw crusher

Figure IV - 11

BELT LOADING STATION CONFIGURATIONS



MATERIALS, SITE AND WORKING CONDITIONS

The materials being handled, the mining layout and facilities, and the working conditions can, of course, affect both the performance and feasibility of a front-end loader used to load-and-carry. Two checklists are included in this part of the section to assist in identifying these significant evaluation criteria -- the Geologic Information Checklist and the Site and Operating Conditions Checklist.

MATERIAL CHARACTERISTICS

The possible effects of the material (geological) characteristics on the successful use of FEL's in a load-and-carry mining application are extensive. Because of the potentially high costs of an error in planning and implementation of this mining scheme, it is imperative that the user become what has been called "rock-conscious". This basically means that the user recognize the nature and variability of natural geolgic materials, not only in terms of mechanical and spatial relationships, but also in terms of time - the "before, during, and after" mining context.

The most fundamental classification of the engineering properties of rocks might consist of the following elements, almost all of which are amenable to a quantitative analysis:

- composition
- texture
- fabric
- weight
- porosity
- permeability
- tensile strength
- compressive strength
- elasticity
- solubility
- resistance to weathering and erosion
- fragmentation (wear, ripping, blasting, drilling)

With application to mining by FEL's, these characteristics can be combined and summarized to form a group of material characteristics of concern that are often available in the manufacturers' equipment handbooks and general mining industy references. Thus, for a proposed application, the following information is usually available or can be reasonably estimated:

- unit weight of the material
- angle of repose
- hardness
- abrasiveness
- swell
- allowable bearing pressures
- coefficients of traction
- rolling resistance

In addition to the above characteristics, there are several other considerations that are not included in the above and that tend to be much more site specific in their possible impact on the operation. A field investigation and/or literature review of the particular geologic formations involved, by professional geologists or mining engineers, can provide estimates of the following additional material characteristics:

- general excavation requirements and nature

- special preparation requirements, such as blasting and/or ripping prior to excavation, including possible provisions for special handling of oversize

- structural features such as joints and bedding planes that influence blastability, rippability, and proportion of oversize

- evaluation of the ground water situation in the mine area

- strength properties of the material and face stability analyses affecting excavation characteristics and safety of the operation

- further properties, such as angularity and material size distribution

Given that the material characteristics in both of the above lists are available at least qualitatively, it remains necessary to identify those factors which will most significantly influence the cycle time, machine operation and maintenance requirements, or otherwise impact production rates. The extremely high variability inherent in geologic materials, even within one potential site, prevents a quantitative evaluation of the combined effect of all of these factors on the load-and-carry operation. It is most important to identify those characteristics which are extreme, and hence most likely to influence machine selection, performance, and basic mine planning.

However, the broad areas of influence by material characteristics on expected machine performance can be summarized as follows:

- almost all of the characteristics will combine to influence the cycle time required to excavate the material at the working face

- these same characteristics can cause the required penetration forces to become so great that abuse of the machine results in excessive maintenance

- abrasiveness of the material reduces bucket and tooth life

- angularity and hardness can cause reduced tire life both during excavation and on the haul road

- the allowable bearing pressures and ground water conditions must permit repetitive maneuvering at the working face

- these same characteristics combined with the angularity and material hardness will influence haul road conditions, maintenance, and rolling resistance

- similarly, the coefficients of traction and rolling resistance must permit adequate traction during excavation and sufficient acceleration, deceleration, and control during the haul

- high material swell will decrease the effective bucket capacity and high moisture content will increase the material weight to be handled; while the angularity, size distribution, and angle of repose will influence the bucket fill characteristics, as will highly plastic ("sticky") materials

- the same group of characteristics will affect design and configuration of the hopper, grizzly, in-pit type mobile crushers, conveyors, and stockpiles, in terms of the crushability and plasticity characteristics

- in both hard rock and unconsolidated material application, the analysis of face and slope stability will determine the safety of the operation at the working face and the type of failure to be expected due to caving of excessively high and steep faces

Because of the possibly crucial impact of the various material characteristics on the FEL application, the following Geologic Information Checklist should be thoroughly evaluated. Note that the purpose of this is simply to define the nature of the available information. The worksheet defines three levels of knowledge for each geologic condition. These range from well-known, thoroughly understood factors that are determined to affect expected performance (Category A) through well-know conditions that do not impact performance of the operation (Category B). Category C is for geologic conditions or material properties that have not been evaluated or considered. It is, therefore, important for the user to attempt to have no Category C items insofar as possible. The "note" column is provided to record for future reference specific decisions on site conditions such as unit weight, swell, etc. This information is the basis for other evaluations to be made later related to machine selection, production, costs and safety.

A selection of tables (Tables IV - 2 to IV - 5) on material properties have been included to assist in the assessment of the anticipated site conditions. Many of these relate to operational effectiveness in the actual digging face and potential machine abuse. Emphasis has been placed on the relative characteristics of the various face materials, rather than specific numbers so as to permit recognition of unusually severe and/or easy digging conditions. Similar data on traction, rolling resistance and material weights have been included in Section V on production estimating to facilitate these calculations.

The potential user of the FEL load-and-carry system should not feel intimidated by the large volume of information needed to evaluate material characteristics. Table IV - 6 presents a summary of the numerous sources of information available. Although principally oriented to new property development, the information sources should also prove helpful to operators of existing mines.

The various sources of information identified in Table IV - 6 should be utilized to the fullest extent practicable within the constraints of the user's planning/evaluation budget. Many of these information sources fall in the public sector and are, therefore, relatively inexpensive, while other professional sources are private and thus more costly. The importance, however, of seeking professional assistance (especially those firms and individuals familiar with local conditions) cannot be over-emphasized. One must also remember that it is not always necessary to know the "numbers" for all the characteristics; rather it is crucial to know which (if any) of the identified material characteristics can adversely affect the performance of the FEL load-and-carry mining system.

GEOLOGIC INFORMATION CHECKLIST

FRONT-END-LOADER

Date: ______________
Prepared by: __________________
No: ______________

Location: ____

	Category* A	B	C	Notes
GENERAL SITE CONDITIONS				
Topography and Climate				
Surface and Groundwater Hydrology				
Regional and Local Geology				
SPECIFIC SITE CONDITIONS				
Unique Adverse Material Properties				
Hardness (excavation & crushing)				
Abrasiveness				
Unit Weight				
Swell				
Angle of Repose				
Compressive Strength				
Traction (all possible working conditions)				
Rolling Resistance				
Particle Shape, Angularity, Size Distribution				
Jointing, Bedding, Faulting, Shear Zones				
Bank Preparation (blasting, ripping, dozing)				
Face Stability				
Face Height				

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*CATEGORIES

A. Well-defined, evaluated, determined to be significant
B. Well-defined, evaluated, determined not significant
C. Not observed and/or evaluated, possible significance on operation is unknown

Table IV - 2

MATERIAL ANGLE OF REPOSE AND CONVEYANCE

Material	Angle of Repose (°)	Maximum Angle of Conveyance (°)
Asbestos, ore/rock	30 - 44	
Ashes, dry	40 - 45	20 - 25
Ashes, wet	45 - 50	23 - 27
Ashes, fly	42	20 - 25
Barite	30 - 44	18 - 20
Basalt	20 - 28	
Bauxite	20 - 31	17 - 20
Bentonite	42 - 44	20
Clay, dry, lumpy	35	18 - 20
Coal, anthracite	27 - 35	16 - 18
Coal, bituminous	35 - 40	18 - 24
Coal, lignite	35 - 42	20 - 22
Copper ore	30 - 44	20
Dolomite	39 - 44	22
Earth, dry	35	20
Earth, moist	45	23
Earth, dry w/clay	35	20
Earth, wet w/clay	45	23
Felspar	34 - 38	17 - 18
Granite	30 - 44	20
Gravel, pit run	38 - 40	20
Gravel, dry, sharp	30 - 40	15 - 20
Gravel, pebbles	30	12 - 15
Gypsum	30	15 - 20
Iron ore	35	18 - 22
Kaolin clay	35	19 - 20
Lead ore	30	15 - 22
Lime, pebble	30	17 - 18
Limestone, crushed	38	18 - 20
Manganese, ore	39	20 - 22
Marble	30 - 44	20
Mica	34	20 - 23
Phosphate, rock, broken	25 - 30	12 - 15
Phosphate, rock pulverized	40	20 - 25
Rock & stone	20 - 29	18 - 22
Sand, bank, dry	35	15 - 18
Sand, bank, damp	45	20 - 22
Sand, silica, dry	20 - 29	10 - 15
Sandstone, broken	30 - 44	15
Shale, crushed	39	22
Slate	28	15
Traprock	30 - 44	20
Zinc, ore	38	20 - 22

Table IV - 3

MATERIAL ABRASIVENESS

Non-Abrasive	Abrasive	Very Abrasive
Antimony ore	Alumina, calcined	Aluminum oxide
Coal, bituminous	Amorphous silica	Chert
Coal, lignite	Ashes, dry	Coal, cinders
Diabase rock	Ashes, wet	Copper ore
Diatomaceous shale clinker	Barite	Granite, broken
Lime, pebble	Bauxite, calcined	Gravel, pitrun
Oil shale	Bentonite	Gravel, sharp
Sandstone/ California	Coal, anthracite	Manganese ore
Weathered shale	Dolomite	Marble, crushed
Zinc oxide	Earth, loam, dry	Sand, bank, dry
	Earth, clay, dry	Sand, silica, dry
	Earth, moist	Sand, bank, damp
	Feldspar	Sand, wet
	Ferro-phosphorous	Sandstone/ Pennsylvania
	Fluorspar	Stone & bauxite clinker
	Gravel, pebble	Traprock
	Gypsum	White quartz
	Hematite	
	Iron ore	
	Kaolin clay	
	Limestone, crushed	
	Mica	
	Phosphate rock	
	Shale, crushed	
	Shale	
	Stone, crushed	

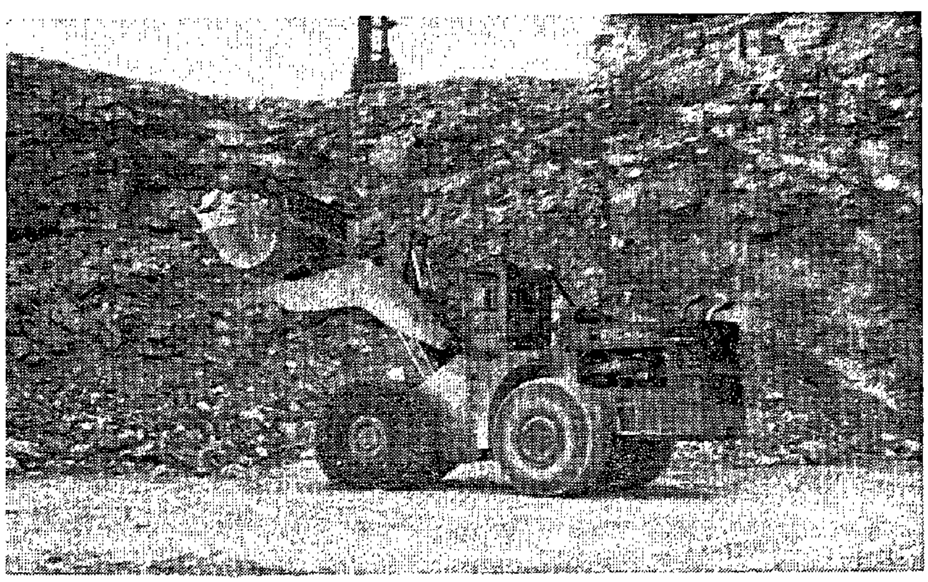


Figure IV - 12
Digging Shot Rock

Table IV - 4

MATERIAL HARDNESS

Material	Moh's Scale (1 = soft, 10 = hard)
Diamond	10.0
Carborundum	9.5
Sapphire	9.0
Chrysoberyl	8.5
Topaz	8.0
Zircon	7.5
Quartzite	7.0
Chert	6.5
Traprock	6.0
Magnetite	5.5
Schist	5.0
Apatite	4.5
Granite	4.0
Dolomite	3.5
Limestone	3.0
Galena	2.5
Potash	2.0
Gypsum	1.5
Talc	1.0

Soft	Medium	Hard	Very Hard
Asbestos rock	Dolomite	Dolomite	Felsite
Clay	Iron ore	Granite	Granite
Gypsum, rock	Limestone	Gravel	Granite gravel
Limestone, soft	Porphyries	Iron ore	Iron ore, taconite
Shale	Sandy shales	Limestone	Quartzite
Slate	Sandstone	Quartzite	Traprock
Talc		Siliceous	
		Traprock	

4

Table IV - 5

MATERIAL CUTTING FORCES

Material (unexcavated)	Cutting Resistance (lbs/in)
Alluvial:	
light consolidation	162 - 325
medium consolidation	280 - 447
heavy consolidation	386 - 839
Clay, dry	101 - 655
Clay, wet	162 - 342
Clay, sandy	101 - 342
Coal, hard, normal	280 - 540
Coal, hard, frozen	560 - 885
Earth	45 - 157
Granite, weathered	280 - 560
Gravel, fine	101 - 280
Gravel, coarse	101 - 442
Gypsum	280 - 711
Iron ore	1058 - 1178
Lignite	106 - 375
Lime	157 - 655
Limestone	560 - 1002
Loam, sandy & wet	101 - 325
Loam, dry	101 - 448
Marl	324 - 784
Phosphate	442 - 1120
Sand:	
fine, coarse, wet, dry	45 - 230
Sandstone:	
easy digging	381 - 885
hard digging	890 - 1568
Slate	381 - 1120
Slate w/clay	280 - 885

Table IV - 6

SOURCES OF INFORMATION

Source	Type(s) of Information Available
U. S. Geological Survey (national & regional offices)	regional geology aerial photography possibly regional and local engineering geology and hydrology
State Geological Surveys	regional and local geology and hydrology particular familiarity with local situation (peculiarities)
U. S. Forest Service	maps & aerial photography
Libraries & Professional Publications	local geology operational characteristics of existing mines
Local Land Use/Planning Organizations	mine planning assistance
Engineering Firms and Consultants	familiarity with geology & mine practices & problems professional assistance in all aspects of project evaluation including testing (civil, soil mechanics, hydrology/ hydraulics, geology, geophysics)
Local Mining Community	practical information regarding local material characteristics
Results of Original Mine Studies, Evaluations, Drilling (in house)	local mapping drill hole logs and sample analyses
Equipment Manufacturers	general material properties as they affect machine performance

HAUL ROAD CONFIGURATIONS AND PROFILES

Haul road configurations and profiles vary with different operations and, of course, must be designed to optimize productivity at each specific site. Possibly the only significant limitations are those of economic haul distances, assumed to be generally less than 1000 feet, and reasonble maximum grades which appear to range from 8% for long inclined distances to 12% for short ramps. Since dumping into a hopper and feeding a conveyor is a common load-out technique, it should be remembered that this can involve carrying up or down ramps between benches.

Because of the short travel lengths, frequent route changes and because road preparation and maintenance is generally performed by the loader, elaborate haul road planning is not a necessity unless a ramp is involved between benches. The primary goal, obviously, is to provide a straight route of minimum length.

Very little detailed information is available on minimum haul road curve radius for the FEL (see Table III - 17) and the associated cycle time penalty. The loader with its pivoted frame design has inherent sharp turn capabilities which are utilized during the dig and dump positioning. In the loaded carry operation, however, the speed on the turns must take into account the reduction in machine stability as the front of the machine is angled with respect to the rear. In this operation, the front tires are highly loaded and the machine inertia tends to further super-load the outside tires on curves, which can contribute to reduced tire life. Traction limitations and operator comfort place an upper limit on the travel speeds but this is difficult to correlate either with safety or tire abuse. The best approach is simply to maximize the curve radius in all haul road planning.

The loader has excellent capabilities for climbing steep grades with or without a load in the bucket. Any uphill grades, however, increase fuel consumption and increase the cycle time, and therefore should be minimized. Traction must be adequate to sustain the required rimpull and/or provide steering control. The larger loaders are designed primarily for truck loading and, hence, the brakes are not sized for long downhill braking (electric drive units do have retarding capability). Long, steep downhill grades while carrying a load should, therefore, be minimized.

Table IV - 7

TURNING RADIUS

Speed in Turns MPH	Maximum Turn Radius (ft) Flat Turn	Maximum Turn Radius (ft) Elevated Turn
5	50	
6	70	
7	90	
8	120	
9	150	75' @ 6%
10	190	100' @ 3.5%
11	230	150' @ 1%
12	270	
13	320	
14	370	100' @ 12%
15	420	150' @ 7%
16	480	200' @ 4.5%
17	540	250' @ 2.5%
18	610	
19	680	200' @ 10%
20	750	250' @ 7.5%
		300' @ 5.5%
		350' @ 4%

(Courtesy Michelin Tire Corporation)

FLOOR AND HAUL ROAD CONDITIONS

Floor and haul road conditions have a major impact on tire life. Ruts, potholes and sharp abrasive rocks on the floor at the digging face, on the haul road, or at the dump site, can reduce tire life to less than 25% of that experienced on a flat well-graded surface. If sharp rocks cannot be avoided, special precautions such as the use of tire chains or tire guards (beadless tires) should be considered, at increased cost.

Soft ground which results in high tire penetration will increase rolling resistance and result in higher fuel consumption. Additional engine power is required, reducing maximum grades and speeds.

Wet conditions reduce traction and increase the susceptibility of the tire to cuts. Good drainage to minimize standing water is essential in loader operating areas.

Figure IV - 13
Hauling on Wet Surface

As noted earlier, the loader generally prepares its own working surface and roads. This avoids the added cost of auxiliary equipment and the delays associated with waiting for this work to be scheduled and/or performed. These activites can frequently be performed by the loader in the normal operational cycle with minimum delay, but in some cases may significantly reduce the productive time. It should be recognized that while the loader is capable of grading, it is not very efficient and the resulting surface, while free of obstructions, generally has pockets and tends to be wavey.

TRAFFIC AND WORK AREA CONGESTION

The loader requires forward and reverse maneuvering at the digging face and dump site. Rear visibility, particularly on the larger units, is limited which means that, when possible, these operational areas of the loader should be free of other activities.

With the short hauls common to load-and-carry, the actual haul route, except on the ramps, can be quite variable and generally is a single lane used for both haul and return.

This seems to work well, consequently there is a tendency to have each loader in a multi-machine operation work a separate face with its own haul road, and an overlap possibly only at the hopper. Some prefer to dump from different sides into the hopper, so that the units are totally independent. This approach to minimizing the traffic and congestion provides maximum safety and minimizes lost time. See Figure IV - 14.

The area required for reversal and change in direction is approximately twice the length of the loader. Note that the absence of trucks eliminates all time loss associated with waiting and also the special maneuvering to spot the load. Dependent on hopper size, simultaneous dumping from two sides may or may not cause any physical interference but this practice generally should be avoided because of the potential for overloading and jamming the discharge feed.

4

DUST CONTROL

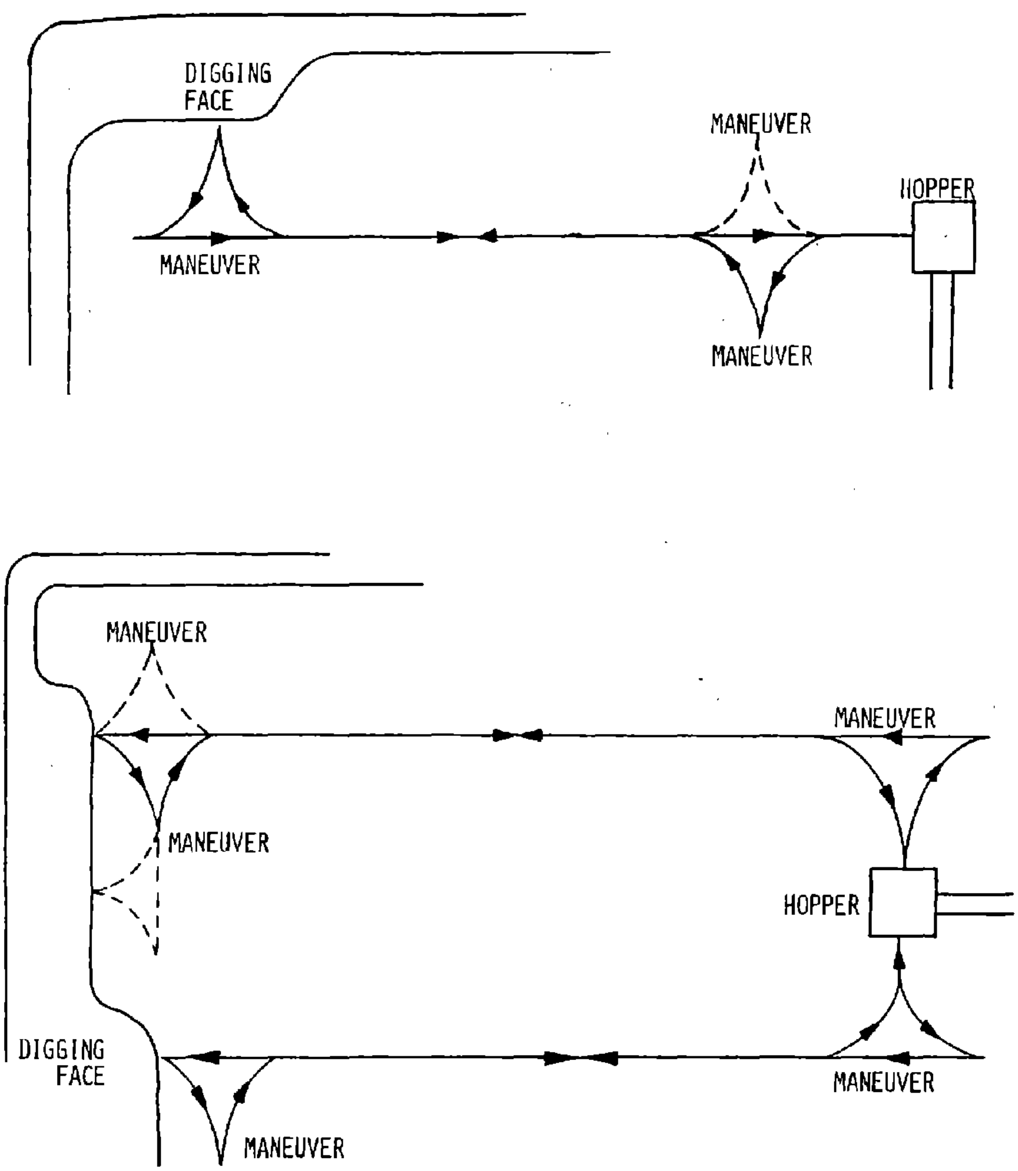
As with any haul road with heavy traffic and deep tread tires, excessive dust can be generated under dry conditions. This may require a water truck and periodic wetting down in a conventional manner. If there is standing water on the pit floor adjacent to the operation, however, the loader can obtain a load in the bucket and spread it along the haul route.

CLIMATE

Wet weather, icing conditions and/or material conditions that reduce traction will reduce travel speeds and, in the extreme, may shut down operations. Normal loader operations on a bench or pit floor are generally less affected by these conditions than scrapers and will out-perform trucks, recognizing that both can have problems on steep down grades. Application of the beadless tire (track-type shoes on the tire) on the loader could improve traction if this was a frequent problem, but at increased cost.

Figure IV - 14

TYPICAL MANEUVERING PATTERNS, L & C OPERATIONS
(Hopper located on pit floor)



SUPPORT EQUIPMENT

Since the loader can prepare its own working surface, ramps, and roads, it requires no operational support equipment. It was noted earlier, however, that in extreme dust conditions a water truck may be required.

The loader's high mobility permits most of the service operations to be performed in the shops.

Tire handling equipment may be the only special equipment required and this type of work can often be advantageously subcontracted to the tire supplier.

It is worth noting that the loader is one of the primary tools used in the shifting of conveyors and/or hoppers.

GENERAL SITE REQUIREMENTS

There are a number of considerations with respect to the site which do not require any discussion but impact system performance, such as maintenance personnel and facilities, supplier service support, parts inventory, and the quality of the supervision and operators. Pertinent information required on these have been included in the Site and Operating Conditions Checklist on the following pages.

SITE AND OPERATING CONDITIONS CHECKLIST

FRONT-END-LOADER
LOAD-AND-CARRY

Date:_______________
Prepared by:_______________
No:_______________

Location :____
Application :____

Production Requirement:___________TPH

Hopper/Conveyor Rated Capacity:____________TPH
Estimated Mech/Elec Availability:________%

Hopper/Conveyor Thru-put:____________TPH

Material to be handled:____

|__| Ore |__| Waste
|__| Abrasive |__| Hard

Bank Preparation:
None |__|
Dozed |__|
Ripped |__|Good |__|Avg |__|Poor
Blasted |__|Good |__|Avg |__|Poor

Digging Face Conditions:
|__| Stockpile
|__| Loosely Consolidated
|__| Tightly Consolidated
|__| Severe Rock

Face Height:________ft

Dump Conditions:
|__| Spoil
|__| Stockpile
|__| Hopper:
Height from ground
|__|low |__|medium |__|high
Ramp
|__|none |__|<50 ft |__|>50 ft
Target size
|__|small |__|adequate |__|large

4

Digging Floor: ____________________
[ ] Wet [ ] Dry

Haul Road: Length ________ft @ Grade ____% & Max Speed ____mph
Length ________ft @ Grade ____% & Max Speed ____mph
Length ________ft @ Grade ____% & Max Speed ____mph
Length ________ft @ Grade ____% & Max Speed ____mph

Turns: ______, ______, ______

Road Surface: ____________________
[ ]Good [ ]Avg [ ]Poor

Traffic: ____________________

Dumping Floor: ____________________

Ambient Temperature:

	Summer	Winter
Max	______	______
Avg	______	______
Min	______	______

Elevation: __________ft

Wind: Avg Wind Velocity __________mph
Max Wind Velocity __________mph

Dust Conditions: ____________________

Work Schedule: Hours/Shift ________
Shifts/Day ________
Days/Week ________..........________hr/wk

Maintenance Conditions: Notes
Scheduled service [ ] ____________________
Organized Maintenance Program [ ] ____________________
Maintenance Records [ ] ____________________

Competent Personnel:
Mechanical [ ] ____________________
Hydraulic [ ] ____________________
Electrical [ ] ____________________

Shop Facilities:

Adequate Space	[ ]	________
Hoisting Equip.	[ ]	________
Machining Equip.	[ ]	________
Welding Equip.	[ ]	________
Hand Tools	[ ]	________
Tire Shop	[ ]	________
Test Equip.	[ ]	________
Steam Cleaning and/or Washing Facilities	[ ]	________
Lubricant Storage	[ ]	________
Tire Storage	[ ]	________

Mobile Maintenance Equipment:

Lube & Fuel Truck	[ ]	________
Welding Truck	[ ]	________
Mobile Crane	[ ]	________

Fueling Area [ ] ________

Parts Inventory: Parts for preventative maintenance [ ]
____

Repair Parts [ ]
____

Supplier Service Support: Availability ________ miles

	Good	Avg	Poor	Notes
Service Representative	[ ]	[ ]	[ ]	________
Shop Facilities	[ ]	[ ]	[ ]	________
Parts Inventory	[ ]	[ ]	[ ]	________
Training Facilities	[ ]	[ ]	[ ]	________
Safety Programs	[ ]	[ ]	[ ]	________

Equipment Parking Area: [ ] Hard Surface
[ ] Prepared-Dry
[ ] Auxiliary Heater Hook-ups

Operators: [ ] Good [ ] Avg [ ] Poor

Shift	1st	2nd	3rd
Prior FEL Exp	[ ]	[ ]	[ ]
Same Size Unit	[ ]	[ ]	[ ]

Supervision: [ ] Good [ ] Avg [ ] Poor
Previous Experience with Load-and-Carry [ ]
____

SECTION V

MACHINE SELECTION CONSIDERATIONS

MACHINE SIZE

The size indicated by the procedures outlined on Form 1 (General Considerations Worksheet) provides a starting point for machine selection. Subsequent sections (VII & VIII) establish procedures for determining the production capabilities, ownership and operating costs for any selected FEL size. They can be utilized for verification of preliminary selection and/or as a basis for evaluating alternate machine sizes and mine plans. Ultimately, machine size is established by progressive repeating of these calculations to optimize the overall system plan.

The final selection must also incorporate many other factors, some of which were discussd in Section III:

- production requirements
- operating hours
- blending requirements
- frequency of hopper moves
- material characteristics
- site conditions

There are other considerations which have not been introduced because they relate either to broad management decision areas or specific data normally compiled after the preliminary system analysis has been completed:

- compatibility with other mine equipment (for example, if the mine also uses trucks, the FEL may be sized so that it can alternately load trucks)

- the FEL may also be required for certain utility work

- anticipated future growth in production requirements or major changes to the mining plan

- standardization for service and maintenance purposes

- fleet size may be defined by specific production commitments which necessitate unit back-up

- net machine prices

- machine deliveries

- financing alternatives

Beyond these aspects, there remains consideration of the features and characteristics of the loader related to operating performance, servicing and maintenance.

MACHINE DESIGN

Site and production requirements must be matched to the front-end loaders commercially available. There is a broad selection in terms of sizes, purchase prices and optional features. This product market is dominated by well established U. S. manufacturers who, through their distributor organizations, generally provide nearby customer service and maintenance support. The machines in all but the larger sizes have a short delivery cycle.

Typical machines might be summarized as follows:

- 3.5 to 24 yd^3 nominal bucket capacity
- rubber tired (loader service design)
- four wheel drive
- articulated steering (35° to 45°)
- short coupled front-end geometry
- hydraulic cylinder bucket positioning and tilt
- automated bucket leveling and dump cut off
- diesel powered (6 - 16 cylinders)
- power train
  - torque converter, power shift transmission, axle differentials } or DC Motors
  - planetary gear reductions in wheels
- hydraulic system
  - closed pressurized, filtered
  - gear pumps
  - maximum pressures of 2500 to 3500 psi
  - 2 - bucket lift cylinders
  - 2 - bucket tilt cylinders
  - 2 - steering cylinders
- 24 volt electric system
- air/hydraulic service brakes (dual system)
- disc or band type parking brakes
- oscillating rear axle
- welded high strength low alloy steel frame
- ROPS cab
- operator station located on front or rear frame (varies with manufacturer)
- optional bucket configurations
- monitoring instruments
- anti-vandalism features

Front-end loaders are complex machines, involving comprehensive and sophisticated engineering, analytical and test techniques during their design. Design considerations include not only those directed towards machine operating performance but also include machine service and maintainability, safety, cost minimization, manufacturing limitations, purchased component availability, quality assurance, code compliance, etc. The user is concerned primarily with the first two and, in particular, with the selection of the best combination of features from those available with due regard to cost and product support by the manufacturer.

Evaluation of the design adequacy of a specific FEL or the relative performance of similar designs is at best a judgment determination since the data available is limited, the procedures highly technical and time consuming, and ultimately very dependent on the actual service requirements and operating practices. Further, since there are a great number of detail design features inherent in any loader design, it is difficult to identify those that might be significant with respect to selecting the optimum machine for load-and-carry service. A checklist (see following page) has been prepared to aid in such an analysis, highlighting the factors meriting consideration and, where possible, attempting to correlate them with related performance requirements. Some factors have an obvious impact, such as dump height, but most are more subtle. The features that impact on service and maintenance are, in particular, difficult to assess in any evaluation. Some complex relationships such as control characteristics and drive system response can only be discussed practically in terms of specific machines and are, therefore, omitted. The discussions and data which follow attempt to provide some insight into the reasoning involved in the design choices.

MACHINE SELECTION CHECKLIST

FRONT-END LOADER
LOAD-AND-CARRY

Date:_______________
Prepared by:_______________
No:_______________

Location:____

Machine model:___________ Manufacturer:_____________________
Bucket size:_____________yd³ (heaped)

DIGGING CAPABILITY

Machine weight______________lb.(incl.CWT)
Rimpull______________________lb.
Tipping load (straight)______________lb.
Breakout Force______________lb.
Hydraulic lift capacity______________lb.
Digging depth_______________inches

MANEUVERING CAPABILITY

Clearance circle____________ft.
Tiping load (full turn)______________lb.
Propel speed:
1st gear forward_______________mph
1st gear reverse_______________mph

TRANSPORT CAPABILITY

Maximum load_________________lb.
Wheel base___________________ft.-in.
Wheel tread__________________ft.-in.
Ground clearance____________ft.-in.
Bucket rollback (carry)_____________°
Propel speed:
2nd gear forward_______________mph
3rd gear forward_______________mph
4th gear forward_______________mph
2nd gear reverse_______________mph
3rd gear reverse_______________mph
4th gear reverse_______________mph

5

DUMP CAPABILITY	Maximum dump height______________ft.-in. Reach (@_______) ______________ft.-in. Bucket width ______________ft.-in. Bucket dump time ______________seconds
TIRES	Manufacturer_______________Model_________ Size____________Ply rating___________ Service code_________Construction_________ Front tire load (loaded bucket)_________lb. Load rating (limit @ 5mph)______________lb. (inflation pressure_____________psi) Work factor capability____________ (assumed average speed _________mph average load____________________tons haul distance___________________ft.) Ballasting: front axle____________lb. rear axle____________lb.
HYDRAULIC SYSTEM (Bucket)	Maximum pressure_______________psi Filtration level_______________microns
FRONT END GEOMETRY	No. of pivot points____________ Hydraulic plumbing & fittings [ ] good [ ] avg [ ] poor Bucket tilt [ ] good [ ] avg [ ] poor Automated bucket controls________________ ________________ ________________
BUCKET TEETH	Weight__________________lb. Construction____________________ Cutting edge____________________ No. of teeth____________type_____________ Special features________________________

ENGINE (diesel)

Manufacturer________________________________
Model____________________
Flywheel HP___________ ____________RPM
Fuel consumption (avg.cond.)__________GPH
Turbocharged|_| Aftercooled|_|
Performance curves provided|_|
Engine speed - constant|_| variable|_|

DRIVE TRAIN Mechanical|_| Electric|_|

DIFFERENTIAL Type_______________________

SERVICE BRAKES Type_______________________
Size_______________________

OPTIONAL EQUIPMENT

Outside mirrors |_| ____________________
Fast fill system |_| ____________________
Automatic lubrication system |_| ____________________
Night lighting equipment |_| ____________________
Heaters |_| ____________________
Counterweight |_| ____________________

SERVICE AND MAINTENANCE ASPECTS
good|_| average|_| poor|_|

COMPARATIVE MACHINE SPECIFICATIONS

A tabular comparison has been made (see Appendix A) of the available machines larger than 2 1/2 cubic yards, based on published literature and other information provided by the manufacturers. It must be recognized that such comparative summaries are always, to a degree, incomplete. Only a limited number of specifications are standardized (Society of Automotive Engineers), so that the meaning of the terms used may not be consistent; and the data provided varies significantly in scope and in detail. The machines themselves are constantly being modernized to improve capabilities, leading to inconsistencies in the literature which is only updated periodically.

5

The tabulation, which includes definitions of some terms, was prepared from literature received in the fall of 1980. It provides a comprehensive overview of available information to be considered in machine evaluation and selection. (See Table V - 1) As would be expected, there is a substantial overlap in dimensions, power and features of machines of the same general size. However, each manufacturer has combined these characteristics differently to provide what each considers optimal performance. Since the loader has broad application potential, numerous design compromises are required to provide the desired operational versatility.

POWER AND GEOMETRY CONSIDERATIONS

The engine power is applied to providing the propel rimpull and the hydraulic actuated motion of the bucket. In the carry and return portions of the operating cycle, total power is applied (neglecting accessory equipment) to rimpull to meet rolling resistance requirements, acceleration, and to maintain desired propel speed. Maximum rimpull is a function of available flywheel torques, torque characteristics in the different speed ranges, torque converter design, and the gear reductions in the drive system to the wheels, mechanical and/or electrical efficiencies, loaded radius of the tire, and finally, limited by traction conditions. For comparable size units, most of these factors are very similar so that the most significant differences are in engine flywheel horsepower.

Table V - 1

MACHINE SPECIFICATIONS TABULATED
(See Appendix A)

Operating Data
- bucket size
- breakout force
- payload
- tipping load
  - straight
  - 35° turn
  - full turn
  - full turn w/ctw
- dump height
- reach - @ 45°
  - 45° @ 7 ft.
- digging depth
- cab position
- standard operating weight

General Dimensions
- bucket size range
- bucket width
- overall machine
  - raised bucket
  - top of cab
  - top of exhaust
  - length
  - width
- clearance circle
- wheel base
- ground clearance
- height - hinge pin
- wheel tread
- bucket rollback
  - at ground
  - at carry

Auxiliary Systems
- tire size (std)
- service brakes (type)
- parking brakes (type)
- electrical
  - volts - amps
- steering
  - maximum angle (°)
  - pump type
  - GPM
  - maximum psi
- cylinder, no. - sizes

Operational Speeds
- bucket raise
- bucket dump
- bucket lower
- total
- propel forward
  - 1st,2nd,3rd,4th
- propel reverse
  - 1st,2nd,3rd,4th

Hydraulic System
- pump
  - type, GPM, max. psi
- cylinders
  - lift, no.-size
  - tilt, no.-size

Engines
- type
- no. of cycles
- no. of cylinders
- model no.
- gross HP @ RPM
- flywheel HP @ RPM
- max. torque @ RPM
- displacement

Power Train
- torque converter
  - make, type, ratio
- transmission
  - make, type
- differential
  - make, type
- final drive
  - type, ratio
- rear axle
  - oscillation
  - vertical travel

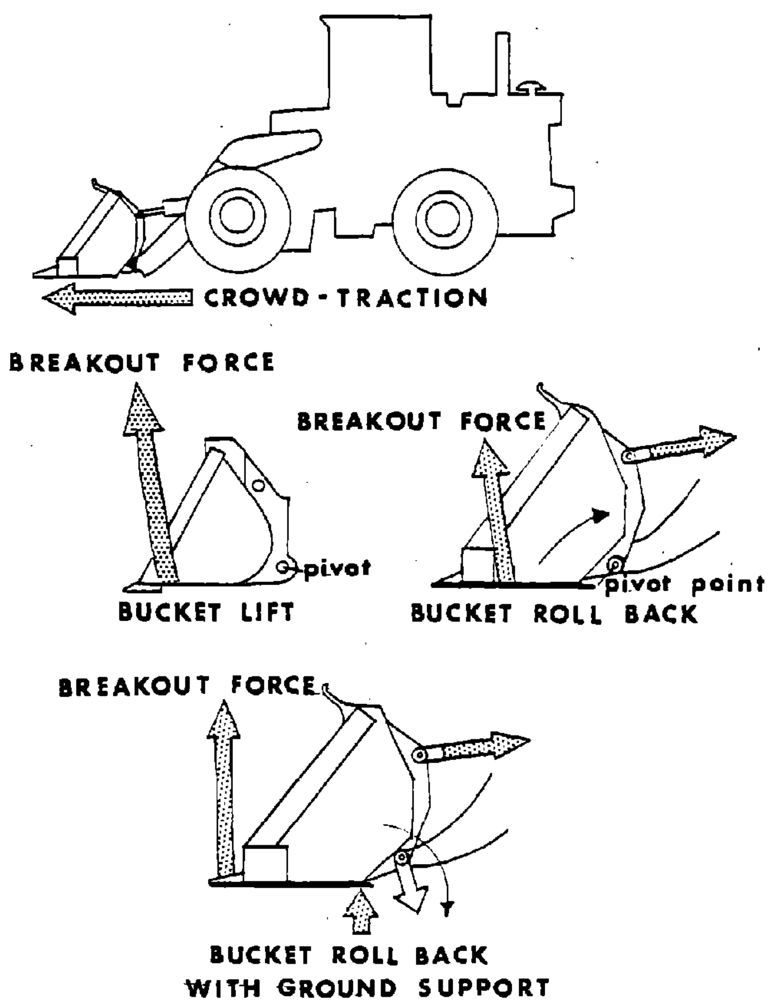
Service Capacities
- hydraulic system
- hydraulic tank
- fuel tank
- cooling system

Fuel Consumption
- easy conditions
- average conditions
- severe conditions

Initial bucket penetration of the bank is dependent, to a large degree, on the face conditions but will vary with the force per unit of bucket width generated by the loader, modified by the use of teeth and subject to the sharpness of the teeth and bucket lip. Since bucket width approximates tread width, penetration effectiveness reflects the forward crowd action developed by the loader. (See Figure V - 1) Crowd force is a combination of rimpull (limited by traction) and machine inertia. Inertia is a function of speed and is essentially controlled by the operator and limited by potential abuse to the bucket and machine. The larger machines generally approach the face slower but their increased weight maintains the high inertia forces.

Figure V - 1

DIGGING FORCES



Once the initial inertia forces have been dissipated, forward horizontal crowd forces are essentially dictated by traction conditions. All of the larger loaders have sufficient rimpull at digging speeds to spin the wheels under most traction conditions.

Bucket filling, however, also requires the ability to pry out boulders and consolidated materials which cannot be effectively penetrated. Further, the bucket must be progressively reoriented to expedite filling and retention of the accumulated load. These actions must occur before the tires penetrate too deeply into the toe of the digging face; this means a relatively short forward motion.

The rollback (rotating) capabilities of the bucket, generally indicated as the break-out force, provides the essential "prying" action. These forces are generated by the hydraulic wrist cylinders rotating the bucket around its hinge pin. Breakout force is not limited by machine stability if the bucket is supported partially by the material under the bucket. Maximum forces are dictated by design relationships which are limited by bucket strength. The utilization of these wristing forces is dependent on the severity of the digging conditions.

Vertical motion (actually a forward arc) of the bucket penetrating the face and raising the loaded bucket out of the bank is achieved by the lift cylinders rotating the bucket arms about the machine hinge point. Forces are a function of the lever arms, cylinder size and hydraulic pressures. The maximum force is limited by the machine forward "tipping load" which is specified by the manufacturer. Most loaders are designed such that the lift forces which can be generated will reach the maximum tipping load.

Crowd, breakout and tipping load relationships, dependent on machine design, vary with the bucket position in its travel arc, which makes overall digging performance comparisons difficult. Similarly, the relative speeds of the various motions and smoothness of the controls affects the ability of the operator to optimize performance. There are also differences in how the total available engine power is distributed during digging between the propel and hydraulic functions. If possible, comparative operating trials with an experienced operator may add insight into the design balance of the digging forces.

INFLUENCE OF MACHINE SIZE

Front-end loaders have been utilized in the sizes through 10 cubic yards for sufficient years to be assured of optimal design characteristics. The very large sizes, above 20 yards, however, are a more recent development; there are fewer in service and they are in a period of design refinement. If an analysis is made of machine specifications, it reveals the following:

- hydraulic cycle time increases with size
- maximum breakout forces/inch of bucket width increase sustantially with size
- maximum tractive force/inch of bucket width increases substantially with size
- carrying capacity remains relatively constant at about 20% of machine weight for all sizes
- propel speeds change little with size
- wheel base does not increase in proportion to machine size
- tipping loads are 60 to 80% of machine weight
- dumping height increases from 10 ft. to about 18 ft. as machine size increases from 5 to 20 yd^3
- machine reach increases from about 4 ft. to 8 ft. as machine size increases from 5 to 20 yd^3

Some general observations from the above are possible.

The larger machines appear to be more rugged with increased effective power and, hence, should have improved performance in hard digging conditions.

The increase in physical size of the larger machines does permit working on higher faces and dumping into higher and deeper hoppers and trucks. This increased range, however, is not in direct proportion to the increased size.

Relative carrying capacity, wheel base and travel speeds do not improve with size, indicating that with increasing size, there is no added inherent advantage from the standpoint of productivity in load-and-carry service.

The larger, more rugged machines are substantially heavier, have more inertia, require more power with increased fuel consumption. Available power and structural strength restrict the maximum breakout force. To provide close quarter maneuverability, the large loaders have proportionally shorter wheel bases and reduced fore and aft stability.

Basic machine weight/nominal bucket size:

3 - 6 yd^3 sizes	10,000 to 11,000 lb/yd^3
7 - 10 yd^3 sizes	10,500 to 13,000 lb/yd^3
11 - 15 yd^3 sizes	11,000 to 15,500 lb/yd^3
16 - larger sizes	13,000 to 16,500 lb/yd^3

Basic machine weight/flywheel horsepower
(gross horsepower for electric machines)

3 - 6 yd^3 sizes	175 to 215 lb/HP
7 - 10 yd^3 sizes	200 to 250 lb/HP
11 - 15 yd^3 sizes	215 to 285 lb/HP
16 - larger sizes	265 to 399 lb/HP

Breakout force/basic machine weight

3 - 6 yd^3 sizes	0.70 to 1.00
7 - 10 yd^3 sizes	0.60 to 0.85
11 - 15 yd^3 sizes	0.60 to 0.75
16 - larger sizes	0.40 to 0.65

FRONT END LINKAGE

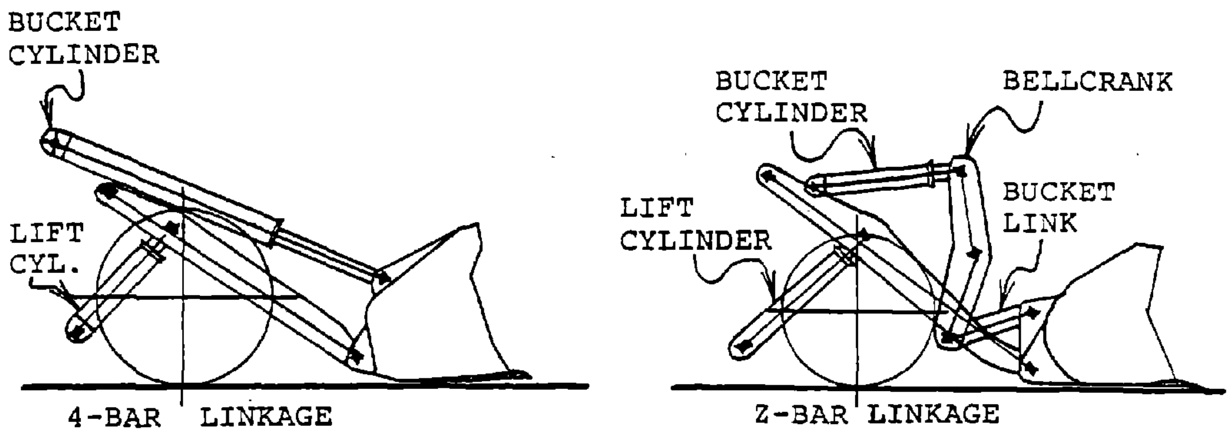
There are numerous configurations possible in the front end geometry and linkage that will provide the necessary digging path and dump characteritstics. (See Figure V - 2) Generally, the hydraulics have engine power priority over the propel so that the maximum forces applied to the bucket are dictated by the cylinder sizes and relief valve settings. Peak breakout forces are a function of the cylinder force and the lever arm geometry. It should be noted, however, that the front end can be severely loaded if the machine is propelled into the face with the bucket tipped back. Desirable design characteristics to look for are:

- low overall linkage weight
- minimum parts and joints
- simple, well attached hydraulic lines
- general in-line construction
- accessibility for servicing
- high bucket roll-back at ground level and carry positions
- good bucket deceleration characteristics at end of dump cycle to minimize shocks
- high breakout forces
    - improve bucket filling
    - lower operating pressures during digging
    - less hydraulic heat due to blowing of relief valve
- highest lift and breakout forces developed at lower digging heights

Operational features built into the bucket control system (see Figure V - 3), such as bucket positions (self-leveling), lift kick-out, and dump kick-out, are effective in reducing operator fatigue and relieving him/her of these control commands during periods when full attention should be concentrated on machine maneuvering.

Figure V - 2

FRONT END LINKAGES



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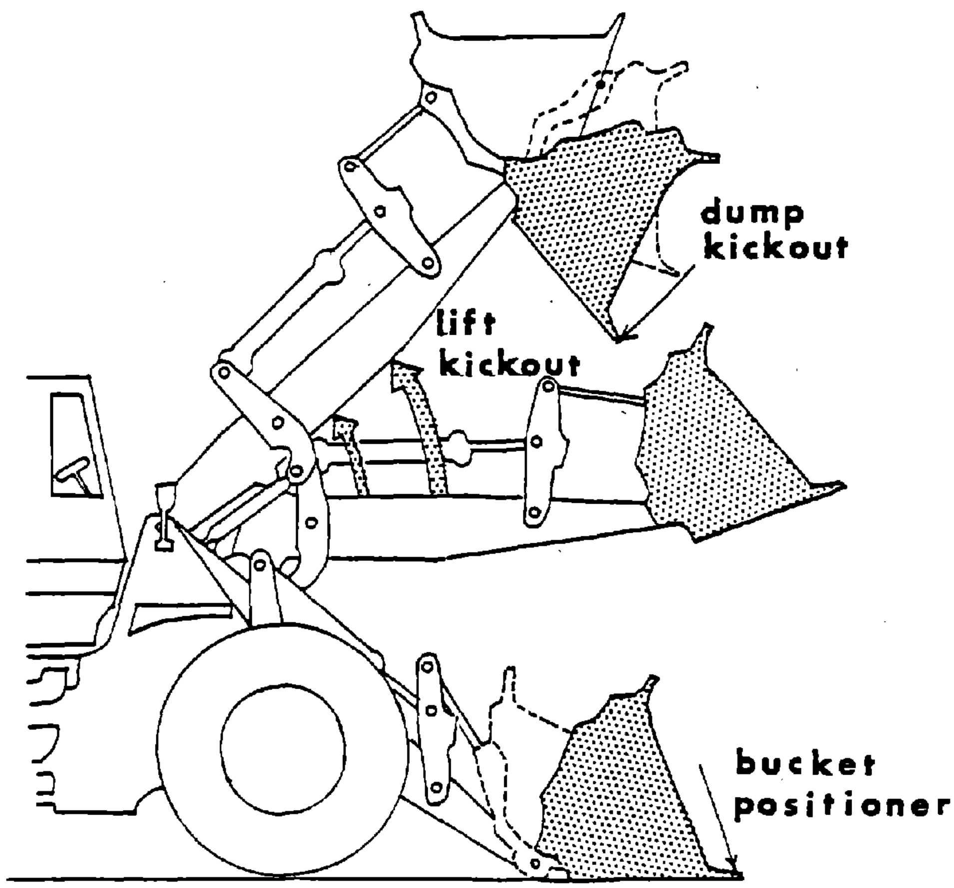
Hydraulic cycle times provided by the manufacturers are of interest only for the "dump" and "lower" portions of the cycle, since the actual "hoist" (dig) time is tied to bank conditions. These times, however, represent a very small portion of the load-and-carry cycle and do not differ substantially between machines of the same size.

Figure V - 3

AUTOMATED BUCKET FUNCTIONS



HYDRAULIC SYSTEM

Since the hydraulics involve only pumps, valves and cylinders for power transmission, the systems are relatively simple. (See Figure V - 4) Two separate systems are generally provided, one for the steering and one for bucket motions. They are both closed, pressurized and filtered systems operating at medium pressure levels. Large reservoirs are common, which aid in hydraulic fluid temperature control. Valves are power assisted to permit handling large flow volumes with minimum manual effort. Pumps are frequently of the gear type, which are the most tolerant of contamination.

While the systems are well proven, they can be a source of problems due to detail design deficiencies, abusive operation and/or poor maintenance practices. The primary problem areas are:

- oil contamination,
- failure of joints, hoses and support brackets,
- seal failures,
- excessive heat build-up.

Contamination, since it leads to progressive failure of the pumps, valves and seals, and cylinder scoring, is the most serious and, unfortunately, the most difficult to control. It results from:

(1) chips, welding scale, sand from castings, dust and dirt introduced into the system during manufacturing and/or maintenence work

(2) seal failures, wear and chemical reactions during operation

The design can only minimize this problem by incorporating filters of sufficient size, construction, and fineness, (maximum of 10 micron), properly located to protect critical components such as the pumps and valves which have extremely small internal clearances.

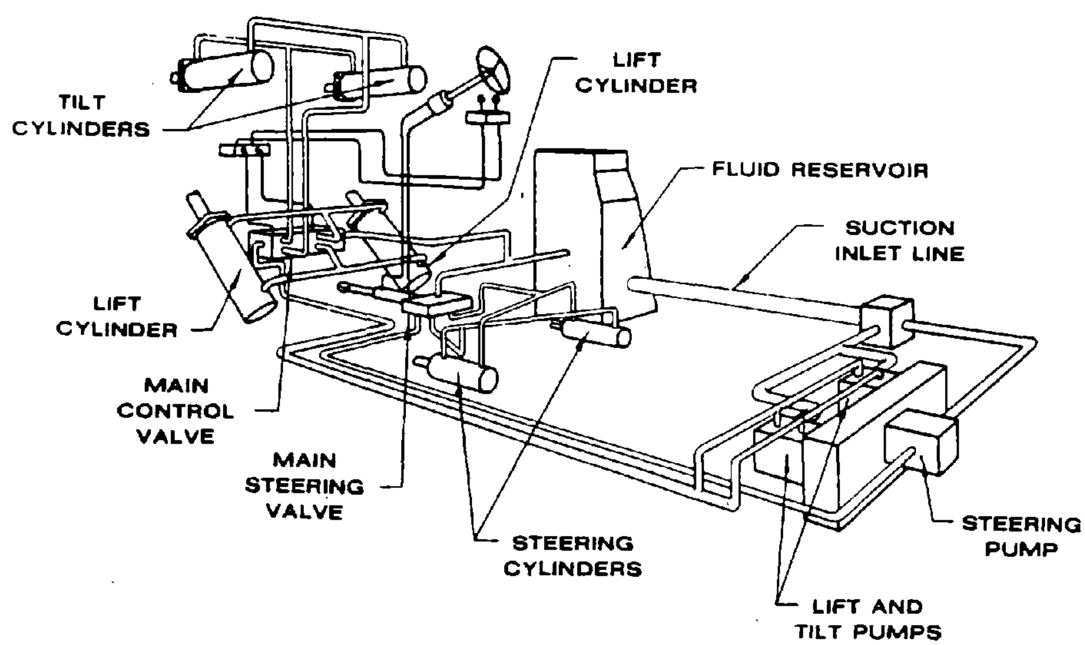
Failures in the piping system result from external damage during operation, excessive machine bounce and vibration, contact with other parts of the stucture, pressure peaks from machine overloading and sticking valves, and defective fittings and straps. Hose is employed where a flexible connection is required; metal tubing (rigid) is used in other sections where its lower cost, greater strength and resistance to vibrations, plus better heat dissipating characteristics are desired. Hose life is dependent on its flexibility, operating pressures, the tightness of the curves (as installed), the sharpness and frequency of the bending, and proper installation procedures. There is a difference in the quality and performance of hose and fittings available. The physical arrangement and components employed should be carefully examined to ascertain their quality. In service, regular inspections are required to indentify any component deterioration.

Some seal failures can be recognized externally by leakage. But there is equal or greater concern with failures which permit dirt and/or air to enter the system, which result in a myriad of problems to a variety of components. Despite the apparent simplicity and low cost of seals, the detail design, manufacturing quality and installation procedures vary substantially, impacting on machine mechanical availability for service. Acceptability can only be judged effectively by reviewing prior service experience.

The hydraulic system design should provide for dissipation of the heat developed from fluid friction in the piping, heat generated in the valves, pumps, etc. The amount of heat varies with the machine duty cycle, ambient temperatures and the operator's operational techniques. Excessive heat build-up is particularly detrimental to the hydraulic fluids, hoses and seals. Required is a system which has an adequate safety margin in heat dissipating capacity to provide for the most severe circumstances.

Figure V - 4

SCHEMATIC OF A HYDRAULIC SYSTEM
(from Constraints Limiting the Availability of Front-End Loaders, Skelly & Loy, U.S. Dept of Energy Contract No. ET-77-C01-8914, June 1979)



BUCKETS AND TEETH

The smaller to medium size loaders generally have the following buckets available:

- heavy duty or rock,
- general purpose,
- light duty or coal.

For the smaller sizes special side dump and multipurpose (bottom dump) buckets are also available, but these would not normally be used in load-and-carry service because of their increased weight and accompanying reduction in payload. In the larger sizes, generally only the heavy duty or special coal buckets are offered.

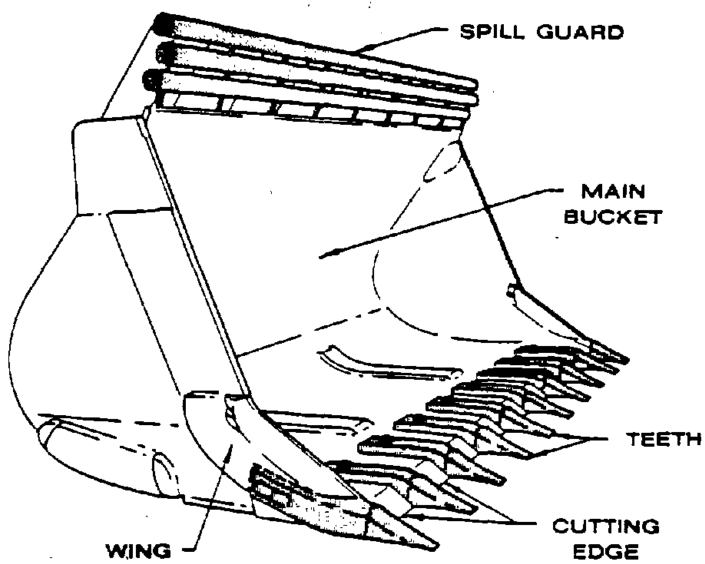
The relative weight of the bucket increases as the overall ruggedness of the structure is adjusted to withstand the tougher digging conditions implied with the heavy duty construction. (See Figure V - 5) Since the loader is rated to carry a fixed load, as bucket weight increases, the amount of material which can be carried decreases. This is a judgement area because increased bucket life is a trade-off with reduced payload. Occasional minor rebuilding may not be a serious penalty when compared with increased production.

The bucket cutting edge can be either straight or "V" shaped. The straight is normally applied to the lighter duty applications and the "V" to hard digging. The edge shape of the "V" concentrates the forces to improve penetration. Bucket shape is generally adjusted so that the load carried does not change with the lip configuration. Because of the increased lever arm possible with the extended lip in the "V" design, the breakout force can be reduced significantly (15 to 25%).

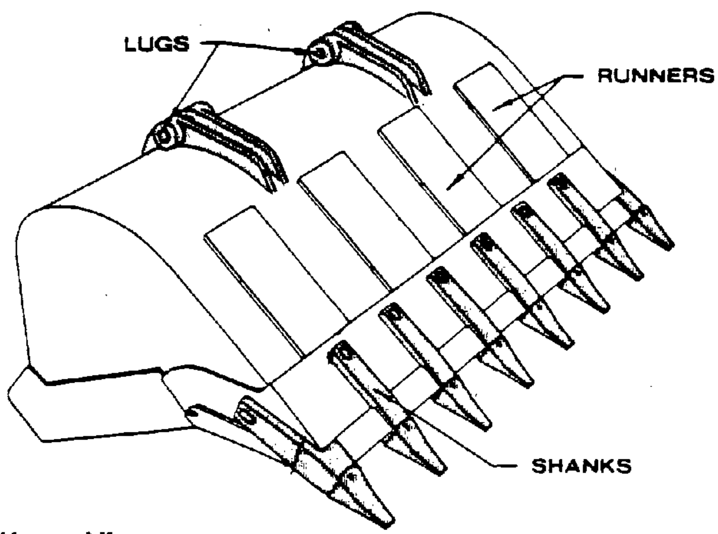
In difficult digging conditions, bucket penetration can be increased and maintenance reduced with the addition of teeth to the bucket lip. The separated teeth extending forward concentrate the digging forces in a small area and tend to shatter or shear the material between the teeth, displacing it for easier penetration by the cutting edge. Teeth are available in a wide variety of styles and sizes from the manufacturer or specialty product groups. Two basic types are in common use -- the solid welded-on tooth, and points and adapter combinations in which the adapter only is permanently attached. Special corner teeth and heavy duty lips are also available.

Figure V - 5

BUCKET CONSTRUCTION
(from Constraints Limiting the Availability of Front-End Loaders, Skelly & Loy, U.S. Dept of Energy Contract No. ET-77-C01-8914, June 1979)



Front Side View



Bottom View

ENGINES

A selection of diesel engines from different manufacturers is available for many loaders. This permits standardization of engines across equipment fleets, reducing parts inventory and generally improving unit reliability, as a result of service and maintenance personnel familiarity. Specific engine performance curves should be studied and compared at the time of loader selection. It should be recognized that within any manufacturer's design series there is a wide range of power ratings achieved through changes in the number of cylinders, size of the injectors, engine revolutions per minute, turbocharging and aftercooling. Turbocharging and/or turbocharging and aftercooling is recommended for operations at altitudes above 3000 feet. Proven engines are available in a wide range of sizes in both the two and four cycle designs. The prime arguments for each are as follows:

two cycle: lower first cost
superior acceleration
less weight

four cycle: lower fuel consumption
less engine heat build-up
efficient on lower grade fuels

Some manufacturers provide average values for fuel consumption under easy, average and severe operation conditions. (Typical data is shown later under operating costs.) The same practices that reduce fuel consumption generally result in slower engine and equipment wear. Diesel fuel economy is related to engine and operating efficiency. Older and/or poorly maintained units have higher fuel consumption. Other influencing factors are:

Direct injection is more efficient than the precombustion design.

Four cycle engines use less fuel than two cycle models.

Large displacement designs with large diameter cylinders provide more complete combustion and lower fuel consumtion.

Turbocharged and turbocharged-after-cooled engines are more efficient.

In the torque converter drive ranges, operating at 50 to 75 percent of the maximum loader speed minimizes fuel consumption.

High altitude and ambient temperatures increase fuel consumption unless special adjustments are made.

DRIVE TRAINS

There are two distinctly different drive train options available, furnished by different manufacturers. The major elements in each can be summarized as follows:

Mechanical (see Figure V - 6)	Electric (see Figure V - 7)
engine	engine
torque converter	A.C. generator
power shift transmission	control converters
drive shaft - differential	D.C. motors (2 or 4)*
wheel planetary reductions	wheel planetary reductions

*In one design the motors drive the axial differentials; in the other the motors drive the individual wheels.

Figure V - 6

MECHANICAL DRIVE TRAIN

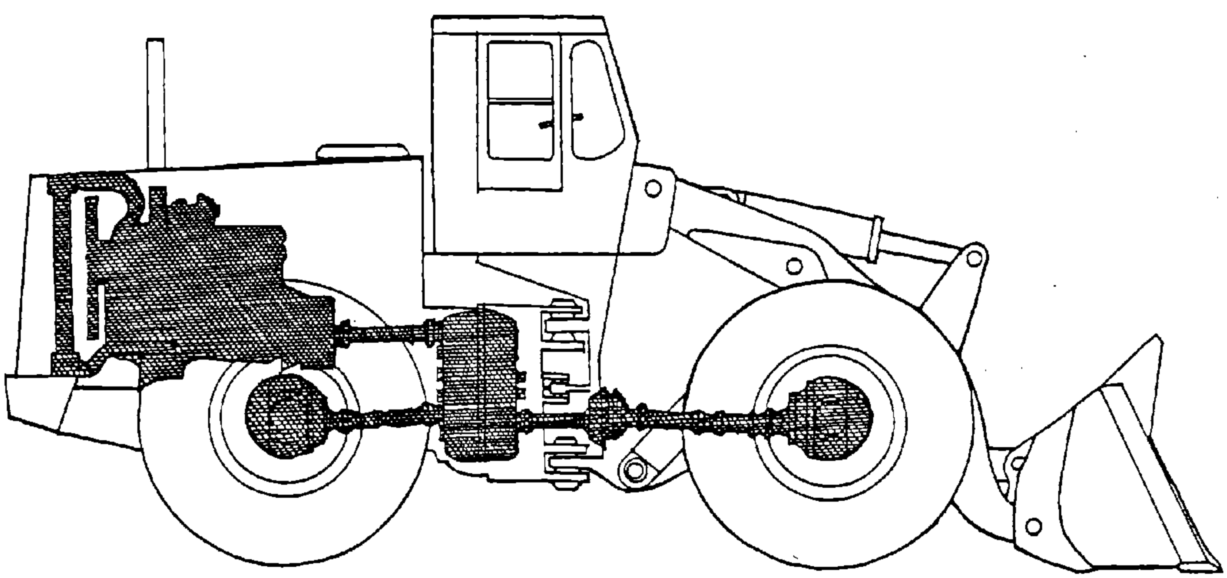
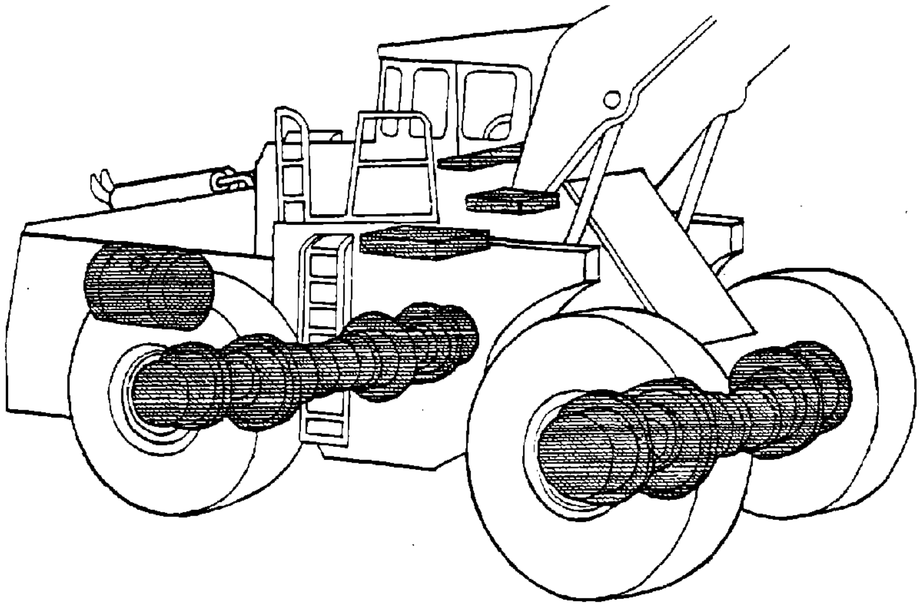


Figure V - 7

ELECTRIC DRIVE TRAIN



Electric drive units are available in the larger FEL sizes. They are generally comparable in terms of power, size and performance, with the equivalent size mechanical drive machines. Their unique performance and characteristics are as follows:

- traction can be controlled to minimize tire slippage
- gear shifting is eliminated - infinite speed control
- dynamic retarding is provided
- comprehensive electronic monitoring of critical functions is provided
- essentially constant engine speed
- motors on each wheel (or axle) are not fully sealed units

- service and repair work requires some electrical expertise

- forced air cooling (filtered) provided for motors in front and rear axle, generator, grid box, and control box

- solid state electronic circuitry - (plug-in printed circuit cards)

- higher torque motors installed on front wheels

DIFFERENTIAL AND BRAKES

There are three basic types of differentials - torque proportioning, limited slip and no-spin. Each has its own unique operating features and application depends upon traction requirements. The torque proportioning is most efficient on high traction surfaces, diminishes in effectiveness as the traction surface or coefficient of friction decreases.

A no-spin differential is a cam operated differential which directs the total axle torque to the slower moving wheel of the axle; a limited-slip differential is a clutch type differential which provides improved traction while maintaining torque to both wheels of the axle.

Brake types commonly used are expanding shoe, dry disc and liquid cooled disc. All three types can be actuated by either air or hydraulic pressure.

The expanding shoe brake is more subject to fade and generally requires the removal of the wheel hub for lining replacement. Dry disc brakes offer easier servicing because linings can be replaced without axle disassembly. Dry disc brakes are not as subject to fade, and lining life is sometimes longer. Liquid cooled disc brakes are enclosed and free from contamination and the life of the brake components is generally expected to equal or exceed the time between complete axle overhauls. In abrasive or other harsh environments, the higher initial cost of these brakes may be offset by savings in brake maintenance costs.

Load-and-carry service, particularly if down grade runs are involved, requires verification that there is adequate capacity in the brakes. As noted earlier, the electric drive machines have dynamic braking capabilities which reduce the demands on the conventional brakes.

OPTIONAL EQUIPMENT

Each manufacturer offers a selected group of optional equipment which is available with the machine. The number of options generally decreases with the machine size. Additional equipment such as tire chains, special teeth and cutting edges, etc., are available from specialty manufacturers. The following listing is intended only to indicate the normal scope of such items.

- Buckets
  - general purpose
  - rock
  - light duty
  - side dumping
  - multi-purpose
- Cutting edges
  - straight
  - V-nose
  - modified V-nose
- Teeth
- Engine
  - manufacturer
  - horsepower
  - turbocharged
  - aftercooled
- Counterweights
- Extended boom
- Tires
- Fast fill fuel system
- Automatic lubrication systems
- Mirrors
- Operator comfort and convenience items
- Vandalism protection
- Night lighting equipment
- Heaters (hydraulic, battery, engine, oil)
- Fire supression devices
- Cold weather starting aids and electric block heaters

SERVICE AND MAINTENANCE CONSIDERATIONS

Service and maintenance procedures are well documented in manuals provided with the machine, or available on request. Many manufacturers, in addition, provide comprehensive training programs and other supportive literature.

From a design standpoint, the machine should meet the following objectives:

- good accessibility to all elements requiring servicing or maintenance on a regular basis
- permit simple and fast inspection and replacement of all filters
- group lubrication points and filters requiring servicing
- service points located to permit work to be done while standing on the ground if possible
- modular units wherever possible to permit rapid interchange/exchange with units from other machines, in stock, with distributor, etc.
- standardized componentry to minimize parts inventory and increase mechanic's familiarity
- diagnostic type instruments which provide an indication of deteriorating conditions
- clean, simple hydraulic plumbing arrangement
- maximum use of sealed bearings aimed at reducing servicing frequency

From an operation standpoint, the prime considerations are:

Service per manufacturer's recommendations.

Make repairs promptly.

Keep good records of work performed on each machine.

Keep the hydraulic system tight and clean.

Check tires for inflation, damage and wear regularly.

Monitor engine conditions with oil sampling techniques if practical.

SECTION VI

TIRE CONSIDERATIONS

OPERATING CONSIDERATIONS

Tires are a critical consideration in terms of loader availability and operating costs. Tire performance in service should be carefully monitored and unsatisfactory results discussed with the tire supplier and other tire manufacturers as warranted to be assured of the best matching with the specific site conditions and job requirements.

Tire life considerations and estimating procedures are discussed in Section VIII on operating costs.

Acceptable tire costs and performance are dictated by proper machine operation and tire selection. Proper machine operation is concerned with recognizing the tire limitations and avoiding abuse, which will shorten tire life or, in the extreme, cause blowouts. The primary causes of tire abuse can be listed as follows:

digging procedures,
floor and haul road conditions,
tire loads,
travel speeds,
tire inflation.

Abuse due to digging procedures is generally related to three operating practices. One is the tendency for the operator to climb the bank, excessively exposing the highly loaded front tires to cutting or penetration by sharp rocks in the face. Second is an overly aggressive attack on the face with maximum wheel torques that cause wheel spinning; substantially increasing the potential for tire damage on sharp or abrasive materials. Third is poor operator propel and bucket lift coordination which transfers the prying forces necessary to break the material free directly to the front tires rather than using hydraulic wristing with the bucket supported partially by the bank. Practices such as these can reduce tire life to a half or a third, particularly if the face material is heavy, sharp and abrasive.

The loader, in load and carry service, turns and maneuvers at the digging face, at the dump location, and transports between these points. Floor conditions in the maneuvering areas and on the haul road significantly influence tire life. In the process of adjusting the bucket to its full rollback position, after digging and/or rolling it forward for the dump, there can be spillage of rocks over the cutting edge or the bucket sides. This can be aggravated if the operator attempts to overfill the bucket and does not attempt to stabilize his load while at the face. Unusually rough turning, bucket movements or accelerations will further dislodge hanging material onto the work floor. In these tight operating areas, the operator's close-in visibility is limited so that little can be done to avoid propelling over fallen material and causing further tire abuse and wear. Continual efforts to keep this floor clean as digging progresses are essential.

The problem of bucket spillage is even more serious on the haul roads because of the increased speed of the machine when striking obstructions. Minimizing this problem, however, is easier with an alert operator because he often can see any obstructions in time to avoid them. Further, return travel on the same route gives the operator an opportunity to clean up the abusive spillage with his bucket.

Tires are selected and applied to machines based on their rated load carrying capacities. Overloads will reduce tire life. While the general operating characteristics of the loader are recognized in tire design and in the calculation of the tire loading, serious overloading does occur unless care is exercised. Tires are often selected based on the machine weight load distribution with the loaded bucket in the carry position, which generally means that 70 to 80% of the total weight is supported by the front tires. Ground bearing pressures under the front tires can typically range from 45 to 55 psi with an empty bucket, 70 to 85 psi with a loaded bucket and up to 150 to 200 psi while leveraging the bucket during digging. Carry operations can significantly increase the opportunity for overloading because of dynamic loads if the speeds are high, the haul roads have potholes or ruts, or overall roughness results in severe bouncing or fore-and-aft pitching. The manufacturer's tire load limit tables reduce the maximum load values for load and carry service to 85%. Doubling the average speed from 5 to 10 MPH reduces the acceptable loads another 15 to 20% depending on tire size and inflation pressures.

Loader tires are commonly selected by the manufacturer (larger sizes) with prime consideration given to truck loading performance since this is the largest machine market. These operations, with minimum loaded travel distances, do not present any serious problems with tire heat build-up. The deep tread designs selected for rock penetration resistance and extended wear life, however, do not have the desired heat dissipating characteristics necessary for tires traveling at higher speeds in a cycling transport operation. The loader's combined operations of digging and transporting, with conflicting tire design requirements, forces a compromise selection with respect to tire characteristics. Consequently, the tires applied are susceptible to deterioration if care is not taken to minimize heat build-up. The heat generated is a function of travel speeds and distance in the load and carry cycle. Since distances are fixed by the mine plan, only speed control can be used to minimize this problem. This means that maximum travel speeds, primarily limited by safety and operator comfort, may have to be further restricted to reduce tire abuse from heat build-up.

Tire inflation also can result in severe tire abuse if it is significantly greater than or less than that recommended to support the tire loads. The impact of these conditions is reflected in:

underinflation:
- irregular tread wear
- sidewall radial cracking
- tread and ply separation
- excessive heat build-up

overinflation:
- harder ride
- reduced traction and skid resistance
- increased danger of rock cutting, tire bruises, blowouts
- abnormal tire growth

Fortunately, there is a simple preventive technique - regular pressure checks. Underinflation for operations in soft soils or sands will provide improved flotation and may be desirable in some applications.

Tires require special handling, storage and maintenance procedures. This information is conveniently documented in manuals available from the suppliers.

SELECTION PROCEDURE

SELECT SIZE

Select tire size based on loader manufacturer's recommendations and/or with their agreement for your application. (See Table VI - 1, Tire and Rim Size Designation.)

SELECT ASPECT RATIO

This is the ratio between tire section height and section width. (Refer again to loader manufacturer's recommendations.) There are three aspect ratios commerically available:

standard - approximately 0.96
wide base - approximately 0.83
65 series - approximately 0.65

The lowering of aspect ratios results in (1) wider tire footprint on the ground, (2) reduced permissible inflation pressures, and (3) improved flotation, machine side stability and ride comfort. Since loader operation involves severe mane uvering requirements on relatively poor floor conditions, the wide base tires are currently the most commonly selected.

Table VI - 1

TIRE AND RIM ASSOCIATION SIZE DESIGNATION

Off-highway tires are designated by an alpha-numeric sequence.
Example: 33.25-49 43 PR L4 (L4 refers to the Service Code)

Section Width Reference	-	Nominal Rim Dia.	Carcass Strength Rating
Standard: approximate width (inches) includes 2 zeros following decimal point (ex. 24.00) Tires have a section height over section width ratio of about 0.96. Maximum width 28.53 inches	Hyphen indicates a bias ply construction Replaced by R for a radial construction	Appropriate nominal rim diameter measured through center of tire (excluding flanges)	Carcass strength indicated by ply rating (PR) or load range (LR) These are indices of tire strength and do not necessarily represent number of cord plies in tire
Wide Base: approximate section width (inches) includes digits following decimal point (ex. 33.25) Tires have a section height over a section width ratio of about 0.83. Maximum width 32.75 inches.		Rim is designated by: a nominal rim width, nominal rim diameter, flange height	
65 Series: (low profile) section width includes digits starting with 65 (ex. 65/40) The first number is the ratio of section height to section width which for this series is 0.65. The second number is the approximate section width (inches).			

SELECT TIRE CONSTRUCTION

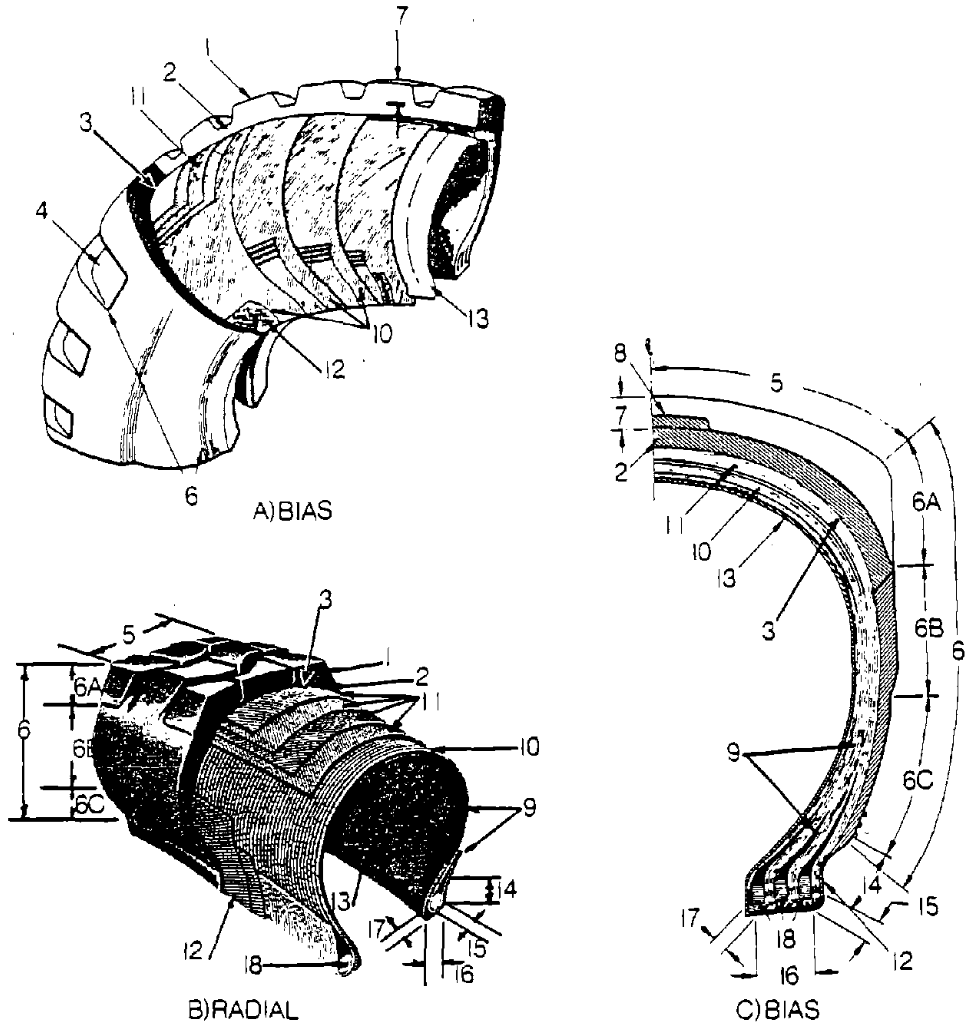
There are three types of tire construction that are available. The selection of the preferred type for a specific application is complex and warrants discussion with tire manufacturers. Some of the reasoning can be summarized as follows: (also see Figure VI - 1: Nomenclature for Off-Highway Tires)

Type	Pros	Cons
Bias Ply	Low cost, Available in variety of sizes, Repair costs low, Thick sidewalls.	Subject to heat build-up.
Radial	Lower tread wear, Lower rolling resistance, Less heat build-up, Good tread penetration resistance.	High initial cost, Thin sidewalls.
Track Type	Improved service life, Simple servicing procedures, Component replacement possible, Good flotation, Good traction, Improved machine stability, No limitations on speed or travel distance.	Limited size availability, Very high initial cost, Rougher Ride, Increased noise level, Increased fuel consumption.

The track type tires (see Figure IV - 2) are relatively new, with limited application experience and available only in selected sizes from two manufacturers - Caterpillar Tractor Company and Goodyear Tire and Rubber Company. The application and cost analysis are substantially different from that for the conventional tires. Any considerations of these types of tires shoud be discussed directly with a supplier's representative.

Figure VI - 1

NOMENCLATURE FOR OFF-HIGHWAY TIRES



1. TREAD (Tread Design, Tread Lug, Lug, Rib)
2. UNDERTREAD (Base Tread, Under Skid)
3. TREAD INTERFACE, junction of undertread and carcass
4. TREAD VOID (Groove)
5. TREAD SURFACE (Tread Face)
6. SIDEWALL
   - (a) Upper Sidewall (Shoulder, Buttress)
   - (b) Mid Sidewall
   - (c) Lower Sidewall
7. TREAD DEPTH (Antiskid, Nonskid, Skid Depth)
8. TIE BAR (Submerged Rib, Running Rib)
9. CARCASS (Body, Cord, Reinforcement)
10. PLIES
11. TREAD PLIES (Shock Plies, Cap Plies, Breakers, Belts)
12. CHAFER
13. LINER (Tubeless Liner, Inner Liner)
14. RIM FLANGE AREA (Chafer Area, Bead Flange Area)
15. BEAD HEEL
16. BEAD BASE (Bead Face)
17. BEAD TOE
18. BEAD BUNDLE (Bead Wire Bundle)

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SELECT SERVICE CODE (Tread Design)

Service classifications (code) have been standardized by the industry for loader service; they are listed in Table VI - 2. Note that while this classification system is aimed primarily at tread design, in reality it significantly affects a number of performance characterisitcs of the tire. Table VI - 3, a summary table on loader tire performance, attempts to show some of the inter-relationships with respect to these classifications. Obviously, site and application significantly impact tire performance so that such a compilation can only be considered as a broad frame of reference.

Another way to look at the tread design is in terms of the operation to be performed and the work surface conditions, as illustrated in Table VI - 4.

Figure IV - 2

TRACK-TYPE TIRE

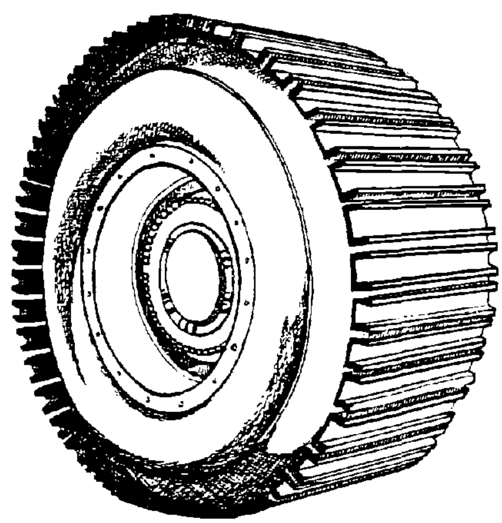


Table VI - 2

SERVICE CLASSIFICATIONS

Code	Tread Design Type	Applications
L-2	Traction	When traction is required over soft soil or sand. Regular tread skid depth.
L-3	Rock	Resistance to moderate cutting and abrasion; light rock conditions.
L-4	Rock Deep Tread	Resistance to shot rock or other severe cutting and abrasive applications. Deep tread skid depth (approximately 50% deeper than L2 & L3.
L-5	Rock Extra Deep Tread	Maximum rock cut and abrasive resistance; quarry work. Extra deep tread skid depth (approximately 67% deeper than L4)
L-3S	Smooth	Completely smooth tread from shoulder to shoulder to with-
L-4S	Smooth - Deep Tread	stand the most severe rock service conditions. Resists severe cuts, snags & tearing due to the smooth tread.
L-6S	Smooth - Extra Deep Tread	Increased footprint area offers excellent traction capability. Provides the flotation and traction required in sand operations.
L-3/ L-3S	Half Track - Regular Tread	Completely smooth tread on the out-board half of the tire. The smooth solid, no void half
L-4/ L-4S	Half Track - Deep Tread	helps to protect against chunking, ripping & slashing from ore, rock and shale -
L-5/ L-5S	Half Track - Extra Deep Tread	balances out tread wear pattern. The deep tread design on the in-board half of the tread provides the required traction.

Table VI - 3

LOADER TIRE PERFORMANCE
(10 rate is optimum*)

Code	Traction	Flotation	Hard Surface Stability	Penetration Resists Tread	Penetration Resists Sidewall	Wear	Load & Carry
L-2	10	10	5	2	6	3	10
L-3	7	10	6	5	7	5	9
L-4	8	7	7	7	8	7	6
L-5	5	5	9	9	10	9	3
L-4S	1	7	7	7	8	6	2
L-5S	1	5	9	9	10	8	1
RL 3	8E	10E	5E	9E	8E	6E	8E
RL 4	8E	9E	5E	10E	5E	8E	6E

*This chart is not presented as a substitute for experienced tire engineering recommendations; but rather as a reminder that tires with varying degrees of the desired characteristics are available.

E = estimated

(Courtesy of Goodyear Tire & Rubber Co.)

Table VI - 4

LOADER SERVICE

Type of Service	Road/Floor Material	Recommended Tread
Loading, maximum traction, transport	Mixed soils, sand, some gravel, smooth materials Silt & clay, high moisture content	Traction type L-2
Loading, transport	Mixed soils, smooth aggregates, some rock	Rock type L-3
Loading, some transport	Rock, rough materials sharp aggregates	Rock type L-4 or L-4S
Severe loading	Sharp rock, abrasive materials	Rock type L-5 or L-5S

6

CHECK LOAD LIMITS

The Tire and Rim Association has established load limits for the various commerical tire sizes. Separate data tables are provided for various selected speeds and service classifications. Each table provides the limit loads for various cold inflation pressures with the corresponding tire ply ratings indicated.

The ply rating (PR), sometimes called the load range (LR), is a measure of the tire carcass strength. Higher ratings reflect higher load carrying capacity which, in turn, means that it can be utilized with higher inflation pressures. The ply rating is a part of the basic tire specification.

See Table VI - 5 for the load ratings (lbs) for wide base and 65 series tires used in loader service, these ratios normally consider 5 mph as the maximum speed. The notes at the bottom of this table indicate the correction for radial tires and suggest a 13% reduction in loads for 10 mph maximum speeds.

Tires should be selected that meet the specified load limits and operate at the corresponding inflation pressure. The front tires are substantially more highly loaded for sustained periods in load and carry service and therefore should be used as the basis for the load limit evaluation.

Table VI - 5

WIDE BASE TIRES FOR SHOVELS, MINING CARS, FRONT-END LOADERS, DOZERS AND FORK-LIFT TRUCKS

Maximum Speed is the peak velocity attained

MAXIMUM SPEED—5 MILES PER HOUR

TIRE SIZE DESIGNATION	TIRE LOAD LIMITS AT VARIOUS COLD INFLATION PRESSURES											
	25	30	35	40	45	50	55	60	65	70	75	80
15.5-25	7500	8340	9130	**9870**(8)	10580	11250	**11890**(12)					
17.5-25	9050	10060	11010	**11910**(10)	12760	**13570**(12)	14350	**15110**(14)	**15820**(16)			
20.5-25	11340	12620	13810	**14930**(12)	16000	**17020**(16)	17990	18930	**19840**(20)	20720	21570	**22400**(24)
23.5-25	14640	16290	**17820**(12)	19270	**20650**(16)	21960	**23220**(20)	24430	25600	**26740**(24)		
26.5-25	18660	**20760**(12)	22720	**24560**(16)	26320	**27990**(20)	29590	**31140**(24)	32630	**34080**(28)		
26.5-29	19950	22190	24280	26260	**28130**(18)	29920	**31630**(22)	33290	**34880**(26)			
29.5-25	23430	26060	**28520**(16)	30840	33040	**35140**(22)	37150	39090	**40970**(28)	42780	44550	**46260**(34)
29.5-29	24950	27750	**30370**(16)	32840	35180	**37420**(22)	39570	41630	**43630**(28)	45560	47440	**49260**(34)
29.5-35	27150	30210	**33060**(16)	35750	38300	**40730**(22)	43070	45320	**47490**(28)	49590	51630	**53620**(34)
33.25-35	32470	36130	39540	**42750**(20)	45800	48710	**51500**(26)	54190	**56790**(32)	59310	61750	**64130**(38)
33.5-33	33120	36850	40320	**43600**(20)	46710	49680	**52530**(26)	55270	**57920**(32)	60490	**62980**(38)	
33.5-39	35670	39690	43430	**46960**(20)	50310	53510	**56580**(26)	59530	**62390**(32)	65150	**67830**(38)	
37.25-35	39580	44030	48190	52110	55820	59370	**62780**(30)	66050	**69220**(36)	72290	**75260**(42)	
37.5-33	40390	44940	49180	**53180**(24)	56970	60590	**64070**(30)	67410	**70650**(36)	73780	**76810**(42)	
37.5-39	43350	48230	52780	57070	61140	65030	68750	72350	**75810**(36)	79170	82430	**85600**(44)
37.5-51	49010	54530	59670	64520	69120	**73520**(28)	77730	81790	**85710**(36)	89510	93200	**96780**(44)

NOTES 1: Figures in parentheses denote ply rating for which bold face loads and inflations are maximum.

2: For 10 MPH service the above loads must be reduced 13% at the same inflation pressures. For front-end loaders or shovels used in load and carry service, consult tire manufacturer.

3: For static loading conditions, the above loads may be increased up to 57% with no increase in inflation.

4: For Radial Ply tires, increase the inflation pressures shown above by 10 PSI with no increase in load ratings and add an "R" to the size designation. Example: 20.5R25

5: Recommended shipping pressures are the maximum inflation pressures for the tire sizes and ply ratings shown.

MAXIMUM SPEED—5 MILES PER HOUR

TIRE SIZE DESIGNATION	TIRE LOAD LIMITS AT VARIOUS COLD INFLATION PRESSURES								
	25	30	35	40	45	50	55	60	65
65/35-33	27360	30430	**33310**(18)	36010	38580	**41030**(24)	43390	**45650**(30)	
65/40-39	37650	41890	45850	49570	**53110**(24)	56480	**59720**(30)	62840	**65850**(36)
65/50-51	63920	71120	77830	**84150**(30)	90160	95890	**101380**(38)	106680	**111790**(46)

NOTES 1: Figures in parentheses denote ply rating for which bold face loads and inflations are maximum.

CHECK WORK CAPABILITY FACTOR RATING

A load and carry operation with travel distances greater than 50 ft. and speeds in excess of 5 MPH increases heat build-up in the tires, necessitating special considerations in the selection of the tire. Goodyear has developed a Work Capability Factor (WCF) which provides guidelines for these applications similar to the ton-mile-per hour (TMPH) approach used for truck tire selection. It provides a basis for establishing the tires' operational limits based on job requirements and is broadly utilized by the industry.

The basic formula is as follows:

average tire load (tons) x maximum average speed (MPH) = work capability factor rating

Note: tire load (tons) = $\frac{\text{empty tire load + loaded tire load}}{2}$

6

If axle load data is not available, assume the typical case per tire loads of 25% of empty machine weight and 40% of loaded machine weight (front tires).

Maximum average travel speed (MPH) = round trip distance in miles x maximum number of cycles per hour of continuous load-and-carry operations. Short periods of downtime should not be included in average speed calculations due to relatively slow static cooling of tires.

The work capability factor calculated is then matched to one of the following tables to select proper tire size:

haul lengths less than 500 ft. one way
haul lengths of 500 to 2000 ft. one way

There is significantly higher tire heat build-up on the shorter hauls, hence the separate tables. (See Tables VI - 6 and VI - 7).

Table VI - 6

LOAD & CARRY TIRE LIMITATIONS

LOAD & CARRY TIRE LIMITATIONS

(WORK CAPABILITY FACTORS FOR HAUL LENGTHS OF LESS THAN 500 FEET ONE WAY)

INDUSTRY CODE	E-3	L-2	L-3	L-4	L-4S	L-5	RADIAL RL-2	RL-3	RL-4	RL-5
**CUSTOMIZED CODE	3S	3S	3S	3S	3S	3S	2S	2S	3S	
TIRE SIZE										
15.5-25	55	50	45							
17.5-25	65	60	55							
20.5-25	70	65	65			55				
23.5-25	75	70	65	60		55	105			
26.5-25	90	85	75	70		65	120			
26.5-29	100	95	90	80						
29.5-25	95	90	80	75						
29.5-29	120	115	110	100	70	90	150	160		
29.5-35	150	140	130							
33.25-35	170	155	145	125		115	215	225	180	
33.5-33	170	155	145	125						
33.5-39	190		165							
37.25-35	200		175	155		135				
37.5-33	175	170	155							
37.5-39	205		180	155		145		240		
37.5-51	290		240			200				
6530-29*						60				
6535-33*				110		90				
38-39*				140		115				
6540-39*				140		115				
41.25/70-39*						135				
6545-45*						145				
6550-51*				195		170				
67-51*						225				

These values are subject to change. For latest values consult your Goodyear Representative. March, 1979

** Customized Code 3S—Standard 2S—Heat Resistant [illegible]—Standard Tread—Steel Breaker
These tires are 3J construction.

(Courtesy Goodyear Tire & Rubber Company)

Table VI - 7

LOAD & CARRY TIRE LIMITATIONS

LOAD & CARRY TIRE LIMITATIONS

(WORK CAPABILITY FACTORS FOR HAUL LENGTHS OF 500-2000 FT. ONE WAY)

							RADIAL			
INDUSTRY CODE	E-3	L-2	L-3	L-4	L-4S	L-5	RL-2	RL-3	RL-4	RL-5
**CUSTOMIZED CODE	3S	3S	3S	3S	3S	3S	2S	2S	3S	
TIRE SIZE										
15.5-25	60	55	50							
17.5-25	70	65	60							
20.5-25	80	75	70			60				
23.5-25	85	80	75	70		65	115			
26.5-25	100	95	85	75		70	135			
26.5-29	110	105	100	90						
29.5-25	105	100	90	85						
29.5-29	135	130	120	110	80	100	165	175		
29.5-35	165	155	145							
33.25-33	190	175	160	140		130	240	250	200	
33.5-33	190	175	160	140						
33.5-39	210		185							
37.25-35	225		195	175		150				
37.5-33	195	190	175							
37.5-39	230		200	175		160		265		
37.5-51	320		270			220				
6530-29*						65				
6535-33*				125		100				
38-39*				155		130				
6540-39*				155		130				
41.25/70-39*						150				
6545-45*						160				
6550-51*				215		190				
67-51*						250				

These values are subject to change. For latest values consult your Goodyear Representative. March, 1979

** Customized Code 3S—Standard 2S—Heat Resistant 3J—Standard Tread—Steel Breaker

* These tires are 3J construction.

(Courtesy Goodyear Tire & Rubber Company)

The following example illustrates a calculation procedure which permits determination of the maximum cycles per hour for a given tire size, tire loading, and haul distance (from Goodyear literature).

Conditions:

front tire loads - empty = 30,000#
loaded = 60,000#...average = 22.5T
one way haul distance = 400 ft.

Selected tire for loader: 33.25-35 (L5)
from Table (Table VI - 6) WCF = 115

Determination of maximum allowable average speed:

$$\frac{115\ \text{WCF}}{22.5\ \text{T}} = 5.11\ \text{MPH}$$

Determination of maximum number of cycles per hour:

$$\text{cycles/hour} = \frac{\text{MPH} \times 5{,}280\ \text{ft/mile}}{\text{ft/haul cycle}}$$

$$= \frac{5.11 \times 5{,}280}{2 \times 400} = 33.7\ \text{cycles/hour}$$

Tires can be selected based on the WCF factor anticipated for the job requirements. If there is a multiple choice of tires with WCF factors adequate for the job, select the tire with the lowest factor which will meet the requirements.

Calculations of this type are generally not required for the beadless (tractor tread type) tires which have good dissipation characteristics and, therefore, no critical limits on haul cycles.

As an alternative to the WCF approach, another manufacturer suggests that for load and carry service ranging from 400 to approximately 6000 ft. cycle lengths, and maximum speeds of 15.6 MPH, the average work day speeds should be limited to roughly 8.5 to 10 MPH.

There can be a variance in performance between specific tires dependent on composition. The tire supplier should be requested to provide ratings or approve the selection of the tires under consideration for load and carry service.

TIRE LIFE

This topic is discussed later in Section VIII in conjunction with ownership and operating costs.

SELECT TIRE SUPPLIER

Having determined the basic tire specifications, the next step is to pick the manufacturer. Included in Appendix C is a listing of manufacturers and the various tire designs they offer.

Although tire manufacturers all comply with the basic industry standards, similar tires of different makes will differ in composition, internal design, etc. Manufacturers do not all offer a full range of sizes in all classifications. Some, based on experience or specifically at the buyer's request, will make special compositions to meet unique site requirements. Special compositions may be desirable to increase heat resistant characteristics for load and carry service. All will offer application advice.

At this point, tire costs and delivery are established by negotiation and competitive quotations. Because of the high inflation rates associated with petroleum-based products and the very competitive nature of the market, competitive price tabulations are not included in this manual.

Tread configurations vary significantly and are difficult to evaluate with performance being dependent on floor conditions. The goal is to optimize traction in forward and reverse, to provide heat dissipation, minimize cutting and retention of rocks in the gaps, and minimize tire side slipping.

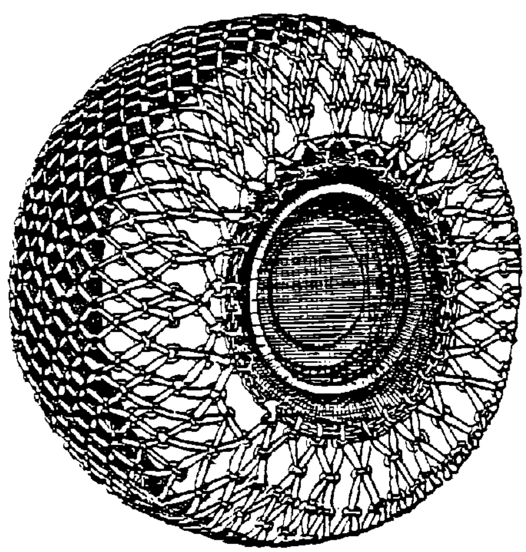
ACCESSORIES

The rim and wheel design are specified by the loader manufacturer to meet service requirements and be compatible with the tires. They can be a problem area, generally because of (as a result of) carelessness in handling, improper mounting and/or lack of maintenance. Figure VI - 4 shows the common rim configurations and Figure VI - 5 provides additional nomenclature and wheel design characteristics. Regular inspection is essential with particular care to check for evidence of corrosion, imbalance, tire to rim slippage and initial cracks associated with progressive fatigue-type failures.

Tire chains are available for applications on surfaces containing sharp abrasive rocks which result in unacceptable life for extra deep tread tires. The chains are available from a number of suppliers with relatively minor differences in design. Most permit individual link replacement to extend overall life. They have a high initial cost with widely varying operating cost, dependent on site conditions, amount of wheel spinning at the digging face and maintenance level. Best performance appears to be associated with applications on smooth tires. The chains will improve resistance to penetration, reduce wear, improve traction and machine stability.

Figure VI - 3

TIRE CHAINS



Tire ballasting is possible as a means of providing more machine weight and/or stability. The manufacturers believe that this is generally unnecessary for the newer FEL models; that the machines are properly balanced and the additional drive train loading is detrimental. Obviously the weight/power ratio increases as well as the handling problems. Some operators, however, feel there has been a recognizable improvement in performance with ballast in the rear tires which tends to counterbalance the front-heavy machine when the full bucket is in the carry or raised position. Others believe that increasing overall machine weight with ballast in all tires has advantageously improved traction, and reduced wheel spinning and tire wear. The ballasting reduces ride bounce, may decrease fuel consumption and does reduce the air pressure loss during operation.

There are three ballasting techniques available - foam, dry powder (barium sulfate or powdered lead) and liquid (calcium chloride and water). The most common is the liquid because of its cost and the simpler techniques for adding to the tire. A solution of 75% calcium chloride is recommended. (See Table VI - 9) This provides up to a 50% increase in weight over water and it is a low cost antifreeze mixture which is not harmful to the rubber. It can be utilized with tube or tubeless type tires. To permit some variations in pressure with changing load conditions, a 100% fill is not recommended. The antifreeze characteristics of this solution are given in Table VI - 8.

Dry ballast in the tires achieves the same results as the liquid, but is a little more complex in terms of the actual procedures for installing or removing from the tire. Tubeless tires are recommended. Mixtures can be varied to provide a range of tire loads. The distributor of the dry ballast compound should be consulted for proper application. There is less heat dissipation in the tires which suggests that this approach would not be desirable for load and carry service.

There is limited experience with the foam filled tires. While providing ballast, this approach results in a tire which requires no air pressure maintenance, remains usable after a cut or puncture and may reduce tread wear. The trade-offs are increased cost and increased heat build-up.

Figure VI - 4

RIM CONTOUR

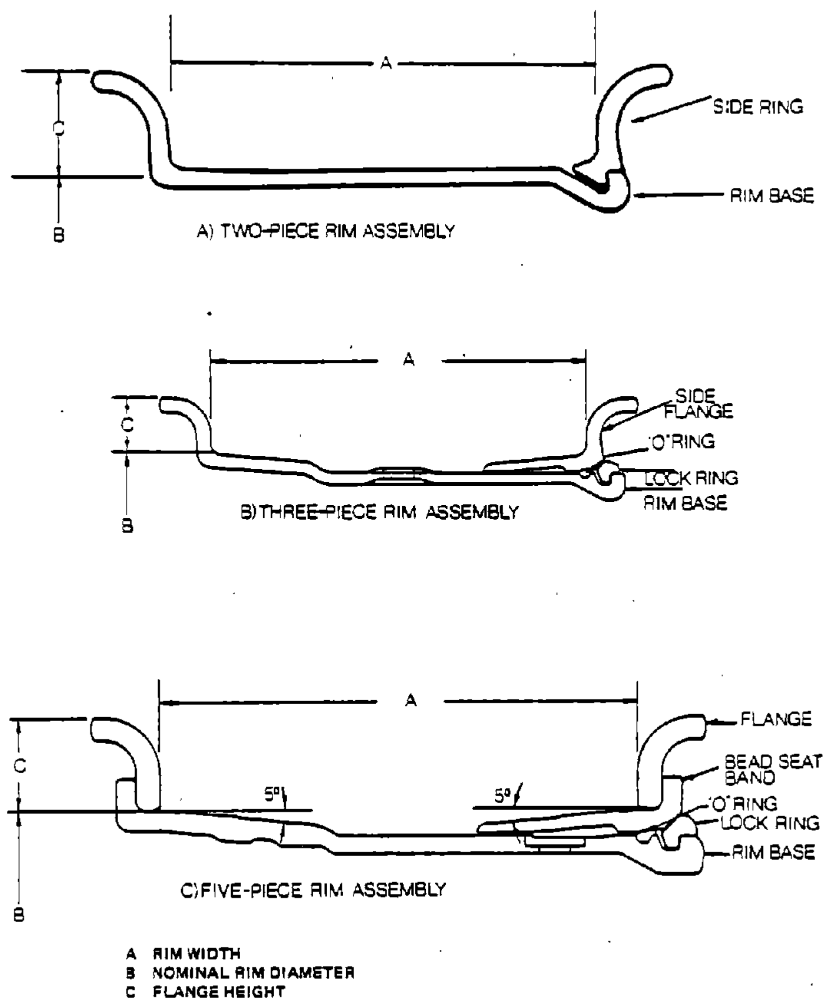


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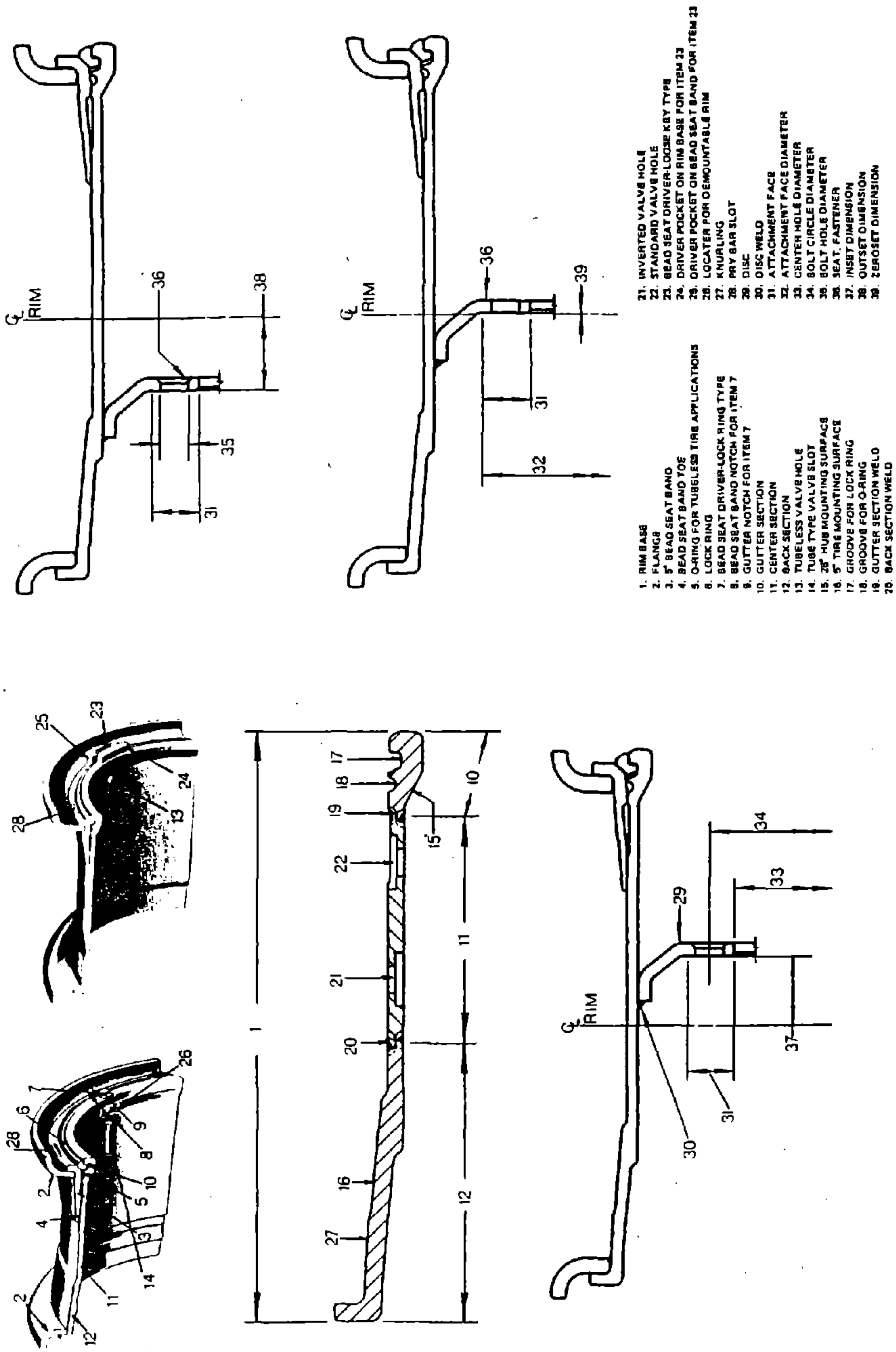
Figure VI - 5

RIM AND WHEEL NOMENCLATURE
COMMON TO LARGE OR GIANT HEAVY SERVICE TIRES



(Reprinted with permission from the <u>SAE Handbook</u>, 1979, Society of Automotive Engineers, Inc.)

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Table VI - 8

ANTI-FREEZE CHARACTERISTICS OF CALCIUM CHLORIDE SOLUTION

Specific Gravity at 62°F.	Lbs. of $CaCl_2$ per gallon of water	Freezes below °F.
1.000	0.0	+32
1.050	0.7	+21
1.100	1.5	+ 7
1.150	2.3	-10
1.218	3.5	-30
1.250	4.2	-42

Table VI - 9

LIQUID INFLATION CHART

CONVENTIONAL SIZES — 75% FILL OR VALVE LEVEL

Tire Size	Gallons Water 75%	3½ Lbs. Calcium Chloride Per Gallon Water			5 Lbs. Calcium Chloride Per Gallon Water		
		Gallons Water	Lbs. $CaCl_2$	Total Weight	Gallons Water	Lbs. $CaCl_2$	Total Weight
16.00-20	60	52	182	615	49	245	654
16.00-24/25	67	58	203	686	55	273	729
18.00-24/25	96	82	287	971	77	387	1032
18.00-33	114	98	343	1157	92	460	1231
18.00-49	152	130	455	1543	123	615	1641
21.00-25	131	112	394	1332	106	531	1416
21.00-29	143	123	430	1455	116	580	1547
21.00-35	162	139	485	1641	131	654	1744
21.00-49	206	176	618	2090	167	835	2220
24.00-25	171	146	512	1732	138	690	1841
24.00-29	186	159	577	1885	150	751	2004
24.00-35	211	181	630	2140	170	850	2260
24.00-49	264	226	790	2680	213	1069	2850
27.00-33	284	244	854	2888	230	1151	3071
27.00-49	366	314	1099	3714	296	1480	3949
30.00-33	363	311	1089	3684	294	1470	3917

WIDE BASE AND GRADER SIZES — 75% FILL OR VALVE LEVEL

15.5-25	46	40	139	470	37	187	500
17.5-25	60	51	180	609	48	243	647
20.5-25	90	77	269	910	72	362	967
23.5-25	118	101	354	1198	95	478	1274
26.5-25	159	136	477	1614	129	643	1716
26.5-29	174	149	521	1764	141	703	1875
29.5-25	207	177	618	2090	167	833	2223
29.5-29	224	192	673	2275	181	907	2419
29.5-35	251	215	753	2547	203	1015	2708
33.25-35	319	274	958	3242	258	1292	3447
33.5-33	328	281	983	3326	265	1325	3536
33.5-39	363	311	1089	3684	294	1470	3917
37.5-33	423	362	1268	4290	342	1710	4562
37.5-39	466	399	1397	4729	377	1885	5028
37.5-51	552	473	1656	5603	447	2235	5958
		380	1400				
12.00-24	34	29	103	348	28	139	370
13.00-24	41	35	122	412	33	164	438
14.00-20	45	39	135	458	36	182	487
14.00-24	51	43	152	513	41	205	546
16.00-24	72	62	216	730	58	291	775
18.00-26	113	97	339	1147	91	457	1220

(Courtesy of Rubber Manufacturers Association)

SECTION VII

PRODUCTION ESTIMATING

Obviously one of the primary concerns of the owner/operator is estimating the loader's production capabilities for a given application. If relevant data is available for similar past applications, it usually provides the best basis for projecting production on new jobs. Often this historical data is not available, however, so a generalized estimating procedure must be used. This section presents a procedure for estimating front-end loader production in a load-and-carry application.

IT IS IMPORTANT THE USER UNDERSTAND THAT THE ESTIMATING PROCEDURE PRESENTED IN THIS MANUAL SHOULD BE USED AS A GUIDE ONLY. ANY ESTIMATE DERIVED FROM USE OF THE PROCEDURES PRESENTED IN THIS MANUAL ARE NOT TO BE CONSIDERED AS SPECIFIC GUARANTEES OF ACTUAL PRODUCTION OBTAINED IN THE FIELD.

On the following pages is a Production Estimate Worksheet which summarizes the major considerations and provides a convenient form for recording data and calculations. The remaining text provides additional detail on the estimating procedure as well as basic guideline data.

No attempt is made in this general estimating procedure to make discrete distinctions between different makes and models of front-end loaders. The procedure generates a rough production estimate based primarily on the application, with some variations due to machine size. Production estimates based on specific FEL models are generally available from manufacturers.

The data contained in this section is compiled from numerous references (see Appendix E) and field experience.

PRODUCTION ESTIMATE WORKSHEET

FRONT-END LOADER
LOAD-AND-CARRY

Date:______________
Prepared by:___________________
No:______________

Location:____

Machine:____________________

Material:_____________________________________
loaded from:____________________________
dumped to: ____________________________

Haul length - one way (ft.):____

Work schedule (hr/day):____

Other application considerations:___________________________________
____
____

Bucket size (heaped yd^3):_______[BS]
Bucket fill factor (%/100) ________[BFF]
Material weight (lb/LCY)________[MW]

Max. payload (lb) = _____[BS] x _______[MW] = _______lb.

Payload (lb) = ________[BS] x _______[BFF] x ___________[MW]
= _____________ lb./2000 = _____________ Ton

Machine's rated payload (lb)_____________
Machine's full turn
static tipping load (lb)_____________/2 = ______________

Is the estimated payload greater than the machine's rated payload or half its full turn static tipping load?

Rolling resistance (%)_________[RR]
Grade resistance (%) = $\frac{\text{Vertical distance}}{\text{Horizontal distance}}$ ________x100 = ______[GR]

Total resistance (%) = _________[RR] + _________[GR] = _________%

Is the total resistance so large that the machine's available rimpull will be a limiting factor?

Coefficient of traction (%/100) = ________

Will traction limit the machine's performance? _______%

Will altitude reduce engine power? (>1,000 ft. for 4-cycle or 2 cycle; >10,000 ft. for turbo or supercharged) _______%

Job efficiency factor (%/100) ___________[JEF]

Machine availability factor (%/100) ___________[MAF]

Will there be a special adjustment for operator skill? _______%

Cycle times (minutes):

	Condition {1}	Condition {2}	Condition {3}
Loading	________	________	________
Maneuvering	________	________	________
Hauling	________	________	________
Dumping	________	________	________
Maneuvering	________	________	________
Returning	________	________	________
(Special Adjustment)	________	________	________
Total	________	________	________

Max Cycles per hour = 60 (min/hour)/total cycle time (min)

{1} _________cy/hr {2} _________cy/hr {3} _________cy/hr

Peak production (TPH) = cycles per hour x _________T [payload]

{1} _________TPH {2} _________TPH {3} _________TPH

Average production (TPH) = peak production x ___________[JEF]
x ___________[MAF]

{1} _________TPH {2} _________TPH {3} _________TPH

System consideration that may limit loader production? __________
____
____
____
____

System capacity: ____________Ton/Hour
____________Ton/Shift
____________Ton/Day
____________Ton/Week
____________Ton/Year

Working Schedule: Scheduled - Lost = Actual

Hours/Shift ________ - ________(1) = ________[HPS]
Shifts/Day = ________[SPD]
Days/Year ________ - ________(2) = ________[DPY]

(1) subtract time lost for shift change, lunch, breaks, fuel and lube, scheduled maintenance, etc.
(2) subtract time lost for holidays, weather, moving hopper/conveyor, safety meetings, etc.

Hours/Year = ________[HPS] x ________[SPD] x ________[DPY]
= ________hours

Production per shift = avg. production per hour x hours per shift

{1} ________T/sh {2} ________T/sh {3} ________T/sh

Production per year = avg. production per hour x hours per year

{1} ________T/yr {2} ________T/yr {3} ________T/yr

PAYLOAD

Many manufacturers rate the payload (lbs.) of their machines; where available these values are given in Appendix A, Machine Specifications. Whether or not this value is available, SAE standards specify that the maximum safe operating load for a wheel loader is 50% of its full turn static tipping load. These values are also given in Appendix A, although they will change depending on optional equipment (i.e., counterweight, ballast, and bucket selection).

Given these limits on maximum machine payload, the actual payload can be estimated with bucket size, bucket fill factor, and material density. Front-end loader bucket size is typically given as heaped capacity (material piled at 2:1 slope) although it can also be given as struck capacity (material level with bucket edges). Care must be taken in payload calculations not to mistakenly use one value instead of the other. The addition of rock guards or side rails will change bucket size and therefore capacity.

Depending on the type of material and the digging conditions, the operator may not be able to fill the bucket. Typically, larger chunks of material and/or low bank heights decrease the actual bucket load. Table VII - 1 gives some guideline bucket fill factors to indicate what percent of the loaders rated <u>heaped</u> capacity will actually be used.

The weight of material is usually given as pounds per cubic yard. If the material is still "in place", that is, in its natural undisturbed state, it is called a bank cubic yard (BCY). If the material is in a loose or broken state, it is a loose cubic yard (LCY). These two measures simply reflect the fact that material in its natural state is compact, to move this material it must be broken up so the volume it occupies increases. The swell of a material (usually expressd as a percent) indicates how much more volume loose material will occupy than the same weight of bank material. The swell factor indicates the weight relationship between the same volume of loose and bank material [swell factor = (lb/LCY)/(lb/BCY) = 1/(1 + (%swell/100))]; the swell factor is also called the load factor. For example, dry sand has a percent swell of 12%, so one bank cubic yard of dry sand will swell to about 1.12 cubic yards when it is loosened. Similarly, if one BCY of dry sand weighs 2450 lb., a LCY of dry sand will weigh only 2450/1.12 or 2187 lb. Table VII - 2 gives some typical values for weight of BCY and LCY and swell for various materials. Since the weights of materials can vary in different geographical areas, where possible it is preferrable to check these values at the mining site and use the actual densities in the production estimating calculations. Of course, material handled by a front-end loader is in a loose state.

Table VII - 1

BUCKET FILL FACTORS

LOOSE MATERIAL SIZE	FILL FACTOR
mixed moist aggregates	95-100%
uniform aggregates up to 1/8"	95-100%
1/8" to 3/8"	85- 90%
1/2" to 3/4"	90- 95%
1" and over	85- 90%
Moist loam	100-110%
Soil, boulders & roots	80-100%
BLASTED MATERIAL	**FILL FACTOR**
well blasted	80- 85%
average	75- 80%
poorly blasted*	60- 65%

*with slabs or blocks

(courtesy of Caterpillar Tractor Co.)

The loader's payload is calculated by multiplying the bucket capacity (heaped cubic yard) times the bucket fill factor times the material weight per loose cubic yard. Care must be taken to use the proper units, that is, heaped capacity of the bucket and loose weight of the material.

Once this payload has been calculated, it should be compared to the rated payload for the machine and to one-half its full turn static tipping load. If there is a substantial difference, a larger or smaller bucket should be selected to bring the calculated payload within machine capability.

This calculation can be illustrated with an example: using a Cat 988B to load dry sand and gravel from the bank:

First from the specifications for a Cat 988B, in Appendix A, we find that:
- the standard rock bucket has a heaped capacity of 7 cu. yd.
- rated payload is 21,200 lb.
- full turn static tipping load is 44,740 lb.

From the Material Weight Table (VII - 2) we find:
- loose cu. yd. of dry sand and gravel weighs about 2910 lb.

Using the Bucket Fill Factor Table (VII - 1) we estimate the bucket fill factor will be 0.90.

The estimated payload will then be:

7 LCY bucket x 0.90 fill factor x 2910 lb/LCY
= 18,333 lb. or 9.2 tons

Comparing this to the rated payload and full turn tipping load we find that it is within the capabilities of the machine.

This calculated payload represents the average expected payload. To calculate the maximum load, we could perform this calculation with a 100% bucket fill factor:

7 LCY x 1.0 factor x 2910 lb/LCY = 20,370 lb.

This maximum load is close to the machine's rated capcity, so the bucket size is proper for this application.

As discussed earlier in the text, a comparison of estimated payload and rated payload for the available buckets is the appropriate method for selecting bucket size. The formula used to calculate payload can be written to yield bucket size:

7

$$\text{bucket size} = \frac{\text{rated payload (lb)}}{\text{weight of mat'l (lb per LCY)}}$$

Actual bucket selection will also be based on what is commerically available.

Whenever it is feasible, actual field data and experience should be substituted for the estimated values used for bucket fill factor and material weight. If possible, a field test should be made to actually weigh representative bucket loads in order to determine average payload.

In some applications, production estimates are desired in terms of bank cubic yards (BCY) rather than lbs. or tons. This is common when the application is to move overburden or, as in the construction industry, simply to move a specified volume of material. A very similar calculation to the one just presented is used except, instead of using the lbs./LCY factor, the swell factor is used to convert the LCY capacity of the bucket to BCY:

payload (BCY) = bucket size (LCY) x
swell factor (BCY/LCY) x
bucket fill factor

In the example just used:

swell factor for sand and gravel is .89 (Table VII - 2)

payload = 7 yd. x 0.89 x 0.90 = 5.61 BCY

Table VII - 2

MATERIAL WEIGHTS

Material	Weight in Bank LBS/BCY	Swell %	Swell Factor	Loose Weight LBS/LCY
Andesite	4550	55	0.65	2960
Asbestos	4200 - 5000	90	0.65	2230 - 2650
Ashes, hard coal	700 - 1000	8	0.93	650 - 930
Ashes, soft coal, ordinary	1080 - 1215	8	0.93	1000 - 1130
Ashes, soft coal w/clinkers	100 - 1515	8	0.93	930 - 1410
Barytes	7600	68	0.59	4480
Basalt	5000	51	0.66	3300
Bauxite	3200	32	0.75	2400
Borax	2850	72	0.58	1650
Caliche	3800	82	0.55	2100
Carrotite (uranium ore)	3700	35	0.74	2750
Chalk	3200 - 3900	72	0.58	1860 - 2260
Cinnabar (hg.ore)	13,650	67	0.60	8190
Clay, natural bed	3400	22	0.82	2800
Clay, dry	3000	28	0.78	2340
Clay, wet	3500	25	0.80	2800
Clay with gravel,dry	2800	24	0.81	2260
Clay with gravel,wet	3100	16	0.87	2680
Coal, anthracite, raw	2200 - 2700	35	0.74	1630 - 2000
Coal, bituminous, raw	2150	34	0.74	1600
Coal, lignite, raw	2100 - 2450	50	0.67	1410 - 1640
Copper, ore	3800	35	0.74	2810
Copper, pyrites	7100	67	0.60	4260
Dolerite	4800	52	0.66	3170
Dolomite	4700	62	0.62	2910
Earth, topsoil	2300 - 2550	43	0.70	1600 - 1785
Earth, dry	2450 - 2600	43	0.70	1720 - 1820
Earth, moist	2700 - 3000	33	0.75	2030 - 2250
Earth, compacted	3100	24	0.81	2500
Earth, w/sand and gravel	3100	11	0.90	2790
Feldspar	4400	67	0.60	2640
Flint	4450	71	0.59	2630
Fluorspar	5200	90	0.53	2760
Galena (lead ore)	12,800	67	0.60	7680
Gneiss	4800	54	0.65	3120
Granite	4550	63	0.61	2785
Gravel, pitrun	3650	12	0.89	3250
Gravel, dry	2900	12	0.89	2580
Gravel, wet	3700	18	0.85	3150
Gravel, wet,.2"-2"	3200	12	0.89	2850
Gravel, dry,.2"-2"	3800	12	0.90	3400
Gravel, sandy	3200	14	0.88	2820

Table VII - 2 (Continued)

MATERIAL WEIGHTS

Material	Weight in Bank LBS/BCY	Swell %	Swell Factor	Loose Weight LBS/LCY
Gypsum, fractured	5300	75	0.57	3020
Gypsum, crushed	4700	75	0.57	2690
Ilmenite (FE,Ti,ore)	8100	72	0.58	4700
Iron ore, haematite (brown)	5900 - 7600	75	0.57	3360 - 4330
Iron ore, haematite (red)	7600 - 9100	75	0.57	4330 - 5190
Iron ore, limonite	6400	55	0.65	4160
Iron ore, magnetite	8600	54	0.65	5590
Iron ore, pyrites	8400	67	0.60	5040
Iron ore, taconite	4500 - 9450	56-75	0.57-0.64	2900 - 5400
Kaolin	2800	30	0.77	2160
Lime, slaked				800 - 1500
Limestone, blasted	4200	67-65	0.57-0.60	2400 - 2520
Limestone, marble	4600	67-75	0.57-0.60	2620 - 2760
Magnesite	5050	50	0.67	3380
Marble	4150 - 4800	75	0.57	2370 - 2740
Mud, dry (close)	2160 - 2970	20	0.83	1790 - 2470
Mud, wet (moderately close)	2970 - 3510	20	0.83	2470 - 2910
Phosphate rock (apatite)	5400	50	0.67	3620
Pumice	1000 - 2000	67	0.60	600 - 1200
Peat, dry	800 - 1300	80	0.56	450 - 730
Peat, wet	1600 - 1800	80	0.56	900 - 1010
Quartzite	4450	64	0.61	2720
Rock, decomposed:				
25% rock, 75% earth	2565	25	0.80	2620
50% rock, 50% earth	3833	32	0.76	2895
75% rock, 25% earth	4675	41	0.71	3320
Rock salt	2100 - 3900	67	0.60	1260 - 2340
Rutile (Ti ore)	7100	67	0.60	4260
Sand, dry	2450	12	0.89	2180
Sand, dry, fine	2700	12	0.89	2400
Sand, damp	3200	12	0.89	2850
Sand, wet	3500	12	0.89	3100
Sand & gravel, dry	3275	12	0.89	3100
Sand & gravel, wet	3725	10	0.91	3375
Soapstone (talc)	2500 - 4500	67	0.60	1500 - 2700
Sandstone	3500 - 4300	40-75	0.71-0.57	2000 - 3050
Shale, riprap	2800	33	0.75	2100
Slate	4590 - 4860	30	0.77	3530 - 3740
Trap rock	4625	49	0.67	3100
Zincblende	6750	67	0.60	4050

PERFORMANCE FACTORS

Many of the factors affecting the performance of a front-end loader have already been covered in this text; some will be briefly repeated here in an attempt to relate them to estimated cycle time.

ROLLING AND GRADE RESISTANCE

Rolling resistance is the force that resists the movement of the machine. It is caused by the flexing of the tires and the penetration of the tires into the ground. Rolling resistance can be expressed in terms of percent of vehicle weight or in pounds. A 2% resistance would indicate a force equal to 2% of vehicle weight. This 2% could also be expressed as 40 lb. resistance per ton of vehicle weight (40/2000 = 0.02 = 2%). This resistance will vary with ground conditions and some guidelines are given in Table VII - 3. The data in this table assumes proper tire inflation.

Rolling resistance can also vary somewhat with tire selection (bias vs. radial, wide vs. narrow, pressure); these considerations are discussed in the previous part of the text on tire selection. For estimating purposes these variations are neglected.

Grade resistance is the force due to gravity that the loader must overcome to move up an incline. Grade assistance is the force due to gravity that assists the loader as it goes down an incline. This force is proportional to the slope of the incline. The most common method of expressing slope is by percent; if a surface rises 1 ft. in a horizontal distance of 100 ft., it has a 1% slope. Slopes are positive for uphill grades, negative for downhill grades as indicated by the direction the vehicle is taveling. To overcome a grade resistance, the vehicle must use a force approximately equal to the % grade times the total vehicle weight.

The concepts of rolling and grade resistance can be illustrated by considering the Cat 988B discussed under payload calculations, moving up a ramp carrying its full load. Assume this ramp goes up to a dumping level 30 ft. higher in a horizontal distance of 250 ft., and the road is a hard, dry, smooth dirt road that is well maintained. (Note that when using %'s in an equation, they are always expressed in the decimal form, i.e. 14% = .14)

grade resistance equals the slope of the incline:
30 ft/250 ft = 12%

rolling resistance is estimated from Table VII - 3 at 2%

from the specifications in Appendix A:
vehicle weight = 90,000 lb.

from the payload calculations: load = 18,300 lb.

therefore: total resistance = 12% + 2% = 14%
total weight = 90,000 + 18,300 = 108,300 lb.

the force this loader must exert to overcome the rolling and grade resistance is:
0.14 x 108,300 lb. = 15,162 lb.

Another resistance to vehicle movement is air resistance. This factor is typically not calculated for front-end loaders because it is normally of small magnitude. It should be noted, however, that in extreme cases it may affect performance.

Table VII - 3

ROLLING RESISTANCE

Ground Surface	Lbs/ Ton	% Vehicle Weight
Asphalt	47	2.4
Coal, crushed	120	6.0
Concrete, smooth	35	1.7
Concrete, rough & dry	40	2.0
Dirt - well maintained, no loose mat'l, hard, smooth, & dry.	40	2.0
Dirt - dry, not firmly packed, some loose material	40	2.0
Dirt - poorly maintained, soft and unplowed	80	4.0
Dirt - soft, plowed, tire penetration to 4 in	160	8.0
Dirt - unpacked fills	160	8.0
Dirt - deeply rutted	320	16.0
Gravel - well compacted, free of loose material, dry	60	2.0
Gravel - not firmly compacted, but dry	60	3.0
Gravel - loose	200	10.0
Mud - with firm base	80	4.0
Mud - soft,spongy base, tire penetration to 8 in	320	16.0
Quary pit	40	2.0
Sand - loose	200	10.0
Sand - wet or watered	180	9.0
Sand & gravel - loose	240	12.0
Snow - packed	50	2.5
Snow - loose to 4 in depth	90	4.5

RIMPULL

Rimpull is the term used to describe the tractive force between the loader's tires and the ground. Maximum rimpull is a function of the engine's power, transmission characteristics, and the gear ratios of the drive train. Usable rimpull can be limited by the traction between the wheels and ground.

Rimpull curves showing the relationship between rimpull force and vehicle speed for a specific front-end loader are typically not available from the manufacturer. A rough estimate of rimpull can be obtained from the following formula:

$$\text{Rimpull(lb)} = \frac{375 \times \text{HP(rated flywheel)} \times \text{efficiency factor}}{\text{speed (MPH)}}$$

Horsepower actually varies with engine RPM (and thus with MPH) and the propel efficiency factor is unique to a specific machine. The efficiency, as used in this equation, for most mechanical drive loaders will range from 65 to 75 percent. The efficiency for an electric drive loader should be approximately 80 percent.

Knowledge of the available rimpull (estimated or actual) can be used to calculate the gradeability of a machine. Using the Cat 988B as introduced earlier, the maximum rimpull at 4 MPH can be found.

Using Appendix A:
- flywheel HP = 375

Estimate mechanical efficiency factor to be 65%

$$\text{So maximum rimpull @ 4 MPH} = \frac{375 \times 375 \times .65}{4} = 22{,}850 \text{ lb.}$$

Total loaded machine weight is 108,300 lb., so maximum gradeability at 4 MPH is:

$$\frac{22{,}850 \text{ lb}}{108{,}300 \text{ lb}} = 21\%$$

This 21%, of course, includes both rolling and grade resistance. At 2 MPH, gradeability would be 42% so it is apparent that power alone will generally not restrict the practical gradeability of a front-end loader.

Continuing the example of the Cat 988B, we could use this rimpull formula to estimate the loader's speed on the previously discussed ramp. We have already calculated that the loader must use 15,200 lb. of force to overcome rolling and grade resistance. If the machine is to accelerate, it will have to deliver more rimpull than this, so when rimpull equals 15,200 lb. it has reached its maximum speed.

$$15{,}200 \text{ lb} = \frac{375 \times 375 \text{ (HP of 988B)} \times 0.65}{\text{speed (in MPH)}}$$

$$\text{speed} = 6.0 \text{ MPH}$$

Comparing this figure to the 988B's specifications, in Appendix A, we find that the maximum speed in second gear is 7.6 MPH - so the loader will be traveling in 2nd gear. Average speed on this ramp will, of course, also be influenced by other factors such as road conditions, turns, and speed of the loader as it starts up the ramp.

7

The rate of acceleration the loader can accomplish is proportional to the net rimpull available after the resistance forces have been subtracted from the available rimpull. These calculations are complicated and generally not made when estimating loader production, so they are not presented here. Most loaders are fairly comparable and have sufficient power for acceleration. However, it is obvious they will have slower acceleration when loaded and/or going up a steep incline.

TRACTION

Traction is a term used to describe the proportion of a vehicle's weight which can be transferred as power (rimpull) from the vehicle's tires to the ground. If more power is applied than the limits of traction, the tires will spin. The major factor affecting traction is the ground material and condition. Tire selection can also be influential since the tire will typically have some penetration into the ground surface and the tread design and condition will make a difference. Tire selection criteria are discussed earlier in the text. The degree of traction between the tire and ground is called the coefficient of traction; typical values are given in the following table.

The maximum tractive force (rimpull) which can be applied by the tires to the ground is obtained by multiplying the vehicle's weight by the coefficient of traction.

Table VII - 4

COEFFICIENTS OF TRACTION

GROUND SURFACE	TRACTION FACTORS (%) Dry Surface	Wet Surface	Beadless Tires
Blacktop, smooth	90	75	-
Concrete, rough	95	90	45
Clay, hard & smooth	80	20	-
Clay loam, dry	65	28	70
Clay loam, wet	50	23	55
Clay loam, rutted	40	23	55
Coal, stockpiled	45	-	50
Earth, firm	58	-	75
Earth, loose	45	-	50
Gravel road, firm	65	60	-
Gravel, not compacted	40	50	60
Gravel, loose	30	40	-
Ice, rough	20	10	-
Ice, smooth	6	0	10
Quarry pit	65	-	70
Sand, firm	25	35	35
Sand, loose	15	25	-
Sandy loam	60	53	-
Sandy loam, rutted	35	35	-
Snow, packed	25	15	25

The previously used example had the Cat 988B (total loaded weight 108,400 lb.) traveling on a hard dirt road.

Table VII - 4 indicates the coefficient of traction should be .58; so:

maximum tractive force = 108,300 lb x 0.58
= 62,814 lb.

Obviously, traction will not limit the loader's performance in this case (at 4 MPH, the loader has power capable of delivering only about 23,000 lb. of rimpull). However, if the ramp was covered with packed snow, the coefficient of traction could be 0.20 and maximum tractive effort reduced to 21,600 lb.; this could slightly affect performance (rolling and grade resistance was 15,200 lb.). If the ramp became covered with ice, the maximum tractive force could be reduced to the point where the loader would be unable to move up the incline.

Since traction limits the amount of rimpull which can effectively be transmitted from the tires to the ground, it will also affect the loader's digging capability. As discussed earlier, the first phase of the digging cycle is to propel into the material, and rimpull is one component of that propel force, (the machine's inertia is the other major factor.) Experience, however, indicates that most loosened materials can be readily handled by front-end loaders working from a typical pit floor (coefficient of traction of 0.45 to 0.65), while adverse conditions (coefficient of traction of 0.20 to 0.35) may impede loading.

ALTITUDE

Engines are rated for their performance at sea level and increases in altitude may cause a decrease in power. Internal combustion engines (both gasoline and diesel) operate by combining oxygen (in air) and fuel and then burning the mixture. As altitude increases the density of air decreases, and so does the density of oxygen. As this fuel to air ratio in the engine is affected, so is engine performance. Each engine is unique, so in considering altitude effects, it is preferable to consult the manufacturer. If this data is unavailable, the following guidelines may be used to estimate the percent loss of power (and rimpull) due to altitude.

- Four-cycle engine: derate engine HP 3% for every 1000 ft. of altitude above 1000 ft.

- Two-cycle engine: derate engine HP 1 1/2% for every 1000 ft. of altitude above 1000 ft.

- Engines with a turbo-charger or supercharged: no loss of power up to 10,000 ft. altitude.

As an example, consider a 500 HP four-cycle engine operating at 9,000 ft. Estimated available HP would be: 500 HP minus loss due to altitude (8 x 3% x 500 HP = 120 HP) or 380 HP. This loss can be an important factor in machine performance which is the reason why many large engines are turbo-charged.

If a machine's engine is derated for altitude, it will, of course, affect the job factors previously discussed such as gradeability, speeds and acceleration. Engine power will also affect the machine's digging capability.

EFFICIENCY FACTORS

Production estimates should be further reduced to reflect the practical fact that front-end loaders cannot be expected to operate at peak production continuously over a long period of time. These limiting output considerations can be classified into three primary areas:

- job factors
- machine availability
- schedule factors

JOB FACTORS

Certain unavoidable delays will be encountered in all operations such as those caused by weather, traffic, blasting, manangement and supervisor efficiency, operator experience, personnel delays, road maintenance and clean-up around loading and dumping areas. The maximum productivity estimate for the loader should be derated to account for these actual conditions. The following table gives common job factors for front-end loaders, if actual job data is unavailable:

Table VII -5

JOB EFFICIENCY

Job Efficiency	Favorable	Average	Unfavorable
Working min/hr	57	51	42
Percent	95	85	70

When the front-end loader is used in a load-and-carry application, it often has a "favorable" job efficiency because there is minimum interference and coordination with other machines, and the operators normally are experienced, requiring a minimum of supervision. Job efficiency will drop slightly if more than one machine is working in the same area, or dumping in the same hopper.

MACHINE AVAILABILITY

While the job efficiency factor accounts for those delays normally encountered on the job, there will also be times when the loader cannot work because it needs repair. Again, when available, actual job data is the best estimate for machine availability. However, the following data can be used to estimate availability:

Figure VII - 6

MACHINE AVAILABILITY

Machine Availability	Good	Average	Poor
Percent	95	85	65

As discussed earlier in this manual, machine availability is primarily influenced by the preventive maintenance program and the age of the machine. Average availability is accomplished with a reasonably complete preventive maintenance schedule. Generally, availability decreases as the machine gets older. Machine availability is also influenced by the number of operating hours/week; the more a machine is scheduled, the more severe the application and the more maintenance will interfere with production, so availability decreases.

Neither this machine availability factor nor the job efficiency factor accounts for the time set aside to fuel and lube the loader.

SCHEDULE

It should be noted that these production calculations are aimed at estimating production per scheduled work hour. When production over longer periods is estimated, some care must be taken in figuring the scheduled hours of work. For example, a shift may be 8 1/2 hours long, with 1/2 hour for lube and fuel, 1/2 hour for lunch, and 1/4 hour for supervisor's meeting; scheduled work for the loader would then be 7 1/4 hrs/shift. Similar care must be taken over longer periods; some factors to consider are holidays, days lost to weather, monthly safety meetings, lost time due to hopper/conveyor moves, etc.

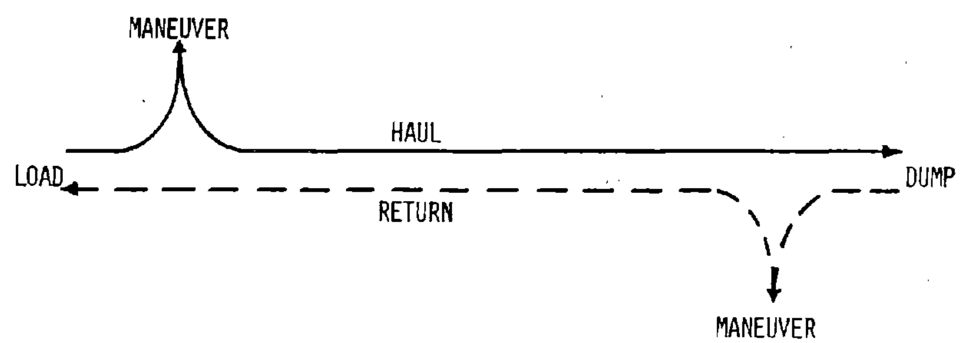
CYCLE TIMES

The estimate of the cycle time is, of course, a key step to forecasting the probable production of a FEL in a given application. Where time studies of the operation are available, they should be used. If studies of similar operations are available, they should be compared to the estimates. If no other data is obtainable, the following procedures can be used to estimate cycle time. Most of the considerations affecting loader performance have already been reviewed in this manual, therefore they will be only briefly mentioned.

The following sketch (Figure VII - 1) illustrates the components of cycle time as discussed here:

Figure VII - 1

TYPICAL LOAD-AND-CARRY CYCLE



LOADING

Loading time is highly variable depending on the nature of the digging conditions. Considerations are:

- material being excavated
- compactness and size distribution of material
- bank height
- ground conditions as related to traction
- power as related to altitude
- machine size
- maneuvering room

Table VII - 7 can be used to estimate loading times.

Table VII - 7

LOADING TIME (MINUTE)

Basic Machine Size (yd^3)	Easy	Average	Hard
5	0.10	0.15	-
7	0.08	0.13	0.22
12	0.12	0.17	0.23
15	0.13	0.17	0.24
22	0.14	0.18	0.25

For extremely hard digging....add up to .08 to the time for hard digging

7

DUMPING

Dumping time is not extremely variable but is affected by the nature of the target and, in some cases, the nature of the material. Considerations are:

- target size
- height of dump
- fragility of target
- flow characteristics of material
- fullness of hopper

Table VII - 8 can be used to estimate dumping time.

Table VII - 8

DUMPING TIME (MINUTE)

Basic Machine Size (yd^3)	Average
5	0.05
7	0.07
12 - 22	0.08

for small target........add up to .04
for fragile target......add up to .05
for sticky material.....add up to .08

MANEUVERING

In a typical load-and-carry operation, the loader must reverse and make a 90 degree to 180 degree turn after loading and dumping. The back-up distance is normally two to three times the length of the machine but can be greater, for example, backing down a ramp to a dump site. Some considerations are:

- floor conditions as they affect traction and rolling resistance
- grade
- maneuvering room.

Table VII - 9 can be used to estimate maneuvering time.

Table VII - 9

MANEUVERING TIME (MINUTE)

Basic Machine Size (yd^3)	Loaded	Empty
5	0.11	0.09
7	0.13	0.12
12	0.16	0.14
15	0.17	0.15
22	0.19	0.17

TRAVELING

Travel time is, of course, highly variable. Some considerations are:

- distance traveled
- rolling resistance
- grade resistance
- traction
- power as affected by altitude
- turns
- speed limits
- traffic

For estimating purposes, the criteria used to determine traveling time are distance (ft.), total resistance (%), and machine size (yd.^{3}). The haul and return lengths are considered to be the distance between the two maneuvering positions (2 to 3 machine lengths from loading and dumping areas even if pit conditions dictate the maneuvering position be farther away - because maneuver times are based on this distance). The graphs on the following pages are used in the following manner:

1) Select graphs representing the size of machine (based on machine's standard bucket size)

2) There are two graphs - one for the haul (loaded) and one for the return (empty).

3) Select the curve on the desired graph corresponding to the total resistance (grade and rolling) - positive for resistance, negative for assistance. Whether using the haul or return graph, use the total resistance calculated for the haul. This is suggested because when going down an incline (grade assistance) on the return, speeds are adversely affected by increasing steepness. If the total resistance is < 2%, use the 2% curve.

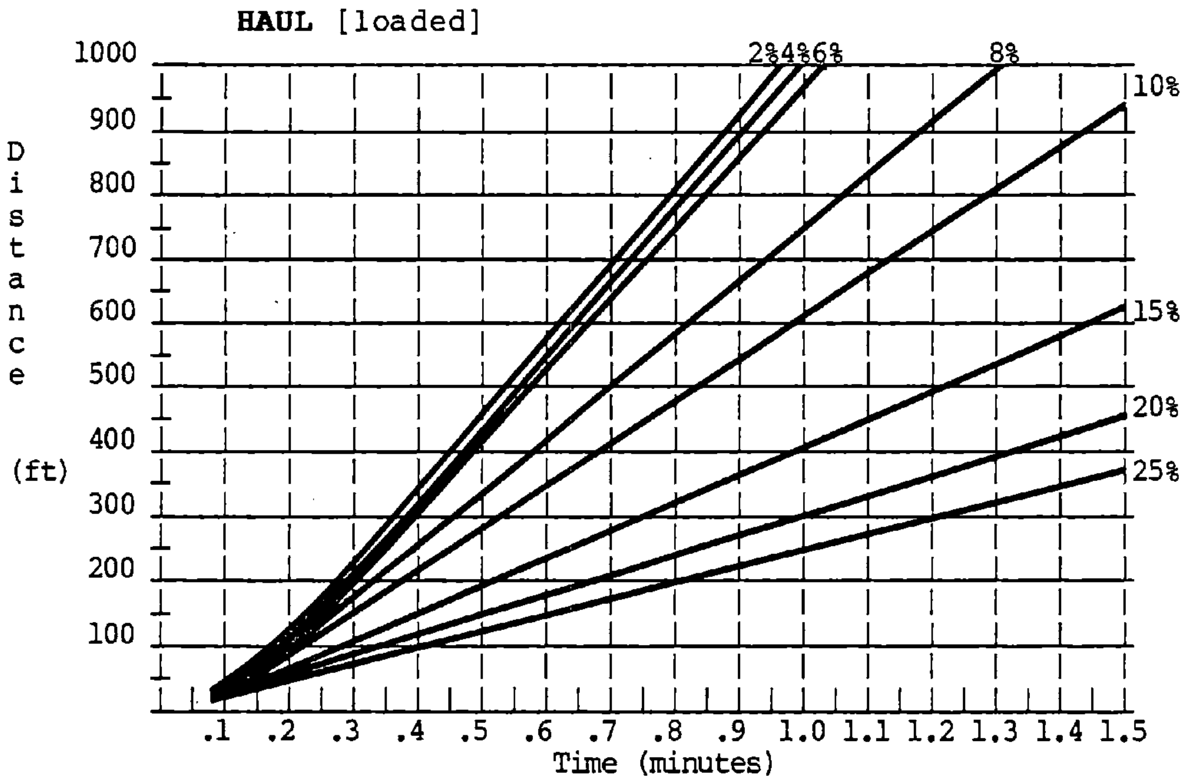
4) Find the appropriate distance on the left hand axis and project a horizontal line from it to the selected curve.

5) From this point on the curve, project a vertical line down to the time scale. This is the estimated travel time.

Based on experience and judgement, the estimator may want to increase this number up to +10% if the haul route has sharp turns and/or other obstacles that may decrease average speed.

Figure VII - 2

TRAVEL TIME VS. DISTANCE
5 YD^3 WHEEL LOADER



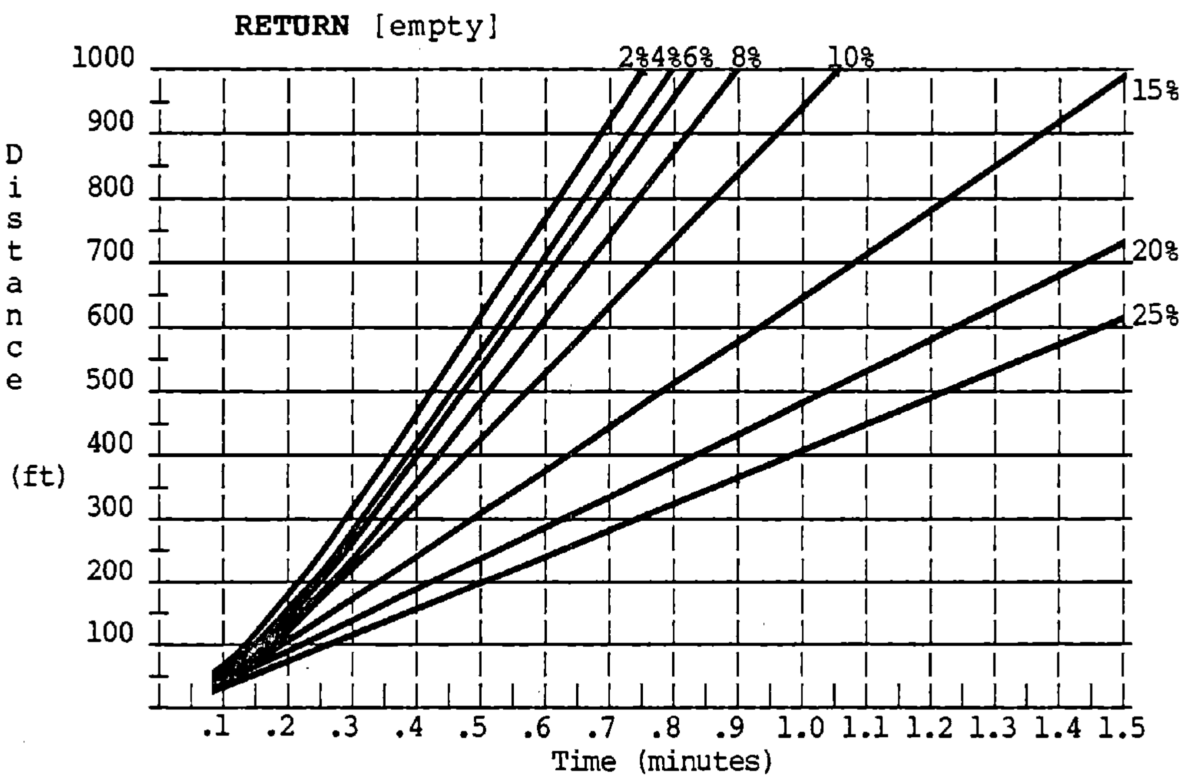
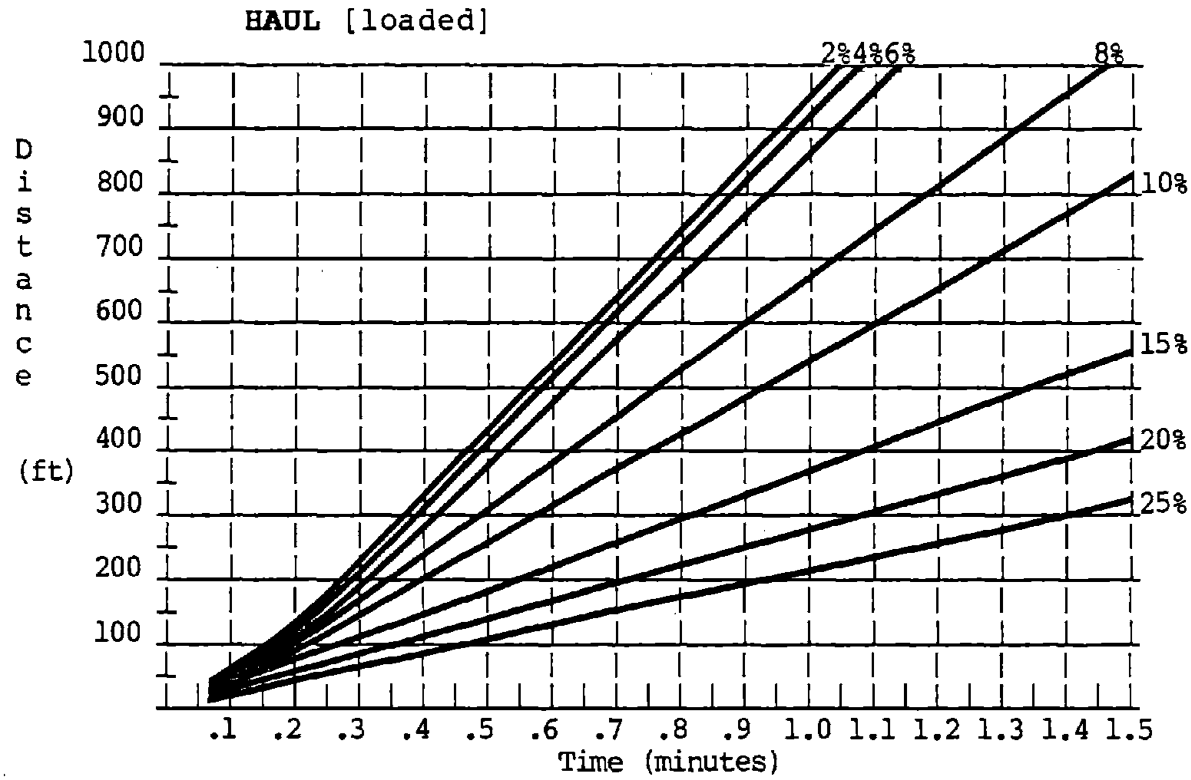


Figure VI - 2 (Continued)

TRAVEL TIME VS. DISTANCE
7 YD^3 WHEEL LOADER



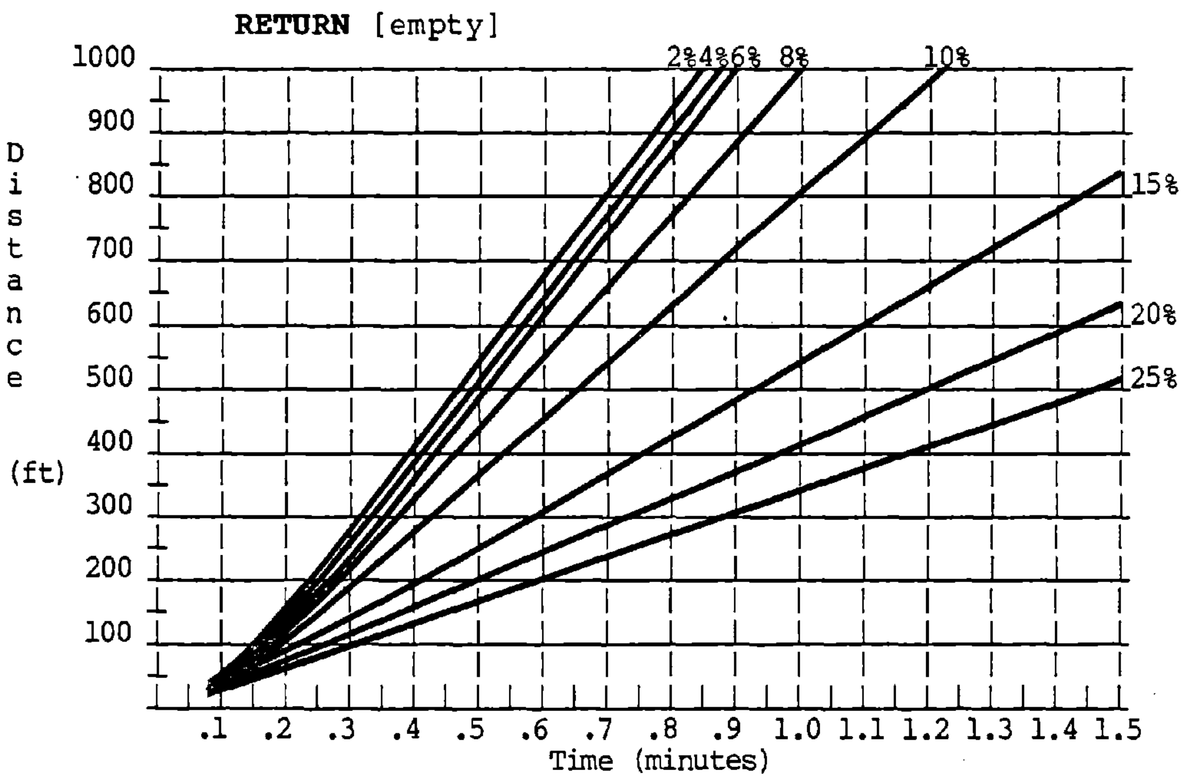
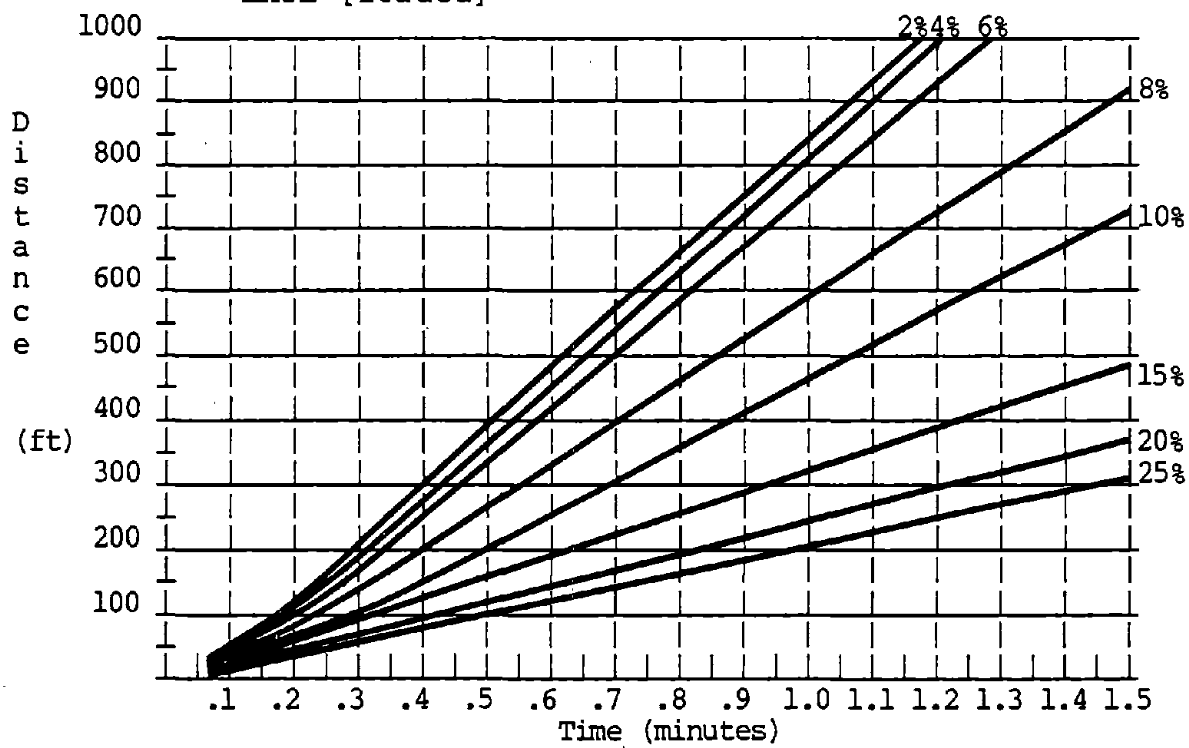


Figure VII - 2 (Continued)

TRAVEL TIME VS. DISTANCE
12 YD^3 WHEEL LOADER

HAUL [loaded]



RETURN [empty]

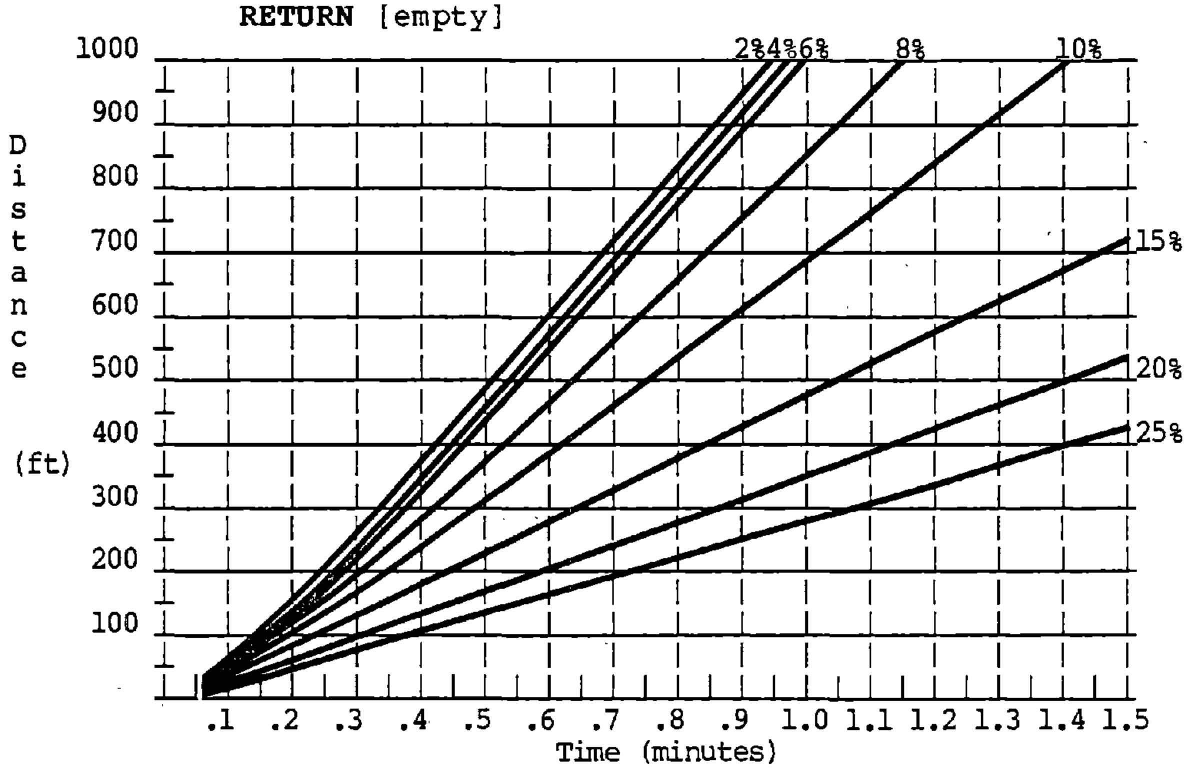
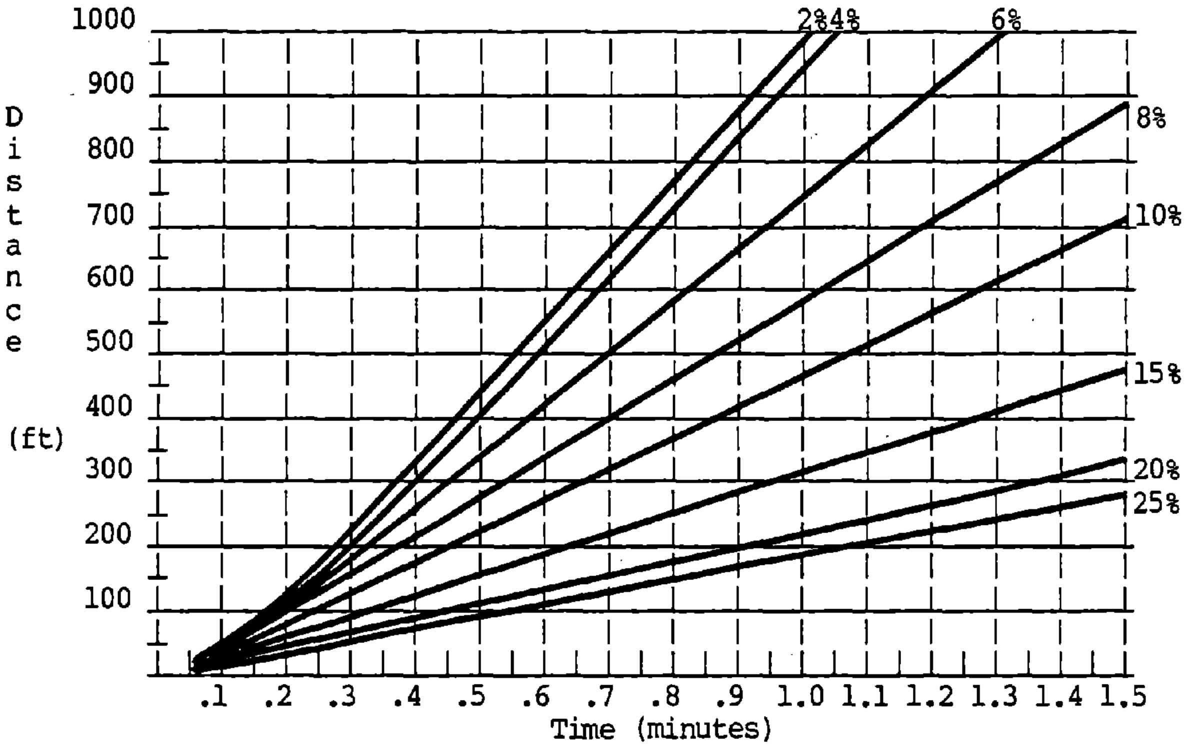


Figure VII -2 (Continued)

TRAVEL TIME VS. DISTANCE
15 YD^3 WHEEL LOADER

HAUL [loaded]



RETURN [empty]

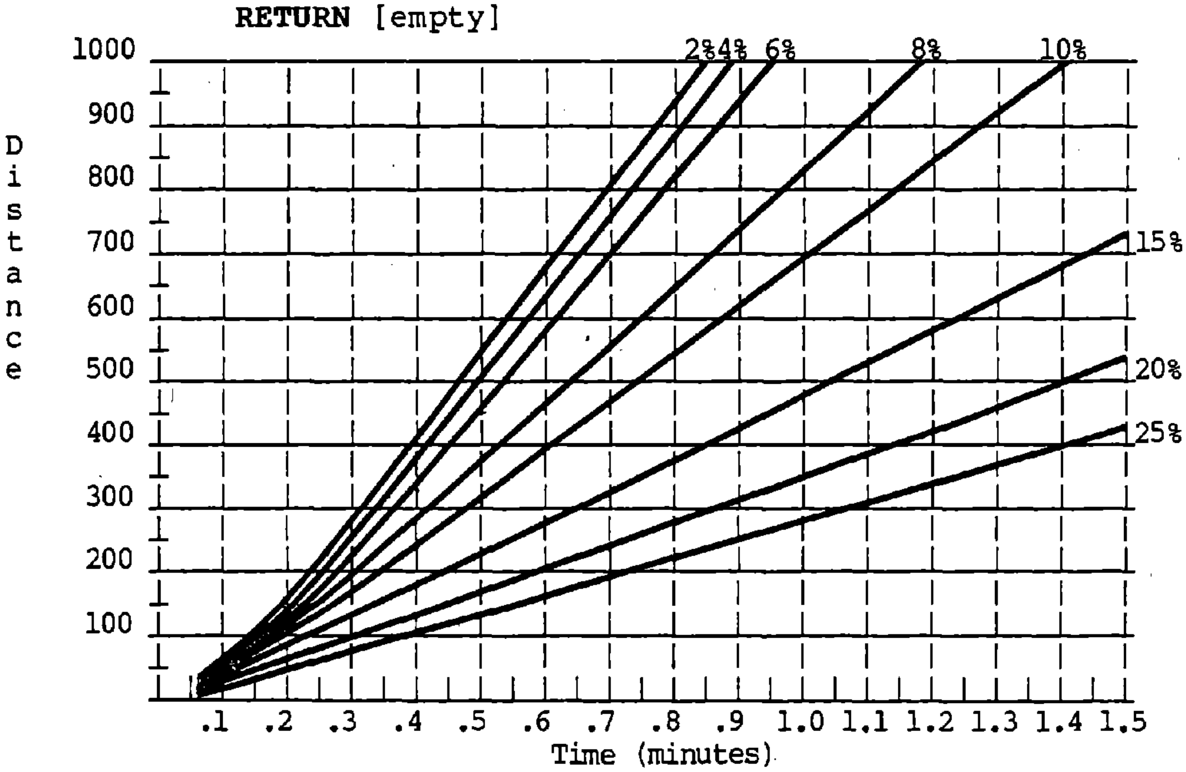


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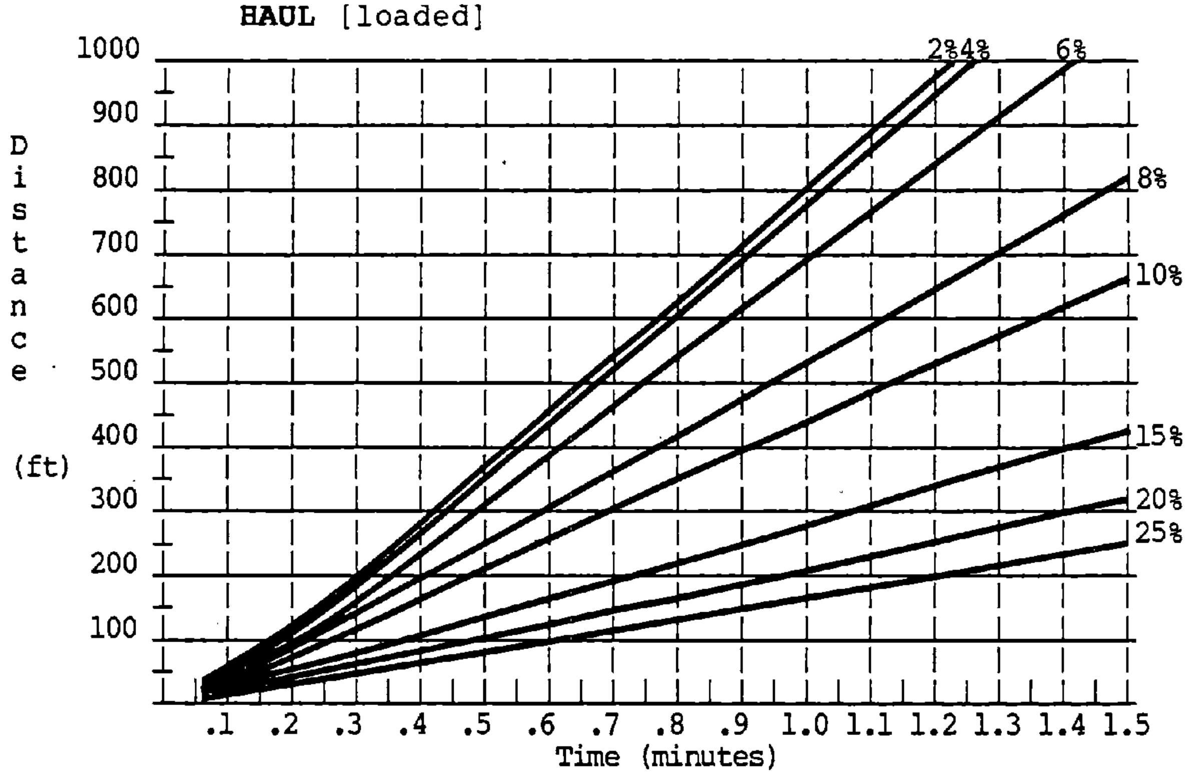
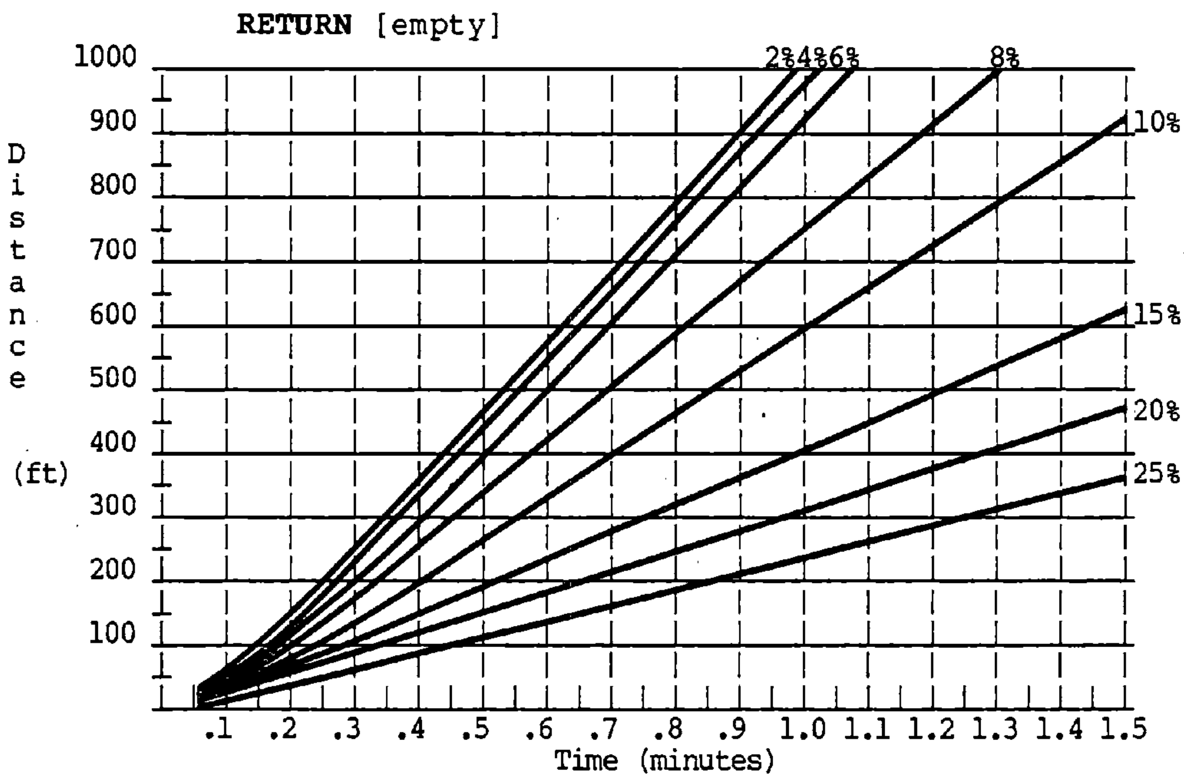
Figure VII - 2 (Continued)

TRAVEL TIME VS. DISTANCE
22 YD^3 WHEEL LOADER





An alternate approach to estimating travel times is to estimate the average speed and then calculate the time to travel the desired distance:

$$\text{time (min)} = \frac{\text{travel distance (ft)}}{\text{average speed (MPH)} \times 88}$$

Some typical average speeds on a level haul with compact surface are given in the following Table VII - 10.

Table VII - 10

AVERAGE FEL TRAVEL SPEEDS (level - mph)

HAUL (loaded)

Machine Size (yd^3)	Distance (ft.) $\leq$ 150	150-400	$\geq$ 400
5	6	9	11
7	5	9	10
12-15	5	8	9
22	5	7	8

RETURN [empty]

Machine Size (yd^3)	Distance (ft.) $\leq$ 150	150-400	$\geq$ 400
5	7	11	14
7	7	11	12
12-15	6	10	11
22	6	9	10

TOTAL CYCLE TIME

The total cycle is, of course, just the sum of the times for each part of the cycle. Although it would (under normal circumstances) be unusual, this estimate might be further adjusted to account for special conditions. These adjustments can be made by changing the total cycle time by an estimated percentage. Some examples are:

- altitude: If high altitude causes a decrease in available engine power, increase cycle time by % engine is derated.

- traction: If poor traction (demonstrated by excessive slipping or spinning tires) causes decreased performance, increase cycle time by estimated percentage. No guidelines are readily available on how much the effect may be and, if this factor is incorporated, it should probably be based on historical experience with similar conditions. The factor might range from 5 to 25%.

- operator skill: This is another subjective factor that can only be based on experience. A typical range might be + or - 10% The other approach to account for operator skill is to have it reflected in the job efficiency factor.

Again, these factors are not often applied to production forecasts unless the estimator believes they will materially affect the results.

In the continuing example of the Cat 988B (7 yd^3), we can estimate its cycle time as follows:

- average loading conditions

- dumping into a hopper, the hopper's size is somewhat small for the loader, so there is some delay in positioning bucket

- hauling a total distance of 350 ft. with average grade of 9% - the actual haul is 100 ft. @ 0% and 250 ft. @ 12%

- rolling resistance is 2% so total resistance on the haul is 9% + 2% = 11%

- average operator

- no problems limiting available power such as high altitude or poor traction

The resulting cycle time data taken from the preceeding tables is:

load...............	.13
maneuver.........	.13
haul..............	.71
dump..............	.10
maneuver.........	.12
return...........	.50
total cycle time	1.69 minutes

If historical data on cycle times is available for similar operations, it should be considered before finalizing the cycle time estimate.

PRODUCTION

With the estimates previously covered in this section, production can be calculated as follows:

max. cycles per hour = 60 min per hr/cycle time in min.

peak productivity = cycles per hour x payload

expected average productivity = peak productivity x job efficiency x machine availability.

Again, referring to the continuing example of a Cat 988B hauling average material 350ft. up a steep incline, a production estimate can now be calculated:

- cycle time was 1.69 minutes, so
  max. cycles/hour = 60 min/hr/1.69 min cycle time
  = 35.5 cycles/hr

- payload was 9.2 ton, so
  peak productivity = 9.2 ton x 35.5 cycles/hr
  = 327 tons/hr
- estimating the job factor to be good (95%) and availability to be average (85%)

- expected average production = 327 x 0.95 x 0.85
  = 264 tons/hour

When considering the production capabilities of a front-end loader used in a load-and-carry situation, it is often desirable to consider the expected variations in production. The most common cause of this variation is that the haul length changes with time. Another cause of uneven production rates is the random nature of the delays incorporated into the job efficiency factor and machine availability. The Production Estimating Worksheet has spaces to estimate three different cycle times so the sensitivity of production to some of these variations can be calculated.

The above procedures for calculating a loader's production rate result in a general estimate; as such, they can be improved by considering and incorporating actual historical data from similar operations. Nevertheless, it is important to decide whether or not historical data is relevant to the operation being planned. When new equipment is being purchased, manufacturers will often provide production estimates based on their own procedures; care should be taken to reconcile differences that may be due only to different estimating procedures when comparing different machines. However, manufacturers can often develop estimates based on the particular operating characteristics of a specific machine more closely than the generalized procedures presented in this manual.

The FEL's production capability in load-and-carry is logically one of the criteria used in evaluating system design; the other criteria are costs, mine planning alternatives, and the capabilities of other system components. Front-end loader production is most affected by:

- number of FEL's
- size of FEL
- length of haul.

To convert the production estimate calculated in this section to the FEL-L&C Production Index presented in Section III and Form 1:

$$\text{FEL-L\&C Production Index} = \frac{\text{production per shift (T/sh)}}{\text{bucket capacity yd}^3}$$

This index is used in the conceptual pit planning phase of evaluation.

SYSTEM CONSIDERATIONS

It must be remembered that if the front-end loader is part of a system requiring it to interface with other equipment, its production capabilities may be affected by this other equipment. In general, the capacity of a system is limited by the capacity of its lowest volume component and the efficiency is the product of each unit's efficiency. For example, if a loader capable of hauling 650 tons/hr. is loading a conveyor capable of handling 500 tons/hr., the capacity of the system is 500 tons/hr. and loader production will be limited to this amount. If a loader with efficiency of 85% is loading a conveyor of 90% efficiency, both loader and conveyor will be operating together (85% x 90%) 77% of the time. In actual practice, the effects of the entire system on production are not always so simple.

The system most commonly employing a loader in an load-and-carry application involves the loader dumping into a hopper. As just stated, the loader cannot actually produce more material than the hopper/crusher/conveyor system is capable of handling - even if this means the loader must sit idle part of the time. As noted in the section of this manual on equipment selection, there is often a philosophy of sizing the front-end loader so either its capacity exceeds that of the more expensive conveyor system, or of sizing the loader for current production needs but having a greater capacity conveyor to allow for future expansion. In any case, it is important to understand each component of the total system to forecast production. Besides those components already mentioned, some other potential production limiting system components are plant capacity, stockpile capacity, and loading system capacity. The production capability of the system can often be readily changed by such actions as replacing equipment with higher capacity units, purchasing additional units to work in parallel with the existing (as in acquiring additional front-end loaders), expanding working hours, improving productivity of existing units either by reducing non-productive time (by improved management and/or maintenance), or by modifying the job (for example, reducing the haul length for the loader, or by increasing the speed of a belt conveyor).

It is beyond the scope of this manual to analyze all the factors which could affect the production of a system using the front-end loader in a load-and-carry application. Most of these considerations involve common sense and will be properly accounted for if an effort is made to study them.

SAMPLE CALCULATIONS

Besides the example presented within the description of the estimating procedure, two other samples are presented here to illustrate this procedure. The applications are briefly described below and followed by completed Production Estimate Worksheets.

CASE 1

Use a LeTourneau L-800 to load and haul overburden distances of 200 to 800 ft. and then dump over bank to spoil. Standard size bucket is 15 yd^3 but based on the payload calculations, use the optional 17 yd^3 bucket. There are no corrections necessary for altitude or traction. The job efficiency is rated good and machine availability is average. Calculate sensitivity of production estimate to the haul length.

CASE 2

Use an International Harvester 580 (22 yd^3) to load blasted gypsum and haul 300 ft. to a breaker loading a conveyor. Two machines will be dumping to the same breaker so job efficiency is rated good/average. Machine availability is rated average/poor because it will be operated 24 hrs./day, 6 days/week. Calculate production estimate.

PRODUCTION ESTIMATE WORKSHEET

FRONT-END LOADER
LOAD-AND-CARRY

Date: 4-14-81
Prepared by: John Doe
No: Case 1

Location: ______

Machine: L-800

Material: Overburden: 50% rock, 50% earth
loaded from: bank
dumped to: spoil

Haul length - one way (ft.): 500 ft. avg., range 200 to 800 ft.

Work schedule (hr/day): 8 hr/shift, 2 shift/day

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Other application considerations: ______

Bucket size (heaped yd^3): 17 [BS]
Bucket fill factor (%/100) .95 [BFF]
Material weight (lb/LCY) 2895 [MW]

Max. payload (lb) = 17 [BS] x 2895 [MW] = 49,214 lb.

Payload (lb) = 17 [BS] x .95 [BFF] x 2895 [MW]
= 46,754 lb./2000 = 23.4 Ton

Machine's rated payload (lb) 51,000
Machine's full turn
static tipping load (lb) 116,000 /2 = 58,000

Is the estimated payload greater than the machine's rated payload or half its full turn static tipping load? no

---

Rolling resistance (%) 2.0 [RR]
Grade resistance (%) = $\frac{\text{Vertical distance}}{\text{Horizontal distance}}$ 0 x100 = 0 [GR]

Total resistance (%) = 2 [RR] + 0 [GR] = 2 %

Is the total resistance so large that the machine's available rimpull will be a limiting factor? no

---

Coefficient of traction (%/100) = 0.65

Will traction limit the machine's performance? no - %

Will altitude reduce engine power? (>1,000 ft. for 4-cycle or 2 cycle; >10,000 ft. for turbo or supercharged) no - %

Job efficiency factor (%/100) 0.95 [JEF]

Machine availability factor (%/100) 0.85 [MAF]

Will there be a special adjustment for operator skill? no - %

Cycle times (minutes):	200 ft. Condition {1}	500 ft. Condition {2}	800 ft. Condition {3}
Loading	0.17	0.17	0.17
Maneuvering	0.17	0.17	0.17
Hauling	0.27	0.55	0.83
Dumping	0.08	0.08	0.08
Maneuvering	0.15	0.15	0.15
Returning	0.23	0.47	0.69
(Special Adjustment)	-	-	-
Total	1.07	1.59	2.09

Max Cycles per hour = 60 (min/hour)/total cycle time (min)

{1} 56.1 cy/hr {2} 37.74 cy/hr {3} 28.7 cy/hr

Peak production (TPH) = cycles per hour x 21.8 T [payload]

{1} 1,222 TPH {2} 823 TPH {3} 626 TPH

Average production (TPH) = peak production x 0.95 [JEF]
x 0.85 [MAF]

{1} 987 TPH {2} 664 TPH {3} 505 TPH

System consideration that may limit loader production? ___none___

System capacity: ____________Ton/Hour
____________Ton/Shift
____________Ton/Day
____________Ton/Week
____________Ton/Year

Working Schedule: Scheduled - Lost = Actual

Hours/Shift ___8___ - ___0.75___(1) = ___7.25___[HPS]
Shifts/Day = ___2___[SPD]
Days/Year ___260___ - ___10___(2) = ___250___[DPY]

(1) subtract time lost for shift change, lunch, breaks, fuel and lube, scheduled maintenance, etc.
(2) subtract time lost for holidays, weather, moving hopper/conveyor, safety meetings, etc.

Hours/Year = ___7.25___[HPS] x ___2___[SPD] x ___250___[DPY]
= ___3625___hours

Production per shift = avg. production per hour x hours per shift

{1} ___7156___T/sh {2} ___4814___T/sh {3} ___3661___T/sh

Production per year = avg. production per hour x hours per year

{1} 3,578,000T/yr {2} 2,407,000T/yr {3} 1,831,000T/yr

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PRODUCTION ESTIMATE WORKSHEET

FRONT-END LOADER
LOAD-AND-CARRY

Date: 4-15-81
Prepared by: John Doe
No: Case 2

Location: ____________

Machine: IHC 580

Material: gypsum
loaded from: bank, well blasted
dumped to: breaker

Haul length - one way (ft.): 300 ft.

Work schedule (hr/day): 7 1/2 hr/shift, 3 shift/day, 6 day/week

Other application considerations: two machines dumping to same location

---

Bucket size (heaped yd^3): 22 [BS]
Bucket fill factor (%/100) .85 [BFF]
Material weight (lb/LCY) 3020 [MW]

Max. payload (lb) = 22 [BS] x 3020 [MW] = 66,440 lb.

Payload (lb) = 22 [BS] x .85 [BFF] x 3020 [MW]
= 56,474 lb./2000 = 28.3 Ton

Machine's rated payload (lb) 66,000
Machine's full turn
static tipping load (lb) 169,235 /2 = 84,617

Is the estimated payload greater than the machine's rated payload or half its full turn static tipping load? no

---

Rolling resistance (%) 2 [RR]
Grade resistance (%) = $\frac{\text{Vertical distance}}{\text{Horizontal distance}}$ 0 x100 = 0 [GR]

Total resistance (%) = 2 [RR] + 0 [GR] = 2 %

Is the total resistance so large that the machine's available rimpull will be a limiting factor? no

---

Coefficient of traction (%/100) = 0.65

Will traction limit the machine's performance? no - %

Will altitude reduce engine power? (>1,000 ft. for 4-cycle or 2 cycle; >10,000 ft. for turbo or supercharged) no - %

Job efficiency factor (%/100) 0.90 [JEF]

Machine availability factor (%/100) 0.75 [MAF]

Will there be a special adjustment for operator skill? no - %

Cycle times (minutes):

	Condition {1}	Condition {2}	Condition {3}
Loading	0.25		
Maneuvering	0.19		
Hauling	0.43		
Dumping	0.08		
Maneuvering	0.17		
Returning	0.35		
(Special Adjustment)			
Total	1.47		

Max Cycles per hour = 60 (min/hour)/total cycle time (min)

{1} 40.82 cy/hr {2} ______ cy/hr {3} ______ cy/hr

Peak production (TPH) = cycles per hour x 28.3 T [payload]

{1} 1155 TPH {2} ______ TPH {3} ______ TPH

Average production (TPH) = peak production x 0.90 [JEF]
x 0.75 [MAF]

{1} 780 TPH {2} ______ TPH {3} ______ TPH

System consideration that may limit loader production? ___none___

System cpacity: ____________Ton/Shift
____________Ton/Day
____________Ton/Week
____________Ton/Year

Working Schedule: Scheduled - Lost = Actual

	Scheduled	-	Lost		=	Actual	
Hours/Shift	7 1/2	-	1/2	(1)	=	7	[HPS]
			Shifts/Day		=	3	[SPD]
Days/Year	312	-	12	(2)	=	300	[DPY]

(1) subtract time lost for shift change, lunch, breaks, fuel and lube, scheduled maintenance, etc.
(2) subtract time lost for holidays, weather, moving hopper/conveyor, safety meetings, etc.

Hours/Year = ___7___[HPS] x ___3___[SPD] x ___300___[DPY]
= ___6300___hours

Production per shift = avg. production per hour x hours per shift

{1} ___5460___T/sh {2} _________T/sh {3} _________T/sh

Production per year = avg. production per hour x hours per year

{1} 4,914,000T/yr {2} _________T/yr {3} _________T/yr

SECTION VIII

OPERATING AND OWNERSHIP COSTS

Prior to final selection of a machine for a given materials handling application, the owner/operator should analyze the economic comparisons between the several machines which could physically perform the job in question. Such economic comparisons are typically based on estimated costs expressed in units of dollars per operating hour ($/hr.) or dollars per ton or cubic yard of material moved ($/ton, $/yd^3). Presumably the potential owner/operator will choose the machine which promises to perform the job in the time provided and at the lowest overall cost - all other factors being constant.

In most economic comparisons between machine alternatives, the estimated costs per unit of time or quantity include operating and ownership costs (O&O costs). Unfortunately, cost estimates for a given type of machine can vary widely from one estimator to another. Indeed, these cost estimates will vary with specific models of machines within a general classification of machine type (front-end loaders). The cost estimate determined will ultimately be a function of the estimator's perception of the job to be performed under a given suite of conditions. Some of the many factors which influence O&O cost estimates are: work the machine performs; maintenance procedures; local prices of fuel, lubricants, parts, etc.; type of material (density, size, abrasiveness, etc.); freight charges; climatic conditions; variation in job application; etc. It is not surprising then that O&O cost estimates can vary significantly for pieces of equipment depending upon application, material characteristics and climatic conditions.

Developing O&O cost estimates for a piece of capital equipment is an inexact process. The cost estimate resulting from any estimating procedure is only as good as the input information. For instance, it is extremely important that the estimator adequately understands the application under consideration in a given locality and incorporates this information into the estimating procedure. It is also important to incorporate the actual cost values associated with labor rates, fuel, services, parts, supplies, etc., for the locale where the job is being performed. With the incorporation of reasonably accurate estimates of the above factors into the estimating procedure, the final O&O cost estimate should be reasonably representative of the actual cost incurred in performing the job.

In the absence of specific data relating to an application in a given locality and the various prices and costs inherent to that locality, it becomes necessary to establish a general estimating proceudure which can be utilized for O&O estimation. The general or standard estimating approach which is incorporated in the following section is presented as a mechanism for helping owners and operators make an economic determination or estimate of the cost associated with performing a given job with a specific size of machine. The approach presented does not determine the total cost associated with a given job, in that cost items such as supervision, general overhead, ancillary support and facilities, etc., are not considered. Only estimates of direct O&O costs for the machine are illustrated.

IT IS IMPORTANT THE USER UNDERSTAND THAT THE ESTIMATING PROCEDURES ILLUSTRATED IN THIS MANUAL SHOULD BE USED AS A GUIDE ONLY. ANY ESTIMATES DERIVED FROM USE OF THE PROCEDURES PRESENTED IN THIS MANUAL ARE NOT TO BE CONSIDERED AS SPECIFIC GUARANTEES OF ACTUAL COSTS OBTAINED IN THE FIELD.

<u>STANDARD O&O COST ESTIMATING PROCEDURE</u>

Standard cost estimating techniques should be available to the owner/operator which would provide him the capability of estimating an overall O&O cost for the job <u>prior</u> to selecting a specific piece of equipment from one of several manufacturers.

Most of the equipment manufacturers having front-end loaders in their product line have some form of cost estimating procedure which they advocate for calculating O&O costs for front-end loaders. Although the major cost components are essentially the same, there are some differences in estimating procedures employed. These differences can result in substantial variations in O&O machine cost estimates. It is unclear if these differences are the result of the specific estimating procedures themselves, or if they relate to actual machine differences. It is also unclear if these proposed estimating methods are general in nature or if they have been derived from actual machine data for a given manufacturer's equipment line. Because of these uncertainties, the estimator is unable to ascertain if machine comparisons can be made: (1) between alternative machines having different manufacturers (e.g., Caterpillar vs. Terex) using their respective estimating procedures, or (2) between alternative machines using only one of the manufacturer's methods of estimating for both machines.

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For these reasons the cost estimator must make every effort to use a consistent or standard estimating approach when calculating preliminary machine costs. Therefore, the cost estimating procedure suggested in this section represents a compilation of several approaches which can be used consistently for preliminary O&O cost estimates for a given machine -- irrespective of specific manufacturer. Although it suffers from the standpoint of preciseness, as do all general estimating procedures, it does have the distinct advantage of being applicable to all machines for initial cost estimates. In addition, the estimating procedure offered: (1) is a compilation of rather standard approaches used throughout the construction and mining industries, (2) is rather simple and straight-forward, (3) makes use of a few readily estimatable machine variables, and (4) produces a cost estimate based on a minimum amount of specific job information. It is also believed this procedure will result in conservative cost estimates in most cases.

It should be noted that this so-called standard O&O cost estimating procedure calculates an average annual cost for a machine. This "representative year" cost calculation is assumed to remain constant over the life of the machine. It is obvious that actual machine operating costs are never so simply distributed over machine life. Therefore, these cost estimates are only an attempt to represent the actual machine costs incurred. However, since the costs are determined on an equal basis they provide a convenient method for comparing prospective machine costs and alternatives.

The worksheet on the following pages will be utilized for front-end loader O&O cost estimates in this manual. It must be stressed that it represents an estimating procedure intended solely for preliminary machine costing for a given job. After the owner/operator has a feel for this cost, he would then approach various front-end loader manufacturers for price quotes as well as any O&O cost estimates for the specific machine size and model being considered. The following sections discuss the specific components of the worksheet in some detail.

The data presented in this section, unless the source is specifically noted, is derived from a number of references and field experience. These references are listed in Appendix E.

HOURLY OWNING AND OPERATING COST WORKSHEET

FRONT-END LOADER

Date: ____________
Prepared by: ________________
No: ____________

Location :____
Application :____

Machine: _______________
Model: _______________

OWNERSHIP COSTS

Amount in
$/Op.Hr.

A. Depreciation:

1. Purchase price (include attachments, extras, taxes)............. $________
2. Freight: __________ lbs.
   @ $___________.............(+)________
3. Delivered price.............. ________
4. Tire replacement cost:
   Front $__________
   Rear __________..........(-)________
5. Resale or trade-in value (optional).................(-)________
6. Net depreciable value........ ________
7. Depreciation period:
   a) service life (hours) _______ hrs.
   b) operating hours/year _______ hrs.
   c) years for write-off _______ yrs.
8. Hourly depreciation costs:

   $\frac{\text{net depreciable value (line A.6)}}{\text{depreciation period in hours (line A.7.a)}}$ $__________

B. Interest, Insurance, Taxes:

1. Annual rates:
   a) interest ________%
   b) insurance ________%
   c) taxes ________%
   d) Total.................__________%

2. Calculation procedure:

a) $\dfrac{(\text{line B.1.d}) \times \frac{N+1}{2N} \times (\text{line A.3})}{\text{line A.7.b}}$

$\dfrac{\_\_\_\% \times \frac{\_\_\text{yr}}{\_\_\text{yr}} \times \$\_\_\_\_}{\_\_\text{hr}}$ .... $______

where N = line A.7.c
or, if salvage is considered

b) $\dfrac{(\text{line B.1.d}) \times \left(\frac{\text{line A.3 (N+1)} + \text{line A.5 (N-1)}}{2N}\right)}{\text{line A.7.b}}$

$\dfrac{\_\_\_\% \times \left(\frac{(\$\_\_ \times \_\_\text{yr}) + (\$\_\_ \times \_\_\text{yr})}{\_\_\text{yr}}\right)}{\_\_\text{hr}}$.$______

3. Hourly IIT costs (select either line B.2.a or line 2.b above.........................$__________

C. Total Hourly Ownership Costs (line A.8 + line B.3).....................$__________

OPERATING COSTS — Amount in $/Op.Hr.

D. Hourly Tire Cost:

1. Replacement cost:

$\dfrac{\text{tire replacement cost}}{\text{estimated life (hrs)*}}$

$\dfrac{\$\_\_\_\_\_\_\_\_}{\_\_\_\text{hrs}}$ ....$________

*see Table VIII - 2 or VIII - 4

2. Repair cost

tire repair factor (%)* x hourly tire replacement cost (line D.1)

_____%/100 x $________......$________

*see Table VIII - 3

3. Hourly tire cost
   (line D.1 + line D.2)................ $__________

E. Hourly Fuel Cost:

est. consumption* __________gph
x unit price $________per gallon............ $__________

*see Appendix A or Figure VIII - 1

F. Service Costs:

factor ratio* x hourly fuel cost

ratio ______ x line E ________............... $__________

*see Table VIII - 5

G. General Repair

repair factor* x hourly depreciation cost

factor ______% x line A.8 ________........$__________

*see Table VIII - 6

H. Hourly Special Items (cutting edges, bucket teeth, etc.)

initial cost ($)
estimated life (hours)*

$____________________......................$__________
hours

*See Table VIII - 7

I. Total Hourly Operating Cost
(exclusive of operating labor)
(add lines D through H)...................$__________

J. Hourly Operator Cost
(including fringes, etc.).....................$__________

K. Total Hourly Ownership & Operating Cost
(add lines C, I, and J).......................$__________

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OWNERSHIP COSTS

Ownership costs are costs incurred as the result of owning a machine, whether the machine is working or not. The major components of ownership cost are: depreciation, resale (trade-in or salvage) value, interest, insurance and taxes.

Depreciation

Depreciation is a tax deduction which reflects exhaustion, wear and tear, and obsolescence of property used in a trade or business. In effect it represents the gradual reduction or loss in value of a piece of capital equipment over time. The intent of the depreciation allowance, for tax purposes, is to enable the owner to recover the original investment in a piece of equipment over its estimated service life. As a result, when a piece of equipment reaches its service life the owner will have recovered its initial purchase price and can then buy a new machine to continue operations. Unfortunately, the depreciation calculation procedure does not account for any capital cost escalations occurring between machine purchases.

There are several methods available for determining depreciation costs or allowances. Some of these methods are oriented more toward tax considerations of the company and are not typically employed in the standard estimating procedure. The straight-line method (S-L) of determining depreciation costs is the approach employed in the standard estimating procedure. This method simply depreciates the equipment in equal amounts over its estimated service life (years or operating hours).

The first step in the calculation procedure is to determine the depreciable value of the piece of equipment. The initial depreciable value would consist of machine purchase price (including attachments, extras, and taxes) plus freight. From this value must be deducted the price of the tires on the machine since these are non-depreciable items and are accounted for in operating costs. In addition, consideration should be given to potential resale, trade-in, or salvage value of the machine at the end of its service life. The normal assumption of a zero value is typically used by most estimators; however, resale value is an important item in view of the current trend toward higher and higher equipment costs. Also, many equipment owners look to potential resale or trade-in value as a key factor in making investment decisions. If the decision is made to incorporate resale or trade-in machine value into the cost estimate, it should be deducted from the depreciable basis of the machine. An estimate of the resale value should be obtained from a dealer familiar with the used machinery market in a given locale. In addition to local considerations, other factors which significantly influence resale value are the number of operating hours on the machine, physical condition of the machine, maintenance history, and the job conditions in which it was operated.

Now that the "net depreciable value" of the machine has been established, the next requirement is to estimate the service life of the machine. The economic or service life of a machine will primarily be a function of maintenance practices as well as job conditions. Most owners will establish a life based on their own experience and estimate of the job conditions. When this is not possible, an estimate may be obtained from the following table.

Table VIII - 1

USEFUL LIFE OF FRONT-END LOADER (HOURS)

Machine Size	Working Conditions		
	Favorable	Average	Unfavorable
< 5 yd^3	12,000	10,000	8,000
> 5 yd^3	15,000 to 20,000	12,000	10,000

Favorable:	Free flowing, low density materials. LHD on good surface, short distances, no grades.
Average:	Low to medium density materials. No overloading. Loading from bank in good digging. LHD on poor surface and slight grades.
Unfavorable:	High density materials, hard digging. LHD on poor surfaces, long distances, with adverse grades.

After selection of machine service life, the hourly depreciation cost is calculated by dividing the net depreciable value by the service life. By estimating the anticipated number of operating hours the machine will be used each year, the number of years of use can be calculated by dividing the service life by the number of operating hours per year.

Interest, Insurance and Taxes (IIT)

An additional component of ownership cost is associated with interest, insurance and tax charges. Some owners prefer to allocate these charges to general overhead associated with the operation. However, the normal procedure is to as sign these costs to machine ownership.

Interest is generally considered to be the cost of using investment capital. This is a real cost whether the machine is purchased outright for cash or financed over some time interval. Prevailing rates are used for the estimate.

Insurance represents charges for comprehensive and liability insurance policy premiums that apply to the machine. Although existing local rates should be used whenever possible, a value of 2% or 3% of average yearly value is often used for estimating purposes.

Taxes refer to property or use taxes which can be allocated to a specific machine. These rates will vary according to state and local tax statutes. Values of 2% or 3% are typically used for estimating purposes.

Annual percentage rates are individually estimated for interest, insurance and taxes and then combined into a total rate which is normally applied to the owner's average annual investment in the machine. The average annual investment (value) may be defined as the delivered price of the machine (purchase price + freight) multiplied by the factor

$(N + 1) / 2N$ where

N = years of useful life (line A7c on the worksheet)

In terms of the line items on the worksheet, the calculation for the IIT portion of ownership cost is performed as follows:

$$IIT = \frac{(\text{line B.1.d}) \times \frac{N+1}{2N} \times (\text{line A.3})}{(\text{line A.7.b})}$$

When resale or salvage value is used in the estimate, the average yearly value sould be calculated as follows:

$$\text{average yearly value} = \frac{P(N+1) + S(N-1)}{2N}$$ where

P = purchase (delivered) price
N = years of useful life
S = salvage (resale) value

In terms of the line entries on the worksheet, the calculation procedure including an adjustment for resale value would be as follows:

$$\text{IIT} = \frac{(\text{line B.1.d}) \times \left(\frac{\text{line A.3 (N+1) + line A.5 (N-1)}}{2\text{N}} \right)}{\text{line A.7.b}}$$

Total hourly ownership cost for a machine is simply the sum of depreciation charges and costs associated with interest, insurance and taxes. In general, ownership costs are less difficult to estimate than operating costs; however, it is also obvious that they can vary considerably based on the assumptions made.

OPERATING COSTS

Operating costs represent expenses associated with operating a piece of equipment and include consumables such as fuel, lube, filters, tires, etc., as well as service, repair and labor. These costs fluctuate according to usage rates and are typically calculated on the basis of "average hourly costs".

Operating costs for a given machine are always difficult to estimate because of machine characteristics, job application, operating conditions, etc., previously mentioned. Nevertheless, these cost estimates must be prepared if appropriate machine comparisons are to be made. Before a meaningful cost estimate can be generated, however, it is extremely important that the major cost parameters associated with machine operation be identified. The primary cost categories most cost estimators associate with front-end loaders are as follows:

- tires
- fuel
- service (lubricants, filters, grease)
- repairs
- operating labor.

The standard approach to estimating operating costs incorporates actual estimates of consumption for the above major cost items with respect to various operating demands on the machine. For example, in a given job application, estimates are made of tire life, fuel, lubrication, grease, and filter consumption, repairs, etc., and then multiplied by current unit prices. These cost components are then cumulated and total estimated operating cost per hour is determined.

Tires

Tire costs are often the most important single component of operating cost (exclusive of labor) for any rubber-tired machine. The best estimate of tire costs is the one based on actual tire life experiences and prices actually paid by the owner for tire replacements. Tire replacement costs are equal to the original cost of the tires divided by the estimated life of the tires.

Determination of expected tire life is difficult because it is influenced by many operating conditions. As a result, variations in actual tire lives recorded in the field can be extreme. Where tire experience is not available, tire life estimates may be obtained from Table VIII - 2.

Table VIII - 2

TIRE LIFE ESTIMATES (HOURS)
(life based on new tires run to destruction)

Industry Code	Conditions: Favorable	Average	Unfavorable
L-5 types	5,500 to 4,000	4,000 to 3,000	3,000 to 1,000
L-4 types	4,400 to 3,200	3,200 to 2,400	2,400 to 800
L-3 types	2,200 to 1,600	1,600 to 1,200	1,200 to 400

(Courtesy of Goodyear Tire & Rubber Co.)

In the situation where a front-end loader is being used in a load-and-carry application, some adjustments should be considered when estimating tire life. These adjustment factors relate to variables such as maintenance, curves, speeds, loads, grades and surface conditions of haul roads and work areas (discussed in an earlier section). Although all of these factors may not be pertinent in typical FEL load-and-carry applications -- because of the reaonably short hauls -- they should be considered in the final analysis in order to assess their potential impact. Table VIII - 4 lists the commonly used factors which could relate to FEL's in a load-and-carry application. These factors can then be used as an alternate method of estimating tire life. Consider the example: FEL with extra tread tires, average maintenance, 10 mph maximum speed; soft earth with some rocks, recommended load, medium curves, and 6% maximum grade. The factors would then be (1) 0.981, (2) 1.090, (3) 0.981, (4) 1.090, (5) 0.981, (6) 0.981 and (7) 1,090; estimated tire life would be:

base life of 2680 hr x 0.981 x 1.090 x 0.981 x 1.090
0.981 x 0.981 x 1.090 = 3200 hrs.

Because tires are such a high cost item, it is generally advisable to build a tire repair cost into the estimate in addition to the tire replacement cost. This tire repair cost may be calculated as follows:

hourly tire repair cost = tire repair factor
x hourly tire replacement cost.

Table VIII - 3 shows the suggested factors for various operating conditions which are applied to the hourly tire replacement cost. This tire repair cost essentially represents a margin of safety for tire costs in the estimate.

The tire life estimating procedures and information presented thus far have been based on running standard tires to destruction. However, many operators recap tires on a regular basis. Recapping costs are normally about 50% of the original value of the tire. Recapped tire life varies but most operators obtain approximately 70% to 90% of the original tread life. When recappng does occur or is planned, it should be incorporated into the cost estimate. In the absence of specific information, the average cost for tire replacement, including recapping, may be determined by multiplying the original estimate of tire replacement cost by a factor - usually 0.80. When precise recapping costs and good estimates of resulting life can be obtained, the following expression should be used to determine hourly tire cost:

$$\text{hourly tire cost} = \frac{\text{replacement cost + recapping cost}}{\text{original life + recap life}}$$

Table VIII - 3

TIRE REPAIR FACTORS

General Working Conditions	Tire Repair Factor With or Without Recapping
Favorable	12%
Average	15%
Unfavorable	17%

(Courtesy of Terex, Corp.)

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Table VIII - 4

TIRE LIFE FACTORS

No.	Condition	Factor
1	Maintenance:	
	excellent	1.090
	average	.981
	poor	.763
2	Speeds (maximum):	
	10 MPH	1.090
	20 MPH	.872
3	Surface Conditions:	
	soft earth, no rock	1.090
	soft earth, some rock	.981
	well maintained, gravel road	.981
	poorly maintained, gravel road	.763
	blasted - sharp rock	.654
4	Loads (see #7 note):	
	T & RA recommended	1.090
	20% overload	.872
5	Curves:	
	none	1.090
	medium	.981
	severe	.872
6	Grades:	
	level	1.090
	6% maximum	.981
	15% maximum	.763
7	Other Miscellaneous Combinations:	
	none	1.090
	medium	.981
	severe	.872

Condition 7 is to be used when overloading is present in combination with one or more of the first four conditions maintenance, speeds, surface conditions or curves. The combination of these conditions with an overload will create a new and more serious condition which will contribute to early tire failure to a larger extent than will the individual factors of each condition.

Note: Use 1915 hours as a base and 2680 hours for extra tread tires.

(Courtesy of the Goodyear Tire & Rubber Co.)

Fuel

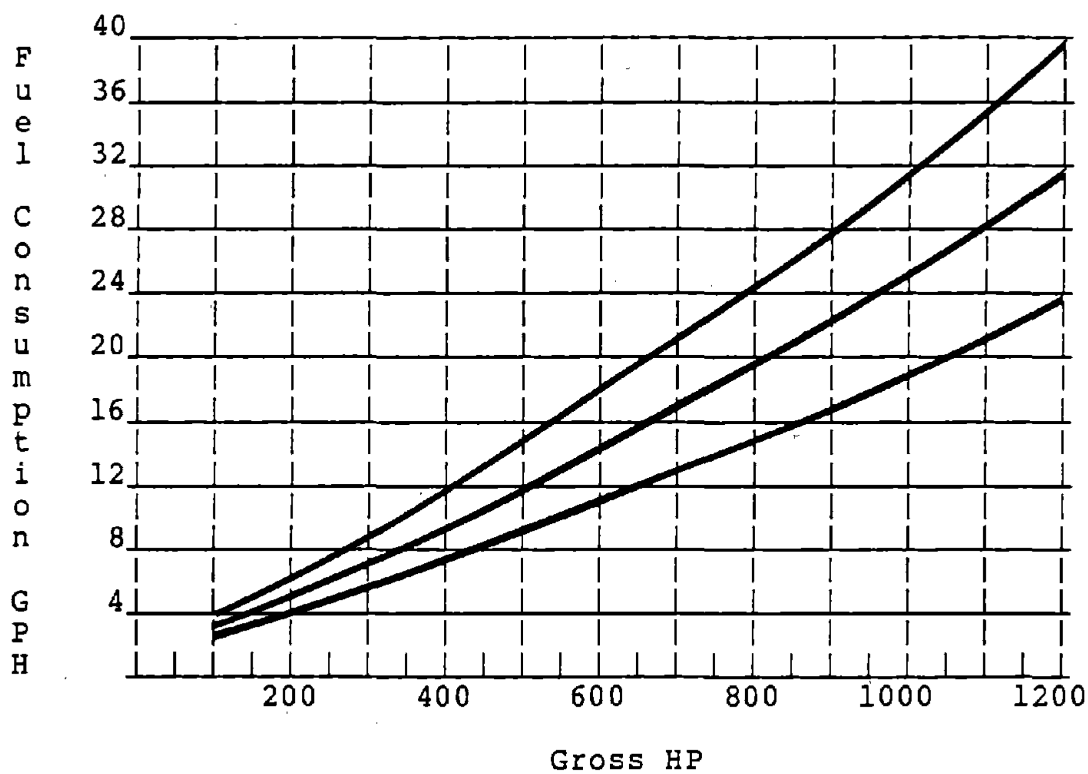
Hourly fuel costs are based on local rates and engine fuel consumption. Engine fuel consumption is a function of engine horsepower and job application. Once the hourly fuel consumption for a machine is determined, the hourly fuel cost is calculated as follows:

hourly fuel cost = hourly consumption
x local price per gallon

Hourly fuel consumption can be determined quite accurately in the field for a machine operating under a given set of conditions. Where such information does not exist, fuel consumption may be estimated from the data provided in Appendix A or from the relationships shown in Figure VIII - 1.

Figure VIII - 1

FUEL CONSUMPTION



Service Costs

Service costs refer to expenses associated with oil, grease , and filters consumed during machine operation. These hourly costs will vary with the frequency at which servicing is performed and should be based on local unit prices.

A very general approach may be utilized in estimating service costs. The estimate may be based on the size of the engine in the machine and its associated fuel consumption. Table VIII - 5 shows the service cost estimate expressed as a fraction of the hourly fuel cost for various operating conditions. This estimate includes the labor involved in performing normal service items. Although this form of estimate is general in nature, it is also convenient in that the hourly fuel cost has previously been determined and no further calculations or estimates are necessary.

Table VIII - 5

HOURLY SERVICE COST ESTIMATE

	Conditions	
Favorable (Light-Duty Cycle)	Average (Medium-Duty Cycle)	Unfavorable (Severe-Duty Cycle)
1/5 of hourly fuel cost	1/3 of hourly fuel cost	1/2 of hourly fuel cost

(Courtesy of Terex Corp.)

General Repair

Machine repair costs are most directly related to machine applications, operating conditions, maintenance practices and operator skill. Repair costs, including parts and labor, are associated with the maintenance and periodic overhaul of the machine. These costs are typically a major component of overall operating costs, but they are extremely difficult to estimate or forecast with any degree of accuracy. In general, these costs escalate with machine age and typically are rather erratic and lumpy in occurrence. Hourly repair costs are often rather low during the early years of machine life and then gradually rise over the life of the machine. Predicting these incremental changes in annual repair costs is exceedingly difficult, even when vast amounts of accurate historical performance and cost records are available on similar types of machines. Therefore, most cost estimates are based on average repair costs per operating hour, even though it is reasonable to assume these costs will be overstated early in machine life and understated in the later years of machine life.

Hourly repair costs may be estimated by multiplying hourly depreciation costs by some appropriate percentage value. On this basis the hourly repair cost may be expressed as follows:

hourly repair cost = repair factor (%)
x hourly depreciation cost.

The rationale for this type of estimate is that depreciation directly reflects useful machine life, which is based on severity of operation. Table VIII - 6 shows the recommended percentage rate values to be applied to the hourly depreciation charges. It should be noted that this estimating technique applies only when depreciation is evenly spread across the machine's economic life (straight-line).

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Table VIII - 6

REPAIR COST ESTIMATE FACTORS (%)

Job Conditions	% of Hourly Depreciation Costs
Favorable	45 - 50
Average	50 - 65
Unfavorable	65 - 80

Special Items

Some added cost allocation should be made for high-wear items on the machine. On front-end loaders these cost items primarily include bucket teeth and cutting edges. These costs will vary greatly depending on applications, materials, and operating techniques. Hourly costs should be determined by dividing the initial cost of the items by the estimated life in hours. Local supplier quotes are very important to the estimate. Table VIII - 7 provides a rough estimate of cutting edge life under various conditions when no other information is available.

Table VIII - 7

ESTIMATE OF CUTTING EDGE LIFE (HOURS)

Conditions		
Favorable	Average	Unfavorable
3500 hrs.	2000 hrs.	500 hrs.

(Courtesy of Terex Corp.)

Operator:

Operator wages will vary considerably from one location to another. It is important to use the local wage rate where the machine is being utilized. Operator cost should include the direct wage rate as well as any fringe or other benefits paid by the owner.

EXAMPLE OF O&O COST CALCULATIONS

To illustrate the previously discussed procedures for determining O&O cost estimates for a front-end loader, an example has been prepared. The following completed worksheet shows the O&O cost estimate determined for the example data provided. Note that only a minimum amount of information on the machine itself is necessary at this point in order to calculate the estimate.

Example:

Machine:

12 yd^3 FEL; no attachments
Gross horsepower: 685
Standard tires: 4 @ $7,800 each
Purchase price (including taxes): $530,000
Estimated weight: 200,000 lbs.

Application:

Loading from bank in good digging, medium density material. Haul approximately 600 ft. to hopper; hauling surface is rather poor with a low-to-medium rolling resistance. The machine will be handling average loads and will be serviced at normal intervals.

Other assumptions:

Service life: 11,000 hours
Annual operating hours: 2200 hours
Trade-in value (5 years): 12% of purchase price
Freight: $5.10/CWT
Interest: 14%
Insurance: 2%
Diesel fuel: $1.04/gallon
Operator cost (including fringes): $20.05/hour
Estimated bucket and teeth cost: $1.25/hour

HOURLY OWNING AND OPERATING COST WORKSHEET

FRONT-END LOADER

Date: 4-15-81
Prepared by: John Smith
No: example

Location : ____________
Application : ____________

Machine: 12 yd^3
Model: ____________

OWNERSHIP COSTS

Amount in $/Op.Hr.

A. Depreciation:

1. Purchase price (include attachments, extras, taxes).............. $ 530,000
2. Freight: 200,000 lbs. @ $ 5.10/CWT ....(+) 10,200
3. Delivered price.............. 540,000
4. Tire replacement cost: Front $7,800 (2) Rear 7,800 (2) ....(-) 31,200
5. Resale or trade-in value (optional).................(-) 63,600
6. Net depreciable value........ 445,400
7. Depreciation period:
   a) service life (hours) 11,000 hrs.
   b) operating hours/year 2,200 hrs.
   c) years for write-off 5.0 yrs.
8. Hourly depreciation costs:

   net depreciable value (line 6) / depreciation period in hours (line 7a) — $ 40.49

B. Interest, Insurance, Taxes:

1. Annual rates:
   a) interest __14__ %
   b) insurance __2__ %
   c) taxes __2__ %
   d) Total.................. __18__ %

2. Calculation procedure:

$$a)\ \frac{(\text{line B.1.d}) \times \frac{N+1}{2N} \times (\text{line A.3})}{\text{line A.7.b}}$$

$$\frac{\_\_\% \times \frac{\_\_ yr}{yr} \times \$\_\_}{hr} \text{.........} \$\_\_\_$$

where N = line A.7.c
or, if salvage is considered

$$b)\ \frac{(\text{line B.1.d}) \times \left(\frac{\text{line A.3 } (N+1) + \text{line A.5 } (N-1)}{2N}\right)}{\text{line A.7.b}}$$

$$\frac{18\ \% \times \left(\frac{(\$540200 \times 6\ yr) + (\$63600 \times 4\ yr)}{10\ yr}\right)}{2200\ hr} . \$\ 28.60$$

3. Hourly IIT costs (select either line 2.a or line 2.b above..........................$__28.60__

C. Total Hourly Ownership Costs
   (line A.8 + line B.3)......................$__69.09__

OPERATING COSTS — Amount in $/Op.Hr.

D. Hourly Tire Cost:

1. Replacement cost:

$$\frac{\text{tire replacement cost}}{\text{estimated life (hrs)*}}$$

$$\frac{\$\ 31,200}{3,200\ hrs} \text{...............} \$\ 9.75$$

*see Table VIII - 2 or VIII - 4

2. Repair cost

   tire repair factor (%)* x hourly tire replacement cost (line D.1)

   __15__ %/100 x $__9.75__ ......$__1.46__

   *see Table VIII - 3

3. Hourly tire cost
(line D.1 + line D.2)................ $ 11.21

E. Hourly Fuel Cost:

est. consumption* 20.0 gph
x unit price $ 1.04 per gallon........... $ 20.80

*see Appendix A or Figure VIII - 1

F. Service Costs:

factor ratio* x hourly fuel cost

ratio 1/3 x line E 20.80 .... $ 6.93

*see Table VIII - 5

G. General Repair

repair factor* x hourly depreciation cost

factor 60 % x line A8 40.49 ....$ 24.29

*see Table VIII - 6

H. Hourly Special Items (cutting edges, bucket teeth, etc.)

initial cost ($) / estimated life (hours)*

$ ______ / hours ....$ 1.25

*See Table VIII - 7

I. Total Hourly Operating Cost
(exclusive of operating labor)
(add lines D through H)...................$ 64.48

J. Hourly Operator Cost
(including fringes, etc.)....................$ 20.05

K. Total Hourly Ownership & Operating Cost
(add lines C, I, and J).......................$ 153.62

OTHER PROCEDURES FOR SPECIFIC COST ESTIMATES

After a potential owner/operator of a front-end loader has determined the preliminary O&O cost for a given machine size in a specific application, the normal procedure is to approach various front-end loader manufacturers and solicit price quotes (and perhaps O&O cost estimates) for specific machines (models, attachments, etc.) being considered for the application. From this economic data, in addition to other pertinent information, the owner/operator must choose which machine to purchase from one of several manufacturers.

As pointed out in the previous section, each of the major equipment manufacturers producing front-end loaders has some form of cost estimating procedure which they advocate for calculating O&O costs. The data and estimating procedures advocated by these manufacturers is typically general in nature and often represents "average" conditions. As a rule, the estimates are based on an assumed equipment life of 10,000 hours and adjustments must be made in the estimate if service lives exceed this base. In general, the estimates are presented in a form which can incorporate actual cost values at the time of the estimate. In other situations ratios or percentage values of base numbers are used for the estimate. These procedures should, however, be continually checked to make certain the procedure continues to yield representative values.

A primary problem remains, however, with these estimating techniques since they do vary from one manufacturer to another. Even though virtually any of the manufacturers' estimating techniques may be employed to obtain an estimate of overall O&O costs for a given application, these variations in techniques are unacceptable when performing direct economic comparisons between machines produced by different manufacturers. Obviously the owner/operator is hard pressed to make the best machine selection (the one having the lowest overall cost) if his economic cost comparison is based on comparing apples with oranges. When making equipment investment decisions based on comparative economic analyses, it is most important that machine comparisons be made on the same basis.

Because the O&O cost estimating techniques do vary from manufacturer to manufacturer, the potential owner/operator is often faced with a wide range of propspective O&O cost estimates for essentially the same basic front-end loader in a specific application. Before the proper economic selection between machines can be made, the owner/operator must be aware of why these cost estimates vary, if they really reflect machine variations, or if they reflect actual machine performance characteristics.

From the above discussion, it is rather easy to imagine that considerable spreads in O&O cost estimates could result between individual manufacturer's estimates. Consequently, it is extremely important for the potential owner/operator to place constraints or guidelines on the cost estimates being prepared by manufacturers. For instance, he should stipulate the depreciation method, insurance, interest and tax rates and labor rates to be used in the cost comparisons developed by interested equipment manufacturers. He should also be prepared to provide specific and consistent information on job conditions, working environment, haul profiles, road conditions, and any other information which might impact a manufacturer's cost estimate.

When comparing O&O cost estimates prepared by various manufacturers, or when using individual manufacturer estimating techniques, the potential owner/operator should be prepared to challenge obvious discrepancies which invariably occur in individual cost components. Manufacturers should be required to defend their cost estimates and reconcile any differences with other manufacturer cost estimates to the satisfaction of the owner/operator. If a given manufacturer can convince the owner/operator that his machine costs are indeed lower because of better machine design, production efficiency, etc., then the owner/operator can make a more informed investment decision which, hopefully, is not unduly influenced by the cost estimating procedure itself. The overriding concern should be to ensure that economic comparisons are performed, as nearly as possible, on the same basis before a final investment decision is reached.

When performing economic comparisons on various machine alternatives, the evaluator must also be cognizant of a number of factors which are often not directly incorporated into the normal O&O cost calculations, but which are often major cost components. For instance, the analyst should consider any economic ramifications which might affect the analysis as a result of variation in the following factors:

- freight charges (machine, ballast, etc.)
- erection (assembly) time,
- options on machine,
- productivity changes with cumulative hours of use,
- relationships between maintenenace procedures, availabilities and scheduling requirements with cumulative hours of use,
- changes in supervisory requirements for given types of machines,
- capital and operating costs associated with supporting machines and/or equipment (e.g., special shop facilities, jigs, tools, etc.)
- costs associated with inventory requirements for a given machine,

- degree of routine maintenenace, rebuilds and overhauls which can be performed in existing facilities as opposed to contracting work
- shop and field requirements for routine maintenance which may relate to specific manufacturer design eccentricities,
- estimated life of the machine,
- quality and availability of specialized repair labor and facilities which may be required,
- probability of significant technological change in the unit in the near future,
- resale value, and others.

Although the above list of factors is not intended to be all-inclusive, it does illustrate that there are some major peripheral considerations associated with machine selection which can represent signficant costs.

ALTERNATIVE COST APPROACHES

The preceding discussion of cost estimating procedures for front-end loaders illustrated the standard, "representative year" approach to O&O cost determinations. This technique is based on working with "average" year values over the machine's life and is typically used when straight cost comparisons are being made between machines. Although this approach is adequate for preliminary cost comparisons, it is loaded with numerous real-world problems.

Perhaps the most unrealistic part of the typical or standard approach to calculating O&O costs for a machine is related to the ownership cost component. The estimate of "useful" life or the life over which the operator expects to utilize the machine "gainfully" is often difficult indeed. Does this represent physical life, service life, economic life or what? What about planned or unplanned overhauls, rebuilds, etc.?

Also the assumption of straight-line depreciation and average annual investment is rather naive and often very misleading for economic analyses. Calculations involving average annual investments can be particularly troublesome when analyzing short-lived equipment such as front-end loaders. It is more appropriate to base cost calculations on estimates of machine tax life and a depreciation schedule which recognizes that the bulk of a machine's value is lost in the early years of its life.

Another troublesome factor is the assumption of consistent, average operating costs over machine life. Machine availabilities, utilization rates, etc., decrease with age while associated operating costs (primarily reflected through repair and maintenance charges) increase with machine life. It would appear to be more appropriate to use these actual annual cost estimates in the economic analysis rather than average them over machine life. By averaging these availability and cost estimates over machine life, the estimator has inherently introduced a procedure by which costs are typically overestimated in the early years of machine life and underestimated in the later years. This exemplifies the problem which is always associated with any averaging technique. It is a particularly important point when performing economic analyses because of the time-value-of-money.

Although the standard O&O cost estimating procedure may be used where economic comparisons are made on an undiscounted "representative year" basis, it is not adequate for normal engineering economic analyses currently being performed by many organizations. When performing machine economic comparisons, it is important to measure the potential economic impact of each machine on the firm or the individual owner. The actual after-tax dollar differential over machine life is the important item for investment decision making, not an average, comparative number which incorporates numerous simplifying assumptions. Because taxes and tax ramifications are such an important part of any economic decision, the cost comparison analysis between alternative machines should be performed on an after-tax basis which measures actual dollar inflows and outflows associated with the investment.

The two alternatives which follow are cost comparison methods which attempt to correct the problems of the standard technique mentioned above. The first alternative is a discounted, after-tax cash flow analysis which is believed to be technically and theoretically superior to other comparative techniques. The second alternative is a middle-of-the-road method. It is not as thorough or complete as the discounted, after-tax cash flow method, but it does have some advantages over the standard approach and is relatively easy to employ. It must be noted that neither of these alternatives address the derivation of specific or basic operating costs associated with supplies, fuel, repair and maintenance, etc. Rather, they address the format of the compartive analysis per se as well as the appropriate treatment of depreciation and other tax deductions associated with ownership.

DISCOUNTED CASH FLOW (DCF) ANALYSIS

A discounted cash flow analysis is utilized by most organizations to determine the potential economic viability of an investment proposal or to help determine which proposal among many is preferred. A cash flow evaluation is perhaps the most representative and useful technique for evaluating engineering projects because it relates all projects on the same <u>cash</u> basis. Cash flows simply relate the actual cash inflows and cash outflows associated with an investment proposal on an annual basis. These annual cash flows are calculated by subtracting annual outflows from inflows. Consequently, net annual cash flows may be either positive or negative.

When analyzing pieces of operating equipment, the analysis is generally performed in terms of costs as opposed to any annual income directly associated with the machine. Under these conditions net annual cash flows are negative and the machine which promises to minimize these costs is the one selected - all other factors being constant. Performing cash flow calculations on a cost basis and using negative values as opposed to positive income or benefits is often disturbing to many people. The analysis is conducted in the same fundamental manner whether costs or benefits are used. The analyst must simply keep track of which items represent cash outflows and which represent cash inflows to the firm as a result of purchasing a piece of machinery. The whole idea is to measure the net after-tax cost associated with owning and operating a piece of machinery. The machine promising the lowest present value of these costs over its life is the one which should be chosen.

It is important to remember that cash flow is basically a combination of two components. It consists of (1) return <u>on</u> the investment and (2) return (recoupment) <u>of</u> the investment. This aspect is crucial to the understanding of any cash flow analysis.

The calculation of annual cash flows for a piece of machinery where generalized costs are the basis for comparison is as follows:

	(Operating Cost)
+	(Depreciation)
+	(Insurance)
+	(Property Tax)
=	(Taxable Income)
+	Federal Tax Savings
+	Investment Tax Credits
=	(Net Costs)
+	Depreciation
+	(Capital Expenditures)
+	Salvage
=	(Net Annual Cash Flow)

Note: Brackets () represent costs or negative numbers.

The format is at first somewhat confusing because the analysis is performed in terms of annual costs and not benefits. As a result, federal taxes are shown as positive numbers because they, in effect, represent tax savings generated for the firm as a whole. The obvious assumption here is that the firm is operating at a profit and can deduct these tax losses from its total tax liability. Similarly, items such as investment tax credit and salvage value represent positive cash inputs contributed by the machine which help reduce total outflows or costs annually.

The fact that depreciation enters into the cash flow calculation in two places often confuses many people. In a cash flow analysis, each investment receives credit for any income taxes saved. Depreciation is simply a bookkeeping technique which reduces the amount of taxable income (and therefore reduces the amount of taxes paid) and, in effect, saves the organization money. In the case of cash flows for machinery where the analysis is performed in terms of costs, depreciation deductions contribute to a larger negative value of taxable income and therefore a larger negative tax liability which can be credited against the total positive tax liability of the firm. Therefore, because the depreciation allowance has the effect of saving the organization tax dollars and because depreciation dollars do not acutally "flow" anywhere, depreciation must be accounted for in the cash flow calculation after determination of net profits.

The following example illustrates the point discussed above. Suppose a piece of equipment has the following annual costs and the owner's tax rate is 46%. Calculate the annual cash flow if there are no investment tax credits, salvage value or capital expenditures for the year.

Operating Cost	(300,000)
Depreciation	(150,000)
Insurance	(8,000)
Property Tax	(10,000)
Taxable Income	(468,000)
Tax Savings @ 46%	215,280
Net Profit	(252,720)
Depreciation	150,000
Net Annual Cash Flow	(102,720)

To illustrate that the depreciation allowance (a non-cash item) does not actually flow anywhere, consider the above example strictly from the standpoint of actual cash flows:

Operating Costs	(300,000)
Insurance	(8,000)
Property Tax	(10,000)
Taxable Income	(318,000)
Tax Savings	215,280
Net Annual Cash Flow	(102,720)

Thus on an annual basis the results are the same. Since the non-cash depreciation allowance is used in calculating taxable income, and therefore income tax savings, it is necessary to add this allowance back into the annual cash flow calculation.

Perhaps the easiest way to illustrate a cash flow determination is through an example. The following example provides some basic information about an application and associated operating costs for a front-end loader. Specific tax considerations are explored as the solution is developed; however, in order to avoid a treatise on tax ramifications, these tax considerations are not explored in great depth.

Example:

A specific front-end loader is being considered for use in a load-carry-dump application in a gravel pit. It is anticipated that the loader will be required to work a scheduled 2500 hrs./year in order to meet production requirements. Further, suppose that the FEL being considered has a 1981 purchase price of $540,200 (tires at $30,100) and has an estimated salvage value of 12% of purchase price at the end of its anticipated 5 year service life.

For illustrative purposes, let us assume that after careful consideration of the job application, conditions, etc., the cost estimation techniques previously discussed were employed to derive the following operating cost estimates for the machine being considered.

Cost Item $	YEAR 1	2	3	4	5
Fuel	17.60	17.60	17.60	17.60	17.60
Tires	14.25	14.25	14.25	14.25	14.25
Lube, filters, etc.	4.25	4.25	4.25	4.25	4.25
Bucket & teeth	1.20	1.20	1.20	1.20	1.20
Labor	18.50	18.50	18.50	18.50	18.50
Repair, maintenance*	32.10	35.63	39.55	45.48	52.31
Total Operating Cost:					
$/hr.	87.90	91.43	95.35	101.28	108.11
$/yr.	219,750	228,575	238,375	253,200	270,275

*The repair and maintenance cost estimate was adjusted to represent anticipated reduction in availability percentages and anticipated increases in repair costs with machine age.

Depreciation

The next step is to calculate annual depreciation allowances which represent the bulk of actual ownership costs. For the purposes of this example it is assumed that the double declining balance method (DDB) of depreciation is selected for tax purposes. The DDB method of depreciation is an accelerated depreciation schedule which recognizes that most of the asset's value is lost in the early part of its life. The rate associated with DDB is 2 times the straight-line depreciation rate.

To qualify for the DDB rate the asset must be new, have a useful life of three or more years, and be classified as personal property. The FEL in this example qualifies on all counts. With the DDB method the depreciable basis for the asset is not reduced by subtracting the estimated salvage value; however, the undepreciated balance cannot be reduced below the estimated salvage value. The basis in the account is reduced each year by the amount of the depreciation deduction declared in the previous year.

It is also possible to switch from DDB to the straight-line method of depreciation once in an asset's life. The switch may be made whenever it is to the taxpayer's advantage to do so. Care must be taken, however, not to depreciate below the asset's estimated salvage value.

The following table illustrates the calculation procedure for the depreciation allowance on the FEL in this example using DDB.

DEPRECIATION DEDUCTION (DDB)

Year	Unrecovered Basis(1)	Rate(2)	DDB Depreciation Deduction	Alternate Straight Line Deduction(3)
1	510,100	0.40	204,040	89,055
2	306,060	0.40	122,424	60,309
3	183,636	0.40	73,454	39,604
4	110,182	0.40	44,073	22,679(4)
5	66,109	0.40	26,444(4)	1,285(4)
				Salvage = 64,824

Notes:

1. The initial basis in the depreciation account is determined as follows:

Delivered price:	$540,200
Less tires:	30,100
Depreciable basis:	$510,100

The basis is adjusted each year by subtracting the depreciation allowance declared.

2. The rate for DDB is 2 times the straight-line (S-L) rate. Since the S-L rate is 1/life = 1/5, the DDB rate is 1/5 x 2 = 0.40.

3. The S-L alternate deduction for switching from DDB to S-L is calculated by dividing the unrecovered basis in the depreciation account for any given year minus anticipated salvage value (12% x $540,000 = $64,824) by the remaining years of asset life. Note, however, that the asset cannot be depreciated below its estimated salvage value of 12% x $540,200 = $64,824.

4. The maximum amount of depreciation which can be declared in year 5 is ($66,109 - 64,824) = $1,285 because of the salvage value limit. This leaves an unrecovered basis in the account of $64,824 and no further depreciation deductions may be declared on the machine.

The depreciation deductions which would be used to maximize pre-tax deductions and not violate the salvage value criteria are as follows:

Year	Depreciation Deduction ($1,000)
1	204,040
2	122,424
3	73,454
4	44,073
5	1,285

Insurance

For this example insurance for the FEL is assumed to be a function of replacement cost and is estimated at 2% of purchase price. This amounts to an annual insurance premium of:

$540,200 x 0.02 = $10,804.

Property Taxes

State and local property taxes are quite variable. The rates and bases upon which taxes are calculated depend upon location. Because these tax obligations can be quite significant, the estimator should carefully ascertain what the tax statutes are for a given location prior to calculating property taxes.

Typically property taxes are computed by multiplying the assessed value of the asset times a mil levy or a unit value (i.e., "x" cents per "y" dollars of assessed value). The assessed value is often expressed as some percentage of the appraised value of the property. In this example it is assumed that the assessed value is equal to 35% of the unrecovered basis in the depreciation account.A mil levy of 50 ($0.050) is applied to the assessed value for property tax purposes.

The following table illustrates the assumed property tax calculation for the example.

Year	Unrecovered Basis of Asset ($)	% Number	Assessed Value ($)	Mil Levy (50)	Property Tax ($)
1	510,100	35	178,535	.050	8,927
2	306,060	35	107,121	.050	5,356
3	183,636	35	64,273	.050	3,214
4	110,182	35	38,564	.050	1,928
5	66,109	35	23,138	.050	1,157

Federal Taxes

It is assumed that the firm which plans to purchase the machine in this example has a taxable income from operations as a whole in excess of $100,000. Therefore the appropriate Federal income tax rate is 46%; however, this rate is subject to legislative change.

8

Investment Tax Credit (ITC)

Investment tax credits are intended as an investment incentive which allows for a reduction of taxes during the year in which the asset was purchased. To qualify for ITC the asset must be real or personal depreciable property excluding buildings, have a useful life of at least 3 years, and be placed in service during the year in which the credit is declared. The ITC is a function of the asset's life and the firm's tax liability. The depreciable life of the asset determines what percentage of the asset's purchase price qualifies for investment tax credit. For instance, the fraction of purchase price which qualifies is given as follows:

Depreciable Life of Asset	Fraction of Purchase Price Which Qualifies
3 - 4 yrs.	1/3
5 - 6 yrs.	2/3
7 or more yrs.	all qualifies

The percentage of credit which applies to the qualifying investment is currently set at 10%.

For the purposes of this example it is assumed that the tax liability of the organization buying the FEL is adequate to allow full credit to be taken in the first year the machine is placed into operation. In reality the credit which can actually be declared in a given year is a function of the firm's tax liability. Those interested in specifics should consult the Federal Income Tax Code.

The ITC associated with the purchase of the FEL being considered is:

Qualifying Investment = Purchase Price x Fraction
= \$540,200 x 2/3 = \$360,133
ITC = Qualifying Investment x % credit
= \$360,133 x 10% = \$36,013

The net effect of the ITC is to lower the purchase price of the asset by reducing the amount of income taxes paid.

Now that the major line items in the cash flow analysis for the FEL have been determined, it is possible to compile after-tax net annual cash flows for the machine being considered. This is performed in Table VIII - 8. The assumption was made that the FEL was purchased at the beginning of the tax year and used throughout the year.

Table VIII - 8

NET ANNUAL CASH FLOW ANALYSIS (\$)

YEAR	1	2	3	4	5
Operating Cost	(219,750)	(228,575)	(238,375)	(253,200)	(270,275)
Depreciation	(204,040)	(122,424)	(73,454)	(44,073)	(1,285)
Insurance	(10,804)	(10,804)	(10,804)	(10,804)	(10,804)
Property Tax	(8,927)	(5,356)	(3,214)	(1,928)	(1,157)
Taxable Income	(443,521)	(367,159)	(325,847)	(310,005)	(283,521)
Federal Tax					
Savings @ 46%	204,020	168,693	149,890	142,602	130,420
Investment Tax Credit	36,013	-0-	-0-	-0-	-0-
Net Costs	(203,488)	(198,266)	(175,957)	(167,403)	(153,101)
Depreciation	204,040	122,424	73,454	44,073	1,285
Capital Expenditure	(540,200)	-0-	-0-	-0-	-0-
Salvage	-0-	-0-	-0-	-0-	64,824
Net Annual Cash Flow	(539,648)	(75,842)	(102,503)	(123,330)	(86,992)

After calculation of the net annual cash flows the net present value of these cash flows can be determined by discounting each of the annual values to the present, or time zero, at some designated interest rate. If the owner's required rate of return on a machine investment is 12%, then the appropriate discount or present value factors to use on each of the annual cash flows are those associated with 12%. As a minimum this percentage number stipulated by the owner represents the cost of money (capital) committed to the investment and therefore incorporates repayment of this money. Consequently when the cost of capital is used as the discount rate in an after-tax cash flow analysis no further treatment of financing charges (interest) is necessary in the analysis since these charges are inherent in the discount rate.

Appropriate present value or discount factors can be found in interest tables for various interest rates. The present value calculations for this example at a 12% required rate of return are given below.

Year	Net Annual Cash Flows ($)	Present Value Factor (12%)	Present Value of Annual Cash Flow ($)
1	(539,648)	0.8929	(481,852)
2	(75,842)	0.7972	(60,461)
3	(102,503)	0.7118	(72,962)
4	(123,330)	0.6355	(78,376)
5	(86,992)	0.5674	(49,359)
Total Present Value of Machine Costs			($743,010)

The above calculation indicates that at 12% interest rate the present value sum of $743,010 is exactly equivalent to the annual cash flows of $539,648, $75,842, $102,503, $123,330, and $86,992 respectively over the next five years.

If the owner is interested in determining the average annual cost for the machine, an annualizing factor is applied to the total net present value number. This annualizing factor is referred to as the "capital recovery factor" and can also be found in interest tables. At a 12% interest rate over 5 years, the uniform average annual cost for the example is determined as follows:

Average Annual Cost = Present Value of Cash Flows x Capital Recovery Factor
= $743,010 x 0.2774
= $206,111

In other words, the above calculation shows that the owner could expect to spend, on average, $206,111 per year if he bought and operated the machine. On a per operating hour basis this would represent an average cost of:

$206,111 per year/2500 hours per year = $82.44 per hour.

The above example illustrates the impact of tax considerations, particularly as they relate to ownership costs, and the importance of proper treatment in an economic analysis. The discounted, after-tax annual cash flow analysis is technically superior to the standard or "representative year" type of calculation where average numbers are used throughout the asset's life. Because of the time-value-of-money concept, the timing of actual cash outflows and inflows is critical in comparative analyses. The discounted cash flow method allows the estimator to compare machine investment alternatives directly by incorporating actual cash costs and tax savings at the time of occurrence into the analysis. The machine promising to minimize total cash costs is the one which should be selected if all other factors are equal.

DISCOUNTED AVERAGE ANNUAL COST ANALYSIS

This approach to comparative economic cost analysis is less rigorous and thorough than the discounted after-tax cash flow method, but perhaps more realistic than the simplistic standard estimating procedure. It recognizes the concept of time-value-of-money and utilizes average annual values, but it does not reflect the effects of taxes on the investment proposal. Therefore this approach is neither fish nor fowl in that there are obvious advantages and disadvantages associated with the technique. Perhaps the most significant advantages are that it is easier to use than the DCF approach and addresses the ownership cost calculation more realistically than the standard approach.

To illustrate this alternative the same example presented in the preceding section on DCF analysis is utilized.

The first requirement is to determine the discounted average annual ownership cost. On a time-value-of-money basis this ownership cost can be compared to the standard problem of solving for the equal annual payments necessary to pay off the purchase price of a new piece of equipment plus interest on the unpaid balance. This can be performed by multiplying the cost basis by an appropriate capital recovery factor. The capital recovery factor is an annualizing factor which can be obtained from interest tables.

The cost basis for a piece of equipment is taken to represent the net cost to the owner of the machine. This is considered to be the net investment in the machine or the depreciable value of the machine. In the example the depreciable value is calculated as follows:

Purchase Price:	$540,200
Less Tire Replacement:	30,100
Less Salvage Value:	64,824
Net Depreciable Value:	$445,276

The estimator may also choose to deduct investment tax credits from the purchase price of the machine although this is typically not done unless a complete after-tax analysis is being performed.

The appropriate capital recovery factor to use in calculating average annual ownership costs is dependent upon the life of the machine and the interest rate. As a minimum, the interest rate chosen must reflect the owner's cost of money (capital) committed to the investment. The owner may also want to escalate this interest rate further in order to account for insurance and property taxes associated with ownership. For instance, the following example illustrates how an interest rate might be estimated:

Cost of Capital (interest)	= 14%
Insurance (estimated)	= 2%
Property Tax (estimated)	= 2%
Total:	18%

In the FEL example, the capital recovery factor for a 5 year life and an interest rate of 18% is given in interest tables as 0.3198. Therefore, the average annual ownership cost can be calculated as:

Average Annual Ownership Cost = $445,276 x 0.3198
= $142,399/yr.

This represents an hourly cost of $142,399/2500 hours per year = $56.96/hr.

The determination of average annual operating costs can be made in a similar manner. Since the hourly operating costs were previously calculated to be:

Year	Estimated Hourly Operating Costs
1	87.90
2	91.43
3	95.35
4	101.28
5	108.11

The average annual operating cost can be determined by multiplying the present value of these costs by the capital recovery factor. If the required rate of return of 14% is used, the calculation procedure is as follows:

Year	Estimated Hourly Operating Costs ($)	Present Value Factor @ 14%	Present Value of Estimated Hourly Operating Costs($)
1	87.90	0.8772	77.11
2	91.43	0.7695	70.36
3	95.35	0.6750	64.36
4	101.28	0.5921	59.97
5	108.11	0.5194	56.15
		Total:	$327.95

Average Annual Operating Cost = P.V. Operating Costs
x Capital Recovery Factor = $327.95/hr. x 0.2913
= $95.53/hr.

On the basis of this average annual cost estimating procedure the hourly ownership and operating cost for the FEL in the example is:

Hourly Ownership Cost:	$56.96
Hourly Operating Cost:	95.53
Total:	$152.49/hr.

COMMENTS

When performing economic cost comparisons between various pieces of the same basic type of equipment, it is important that the estimator be consistent in methodology. Whether the standard estimating procedure or one of the alternative methods offered in this section is used, it is imperative that all machines be compared on the same basis. Otherwise proper investment decisions cannot be formulated.

It is suggested that the DCF after-tax analysis provides the best indication of actual economic effects of the investment proposed on the organization. This recommendation stems from the fact that this approach considers the effects and ramifications of taxation on actual cash flows to the organization as well as the concept of time-value-of-money.

EQUIPMENT REPLACEMENT DECISIONS

In many materials handling applications capital assets, and particularly mobile equipment, may require replacement one or more times during project or job life. Equipment owners must also consider that physical assets ultimately become consumed, obsolete or inadequate for job service and therefore must be considered candidates for replacement periodically. The failure to continually upgrade the equipment fleet can result in a serious reduction in operating efficiency as well as a loss in the corporation's competitive position.

Although most equipment owners have had to make equipment replacement decisions many times, there does not appear to be a generally accepted procedure for arriving at these decisions. Certainly the recent escalation in mining-related capital costs and inflationary trends have amplified the magnitude of new equipment investments and therefore the importance of a proper equipment replacement analysis and policy. Indeed, formulation of an appropriate equipment replacement policy can play a major role in the determination of the basic technological and economic progress of the organization.

GENERAL CONCEPTS

There are three primary reasons for considering replacement of a piece of equipment: physical life, economic deterioration, obsolescence.

Physical life simply refers to the fact that there is a time beyond which a piece of equipment is no longer physically operable. If this physical life is shorter than the project's life then the equipment will obviously have to be rebuilt or replaced.

Economic deterioration, or physical impairment, refers to the amount by which the earning rate of the existing machine has fallen below its original earning rate when it was new. In other words, it represents internal changes on the machine normally resulting from wear and tear on the equipment which typically leads to a decline in the value of the service rendered. Economic deterioration is most often reflected by increased operating costs, increased maintenance costs, or a combination of the two.

Obsolescence refers to technological change in equipment with time and recognizes the advancement or improvement in the tools of production. As such, obsolescence represents external change to the equipment and may be a reason in itself for replacement. Obsolescence costs are rather subtle since they reflect the possibility of a lower initial operating cost with a new, improved piece of equipment as compared with the existing equipment when it was new. Therefore obsolescence, in effect, refers to the opportunity cost of not replacing with the best alternative equipment available. In other words, it represents the cost savings foregone by continuing with the existing equipment in service after better equipment has been made available.

When considering replacement decisions it is important to recognize that three possible alternatives exist. The first possibility is to keep the existing piece of equipment for some additional period of time. The second possibility requires the immediate replacement of the existing piece of equipment with the new, challenging piece of equipment. The last possibility which must be considered is the alternative of overhauling the existing piece of equipment in order to extend its life.

Another important consideration when making equipment replacement decisions is the distinction between replacement and expansion. If any qualitative or quantitative aspect of output is changed when an existing machine is replaced with a new one, then by definition, replacement is not literal. The concept is to replace capacity with capacity and not just the machine itself. As such, replacement is concerned with minimizing the cost of producing a given output. In most cases technological advancement results in new machines having productive capabilities exceeding those of the existing machine. If replacement occurs, then an expansion decision has, in effect, been made. Under these conditions it is important that the analysis recognize this fact and ascertain whether or not the extra production capability can be handled by the rest of the production system, if the extra output can be sold, etc. In short, the demand function must be introduced into the analysis.

EQUIPMENT REPLACEMENT ANALYSIS

Over the years a number of economic procedures have been proposed to address the problem of maximizing equipment replacement decisions. Unfortunately most of these procedures were developed for manufacturing organizations where planning horizons are essentially infinite. In addition, these procedures typically were based on minimizing average annual costs and rarely considered tax ramifications in any detail.

Within the last decade burgeoning capital costs of equipment and double-digit inflation rates have generated renewed interest in developing equipment replacement analysis techniques for mining-related equipment. These procedures have addressed the problem from the standpoint of minimizing costs as well as maximizing benefits. These models clearly demonstrate that an equipment replacement analysis can be as simple or as complex as one's corporate policy dictates.

Most practitioners involved in replacement analyses agree that equipment replacement decisions are investment decisions and should be analyzed on the basis of an appropriate economic analysis as are other investment decisions.

Although it is beyond the intent of this section to discuss the various models which do exist, suffice it to point out that most analysts prefer to address the problem in terms of a discounted, after-tax cash flow analysis which minimizes costs. With such an approach it is essential that tax items (depreciation, investment tax credit, capital gains/losses, income, property, etc.) sunk costs, productivity constraints, capital costs, salvage values, and normal operating costs be properly incorporated into the analysis. Generally such analyses attempt to minimize costs over project life and therefore often address the problem of multiple machine replacements. If these economic considerations are applied to the options of (1) keeping the existing equipment, (2) overhauling the existing equipment, or (3) immediately replacing the existing equipment with a new machine, it is easy to imagine the complexity involved in the analyses. As these models attempt to relate to the real world situation, the complexity increases dramatically. These models require computer analyses of the data and the many alternatives which exist. They are much too complex to handle without computer assistance.

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This brings to light an important factor which should be mentioned. The more sophisticated replacement models which attempt to address the equipment replacement problem in a real world sense require complex analytical solutions. Additionally, these models are very input intensive. Experience has shown that few companies or organizations have the capability of collecting and compiling the necessary input cost data these models really require. Still fewer organizations even attempt to collect such data. Indeed, the collection of complete and accurate itemized maintenance, repair and cost data requires a fairly sophisticated accounting system along with a computerized data retrieval system. The point is that these very sophisticated replacement analyses which are input intensive may defeat the purpose of the analysis for some organizations. It is important to carefully consider the trade-offs between the purpose of the analysis and the quantity and quality of input data necessary to perform the analysis. Equipment replacement policies can be made as simple or complex as desired, based upon the assumptions incorporated in the analysis. All organizations may not choose to perform such replacement analyses at the same degree of sophistication. However, it is important to understand the assumptions and procedures utilized in the analysis performed.

EQUIPMENT LEASING

Many organizations utilizing materials handling equipment are facing enormous capital requirements for existing operations, planned expansion programs, modernization of equipment fleets, etc. Yet, because of existing economic conditions these organizations find it increasingly difficult to obtain reasonable financing for the acquisition of high-cost capital equipment.

One method of obtaining the use of expensive equipment is through leasing. The popularity of this approach is evidenced by the growing number of leasing companies, equipment manufacturers, and financial institutions now offering this service to their customers. Indeed, leasing has become an enormous business in itself and many commercial banks have developed sizeable portfolios in this area.

Companies may decide to lease rather than buy major capital equipment for a number of reasons. Perhaps the most common reasons for leasing equipment are:

- a desire to conserve cash resources and available credit under conventional borrowing arrangements;
- a low cash position within the company which does not allow for direct purchase of the asset;
- the market loan rate for funds is high and, besides, the company might be unable to make a substantial down-payment on the equipment;
- the company is unable to fully utilize the tax benefits of depreciation deductions and investment tax credit which accrue from ownership.

ADVANTAGES AND DISADVANTAGES OF LEASING

Many of the so-called advantages and disadvantages of leasing are a function of the specific type of lease negotiated. Although many advantages and disadvantages are often listed for leasing alternatives, the following are more commonly listed as being most important from the viewpoint of the lessee.

Advantages:

- may increase the company's ability to acquire funds,
- does not appear as a liability on the lessee's balance sheet,
- leaves normal lines of bank credit undisturbed,

- may cost less than other methods of acquiring equipment,
- frees working capital for more productive use (money not tied-up in relatively low-yielding fixed assets),
- allows for hedging of business risks such as the risk of obsolescence,
- can be tailored to the lessee's needs more easily than ordinary financing,
- avoids the necessity of selling equipment no longer needed or wanted,
- acts as a hedge against inflation,
- provides long-term financing without diluting ownership or control, and
- lease payments are tax deductible for true leases.

Disadvantages:

- may provide less attractive tax deductions (than interest plus accelerated depreciation),
- residual equipment value belongs to the lessor,
- establishes a fixed obligation against the firm,
- failure to make payments results in dispossession of equipment, and
- the lease rate may be higher than the lessee's regular interest rate.

TYPES OF LEASES

It is important to recognize that although there are many forms of leasing arrangements and a myriad of variations, there are essentially only two distinct types of leases - operating leases and financial leases.

Operating leases may be characterized as short-term, cancellable contractual agreements between the lessor and lessee. Lease payments to the lessor usually do not exceed the purchase cost of the asset and therefore these agreements are referred to as "non-full payout" leases. In addition, these leases are generally established as "maintenance" leases which specify that all maintenance, service and insurance obligations are the responsibility of the lessor.

The lessee typically views operating leases as a mechanism to obtain relatively short-term use of a piece of equipment without the risk of ownership. By virtue of the cancellability of the contractual agreement the lessor, as owner of the equipment, bears the risks of (a) cancellability at any point in time, (b) equipment obsolescence, (c) the equipment may be idle at times, and (d) the uncertainty of resale value. Therefore, the lessor must look to contract renewals, releases, or the actual sale of the equipment in order to make a profit. Obviously because of the risks borne by the lessor, the lessee can expect to make rather high lease payments to the lessor in order to help subsidize these risks.

Financial leases are arrangements between a lessor and lessee whereby the lessee agrees to make payments to the lessor, which in total exceed the purchase price of the equipment being leased. Financial leases are noncancellable contracts by either party and provide for payments spread over a time interval equal to the major portion of the equipment's useful life. These leases are typically written as "net" leases which makes the lessee responsible for all maintenance, service and insurance obligations. Although the lessor is legally the owner of the equipment being leased, many of the ownership risks (obsolescence, etc.) are borne by the lessee due to the noncancellability of the contract. The primary distinction between financial leases and operating leases lies with the concept of cancellability and not with the length of the contractual agreement specifying lease payments.

Financial leases are tax oriented methods for procuring capital assets and as such offer some very distinct tax advantages to the participants. The tax savings resulting to the owner of the equipment, the lessor, can be substantial and are often shared with the lessee through reduced lease payments. The lessee may also deduct all lease payments as operating expenses for income purposes. One variation of financial leases which is truly an attempt to maximize tax savings is referred to as "leveraged leasing". Leveraged leases are often quite complex (involving trusts, government agencies, investment bankers, financial institutions, etc.) and are characterized by a third party - the lender. The lender or debt participant is usually a financial institution and the presence of this third party distinguishes leveraged from unleveraged leases.

As one might expect, any method of financing equipment which tries to utilize tax savings carries with it some conditions and constraints imposed by the Internal Revenue Service. The normal procedure calls for the lessor and lessee to structure a lease contract which specifically addresses points of concern to the IRS. This document is then submitted to the IRS for a ruling to ascertain if it qualifies as a "true" financial lease. If the ruling is favorable, the tax savings previously eluded to can be realized by the parties involved. If, on the other hand, the IRS rules that the lease contract is not a "true" financial lease, then it is considered a "conditional sales contract" for tax purposes. As such, the lessee can only deduct that portion of the lease payment which represents interest, insurance, taxes, maintenance and repairs as an operating expense for tax purposes.

Financial leases can make equipment available to organizations at relatively low cost. However, it is important that the lease agreement be reviewed by the IRS to insure that the anticipated tax ramifications can be realized.

BUY VERSUS LEASE DECISION

Many organizations are asking the question, "Should we buy or lease new equipment acquisitions?" Unfortunately, many buy-or-lease decisions are often made on an emotional basis -- rather than on a proper financial evaluation which yeilds the highest possible return on invested capital. The analyst must recognize that financial leases, because of their noncancellability and long duration, really represent investment decisions and should be treated as any other investment decision analyzed by the organization. Also it is important to recognize that one is analyzing a lease-versus-buy decision and not a lease-versus-borrow decision. Many analysts have fallen into this trap of assuming that capital must be borrowed if the equipment is purchased. Obviously this is not the case although the capital used for equipment will have a cost associated with it.

Most analysts who have worked on leasing analyses prefer to utilize a discounted, after-tax cash flow approach which compares the cash inflows and outflows associated with purchase of the asset to those associated with leasing the asset. In such an analysis it is important to incorporate the appropriate tax ramifications (depreciation, investment tax credit) as well as the effect of differences in salvage and book values which often exist. The option which promises the highest net return to the organization should be chosen. Although it is difficult to generalize, typically the buy decision will appear more advantageous if: (a) the net residual salvage value of the asset exceeds the extra operating costs of ownership, or (b) the purchase price, less the tax benefits, is less than the lease rental payments.

SECTION IX

OPERATIONAL PRACTICES

The diversity of the FEL load-and-carry applications has led to very limited documentation of actual and/or preferred operating practices. Some of those identified in the literature and observed in the field are summarized briefly on the following pages, together with some illustrative photographs. These have been arbitrarily grouped under the following headings:

- Digging
- Hauling & return
- Dumping
- Utility work
- Hopper & conveyor
- Sequencing & scheduling
- Operators
- Machines & tires.

Safety considerations are presented in a subsequent section.

DIGGING

Aim bucket and machine straight into face. Approach bank with bucket horizontal at ground level; a slightly downward tilt may aid penetration. Keep machine moving forward until bucket is full. Coordinate loader arm lift motion and bucket rollback motion so that the rear of the bucket is filled while the loader is moving forward. Too much rollback will underfill the bucket; too little rollback will overload the bucket. Roll back the bucket fully as the bucket is completing the pass; and avoid pushing material ahead of the bucket. Operate in low speed range at full throttle unless traction limitations cause tire spin.

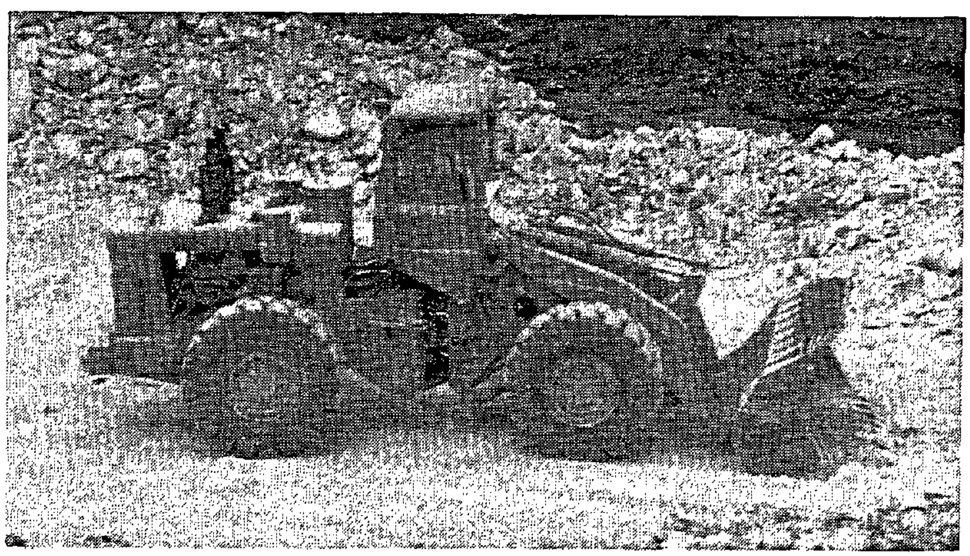


Figure IX - 1
Approaching Face

Figure IX - 2
Propel into Face

Figure IX - 3
Tip and Lift Bucket

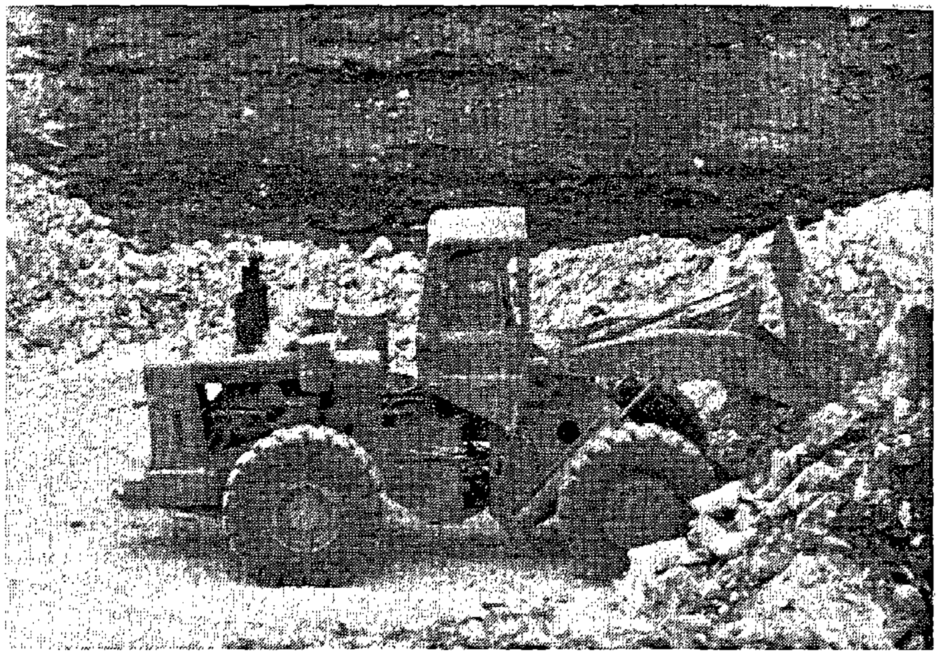


Figure IX - 4
Tip and Lift Bucket

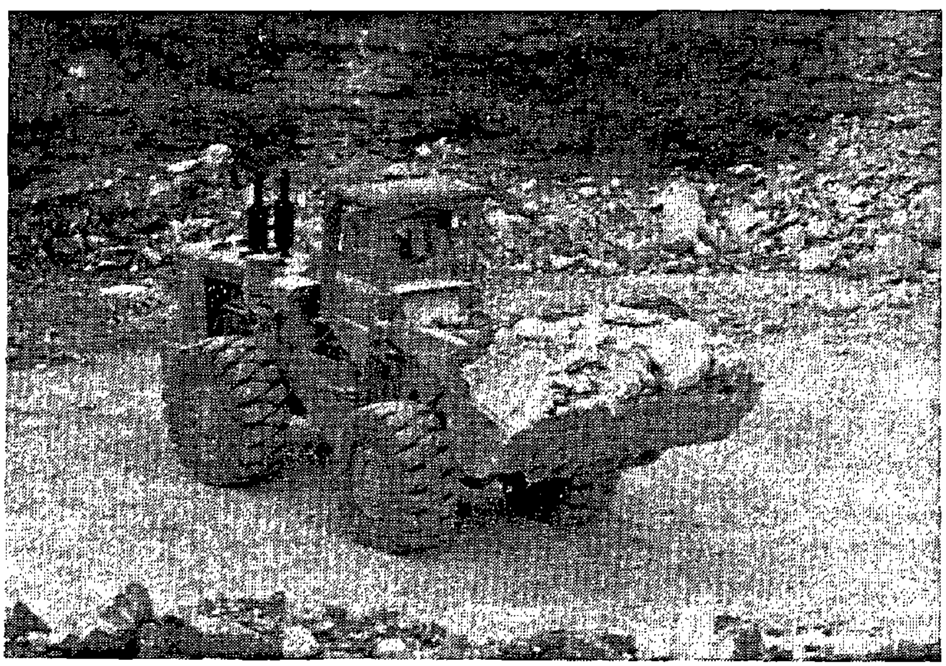


Figure IX - 5
Back and Turn

As the toe material at the digging face is removed, care must be exercised to avoid any major caving of the entire face supported by this material.

Digging floor should be kept flat with a gradual drainage slope to avoid water pockets which adversely affect tire life and traction.

Penetrate the face smoothly and firmly to minimize machine abuse.

Excessive bucket loads result in spillage during maneuvering cycle and tire abuse.

Wider buckets on larger machines, while improving ability to handle larger chunks, make it more difficult to attack single obstructions in the face.

Best bank height (non-caving material) is between height of push arm hinge and maximum lift position of the cutting edge.

Hard digging conditions require heavy duty tires, rock buckets (spade nose with teeth) and possibly machine counterweight and/or tire ballast.

Tire spinning during the digging phase while the front tires are in virgin material is particularly detrimental to tire life.

Highest digging forces are possible at low bucket positions.

Propel inertia can be effectively utilized to assist in penetration, but if face is approached too fast this action leads to wheel spinning.

Maximum prying forces with lip are achieved when bucket is wristed while supported by the bank and/or floor.

Constant maneuvering at face can tear up floor and dilute ore.

Operator skill can make a difference of 25% in digging face productivity,

Low faces require more frequent moves and increases the difficulty of filling the bucket.

When loading trucks, digging cycle times are emphasized; however, in load-and-carry operations greater care is taken to fill the bucket for the haul.

Operator must be able to see over the load to avoid obstructions and/or traffic.

Care must be exercised to be sure standing water on haul roads does not conceal sharp rocks.

Haul road must be maintained adequately and propel speeds adjusted to control machine pitching, which will dislodge material from bucket onto haul road.

High travel speeds and accompanying bouncing causes excessive tire sidewall deflection and tire deterioration.

Increased tire air pressure may be desirable to reduce machine side sway.

Commonly each loader has a separate digging face and haul road to crusher to minimize traffic problems.

Ramps at a hopper should be used as a natural deceleration zone to reduce wear on the machine brakes.

Travel speeds are controlled by the operator. Higher speeds increase productivity but must be balanced against increased fuel consumption, machine abuse and safety considerations.

Operator limits speed based on ride comfort, engine lugging (drop in speed), critical component temperatures (such as torque converter) and traction conditions.

DUMPING

Raising bucket to dumping height just prior to reaching hopper improves operator visibility for machine positioning for dumping.

Bucket roll speed during dumping should be reduced when discharging large rocks, to minimize hopper damage.

Reach over and dump as far into the hopper as possible to prevent excessive build-up on the dump side.

Loads should be distributed as much as possible across hopper to optimize material flow to discharge.

Dust can be minimized by control of dump speed and height of discharge.

Care should be taken to make certain that the bucket load is not excessively one-sided, so as to equalize the load distribution on the front tires.

Loader digging efficiency can be amplified by pushing the mining face down with a dozer, with ripping as required to break up material.

Boulders and/or slab material oversize for the hopper/crusher should be set aside for secondary breakage or disposal beyond the loader's normal maneuvering area.

HAULING AND RETURN

Keep transport distances as short as possible.

Bucket must be carried relatively low to keep the machine center of gravity low.

Bucket should be fully rolled back during carry to minimize rock spillage onto haul road.

Bucket must be carried high enough to prevent any ground contact from machine pitching on rough roads.

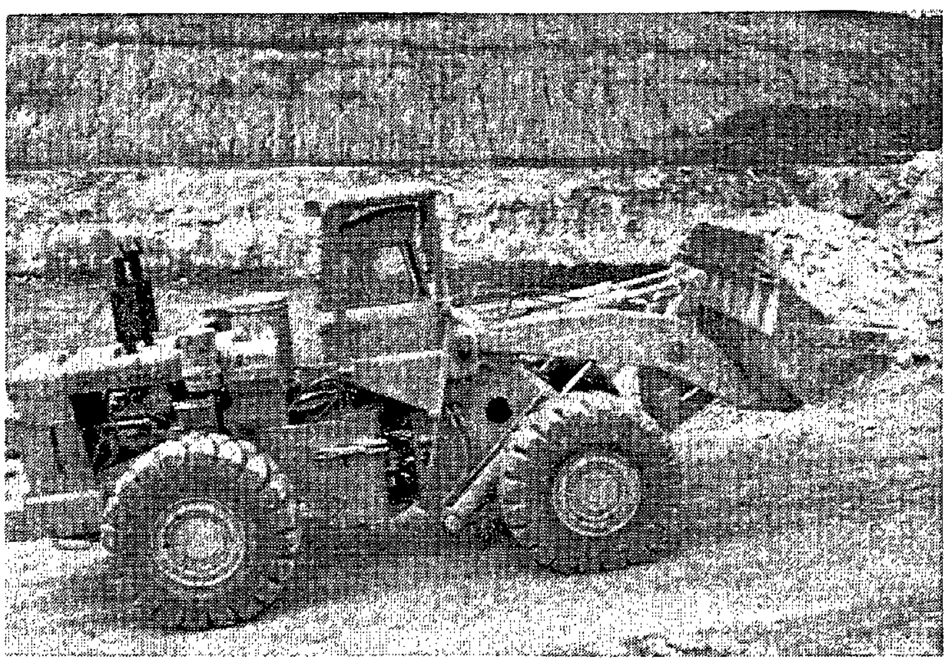


Figure IX - 6
Hauling

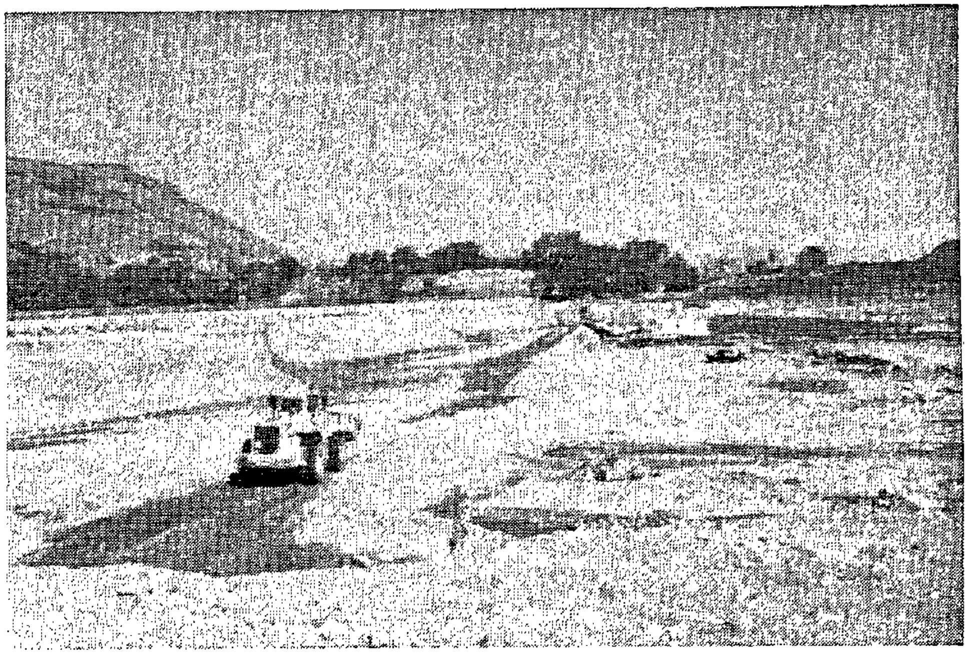


Figure IX - 7
Hauling

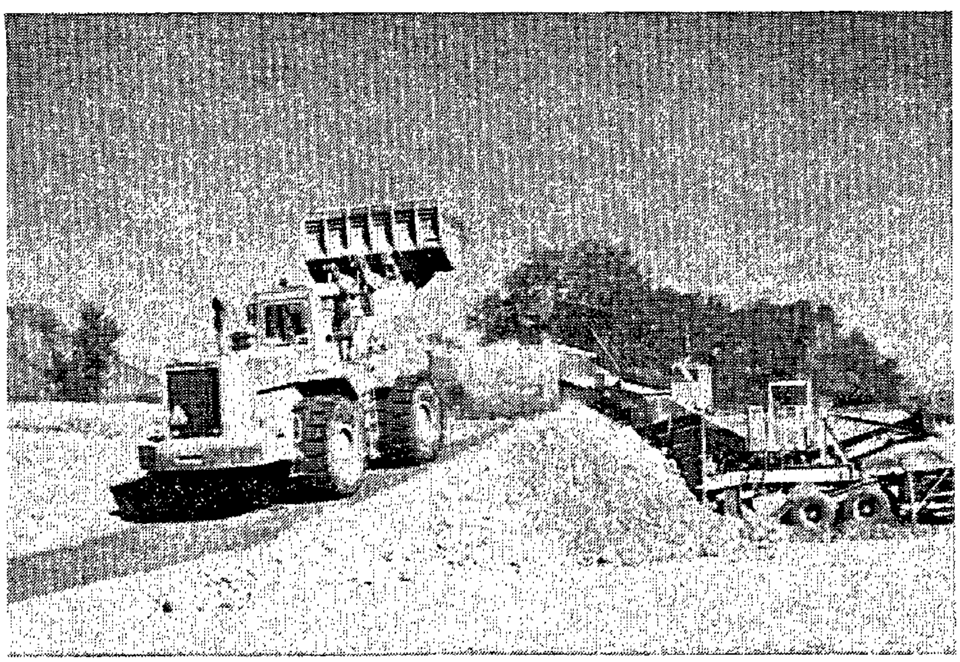


Figure IX - 8
Ramp

9

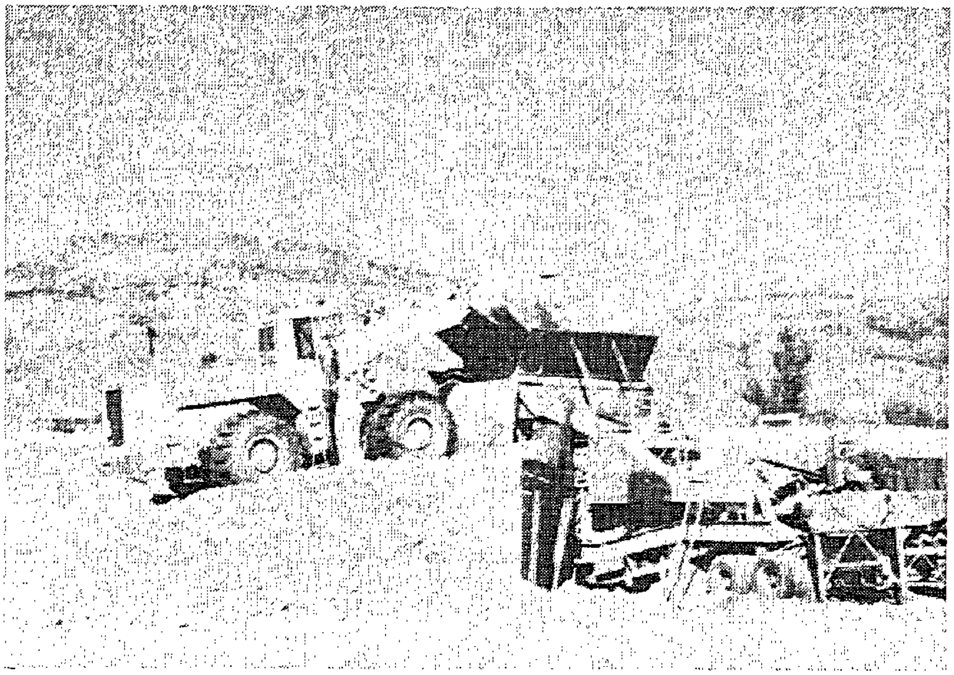


Figure IX - 9
Dump

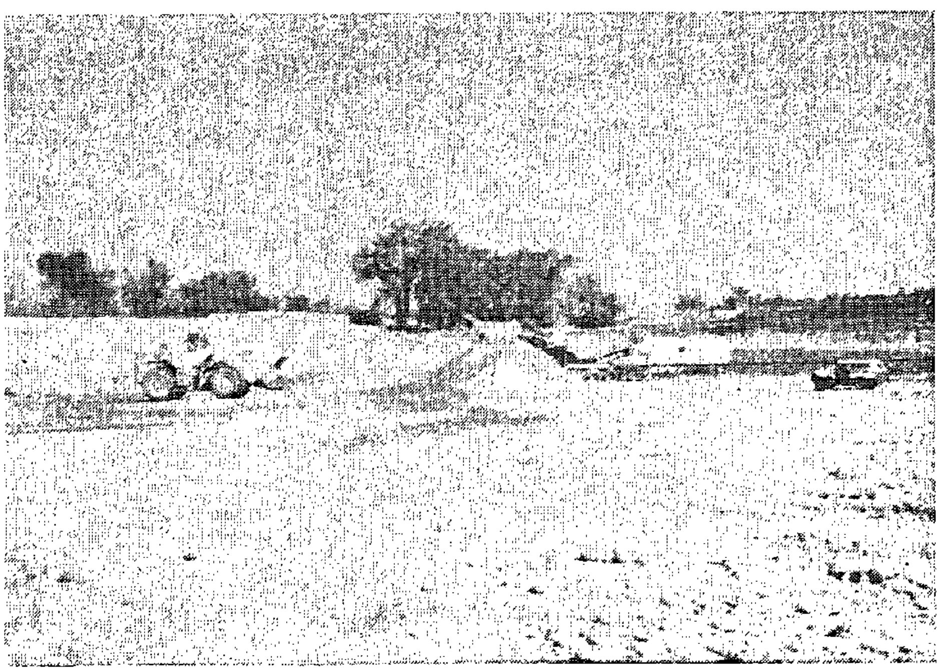


Figure IX - 10
Back and Turn

Sticky material is dislodged by oscillating bucket a small amount to repeatedly strike the dump stops.

If the dumping layout permits, in dusty conditions keep the wind to your back to maximize visibility and reduce air cleaner maintenance.

UTILITY WORK

Bucket can be used to scoop up water from low areas and by controlled dumping action spread over the haul road for dust control.

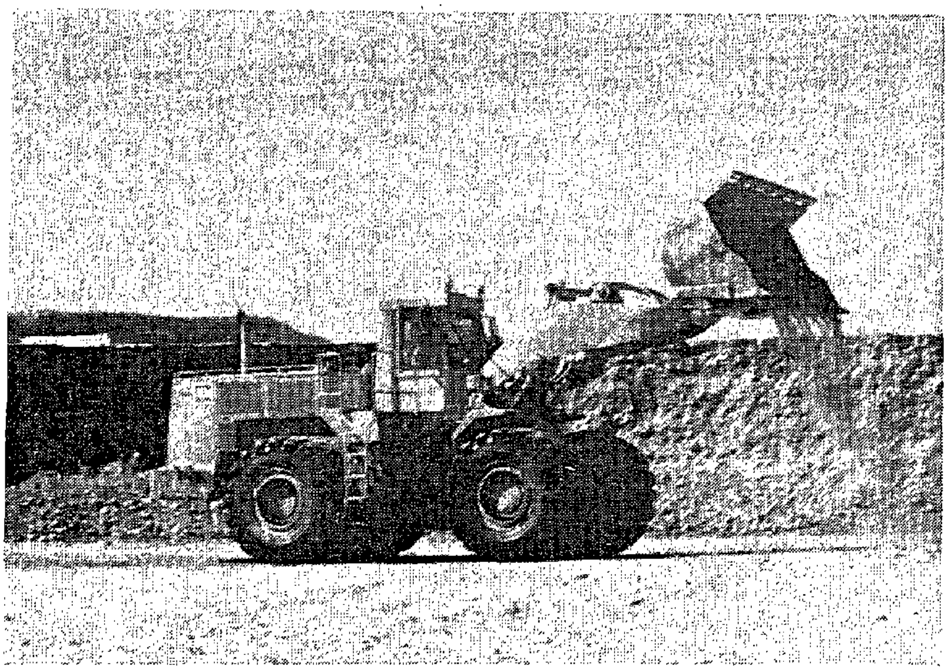


Figure IX - 11
Dumping Water on Road

Bucket wear and abuse can be excessive if haul road clean-up is attempted at high speed.

Machine control while moving between locations under poor traction conditions is improved by carrying a partial load in the bucket.

Holes in the bucket (top edge) or a welded hook facilitate attaching a chain for emergency lifts. (Can be used to remove oversize from hopper but this practice is not recommended by manufacturers.)

9

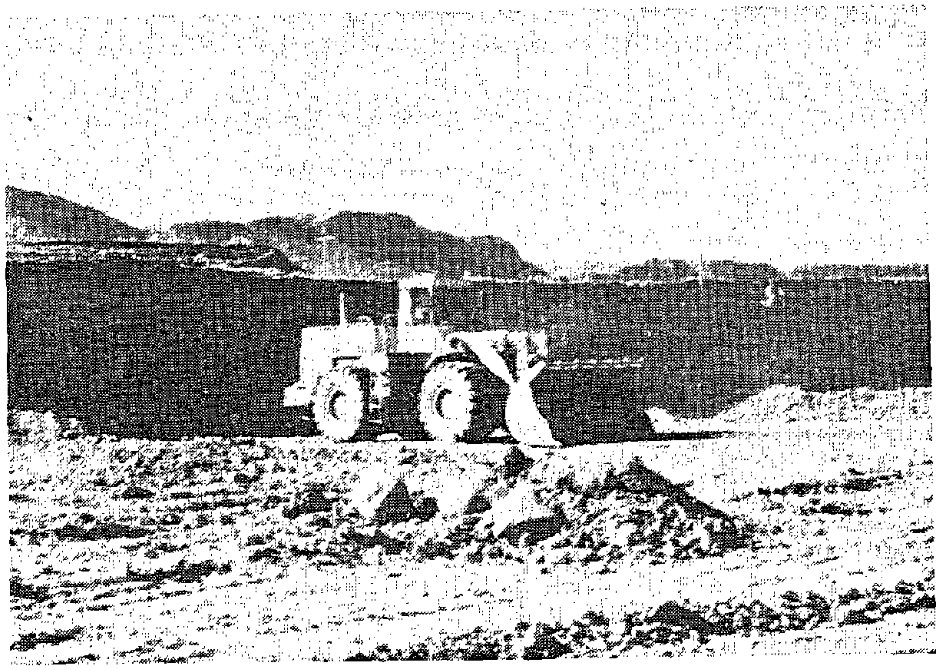


Figure IX - 12
Cleaning Road

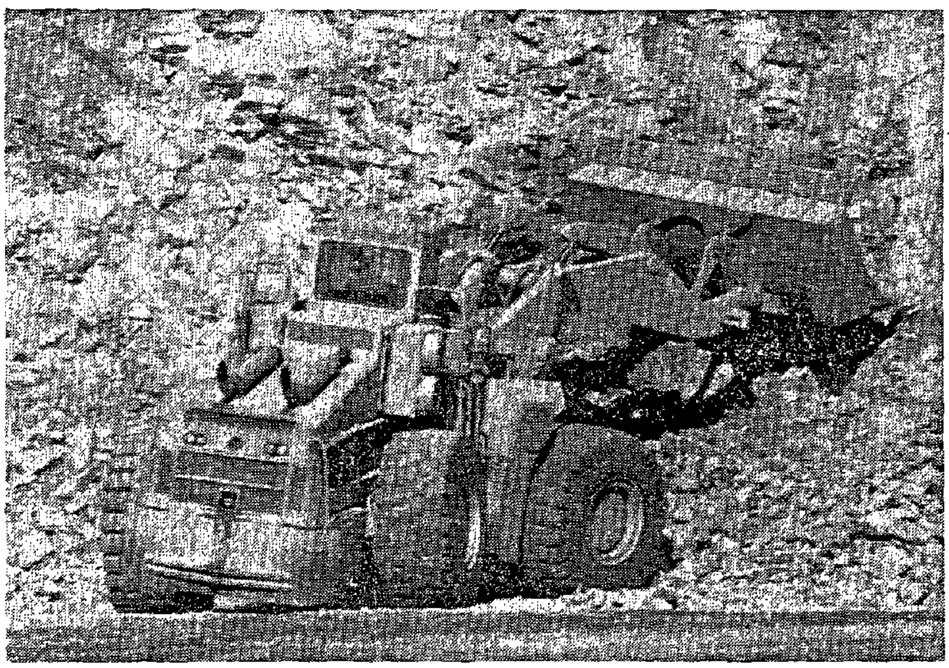


Figure IX - 13
Scaling Bank

Loader can be used effectively for relocating hopper and conveyor sections.

Special plate-type extension which attaches to bucket lip facilitates cleaning under belts and around mobile hopper.

HOPPER - CONVEYOR

Location must recognize potential flyrock damage from blasting.

When practical, hopper should be installed as low as possible to minimize any ramp required for efficient loader dumping.

Long ramps increase length to be backed down during which there is limited visibility.

Hopper width should be 20 to 30% greater than bucket to minimize spotting delays and spillage.

Hopper should be low enough or ramp high enough so the loader can back away after dumping, without rolling bucket back.

Hoppers are equipped with feeder to provide a uniform discharge to the conveyor.

Crushing is generally required if nominal lump size from face is greater than 1/3 the belt width.

Hopper/crusher units currently use breakers or jaw crushers for size reduction.

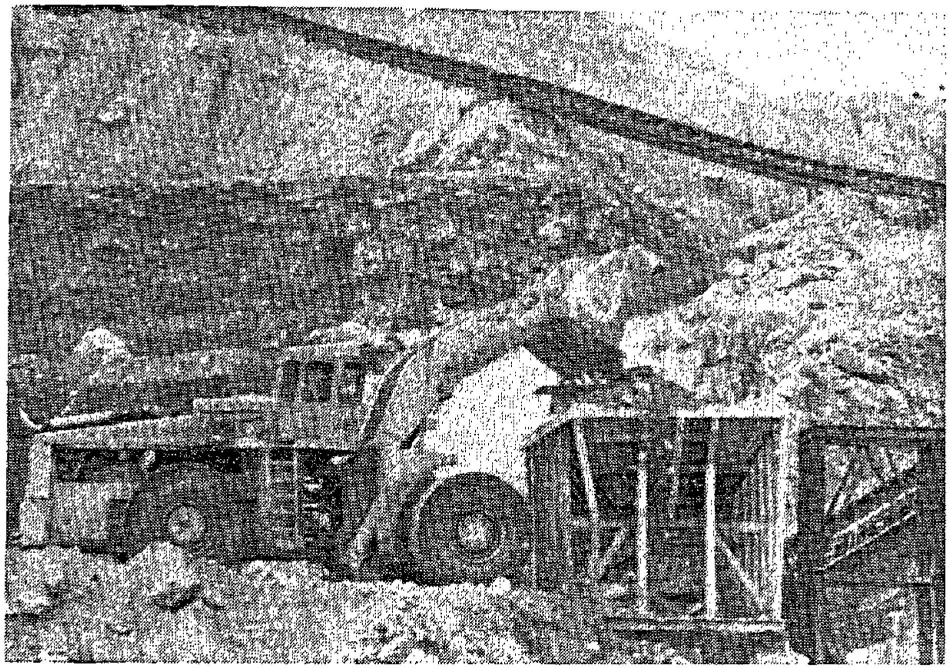


Figure IX - 14
Dumping to Hopper/Crusher

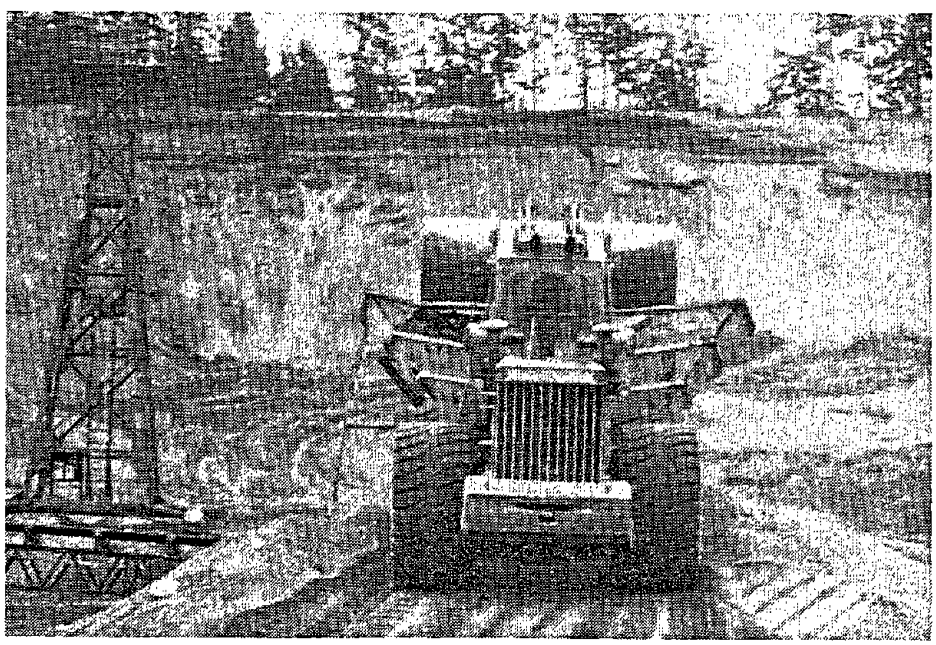


Figure IX - 15
Dumping to Hopper

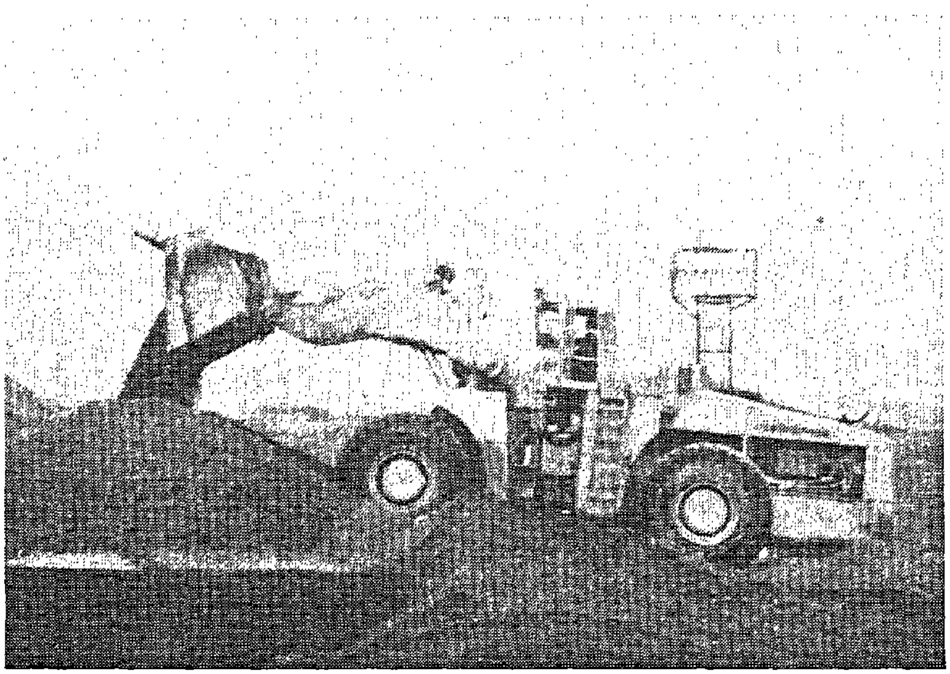


Figure IX - 16
Dumping to Conveyor

Figure IX - 17
Dumping to Low Profile Breaker

SEQUENCING AND SCHEDULING

Haul from farthest digging face (if blending requirement permits) when hopper is full and restricting production.

Build a temporary surge pile next to hopper during periods it is temporarily shut down. Periodically recycle into hopper when service is restored.

If excavated material is excessively wet, develop temporary storage piles near the digging face to permit a period for water to drain off.

Loader idle time is also utilized for shaping the digging face, floor and haul road clean-up, servicing and minor repairs.

Hopper relocation is scheduled when practical to overlap scheduled conveyor (processing plant) shut down period.

Smaller loaders assigned to utility work or stockpile load-out are frequently used if production machine back-up is required.

Changing material blending requirements are communicated directly by the pit supervisor to the loader operator.

OPERATORS

Machine availability is generally improved with a single operator (if scheduling permits) assigned full responsibility for the machine.

The operator is often expected to perform all servicing and minor repairs such as replacing tire chain links.

Many operations schedule 8 to 10 hour shifts without a lunch break.

Operators generally like the freedom and variety in a load-and-carry operation.

There are no special techniques for operator training. They are frequently started on the smaller machines and progress with experience to the larger models. Training periods vary widely, generally lasting from one to six months.

Operators must be reminded of the high cost associated with tire abuse and the necessity for maintaining a clean floor, haul roads and ramps.

MACHINES

Perforations and/or grill work along top edge of the bucket improves operator's view of digging with minimal effect on bucket capacity.

Since the loader is a relatively low investment unit, it generally is selected with excess capacity to assure that it does not limit overall production.

When production requirements are low, operating machines at lower speed can extend component life.

Monitoring of engine and transmission oils through sample analysis has been effective.

Tire abuse is severe if bucket width does not equal or exceed overall width across tires.

Half tread tires (half smooth) have been helpful when tire cutting from sharp rocks is a problem.

Smooth tires work well with tire chains.

Rear tires normally have substantially more life than front tires. A planned rotation program is desirable.

Track type tires, available for some loaders, are effective for bad floor conditions at the digging face and on haul roads.

Tires are frequently ballasted to improve machine stability.

Some have switched to lower service code tires for load-and-carry service to reduce heat build-up.

Foam filled tires are being considered as a means of reducing the risk of tire blowouts but do aggrevate heat build-up.

For most situations high tire lugs give the best traction but smoother tires are better on dry sand and ice.

Tire costs are minimized by: regular tire inspection, maintaining proper air pressure, protecting casing for as many retreads as possible, observing wear indicators and avoiding uneven wear.

Cold Weather Operation

Keep the batteries at full charge.

Use the correct viscosity oil in the engine, transmission and axles.

Use the proper grade of diesel fuel.

Maintain the proper level of antifreeze in the cooling system.

Be sure any liquid ballast in the tires is properly proportioned to prevent freezing.

Fill the fuel tank at the end of each shift.

Park the machine out of any water or mud.

Operate the engine at speeds high enough to maintain proper operating temperatures.

Hot Weather Operation

Keep coolant at proper level.

Keep fan belt tension properly adjusted.

Keep radiator free of bugs, dirt, trash, etc.

Use lubricants of correct viscosity.

Recognize that higher temperatures (above 85°F.), similar to altitude, reduce engine power.

SECTION X

SAFETY CONSIDERATIONS

This section contains a list of safety tips and suggestions. This list is not intended to replace federal, state, and local law, rules or regulations; manufacturers' recommendations and instructions; insurance or corporate requirements; or other safety codes. THIS LIST SHOULD NOT BE TAKEN AS A COMPLETE AND INCLUSIVE COMPILATION OF SAFETY PROCEDURES; rather, it is a list of generally accepted, common sense, good practice procedures compiled from many sources. The major source for these safety tips is the Construction Industry Manufacturers' Association (CIMA), 111 E. Washington Avenue, Milwaukee, Wisconsin 53202. The equipment manufacturers themselves represent another source of safety information. Some manufacturers offer training programs in operator and maintenance safety, and can also assist in establishing ongoing, in-house safety training programs for all personnel.

GENERAL TIPS

- Wear a hard hat, safety glasses, and respirator as required by job conditions.
- Be sure safety link at FEL articulation point is in carrying position before moving loader.
- Do not wear loose clothing or jewelry that could catch on controls.
- Don't rush - be careful.
- Adjust seat before starting to operate. Stay seated while operating. Use seat belt.
- Keep operator's compartment clean.
- Do not smoke while fueling.
- Check controls in a safe area before starting to move.
- Carry bucket close to the ground.
- Do not allow riders.
- Lower bucket and engage parking brake before leaving loader.

- Always look before backing; face in direction of travel.

- Know your employer's safety rules for your job.

PREPARING TO OPERATE TIPS

- Read the manual furnished with your machine to learn its operating and maintenance characteristics, capacities and limitations.

- Be familiar with the safety devices on your machine such as: seat belts, ROPS, articulated steering frame lock, shields and guards, and visible and/or audible warning devices.

- Before you mount the machine, walk completely around it to be sure there are no workmen next to, under or on it. (Don't try to climb muddy/icy ladders.)

- Inspect tires for damage and proper inflation.

- Clean windshield, windows, and mirrors.

- Check engine compartment for trash which could cause fire.

- Warn nearby members of crew that you are starting up.

- Clear personnel from machine and immediate working area.

- Report needed repairs.

- Be sure machine is equipped with clearance lights and turn signals - if required by law.

- Make certain all safety guards and covers are secured in place.

- Clear obstacles from path of machine.

- Be particularly careful if you do not usually operate the machine.

- Check all controls for proper operation.

- Start the engine only from the operator's seat.

- Start engine only in a well ventilated area.

- Test engine accelerator. Listen for unusual noises.

- Test right and left steering while moving slowly.
- Test all brakes.
- When using a cold weather starting aid, follow the manufacturer's instructions. Some starting aids are highy flammable . . . Do not use too much.
- Check function of safety devices such as lights, back-up alarms, etc.
- Move all controls to hold or neutral before starting engine.

OPERATING TIPS

- Look behind machine before backing.
- Do not allow riders on machine.
- Observe all gauges frequently - investigate improper readings immediately.
- Stay clear of overhangs, slide areas or other danger areas.
- Use extra caution in crossing side hills, ridges, ditches and other obstructions.
- Use extreme care to avoid tipping when working on grades.
- Stay safe distance from edge of highwall.
- Use special caution when operating in extremely dry areas to avoid fire hazards.
- Know your stopping distance at any given rate of speed. Regulate travel speed accordingly.
- Keep machine under control - do not try to work machine over its rated capacity.
- Make sure clearance flags and other required warnings are on machine when roading.
- Stop machine frequently at night; walk around and inspect machine - stay alert.
- Report needed repairs noted during operation.
- Carry bucket high enough to clear obstacles.

- Match speed with job conditions; do not coast.
- Learn the traffic rules in the mine.
- Be careful of dust, smoke or fog that might obscure your vision.
- In any work area people constitute a serious safety hazard. Always look out for the other guy . . . a man is no match for a heavy machine.
- If there are bystanders in the work area, warn them and don't start until they are out of danger.
- Never move a load above the heads of other workmen, or over truck's cab.
- Do not use alcoholic beverages while on the job. Beware of medicines, tranquilizers or other drugs which might make you sleepy.
- If there is any indication of fire, shut down machine before exiting.

DISMOUNTING TIPS

- Park machine on level ground.
- Shut off engine before leaving machine.
- If you must park on a grade, park the machine at right angles to the slope and block wheels to prevent movement.
- Make sure the machine is parked on a firm footing to prevent it from tipping or becoming stuck.
- The exact shutdown procedure varies for different machines so always read operator's manual and follow directions carefully.
- Remove the keys when not in operator's cab.
- Bleed accumulators if recommended in the operator's manual.
- To protect machine from tampering or vandalism, secure all locks and protective equipment.
- To prevent accidental or unauthorized starting, disconnect or remove battery. Use master disconnect switch if one is provided.

- Set parking brake before leaving machine.

- Always lower bucket before leaving machine.

- Do not jump off machine - use step and grab irons.

- Do not use the steering wheel or other contols as handholds.

- Don't get on your machine or operate it with wet or greasy hands or muddy boots.

MAINTENANCE AND MACHINE CHECK TIPS

- Watch out for fire hazards when refueling.

- Don't smoke.

- Shut off engine when not required for maintenance.

- Always shut off the engine when checking or adjusting belt tension, If necessary to make adjustments while the engine is running - keep your hands clear of moving parts.

- Avoid standing down wind where spilled fuel could drench you while refueling.

- While refueling, be sure nozzle contacts filler before starting fuel flow to prevent a static spark.

- Replace fuel caps securely.

- Disconnect battery to prevent accidental starting.

- The machine should be parked on level ground. Make sure the wheels are blocked.

- Before working in the pivot area of an articulated machine, securely attach steering frame lock to prevent machine from turning.

- Install lift arm safety bar on lift cylinder if bucket must be left raised.

- Be careful with LP gas - refer to operator's manual when using.

- Never use gasoline as a cleaning fluid. Use a commercial solvent.

- Store flammable starting aids in a cool, well ventilated place, out of reach of unauthorized personnel.

- When charging, leave battery compartment open for ventilation.

- Never use an open flame to check battery, coolant or fuel level.

- Never check battery charge by placing a metal object across the posts . . . the sparks could cause an explosion. Use a voltmeter or hydrometer.

- Fires can occur. Know which fire extinguisher to use and how to use it.

- Keep maintenance area clean and dry. Oily floors are slippery. Wet floors are dangerous around electrical equipment. Greasy rags are a fire hazard.

- Before working on or under a machine, tag controls, disconnect battery, and lock out machine so no one else will start it. Use master disconnect switch if one is provided.

- Never adjust pressure relief valves to obtain higher operating pressures.

- Remove all pressure caps carefully.

- Bleed pressure from accumulators.

- Wait until coolant is below the boiling point before removing the radiator cap.

- Relieve hydraulic pressure before working on machine by working controls in both directions with the engine off.

- Be careful of hot oil when working with hydraulic lines or draining engine oil.

- Keep brakes adjusted.

- Always wear gloves to protect your hands.

- Before you remove inspection covers, stop the engine. Do not let tools or loose objects from your pockets fall into the openings.

- Lower attachments flat to the ground and stop the engine before cleaning or lubricating.
- Make sure machine is securely blocked before lifting machine to change a tire.
- When changing tires, remove valve core carefully and exhaust all air from tire. Run a piece of wire through valve stem to make sure it is not plugged.
- Deflate tire before removing rocks or prying objects from the tread.
- If bead breaker on wheel slips it can fly off with enough force to cause severe injury. Keep your fingers clear of bead breakers and rims,and stand to one side when you apply pressure.
- Always use an inflation cage, safety cables or chains when removing tire lock rings or inflating tires.
- Stand to one side when inflating tires.
- Never begin to inflate a tapered bead tire unless bead seat band has been pried out over lock ring.
- Use extreme caution when tapping of lock ring is required to assist seating.
- Never mix rim parts of different sizes or use damaged parts.
- Never cut or weld on the rim of an inflated tire.
- Never use cable or chains to lift tires.
- Do not approach an overheated tire.

SECTION XI

GOVERNMENT REGULATIONS

The following list is intended as a general reference guide to federal law, mandatory regulations, and other rules and recommendations. These regulations pertain to FEL operation, maintenance, specifications, and required safety equipment, as well as regulations covering site conditions, personnel protective requirements, and various other areas of concern. NO CLAIM IS MADE TO THE COMPLETENESS OF THIS GUIDE AND NO RESPONSIBILITY IS TAKEN FOR ANY OMISSIONS. There may be additional regulations not found in these selected sources. It is the responsibility of the mine operator to comply with any and all regulations pertaining to his/her operation. It is important to note that government regulations, enforcement procedures, violation penalties, etc., are constantly changing so that keeping track of, and complying with these changes must be considered an ongoing mining activity.

State and local laws and regulations are not being covered in this manual because of the sheer volume involved in attempting to list regulations for all parts of the country. City and county land use, planning, and zoning agencies may be a source of information on the local level. State agencies that could be contacted include the Occupational Safety and Health Administration, and the state mining agency. The names of the additional agencies that might be involved with the operation should be obtainable from these two sources.

The Code of Federal Regulations, known as "CFR" is the primary source for federal regulations. The "CFR" is divided into numerical titles (eg. Title 29) to define various areas of enforcement. Each title is further divided into chapters, sub-chapters and parts. Those titles covering regulations that apply to surface mining and reclamation; permitting; personnel safety; equipment specifications; operation and maintenance; and germaine areas are as follows:

29 CFR: LABOR

Subtitle B - Regulations relating to labor
Chapter 17 - Occupational Safety and Health Administration (OSHA), parts 1900 - 1926

Chapter 17 is a complex set of regulations that would seem to cover virtually every conceivable work related situation. Chapter 17 can be broken down into various parts, as follows:

Part 1904 - This part covers the various aspects of accident reporting and record keeping.
Part 1910 - This part is concerned with general industry standards for safety and health. It covers a wide range of diverse areas from worker sanitation, ladders, and toxic fumes to protective clothing, slings, and hand signals.
Part 1926 - Included in this section are the safety and health regulations for construction. Although listed as construction standards many of the regulations are applicable to mining. Subpart O, sections 1926.600 through 1926.1003 cover FEL applications, operation, equipment, definitions and other areas.

30 CFR : MINERAL RESOURCES

Title 30, Mineral Resources, contains the standards and regulations applicable to surface and underground mining, including coal mines, metal and non-metal open pit mines, sand, gravel and crushed stone operations, and metal and non-metal underground mines. Title 30 is divided into the following chapters:

Chapter 1: Mine Safety and Health Administration (MSHA) (part 1-199). Subchapters of interest are:
- G&M - Concerned with accidents, injuries, filing and administrative requirements
- N - Metal and Non-Metal Safety
- O - Coal Mine Safety and Health
- P - Civil penalties for violations

Chapter 2: Geolgocial Survey, Department of the Interior (parts 200 - 290). Parts of interest are:
- 200 - Forms and reports
- 211 - Coal mining regulations
- 290 - Appeals procedure

Chapter 3: Board of Mine Operations Appeals

Chapter 6: Bureau of Mines, Department of the Interior. Chapter 6 has 3 subchapters (A, K,and M) covering such areas as helium and coal, mine fire control, susidence and strip mine rehabilitation.
Subchapter M: Bureau of Mines grant programs (part 651)

Chapter 7: Office of Surface Mining Reclamation and Enforcement (OSM) (parts 700 - 890). Subschapters of interest:

- A - General
- B - Initial program regulations
- C - Regulatory programs for non-federal and non-Indian lands
- D - Federal lands
- F - Areas unsuitable for mining
- G - Surface coal mining permits and regulations
- J - Bonding and reclamation
- K - Permanent performance standards
- L - Enforcement
- P - Protection of employees
- R - Abandoned lands and reclamation

SUMMARY

Title 29 covers general industry standards and regulations for health and safety. Title 30 covers standards and regulations for mining. There may be other regulations in other CFR titles which are also applicable to any given operation. Specific mine sites and mining methods may require interaction with other agencies, such as:

Title 7:	The Department of Agriculture
Title 10:	The Department of Energy
Title 25:	The Bureau of Indian Affairs
Title 36:	National Park Service
	Forest Service
Title 40:	Environmental Protection Agency
Title 43:	Bureau of Reclamation
	Bureau of Land Management
Title 50:	U. S. Fish and Wildlife Service

APPENDIX A

FRONT-END LOADER SPECIFICATIONS

Dimensions are illustrated on page 223
Machine specifications start on page 224

SPECIFICATION DEFINITIONS

Dump Height
The vertical distance from the ground to the lowest point of the cutting edge with the bucket hinge pin at maximum height and the bucket at a 45° dump angle.

Reach - Fully Raised
The horizontal distance from the foremost point on the vehicle to the cutting edge with the bucket hinge pin at maximum height and the bucket at a 45° dump angle.

Rollback
The angle in degrees that the bottom of the bucket cutting edge will rotate above horizontal.

Maximum Rollback at Ground
Maximum rollback without movement of the lift arm.

Digging Depth
The vertical distance from the ground line to the bottom of the bucket cutting edge at the lowest position with the bucket cutting edge horizontal.

Wheelbase
The horizontal distance from the center of the front wheel to the center of the rear wheel.

Overall Width
The maximum outside width of the vehicle specified exclusive of bucket.

Bucket Width
The maximum outside width of the bucket specified.

Ground Clearance
The minimum vertical distance from the ground to the lowest point on the vehicle between the tires or tracks with the lift arm raised.

Tread
The transverse distance between the centerlines of the tires.

Operating Weight

The total weight of the vehicle as specified and fully serviced, including a full fuel tank and a 175 lb. operator.

Tipping Load - SAE Rating

The minimum weight in pounds at the center of gravity of the SAE rated load in the bucket which will rotate the machine to a point where, on wheel loaders, the rear wheels are clear of the ground under the following conditions:

a) vehicle on a hard level surface and stationary;
b) maximum bucket rollback;
c) center of gravity of load at the maximum forward position in the raising cycle;
d) vehicle at operating weight and equipment as specified.

Lift Capacity to Maximum Height

The maximum weight in pounds at the center of gravity of SAE rated load in the bucket that can be lifted from the ground to maximum height with the bucket positioned to retain maximum load, under the following conditions:

a) vehicle on a hard level surface and stationary but not anchored;
b) vehicle at operating weight and equipment as specified.

Breakout Force

Breakout force in pounds is the maximum sustained vertical upward force exerted 4 inches behind the tip of the bucket cutting edge and is achieved through the ability to lift and/or rollback the bucket about the specified pivot point under the following conditions:

a) tractor on a hard level surface with transmission in neutral;
b) all brakes released;
c) unit at standard operating weight, rear of tractor not tied down;
d) bottom of cutting edge parallel to and not more that 1 inch above or below the ground line;
e) if the rear of the vehicle leaves the ground then the vertical force value required to raise the rear of the vehicle is breakout force.

Raising Time

The time in seconds required to raise the bucket from the level position on the ground to full height with an SAE operating load.

Lowering Time

The time in seconds required to lower the empty bucket from the full height to a level position on the ground.

Dump Time

The time in seconds required to move the bucket from the load carrying position at maximum height to the full dump position while dumping an SAE operating load.

Loader Clearance Circle

The smallest diameter measured that the outermost point on the vehicle will describe when turning under the following conditions:

a) brakes cannot be used;
b) loader bucket to be in the carry position.

Bucket Rating - SAE J742b

This standard describes a method for determining the average volume of an average material carried by the bucket of a front-end loader. The calculations used result in a realistically conservative heaped volume. They are based on physical dimensions of the bucket only, without regard to bucket action provided by a specific machine. For rating purposes, a nominal heaped load will have a 2:1 angle of repose when the bucket is oriented so the bucket opening is horizontal and load volume is maximized. This in no way implies that the loader linkage must carry the bucket oriented in this attitude or that all materials will naturally have a 2:1 angle of repose.

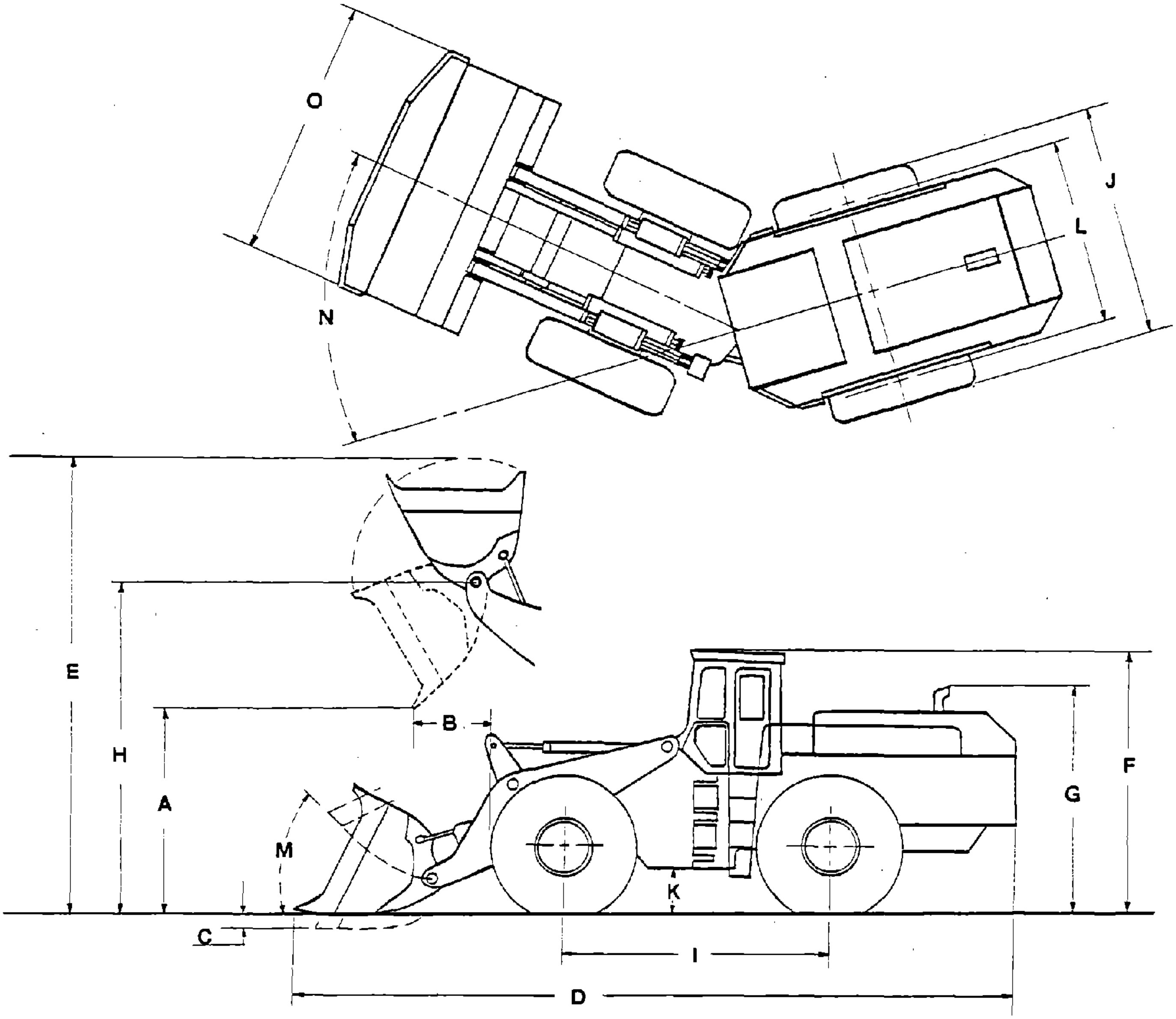
Operating Load - SAE J818b

The rated normal all day operating load (lbs.), taking only hydraulic ability and operating stability into consideration. It will not exceed 50% of the full turn tipping load with the following conditions:

a) lifting ability of the machine in all bucket positions must be greater than the operating load;
b) maximum travel speed of 3.7/MPH.

Figure A - 1

FEL DIMENSIONS



A	DUMP HEIGHT
B	REACH - FULLY RAISED
C	DIGGING DEPTH
D	OVERALL LENGTH - BUCKET ON GROUND
E	OVERALL HEIGHT - BUCKET RAISED
F	HEIGHT TO TOP OF CAB
G	HEIGHT TO TOP OF EXHAUST
H	HEIGHT TO HINGE PIN - BUCKET RAISED
I	WHEELBASE
J	OVERALL WIDTH (w/o BUCKET)
K	GROUND CLEARANCE
L	WHEEL TREAD
M	BUCKET ROLLBACK @ GROUND
N	MAXIMUM STEERING ANGLE (EACH DIRECTION)
O	BUCKET WIDTH

OPERATING DATA

Model	Bucket Size (3000 #/ft³ mat'l)	Payload (lbs)	Breakout Force-(lbs)	Tipping Load (lbs) Straight	35° Turn	Full Turn	Full Turn W/CWT
J. I. Case							
W24C	2.5	7,500	21,200	19,480	17,718	17,201	19,170
W36	3.5	10,500	30,300	25,400	22,250	21,700	25,200
Caterpillar							
950	2.5	7,500	22,750	21,470	19,850	19,850	23,080
966C	3.5	10,500	28,150	28,170	25,900	25,900	29,570
980C	5.25	15,750	58,880	40,760			
988B	7.0	21,000	80,800	49,500	44,740	44,740	51,560
992C	12.5	37,500	147,050	106,480	96,760	96,760	102,580
Clark							
75C	2.5	8,250	25,700	26,830	21,030	21,030	23,610
125C	3.5	12,000	37,000	31,540	24,780	24,780	27,760
175C	5.0	15,000	34,700	39,502	31,693	31,693	35,473
275C	7.0	21,000	51,000	56,890	43,020	43,020	48,960
475C	14.0	42,000	102,200	107,060	87,200	87,200	97,150
675C	24.0	72,000	159,250	185,800	165,360	165,360	
Dart							
600C	15.0	45,000		134,600		118,300	
DE620	15.0	45,000		144,000		128,000	
Deere							
JD644-B	2.5	7,545	24,120	18,040		15,470	19,610
JD844	4.5	14,000	35,070	32,080		28,780	30,450
Trojan (Yale)							
2000	3.0	9,000	22,800	21,070		19,507	20,434
2500	4.0	12,000	36,189	28,651		23,905	27,220
3000	4.25	12,750	36,000	29,885		22,860	26,390
5500	6.0	18,000	49,050	44,405	38,658	38,658	45,914
7500	7.5	22,500	59,000	58,757	51,769	51,769	55,282
Elmac							
500	2.5	8,762	23,000	17,525		14,148	15,736
Fiat-Allis							
645-B	2.5	9,500	28,700	20,261	18,040	16,682	18,762
FR20	4.0	12,500	35,780	30,560	27,030	24,890	27,080
945-B	6.0	19,500	48,000	46,550	41,639	38,642	43,744
Ford							
A66	2.5	7,500	23,000	17,525	14,695	14,048	15,636
IHC							
530	2.5	7,500	31,288	20,220	18,179	18,179	
540	3.75	11,250	35,600	28,125	24,174	24,174	
H-90E	4.0	12,000	37,478	29,924	26,932	26,932	
550	5.25	17,250	40,070	40,770	34,665	34,665	38,822
560	6.5	19,500	64,181	52.207	46,986	46,986	
570	12.	36,000	100,800	97,800		83,130	92,843
580	22.0	66,000	192,500	199,100		169,235	
Kawasaki							
KSS 70	3.0	8,360	22,000	21,870		19,240	
KSS 80	4.0	10,580	27,500	24,250		22,200	
95Z	6.0	18,000	40,565	39,903		36,155	
LeTourneau							
L-600	10.0	30,000	96,636	80,000		72,000	
L-800	15.0	51,000	117,972	136,000		116,000	
L-1200	22.0	66,000	164,000	230,000		195,000	
Terex							
72-31B	3.0	9,750	23,143	20,692	18,967	18,967	21,576
72-51B	4.0	13,500	40,638	34,433		30,318	33,769
72-61	5.5	16,500	42,481	45,182		39,611	43,123
72-71B	8.0	24,000	67,290	62,895		54,084	59,734
72-81	9.0	27,000	62,500	78,695		69,925	76,995

Note: Operating data, as shown, will vary depending on the specific combination of bucket size, counterweight, tire ballast, boom and other options.

OPERATING DATA

Dump Height (ft)	Reach (ft-in) @ 45°	Reach (ft-in) 45°@ 7ft	Digging Depth (in)	Cab Position	Std. Oper. Weight (lb)	Model
						J. I. Case
9'3"	3'0"	4'8"		Front	23,525	W24C
9'8"	3'3"	5'3"		Front	33,150	W36
						Caterpillar
9'3"	2'5"	4'1"	2"	Rear	28,500	950
9'10"	2'7"	4'6"	2"	Rear	36,900	966C
10'4"	4'4"	6'4"	3"	Rear	58,000	980C
11'4"	6'3"	8'0"	3"	Rear	93,650	988B
14'8"	6'10"	10'6"	3"	Rear	198,260	992C
						Clark
9'3"	2'7"	4'3"	2"	Rear	29,050	75C
9'11"	3'2"	4'10"	3"		41,000	125C
10'2"	4'3"	6'0"	4"	Rear	52,770	175C
10'9"	5'0"	6'7"	6"	Rear	76,860	275C
13'6"	6'1"	9'1"	6"	Rear	152,950	475C
18'4"	6'5"	10'8"		Rear	389,500	675C
						Dart
16'0"	6'4"			Front	192,750	600C
16'0"	6'4"			Front	200,100	DE620
						Deere
9'4"	2'10"		2"	Rear	25,105	JD644-B
10'6"	3'5"		5"	Rear	47,490	JD844
						Trojan (Yale)
9'3"	3'6"	5'1"		Rear	28,835	2000
10'2"	3'4"	5'6"		Rear	37,040	2500
10'1"	3'9"	5'11"			37,375	3000
10'9"	4'7"	6'11"			56,924	5500
11'7"	4'9"	7'7"			76,772	7500
						Elmac
9'2"	2'11"		4"	Rear	25,860	500
						Fiat-Allis
9'3"	2'11"	5'0"	3"	Rear	26,880	645-B
10'1"	2'11"	5'9"	4"	Rear	42,780	FR20
10'10"	4'0"	6'5"	3"	Rear	65,090	945-B
						Ford
9'6"	2'11"		2"	Rear	25,860	A66
						IHC
9'4"	3'3"	4'11"	4"	Front	27,565	530
10'0"	3'8"	5'7"	3"	Front	35,750	540
9'10"	3'9"	5'4"	4"	Front	40,260	H-90E
10'6"	3'9"	5'10"	6"	Front	50,050	550
12'4"	4'4"	7'2"	12"	Front	79,210	560
13'1"	6'7"	9'4"	12"	Front	132,180	570
17'7"	7'2"	11'3"	18"	Front	289,100	580
						Kawasaki
9'0"	2'9"		1"	Rear	30,040	KSS 70
9'8"	2'10"		2"	Rear	38,960	KSS 80
9'8"	5'0"			Rear	59,634	95Z
						LeTourneau
13'5"	4'6"		5"	Rear	130,200	L-600
16'6"	7'0"		8"	Rear	185,000	L-800
19'11"	8'5"		5"	Rear	335,000	L-1200
						Terex
9'4"	3'4"	5'1"	13"	Rear	27,525	72-31B
9'11"	3'8"	5'10"	7"	Rear	40,501	72-51B
10'3"	4'7"	6'8"	4"	Rear	56,140	72-61
12'0"	4'5"	7'7"	3"	Rear	83,970	72-71B
12'10"	5'4"	8'11"	5"	Rear	112,390	72-81

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Note: Operating data, as shown, will vary depending on the specific combination of bucket size, counterweight, tire ballast, boom and other options.

GENERAL DIMENSIONS

Model	Bucket Size Range (yds)	Bucket Width (ft-in)	Overall Machine Dimensions (ft-in): Raised Bucket	Top of Cab	Top of Exhaust	Length	Width
J. I. Case							
W24C	2.5-3	8'8"	16'0"	11'0"		22'2"	8'0"
W36	3.5-4	9'6"	17'4"	10'6"		24'3"	8'11"
Caterpillar							
950	2.5-3.5	8'0"	16'4"	10'4"	10'4"	20'3"	8'6"
966C	3-4.5	9'6"	17'7"	10'10"	11'2"	22'5"	8'10"
980C	5.25-5.75	11'0"	19'0"	12'9"	13'5"	28'3"	10'3"
988B	7-8	11'11"	22'9"	13'6"	13'6"	34'1"	11'6"
992C	12.5	15'1"	28'7"	17'8"	13'11"	41'9"	14'11"
Clark							
75C	2.5-4	8'8"	16'0"	10'10"	9'8"	22'4"	8'2"
125C	3.5-6	10'0"	17'1"	11'7"	10'0"	25'2"	9'5"
175C	4.5-6	10'4"	18'7"	12'2"	11'7"	27'5"	10'0"
275C	6.5-8	11'10"	20'2"	12'7"	12'6"	29'10"	11'6"
475C	10-22	13'7"	27'0"	16'7"	14'0"	40'2"	12'8"
675C	18-36	20'10"	34'0"	21'6"	16'6"	53'5"	19'8"
Dart							
600C	7-30	15'6"		18'4"		41'4"	16'5"
DE620	7-30	15'6"		18'6"		41'4"	17'6"
Deere							
JD644-B	2.5-4.5	8'9"		10'8"	9'10"	21'1"	8'2"
JD844	4.5-7	12 8"		11'9"	10'6"	26'2"	10'6"
Trojan (Yale)							
2000	2.5-4	8'4"	17'5"				
2500	3.5-5	9'10"	18'3"				
3000	3.75-5.5	9'10"	18'9"				
5500	5.5-8	11'7"	19'9"				
7500	6.5-8.5	12'	22'				
Elmac							
500	2-3	8'0"	16'7"	10'7"	11'5"	21'7"	7'8"
Fiat-Allis							
645-B	2.5-3.5	8'9"	15'5"	10'10"		20'11"	8'7"
FR20	3.5-4.5	9'10"	17'4"	11'6"		25'8"	9'6"
945-B	6-6.5	11'3"	18'9"	13'6"		27'9"	10'9"
Ford							
A66	2.25-6.0	8'	16'9"	10'8"	11'2"	21'4"	8'
IHC							
530	2.5-3.5	8'7"		10'8"	8'7"	21'8"	
540	3.75-4.75	9'6"		11'0"	11'0"	24'2"	
H-90E	4-7	10'0"		11'7"	11'4"	23'4"	
550	5.25-5.75	10'10"		12'4"	12'10"	26'5"	10'3"
560	6.5-12	11'8"		13'1"	13'2"	29'4"	
570	12-24	14'0"		15'0"	14'6"	36'2"	13'4"
580	22	18'0"		17'7"	20'2"	47'9"	
Kawasaki							
KSS 70	3	8'7"		10'10"		22'3"	8'2"
KSS 80	4	9'8"		11'4"		24'1"	9'1"
95Z	6	10'9"		11'11"		28'10"	
LeTourneau							
L-600	8-20	13'2"	25'5"	14'8"		37'8"	11'10"
L-800	10-30	16'5"	29'6"	16'0"		43'9"	14'10"
L-1200	22	20'8"	34'0"	20'6"		53'8"	19'0"
Terex							
72-31B	3-3.5	9'8"	14'3"	10'9"	10'4"	21'10"	8'11"
72-51B	4-5.5	10'0"	17'8"	11'4"	11'3"	25'8"	9'5"
72-61	5.5-6.5	11'0"	18'10"	11'11"	12'5"	27'11"	10'7"
72-71B	7.5-8	11'11"	22'4"	13'6"	11'0"	33'4"	11'7"
72-81	9	12'9"	24'0"	13'10"	12'1"	35'7"	12'0"

Note: General dimensions, as shown, will vary depending on specific combinations of bucket, boom, tires and other options.

GENERAL DIMENSIONS

Clearance Circle (ft)	Wheel Base (ft)	Ground Clearance (ft)	Height Hinge Pin (ft)	Wheel Tread (ft)	Bucket Rollback° At Ground	Bucket Rollback° At Carry	Model
							J. I. Case
39'5"	10'2"		12'6"	6'5"	46		W24C
41'9"	10'7"		13'0"	7'2"	40		W36
							Caterpillar
40'8"	9'7"	1'5"	12'2"	6'8"	41	45	950
44'4"	10'2	1'4"	13'1"	7'1"	40	45	966C
51'1"	11'7"	1'4"	13'8"	7'9"	40	47.5	980C
56'6"	12'6	1'7"	16'1"	8'6"	40	50	988B
70'9"	15'10"	1'9"	20'6"	10'10"	51	41	992C
							Clark
39'10"	9'5"	1'5"	12'3"	6'5"		38	75C
48'0'	10'3"	1'5"	13'4"	7'4"		45	125C
49'5"	11'3"	1'9"	14'0"	7'5"		44	175C
54'0"	12'2"	1'7"	14'10"	8'10"		44	275C
68'0"	15'2"	1'10"	19'3"	9'6"		46	475C
84'8"	18'8"	3'4"	25'1"	13'10"		42	675C
							Dart
67'6"	16'6"		21'7"	11'5"	50	57	600C
67'8"	16'6"		21'7"	11'5"	50	57	DE620
							Deere
35'10"	8'8"	1'8"	12'0"	6'8"	40		JD644-B
45'8"	10'6"	1'11"	13'11"	7'6"	40		JD844
							Trojan (Yale)
39'2"							2000
42'2"							2500
42'8"	10'6"	1'4"	13'8"	7'4"	40		3000
54'8"	12'4"	1'5"	14'6	8'3"	40		5500
56'10"	13'	1'6"	15'10"	8'10"	39		7500
							Elmac
33'4"	9'3"	1'6"	12'5"	5'10"	45		500
							Fiat-Allis
35'0"	9'8"	1'7"	11'9"	6'7"	39	49	645-B
40'3"	10'10"	1'6"	13'4	7'3"	39	49	FR20
45'0"	12'4	1'9"	14'6"	8'0"	49	41	945-B
							Ford
33'8"	9'3"	1'6"	12'8"	6'9"	45		A66
							IHC
42'0"	9'0"	1'5"	12'2"		33	45	530
49'10"	9'9"	1'3"	13'3"		41.5	50	540
44'9"	10'0"	1'5"	13'1"		26	43	H-90E
49'0"	10'10"	1'2"	14'2"	7'10"	33	47	550
56'4"	12'11"	1'9"	16'7"		38	45	560
59'11"	15'0"	1'10"	18'5"	9'10"	34	45	570
81'2"	21'0"	1'11"	24'6"		40	45	580
							Kawasaki
39'5"	9'7"	1'4"	12'3"	6'5"	44	47	KSS 70
44'4"	10'6"	1'6"	13'2"	7'2"	44	46	KSS 80
	11'7"						95Z
							LeTourneau
56'8"	16'0"	1'8"	18'0"	9'0"	50		L-600
64'8"	18'0"	1'7"	21'8"	11'8"	50		L-800
83'0"	22'0"	2'6"	26'8"	14'4"	50		L-1200
							Terex
41'6"	9'0"	1'5"	12'2"	7'0"	50	67	72-31B
43'11"	10'0"	1'2"	13'3"	7'5"	50	61	72-51B
47'0"	10'6"	1'5"	13'10"	8'4"	50	60	72-61
54'1"	13'4"	1'6"	16'6"	8'11"	40	61	72-71B
57'3"	13'9"	1'6"	18'1"	9'2"	44	64	72-81

Note: General dimensions, as shown, will vary depending on specific combinations of bucket, boom, tires and other options.

ENGINES

Model	Type	No. of Cylinders	Make	Model No.	Gross H.P. RPM.
J. I. Case					
W24C	Diesel	6	Case	A504 BD	158 @ 2200
W36	Diesel	6	Case	A504 BDT1	204 @ 2200
Caterpillar					
950	Diesel	4	Cat	3304	
966C	Diesel	6	Cat	3306	
980C	Diesel	6	Cat	3406	
988B	Diesel	8	Cat	3408	
992C	Diesel	12	Cat	3412	
Clark					
75C	Diesel	4	Detroit	4-71T	152 @ 2300
	Diesel	8	Cummins	V-504-C	171 @ 2800
125C	Diesel	6	Detroit	6V-71N65	236 @ 2300
	Diesel	8	Cummins	VT-555-C	222 @ 2850
175C	Diesel	8	Detroit	8V-71N	304 @2100
	Diesel	6	Cummins	NT-855-C	310 @ 2100
275C	Diesel	6	Cummins	KT-1150-C	400 @ 2100
475C	Diesel	16	Detroit	16V-92N80	702 @ 2000
	Diesel	12	Cummins	VTA-1710-C700	680 @ 2000
675C	2 x Diesel	2 x 12	Cummins	VTA-1710-C675	2 x 675 @ 2100
Dart					
600C	Diesel	12	Cummins	VTA-1710C	700
	Diesel	16	Detroit	16V92T	800
DE620	Diesel	12	Cummins	KT2300	860
Deere					
JD644-B	Diesel	6	Deere		160 @ 2200
JD844	Diesel	8	Deere		290 @ 2100
Trojan (Yale)					
2000*	Diesel	4	G.M.	4-71N	157 @ 2300
2500	Diesel	6	G.M.	6V-71N	203 @ 2300
3000*	Diesel	6	G.M.	6V-71N	236 @ 2300
5500*	Diesel	8	G.M.	8V-92N70	320 @ 2100
7500*	Diesel	8	G.M.	8V-92TN90	430 @ 2100
Elmac					
500	Diesel	6	Ford	401-DT	157 @ 2200
Fiat					
645-B	Diesel	6	A.C.	3500 MKII	
FR20	Diesel	6	Fiat	8215	
945-B	Diesel	6	A.C.	25000 MKII	
Ford					
A66	Diesel	6	Ford	401 DT	157 @ 2300
IHC					
530	Diesel	6	I.H.	DT-414	165 @ 2500
540	Diesel	6	I.H.	DT-466B	200 @ 2500
H-90E	Diesel	8	I.H.	DVT-573B	260 @ 2500
550	Diesel	6	I.H.	DT-817C	320 @ 2100
560	Diesel	6	I.H.	DTI-817C	420 @ 2200
	Diesel	6	Cummins	KT-1150-C	450 @ 2200
570	Diesel	12	Cummins	VT 1710-C	635 @ 2100
580	Diesel	12	Detroit	12V-149T1	1200 @ 1900
Kawasaki					
KSS 70	Diesel	8	Cummins	V504	
KSS 80	Diesel	6	Cummins	NH 220-C1	
95Z	Diesel	6	Cummins	NT855-C335	
LeTourneau					
L-600	Diesel	12	G.M.	12V-71T	525 @ 2100
	Diesel	6	Cummins	KT 1150	525 @ 2100
L-800	Diesel	16	G.M.	16V-92T	860 @ 2100
	Diesel	12	Cummins	KT-2300-C	860 @ 2100
L-1200	Diesel	12	G.M.	12V-149T1	1200 @ 1900
	Diesel	12	Cummins	KTA 2300	1200 @ 1900
Terex					
72-31B	Diesel	4	Detroit	4-71T	170 @ 2300
72-51B	Diesel	6	Detroit	6V-71T	257 @ 2300
72-61	Diesel	8	Detroit	8V-71T	343 @ 2300
72-71B	Diesel	8	Detroit	8V-92T	430 @ 2100
72-81	Diesel	12	Detroit	12V-71T	465 @ 2100

Note: At any time, different engine options may be available.

Note: A * beside any machine model number denotes the availability of a comparable Cummins engine.

ENGINES

Flywheel H.P. @ R.P.M.	Maximum Torque in lb. @ R.P.M.	Displacement cu. in.	No. of Cycles	Model
				J. I. Case
132 @ 2200	372 @ 1400	504	4	W24C
185 @ 2200	503 @ 1600	504	4	W36
				Caterpillar
130 @ 2150		425	4	950
170 @ 2200		638	4	966C
270 @ 2100			4	980C
375 @ 2200		1099	4	988B
690 @ 2200		1649	4	992C
				Clark
142 @ 2300	449 @ 1200	284	2	75C
154 @ 2800	375 @ 1900	504	4	
212 @ 2300	600 @ 1600	425.6	2	125C
210 @ 2850	445 @ 1900	555	4	
273 @ 2100	800 @ 1600	567.4	2	175C
279 @ 2100	930 @ 1500	855	4	
360 @ 2100	1350 @ 1500	1150	4	275C
632 @ 2000	1966 @ 1400	1472	2	475C
612 @ 2000	1925 @ 1500	1710	4	
2 x 635 @ 2100	2 x 2025 @ 1500	2 x 1710	4	675C
				Dart
	1920 @ 1500	1920	4	600C
	2240 @ 1400	1472	2	
	2346 @ 1400	2300	4	DE620
				Deere
145 @ 2200	432 @ 1500	531	4	JD644-B
260 @ 2100	858 @ 1300	955	4	JD844
				Trojan (Yale)
144 @ 2300	400 @ 1600	284	2	2000*
182 @ 2300	550 @ 1200	426	2	2500
215 @ 2300	600 @ 1600	426	2	3000*
288 @ 2100	902 @ 1200	736	2	5500*
389 @ 2100	1186 @ 1400	736	2	7500*
				Elmac
146 @ 2200	394 @ 1600	401	4	500
				Fiat-Allis
151 @ 2200	443 @ 1600	426	4	645-B
215 @ 2100	602 @ 1600	842	4	FR20
335 @ 2100	982 @ 1400	844	4	945-B
				Ford
146 @ 2300	424 @ 1600	401	4	A66
				IHC
155 @ 2500	425 @ 1800	414	4	530
189 @ 2500	510 @ 1800	466	4	540
239 @ 2500	655 @ 1700	573	4	H-90E
290 @ 2100	891 @ 2100	817	4	550
380 @ 2200	1208 @ 1500	817	4	560
415 @ 2200	1350 @ 1500	1150	4	
580 @ 2100	1588 @ 2100	1710	4	570
1075 @ 1900	3445 @ 1600	1792	2	580
				Kawasaki
158 @ 2400		504	4	KSS 70
187 @ 2100		742.7	4	KSS 80
305 @ 2100		855	4	95Z
				LeTourneau
		852	2	L-600
		1150	4	
	2372 @ 1400	1472	2	L-800
	@ 1500	2300	4	
	3445 @ 1600	1788	2	L-1200
	3360 @ 1600	2300	4	
				Terex
160 @ 2300	460 @ 1500	284	2	72-31B
231 @ 2300	690 @ 1400	426	2	72-51B
307 @ 2300	920 @ 1600	568	2	72-61
388 @ 2100	1186 @ 1400	736	2	72-71B
434 @ 2100	1295 @ 1400	852	2	72-81

Note: At any time, different engine options may be available.

Note: A * beside any machine model number denotes the availability of a comparable Cummins engine.

A

POWER TRAIN

Model	Torque Converter Make	Torque Converter Type	Ratio	Transmission Make	Transmission Type
J. I. Case					
W24C		Twn Turb w/Trans	4.92:1		Pwrshft
W36		1 Stge w/Trans	2.70:1		Pwrshft
Caterpillar					
950		1 Stge, 1 Phse		Cat	Plntry Pwrshft
966C		1 Stge, 1 Phse		Cat	Plntry Pwrshft
980C		1 Stge, 1 Phse		Cat	Plntry Pwrshft
988B		Var Cap		Cat	Pwrshft
992C		Var Cap		Cat	Pwrshft
Clark					
75C	Clark	1 Stge	3.09:1	Clark	Cntrshaft Pwrshft
125C	Clark	1 Stge	2.91:1	Clark	Cntrshaft Pwrshft
175C	Clark	1 Stge	3.09:1	Clark	Cntrshaft Pwrshft
275C	Clark	1 Stge	3.05:1	Clark	Cntrshaft Pwrshft
475C	Clark	1 Stge or Turbo	2.96:1	Clark	Cntrshaft Pwrshft
675C	2 Clark	1 Stge	2.96:1	Clark	Cntrshaft Pwrshft
Dart					
600C	Clrk			Clrk	
DE620	G.E.	Elec Drv		G.E.	Elec Drv
Deere					
JD644-B		Twn Turb	4.92:1		Plntry Pwrshft
JD844		1 Stge	2.84:1		Plntry Pwrshft
Trojan (Yale)					
2000		Twn Turb	4.92:1		Plntry Pwrshft
2500			3.14:1		Pwrshft
3000					Pwrshft
5500		Twn Turb	4.7:1		Plntry Pwrshft
7500					Pwrshft
Elmac					
500		2 Stge, Twn Turb	4.60:1	Allison	Plntry Pwrshft
Fiat-Allis					
645-B		Twn Turb	5.05:1		Plntry Pwrshft
FR20		Twn Turb	4.67:1		Plntry Pwrshft
945-B		Twn Turb	4.7:1		Plntry Pwrshft
Ford					
A66		Twn Turb	4.6:1		Plntry Pwrshft
IHC					
530		1 Stge, 1 Phse	2.73:1		Pwrshft
540		1 Stge, 1 Phse	2.25:1		Cntrshft Pwrshft
H-90E		1 Stge, 1 Phse	2.60:1		Pwrshft
550		1 Stge, 1 Phse	2.12:1		Cntrshft Pwrshft
560	I.H.	1 Stge, 1 Phse	3.52:1	I.H.	Cntrshft Pwrshft
570		1 Stge, 1 Phse	4.72:1		Cntrshft Pwrshft
580		1 Stge, 1 Phse	3.83:1		Cntershaft/Plntry
Kawasaki					
KSS 70		3 Ele, 1 Stge	3.7:1		Pwrshft
KSS 80		4 Ele, 2 Stge	5.41:1		Pwrshft
952					
LeTourneau					
L-600		D.C. Elec Drv			
L-800		D.C. Elec Drv			
L-1200		D.C. Elec Drv			
Terex					
72-31B		2 Stge, 2 Phse, 4 Ele	4.80:1	Allison	Pwrshft
72-51B		2 Stge, 2 Phse, 4 Ele	4.92:1	Allison	Pwrshft
72-61		2 Stge, 2 Phse, 4 Ele	6.01:1	Allison	Pwrshft
72-71B		2 Stge, 2 Phse, 4 Ele	3.55:1	Allison	Pwrshft
72-81		2 Stge, 2 Phse, 4 Ele	3.2:1	Allison	Pwrshft

POWER TRAIN

Differential Type	Differential Ratio	Final Drive Type	Final Drive Ratio	Rear Axle Oscillation (°)	Rear Axle Vert Travel (in)	Model
						J. I. Case
Torq Propor		Plntry		11.5	16	W24C
Torq Propor		Plntry		12	17.5	W36
						Caterpillar
Conv		Plntry		15	21	950
Conv		Plntry		17	24.8	966C
Conv		Plntry		15	24	980C
Conv		Plntry		13	22	988B
Conv		Plntry		11	24.8	992C
						Clark
Torq Propor		Plntry		24	15	75C
Ltd-Slip		Plntry		24	15	125C
Ltd-Slip		Plntry		24	15	175C
Ltd-Slip		Plntry		24	11	275C
Ltd-Slip		Plntry		20	20	475C
Ltd-Slip		Plntry		16	22	675C
						Dart
	3.74:1	Plntry	7.50:1	26		600C
3 Reduction Carriers	5.87:1	Plntry	7.50:1	26		DE620
						Deere
F - No Spin, R-Conv				22	15	JD644-B
F - Conv, R-Conv				22	17	JD844
						Trojan (Yale)
Torq Propor		Plntry		12	18	2000
Torq Propor		Plntry		14	21	2500
Torq Propor		Plntry		14	21	3000
Torq Propor		Plntry		12	21	5500
Torq Propor		Plntry		12	21	7500
						Elmac
		Plntry		24		500
						Fiat-Allis
Torq Propor		Plntry		22	15	645-B
Torq Propor		Plntry		22	17	FR20
				22	18	945-B
						Ford
		Plntry		24		A66
						IHC
		Plntry		30	22	530
Conv		Plntry		26	20.5	540
		Plntry		30	23	H-90E
Conv		Plntry		30	26	550
		Plntry		30	26	560
Conv		Plntry		20	10.3	570
		Plntry		18	25	580
						Kawasaki
Spir Bvl, 1 Stge Reduc	5.57:1	Plntry	3.88:1	15		KSS 70
Spir Bvl, 1 Stge Reduc	6.17:1	Plntry	3.88:1	15		KSS 80
						95Z
						LeTourneau
				25		L-600
				25		L-800
				20		L-1200
						Terex
Spir Bvl, Pin & Ring	6.14:1	Plntry		11	16.5	72-31B
Spir Bvl, Pin & Ring	6.17:1	Plntry		11	17	72-51B
Spir Bvl, Pin & Ring	4.88:1	Plntry		11	18.5	72-61
Spir Bvl, Pin & Ring	5.62:1	Plntry		11	21	72-71B
Spir Bvl, Pin & Ring	4.10:1	Plntry		7	13.5	72-81

AUXILIARY SYSTEMS

Model	Tires Standard	Service Brakes Type	Parking Brakes Type
J. I. Case			
W24C	17.5 x 25 - 12PR	Air/Hyd Disc	
W36	20.5 x 25 - 16PR	Air/Hyd Disc	
Caterpillar			
950	20.5 x 25 - 12PR	Air/Hyd Disc	Mech Shoe on Trans Shaft
966C	20.5 x 25 - 12PR	Air Shoe	Service
980C	26.5 x 25 - 20PR	Air/Oil Disc	Disc on Drive Shaft
988B	65/35 x 33 - 24PR	Wet Disc	Disc-Drv Shaft
992C	6545 x 45 - 38PR	Wet Disc	Disc-Drv Shaft
Clark			
75C	20.5 x 25 - 12PR	Air/Hyd Disc	Mech Trans Shaft
125C	23.5 x 25 - 16PR	Air/Hyd Disc	Mech Trans Shaft
175C	26.5 x 25 - 20PR	Air/Hyd Disc	Mech F. Axle Shaft
275C	29.5 x 29 - 22PR	Air Shoe	Mech Disc F. Axle Shaft
475C	37.25 x 35 - 42PR	Air Shoe	Mech Disc F. Axle Shaft
675C	67 x 51SXT - 54PR	Hydraulic Disc	Hyd Disc F. Axle Shaft
Dart			
600C	37.5 x 39 - 36PR	Air/Hyd Shoe	Lock Gear on Imput Shaft
DE620	37.5 x 39 - 36PR	Elec-Dyn & Air/Hyd Shoe	Disc-Motor Shaft
Deere			
JD644-B	17.25 x 25 - 12PR	Wet Disc	Shoe on Trans Shaft
JD844	20.5 x 25 - 16PR	Wet Disc	Shoe on Trans Shaft
Trojan (Yale)			
2000	20.5 x 25 - 12PR	Air/Hyd Disc	Service
2500	23.5 x 25 - 12PR	Air/Hyd Disc	Mech on Prop Shaft
3000	23.5 x 25 - 16PR	Air/Hyd Disc	Mech on Prop Shaft
5500	26.5 x 25 - 20PR	Air	Service
7500	29.5 x 29 - 22PR	Air	Service
Elmac			
500	20.5 x 25 - 12PR	Wet Disc	Shoe on Trans Shaft
Fiat-Allis			
645-B	20.5 x 25 - 12PR	Air/Hyd	Mech Drum on Drv Shaft
FR20	23.5 x 25 - 16PR	Air/Hyd Disc	Mech Drum on Drv Shaft
945-B	29.5 x 29 - 22PR	Air/Hyd Disc	Drum Drive Shaft
Ford			
A66	20.5 x 25 - 12PR	Hyd Wet Disc	Disc
IHC			
530	20.5 x 25 - 12PR	Air/Hyd Disc	Drum
540		Air/Hyd Disc	Drum
H-90E	23.5 x 25 - 12PR	Air/Hyd Shoe	Mech on Drv Shaft
550	26.5 x 25 - 20PR	Air/Hyd Disc	Drum
560	29.5 x 29 - 22PR	Air/Hyd Shoe	Disc on Drv Shaft
570	6540 x 39 - 30PR	Air/Hyd Shoe	Disc on Drv Shaft
580	6550 x 51 - 46PR	Wet Disc	Service
Kawasaki			
KSS 70	20.5 x 25 - 12PR	Air/Hyd Disc	Mech-on Drv Shaft
KSS 80	23.5 x 25 - 12PR	Air/Hyd Disc	Mech-on Drv Shaft
95Z	26.5 x 25 - 24PR	Air/Hyd Disc	Mech-on Drv Shaft
LeTourneau			
L-600	33.25 x 35 - 32PR	Elec-Dyn & Air/Hyd Disc	Disc F. Wheel
L-800	37.5 x 39 - 36PR	Elec-Dyn & Air/Hyd Disc	Disc F. Wheel
L-1200	40.00 x 57 - 44 PR	Elec-Dyn & Air Disc	Disc F. Wheel
Terex			
72-31B	20.5 x 25 - 12PR	Air/Hyd Disc	Mech Shoe-Trans Shaft
72-51B	23.5 x 25 - 16PR	Air/Hyd Disc	Mech Shoe-Trans Shaft
72-61	26.5 x 25 - 20PR	Air Shoe	Service
72-71B	29.5 x 29 - 22PR	Air Shoe	Service
72-81	33.25 x 35 - 26PR	Air Shoe	Fr Whl Brakes

AUXILIARY SYSTEMS

Electrical		Steering					
Volts	AMPS	Max Angle (°)	Pump	GPM	Max. Psi	Cylinders	Model
							J. I. Case
24	40	40	Gear	21	2500	2x3" x 15"	W24C
24	40	40	Gear	34.9	2500	2x4" x 16.9"	W36
							Caterpillar
24		35	Vane	33.5	2500	2x4" x	950
24		35	Vane	40	2500	2x4" x	966C
24		35	Gear	72	2500	2x5" x	980C
24		35	Gear	101	2500	2x5" x	988B
24		35	Gear	185	2500	2x7" x	992C
							Clark
24	70/65	35	Gear	30	1600	2x4" x 16"	75C
24	50	35	Gear	73	1600	2x4" x 20"	125C
24	65/75	35	Gear	98	2000	2x5" x 18"	175C
24	75	35	Gear	86	2400	2x5" x 17"	275C
24	75	35	Gear	77/94	2000	2x6" x 24"	475C
24	75	35	Gear	164	2100	2x7" x 36"	675C
							Dart
24	100	40		126	1600	2x7" x 28"	600C
24		40		126	1600	2x7" x 28"	DE620
							Deere
12		40	Piston	26	2400		JD644-B
24		37	Vane	42	2250		JD844
							Trojan (Yale)
24	42	40	Gear	30	2500	2x4" x 13"	2000
24	42	40	Gear	39	2500	2x4" x 13"	2500
24		40	Gear	39	2500	2x4" x 13"	3000
24	42	35	Gear	78	2500	2x4" x 22"	5500
24	42	35	Gear	100	2500	2x5" x 24"	7500
							Elmac
12	51	45	Gear	18	2500	2x4" x 15"	500
							Fiat-Allis
24	30	45	Gear	18		2x3" x 19"	645-B
24	45	45	Gear	34.5		2x4" x 21"	FR20
24	45	45	Gear	55		2x5" x 21"	945-B
							Ford
12		45	Gear	18	2500	2x4" x 15"	A66
							IHC
24		35	Gear	17		2x3" x 16"	530
24		35	Gear	42		2x4" x 17"	540
24		35	Vane	41.5	2500	2x4" x 17"	H-90E
24		35	Gear	37	3000	2x4" x 17"	550
24		35	Gear	58	2500	2x5" x 19"	560
24		40	Gear	64	3000	2x6" x 22"	570
24		40	Gear	130	3000	2x8" x 26"	580
							Kawasaki
12	24	38	Gear	25.6	2490	2x3" x 14"	KSS 70
24							KSS 80
24	50						95Z
							LeTourneau
24		45		90	1800	2x7" x 30"	L-600
24		45		110	1800	2x7" x 30"	L-800
24		42		140	2200	2x8" x 30"	L-1200
							Terex
24	50	35	Piston	19.4	2000	2x4" x 17"	72-31B
24	50	37	Piston	37	2000	2x5" x 15"	72-51B
24	50	37	Piston	37	2000	2x5" x 15"	72-61
24	50	40	Gear	77	2000	2x6" x 29"	72-71B
24	50	40	Gear	96	2000	2x6" x 29"	72-81

OPERATIONAL SPEEDS

Model	Bucket Raise (L)	Bucket Dump (L)	Bucket Lower	Total
	Hydraulic Cycle Times - Seconds			
J. I. Case				
W24C	6.3	1.9	2.8	11.0
W36	6.7	2.0	5.4	14.1
Caterpillar				
950	6.2	1.8	3.1	11.1
966C	6.2	1.6	3.8	11.6
980C	7.3	2.0	3.4	12.7
988B	9.4	3.0	4.5	16.9
992C	12.0	2.5	4.0	18.5
Clark				
75C	7.1	1.3	3.5	11.9
125C	7.4	1.2	3.2	11.8
175C	6.7	2.0	4.2	12.9
275C	8.7	2.1	6.0	16.8
475C	12.0	3.4	5.8	21.2
675C	12.0	6.5	2.5	21.0
Dart				
600C	10.5	3.8	5.3	19.6
DE620				
Deere				
JD644-B	6.6	1.8	4.5	12.9
JD844	7.0	2.0	4.0	13.0
Trojan (Yale)				
2000	6.6	2.7	5.3	14.6
2500	6.3	2.7	4.9	13.9
3000	6.8	2.7	4.7	14.2
5500	8.2	2.5	6.9	17.6
7500	8.8	2.5	7.0	18.3
Elmac				
500				
Fiat/Allis				
645-B	6.5	3.0	4.8	14.3
FR20	6.5	2.6	4.6	13.7
945-B	7.7	3.6	4.9	16.2
Ford				
A66	6.7	1.6	3.2	11.5
IHC				
530	6.5		4.7	
540	7.0		5.7	
H-90E	7.9	3.8	5.6	17.3
550	7.1	2.0	5.6	14.7
560	9.2		6.9	
570	10.1		5.0	
580	17.4		8.0	
Kawasaki				
KSS 70	6.2	1.8	3.8	11.8
KSS 80	6.8	2.0	3.8	12.6
95Z	7.0	1.3	4.8	13.1
LeTourneau				
L-600	11.0	3.0	7.5	21.5
L-800	14.0	3.0	7.0	24.0
L-1200	13.0	3.0	7.0	23.0
Terex				
72-31B	5.8	1.7	3.2	10.7
72-51B	7.0	2.5	4.3	13.8
72-61	6.5	2.6	4.2	13.3
72-71B	10.0	2.4	4.4	16.8
72-81	11.6	3.2	5.5	20.3

Note: Engine and transmission options may produce different Hydraulic cycle times.

OPERATIONAL SPEEDS

Propel-Forward - mph 1st	2nd	3rd	4th	Propel-Reverse - mph 1st	2nd	3rd	4th	Model
								J. I. Case
2.6	6.5	11.4	22.2	3.6	8.7			W24C
3.4	7.1	11.8	20.3	3.4	7.1	11.8	20.3	W36
								Caterpillar
4.4	7.9	13.5	22.3	5.3	9.5	16.1	26.4	950
4.8	8.5	14.3	23.6	5.7	10.2	17.0	28.0	966C
4.0	7.1	12.4	21.5	4.6	8.1	14.2	24.6	980C
4.0	7.2	12.7	22.5	4.6	8.2	14.5	25.7	988B
4.3	7.5	13.1		4.7	8.3	14.5		992C
								Clark
3.8	7.2	12.5	21.3	3.8	7.2	12.5	21.3	75C
3.1	5.8	10.0	17.5	3.1	5.8	10.0	17.5	125C
3.9	6.9	11.5	20.4	3.9	6.9	11.5	20.4	175C
4.2	7.4	12.5	21.5	4.2	7.4	12.5	21.5	275C
3.4	6.1	10.6	18.3	3.4	6.1	10.6	18.3	475C
4.3	7.0	11.4	18.1	4.3	7.0	11.4	18.1	675C
								Dart
4.9	8.8	15.0		4.9	8.8	15.0		600C
7.0	15.0			7.0	15.0			DE620
								Deere
3.3	7.7	11.8	25.4	3.6	8.3			JD644-B
4.5	7.9	13.3	23.4	4.9	8.8	14.7		JD844
								Trojan (Yale)
2.4	5.7	9.1	20.8	3.2	7.7			2000
3.7	7.1	11.5	21.0	3.7	7.1	11.5	21.0	2500
4.0	7.2	12.5	21.9	4.0	7.2	12.5	21.9	3000
2.8	6.0	10.5	20.2	3.0	6.6	11.5	22.1	5500
3.7	6.6	11.3	19.5	3.7	6.6	11.3	19.5	7500
								Elmac
6.0	21.0			8.0				500
								Fiat-Allis
3.0	6.5	11.7	23.0	2.9	8.8			645-B
2.5	6.0	9.3	20.5	2.7	6.5	10.2	22.2	FR20
2.6	5.1	9.6	20.0	2.8	5.6	10.5	21.9	945-B
								Ford
6.0	21.0			8.0				A66
								IHC
4.8	8.9	22.7		5.2	9.6	24.6		530
4.2	7.8	19.8		4.6	8.4	21.2		540
4.6	8.3	17.3	31.7	4.6	8.3	17.3	31.7	H-90E
4.2	7.6	20.8		4.2	7.6	20.8		550
4.8	8.3	22.2		4.8	8.3	22.2		560
9.1	22.6			9.1	22.6			570
5.10	9.4	17.9		5.1	9.4	17.9		580
								Kawasaki
5.0	9.3	15.2	24.2	5.0	9.3	15.2	24.2	KSS 70
7.0	7.0	22.4	22.4	8.4	8.4	22.4	22.4	KSS 80
6.8	6.8	21.1	21.1	8.7	8.7			95Z
								LeTourneau
Electric - Variable to 15.0				Electric - Variable to 15.0				L-600
Electric - Variable to 15.0				Electric - Variable to 15.0				L-800
Electric - Variable to 12.0				Electric - Variable to 12.0				L-1200
								Terex
2.8	5.9	9.4	18.0	3.3	7.7			72-31B
3.0	6.4	8.4	18.0	3.2	7.0	8.8	19.0	72-51B
2.8	7.0	10.6	23.5	3.1	7.8	11.5	26.5	72-61
4.4	8.5	15.1		4.1	7.9	14.2		72-71B
4.9	9.0	15.0		5.9	10.8	17.0		72-81

Note: Engine and transmission options may produce different Operational speeds.

A

HYDRAULIC SYSTEM

Model	Pump Type	Pump GPM	Pump Max-Psi	Cylinders (No - Dia x Stroke) Lift	Cylinders (No - Dia x Stroke) Tilt
J. I. Case					
W24C	Gear	52	2300	2x5" x 35"	2x5" x 29.5"
W36	Gear	113.3	2500	2x6" x 36"	2x5" x 40"
Caterpillar					
950		60.5	2200	2x6" x 34"	2x6" x 18"
966C		90	2200	2x7" x 36"	2x6" x 19"
980C	Gear	123	3000	2x8" x 32"	2x6" x 23"
988B	Gear	163.4	3000	2x9" x 45"	2x8" x 29"
992C	Gear	256	3250	2x12" x53"	2x10" x 36"
Clark					
75C	Gear	50	2500	2x5" x 35"	2x5" x 16"
125C	Gear	87	2250	2x6" x 39"	2x5" x 25"
175C	Gear	145	2200	2x7" x 43"	2x6" x 24"
275C	Gear	130	2200	2x9" x 45"	2x7" x 26"
475C	Gear	217	2700	2x11" x 58"	2x9" x 33"
675C	Gear	500	2750	4x11" x 72"	2x11" x 55"
Dart					
600C		477	2000	2x10" x 72"	2x10" x 41"
DE620		421	2050	2x10" x 72"	2x9" x 41"
Deere					
JD644-B	Gear	58.2	2250	2x6" x 26"	1x6" x 32"
JD844	Vane	94.5	2250	2x8" x 34"	1x8" x 39"
Trojan (Yale)					
2000	Gear	60	2500	2x6" x 32"	2x6" x 30"
2500	Gear	91	2500	2x6" x 32"	2x6" x 30"
3000	Gear	100	2500	2x7" x 33"	2x6" x 30"
5500	Gear	120	2500	2x9" x 34"	2x6" x 38"
7500	Gear	150	2500	2x9" x 41"	2x7" x 40"
Elmac					
500	Gear	72	2500	2x6" x 28"	2x7" x 34"
Fiat-Allis					
645-B	Gear	71	1825	2x6" x 33"	2x6" x 37"
FR20	Gear	91	2000	2x7" x 36"	2x6" x 40"
945-B	Gear	135	2250	2x9" x 38"	2x7" x 50"
Ford					
A66	Gear	54	2500	2x6" x 28"	1x7" x 34"
IHC					
530	Gear	62.5	2750	2x6" x 34"	2x7" x 20"
540	Gear	82	2750	2x6" x 38"	2x7" x 22"
H-90E	Vane	98	2500	2x7" x 39"	2x8" x 21"
550	Gear	101	3000	2x7" x 39"	1x8" x 22"
560	Gear	172	2500	2x9" x 48"	2x10" x 28"
570	Gear	214	3000	2x9" x 65"	1x12" x 32"
580	Gear	320	3000	2x15" x 65"	2x15" x 49"
Kawasaki					
KSS 70	Gear	44.9	2490	2x6" x 30"	2x6" x 16"
KSS 80	Gear	58.7	2490	2x6" x 33"	2x6" x 17"
95Z					
LeTourneau					
L-600		220	2200	2x11" x 51"	2x11" x 23"
L-800		350	2000	2x12" x 64"	2x11" x 30"
L-1200		480	2250	2x14" x 79"	2x12" x 39"
Terex					
72-31B	Gear	59	2500	2x6" x 30"	2x5" x 28"
72-51B	Gear	90	2500	2x7" x 35"	2x6" x 36"
72-61	Gear	125	2500	2x8" x 37"	2x7" x 38"
72-71B	Gear	134	2500	2x8" x 56"	2x7" x 29"
72-81	Gear	178	2500	2x10" x 54"	2x8" x 30"

SERVICE CAPACITIES - GALLONS

Model	Hydraulic System	Hydraulic Tank	Fuel Tank	Cooling System
J. I. Case				
W24C	35		58	6.75
W36	56	36.5	88	17
Caterpillar				
950	41	29	53	7.5
966C	52	27	65	13
980C	55	33	105	21
988B		62	165	28
992C		143	300	36
Clark				
75C	60	50	70	11
125C	87	76	75	18
175C	124	103	124	20
275C	163	136	165	26
475C	248	150	273	68
675C	650	400	500	2 x 61
Dart				
600C	316	212		
DE620	228	124		
Deere				
JD644-B		17.5	56	12.25
JD844		50	100	20
Trojan (Yale)				
2000		42	55	20
2500		50	76	16
3000		50	76	19
5500		65	129	28
7500		80	146	32
Elmac				
500	62	50	50	9.75
Fiat-Allis				
645-B		47	55	10.5
FR20		58	110	20.3
945-B	144		160	25
Ford				
A66	62	50	50	9.75
IHC				
530	27		60	7.5
540	34		80	16
H-90E	45		97	18
550	59		135	16
560	95		155	24
570	126		270	38
580	126		525	94
Kawasaki				
KSS 70				
KSS 80				
952				
LeTourneau				
L-600	145		230	35
L-800	235		390	55
L-1200	350		650	90
Terex				
72-31B	32	21	60	10
72-51B		24	90	20
72-61		33	125	22
72-71B	80	62.5	180	24
72-81	104	62.5	200	26

Note: Service capacities may vary depending on engine option.

FUEL CONSUMPTION (GPH)

Model	Operating Conditions Easy	Average	Severe
J. I. Case			
W24C	2.63	2.93	3.51
W36	5.3	6.1	7.40
Caterpillar			
950	3.4	4.6	6.3
966C	4.5	6.2	8.4
980C	6.2	8.5	11.6
988B	9.6	13.2	18.0
992C	16.2	22.2	30.3
Clark			
75C			
125C			
175C			
275C			
475C			
675C			
Dart			
600C			
DE620			
Deere			
JD644-B	2.78	4.92	8.39
JD844	4.08	7.71	10.29
Trojan (Yale)			
2000			
2500			
3000			
5500			
7500			
Elmac			
500			
Fiat-Allis			
645-B			
FR20			
945-B			
Ford			
A66			
IHC			
530			
540			
H-90E			
550			
560			
570			
580			
Kawasaki			
KSS 70			
KSS 80			
95Z			
LeTourneau			
L-600	14.0	16.0	18.0
L-800	24.0	26.0	28.0
L-1200			
Terex			
72-31B		4.4	
72-51B		6.4	
72-61		8.6	
72-71B	8.1	10.5	12.8
72-81	9.1	11.7	14.3

APPENDIX B

LIST OF FRONT-END-LOADER MANUFACTURERS
(Distributed in the United States)

	Wheel Mounted	Crawler Mounted
J.I. Case Company 700 State Street Racine, Wisconsin 53404	0.5 to 4 yd^3 32 to 185 FWHP*	0.75 to 2.25 yd^3 39 to 140 FWHP
Caterpillar Tractor Co. 100 NE Adams Street Peoria, Illinois 61629	1 to 12.5 yd^3 65 to 690 FWHP	1 to 5.5 yd^3 62 to 275 FWHP
Clark Equipment Co. Construction Machinery Division P.O. Box 547 Benton Harbor, Michigan 49022	1.5 to 36 yd^3 100 to 1316 FWHP	
Dart Truck Company 1301 Chouteau Trafficway Kansas City, Missouri 64141	7 to 23 yd^3 700 to 860 HP	
John Deere & Company John Deere Road Moline, Illinois 61265	1.25 to 7 yd^3 72 to 260 FWHP	.75 to 3.25 yd^3 42 to 200 FWHP
Trojan Industries, Inc. Trojan Circle Batavia, New York 14020	1.5 to 9.5 yd^3 to 389 FWHP	
Elmac Corporation Division of Eagle Picher Drawer 2848 Huntington, West Virginia 25728	1.5 to 3 yd^3 97 to 157 HP	
Fiat-Allis Construction Machinery, Inc. Box F, 106 Wilmot Road Deerfield, Illinois 60015	1.5 to 6.5 yd^3 80 to 335 FWHP	1.625 to 3 yd^3 88 to 150 FWHP
Ford Tractor Operations 2500 E. Maple Road Troy, Michigan 48084	1.5 to 3 yd^3 92 to 146 FWHP	

*FWHP = flywheel horsepower

	Wheel Mounted	Crawler Mounted
International Harvester Corporation Pay Line Group 600 Woodfield Avenue Schaumburg, Illinois 60196	0.59 to 22+ yd^3 51 to 1075 FWHP	0.75 to 3.25 yd^3 44 to 190 FWHP
Kawasaki Heavy Industries, Ltd. Construction Machinery Manufacturing Division Sumitomo Corp. of America 345 Park Avenue New York, New York 10022	1.5 to 6 yd^3 67 to 305 FWHP	
Komatsu Limited No. 3-6, 2-Chome Akasaka, Minato-Ku Tokyo, Japan		0.5 to 4.3 yd^3 35 to 240 FWHP
Marathon LeTourneau Co. Longview Division P.O. Box 2307 Longview, Texas 75601	8 to 30 yd^3 525 to 1200 HP	
Volvo BM AB Eskilstuna Sweden	1 to 3 yd^3 59 to 128 FWHP	

APPENDIX C

TIRE MANUFACTURER LIST

B. F. Goodrich Company
Tire Division
500 S Main Street
Akron, Ohio 44318

The Firestone Tire & Rubber Company
1200-T Firestone Parkway
Akron, Ohio 44317

The General Tire & Rubber Company
One General Street
Akron, Ohio 44329

The Goodyear Tire & Rubber Company
1144-T E. Market Street
Akron, Ohio 44316

Michelin Tire Corporation
Lake Success, New York 11040

Toyo Tire Corporation
3136 E. Victoria Street
Compton, California 90221

Uniroyal, Inc.
1230 Avenue of the Americas
New York, New York 10020

United Tire & Rubber Co., Ltd.
275 Belfield Road
Rexdale, Ontario, Canada

TIRE MODELS

Loader/Dozer Code	L-2	L-3	L-4
Tire & Rim Assoc. Tread Design Type Code	**Traction**	**Rock**	**Rock Deep Tread**
B.F. Goodrich	power traction - super traction wide base	rock service universal	rock service high tread
Firestone	super groundgrip conventional & wide base	super rock grip	super rock grip deep tread conventional & wide base
General	LD - LD all duty wide base	LD ND LCM	LD ND super LCM - LD 150 belted
Goodyear	sure grip lug D&L	super hard rock lug D&L - super hard rock lug 8 D&L - super hard rock loader	super hard rock lug 8 D&L - super hard rock lug XT D&L - nylosteel xtra tred D&L belted
Michelin	XR type A	XR DN type A	XRDI type A
Toyo	G-15	G-18	G-64 ET G-18 ET
Uniroyal	Design A - Design B	Design C S.R.T. - Design D S.R.T.	Super Con-Trak-T - S.R.T.
United			super mining construction wide profile

TIRE MODELS

Loader/Dozer Code	L-5	L-3S	L-4S	L-5S
Tire & Rim Ass. Tread Design Type Code	**Rock Extra Deep Tread**	**Smooth Regular Tread**	**Smooth Deep Tread**	**Smooth Extra Deep Tread**
B.F. Goodrich	rock service extra high tread			
Firestone	super deep tread			half tread - plain tread
General	LD 250 belted			LD 250 super smooth
Goodyear	super hard rock lug - super xtra dual tred - nylosteel super xtra tred belted			smooth - 5A - AMS - 5/8B
Michelin	XRD2 type A			
Toyo	G-65 EDT - G-25 EDT			
Uniroyal				smooth miner
United	super extra mine haulage - super extra mine haulage half-track			

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APPENDIX D

<u>TABLES</u>

Table D - 1

UNIT CONVERSIONS

English Units		Metric Units
(This unit)	----------(times)----------------	(equals)
inch	0.0254	meter
feet	0.3048	meter
yard	0.9144	meter
mile	1.609	kilometer
inch^2	6.452	centimeter^2
feet^2	0.0929	meter^2
yard^2	0.836	meter^2
mile^2	2.590	kilometer^2
acre	0.4047	hectare
inch^3	16.38	centimeter^3
foot^3	0.0283	meter^3
yard^3	0.7646	meter^3
pint	0.473	liter
quart	0.946	liter
gallon	3.785	liter
short ton	0.907	metric ton
long ton	1.016	metric ton
short ton	907.180	kilograms
long ton	1016.050	kilograms
pound	0.4536	kilograms
pound/yard^3	0.5933	kilogram/meter^3
pound/yard^3	0.0005928	tons/meter^3
miles-per-hour	1.61	kilometer-per-hour
ton-mile-per-hour	1.459	ton-kilometer-per-hour
horsepower	0.746	kilowatts
horsepower	1.014	metric horsepower
foot-pound	0.1383	kilogram-meter
BTU	0.2520	kilogram-calorie
pounds-per-inch^2	0.0703	kilogram-per-centimeter^2
Fahrenheit	$(^{\circ}F-32)/1.8$	celcius
foot-per-second^2	0.3048	meter-per-second^2
(equals)	---------(divided by)-------------	(this unit)

Table D - 2

ENGLISH UNIT EQUIVALENTS

(This unit)	(times)	(equals)
mile	5,280	ft
mile	1,760	yds
ft	12	in
yds	3	ft
$mile^2$	640	acres
acre	43,560	ft^2
ft^3	7.48	gal
gal	231	in^3
gal	4	qts
oz	1.80	in^3
ft^3	1728	in^3
yds^3	27	ft^3
short ton	2000	lbs
long ton	2240	lbs
lbs	16	oz
BTU	778	ft-lbs
BTU	0.000393	HPH
BTU	0.000293	KWH
long tons	1.120	short tons
miles/hour	1.467	ft/sec
miles/hour	88.0	ft/min
HP	0.746	KW

METRIC UNIT EQUIVALENTS

(This unit)	(times)	(equals)
kilometer	1000	meter
meter	100	centimeter
centimeter	10	millimeter
$kilometer^2$	100	hectares
hectare	10,000	$meter^2$
$meter^2$	10,000	$centimeter^2$
$centimeter^2$	100	$millimeter^2$
$meter^3$	1000	liters
liter	1000	$centimeter^3$
metric ton	1000	kilograms
quintl	100	kilograms
kilograms	1000	grams
calorie	427	kilograms/meter
kilograms	0.97	atmosphere

Table D - 3

DECIMAL EQUIVALENTS

1/64 - 0.015625	11/32 - 0.34375	43/64 - 0.671875
1/32 - 0.03125	23/64 - 0.359375	11/16 - 0.68750
3/64 - 0.046875	3/8 - 0.3750	45/64 - 0.703125
1/16 - 0.0625	25/64 - 0.390625	23/32 - 0.71875
5/64 - 0.078125	13/32 - 0.40625	47/64 - 0.734375
3/32 - 0.09375	27/64 - 0.421875	3/4 - 0.750
7/64 - 0.109375	7/16 - 0.4375	49/64 - 0.765625
1/8 - 0.1250	29/64 - 0.453125	25/32 - 0.78125
9/64 - 0.140625	15/32 - 0.46875	51/64 - 0.796875
5/32 - 0.15625	31/64 - 0.484375	13/16 - 0.81250
11/64 - 0.171875	1/2 - 0.500	53/64 - 0.828125
3/16 - 0.1875	33/64 - 0.515625	27/32 - 0.843750
13/64 - 0.203125	17/32 - 0.53125	55/64 - 0.859375
7/32 - 0.21875	35/64 - 0.546875	7/8 - 0.8750
15/64 - 0.234375	9/16 - 0.56250	57/64 - 0.890625
1/4 - 0.250	37/64 - 0.578125	29/32 - 0.906150
17/64 - 0.265625	19/32 - 0.59375	59/64 - 0.921875
9/32 - 0.28125	39/64 - 0.609375	15/16 - 0.93750
19/64 - 0.296875	5/8 - 0.6250	61/64 - 0.953125
5/16 - 0.3125	41/64 - 0.640625	31/32 - 0.96875
21/64 - 0.328125	21/32 - 0.65625	63/64 - 0.984375

Table D - 4

GRADES

Grade in %	Grade in °	Grade in %	Grade in °
1	0° 34'	19	10° 45'
2	1° 9'	20	11° 19'
3	1° 43'	21	11° 52'
4	2° 18'	22	12° 24'
5	2° 52'	23	12° 57'
6	3° 26'	24	13° 30'
7	4° 0'	25	14° 2'
8	4° 34'	26	14° 34'
9	5° 9'	27	15° 7'
10	5° 43'	28	15° 39'
11	6° 17'	29	16° 10'
12	6° 51'	30	16° 42'
13	7° 25'	31	17° 13'
14	7° 58'	32	17° 45'
15	8° 32'	33	18° 16'
16	9° 5'	34	18° 47'
17	9° 39'	35	19° 17'
18	10° 12'		

Grade in °	Grade in %	Grade in °	Grade in %
1	1.75	11	19.44
2	3.49	12	21.26
3	5.24	13	23.09
4	6.99	14	24.93
5	8.75	15	26.80
6	10.51	16	28.67
7	12.28	17	30.57
8	14.05	18	32.49
9	15.84	19	34.43
10	17.63	20	36.40

Table D - 5

COMMON FORMULAE

Circumference of Circle (C) = 3.414 x diameter

Area of Circle (A) = 3.414 r^2

Area of Rectangle (A) = length x height

Area of Triangle (A)= 1/2 x base x height

Area of Sector of a Circle = area of circle x $\frac{\text{central angle}^\circ}{360^\circ}$

Area of Segment of a Circle = area of sector - enclosed area of triangle

Surface Area of Cylinder = 2 x end area x length x circumference

Surface Area of Cone = area of base x 1/2 circumference of base x slant height

Volume of Cone or Pyramid = 1/3 area of base x height

Volume of Cylinder = end area x length

Volume of Wedge = 1/2 area of base x height

Appendix E

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