LOGGING INDUSTRY RESEARCH ASSOCIATION
NEW ZEALAND

PROJECT REPORT

HYDRAULIC EXCAVATORS AS LOG LOADERS

– A REVIEW OF THE NEW ZEALAND SITUATION –

P.R. 25 1985

N.Z. LOGGING INDUSTRY RESEARCH ASSOCIATION (INC.)

P.O. Box 147 Rotorua. New Zealand

N.Z. Logging Industry Research Assoc. Inc.
Project Report No. 25
1985

HYDRAULIC EXCAVATORS AS LOG LOADERS

A review of the N.Z. situation

P.R. 25 1985

PREPARED BY : -

J.F. Langsford

N.Z. Forest Products Limited
(On secondment to N.Z. Logging Industry Research Association Inc.)

For information address the N.Z. Logging Industry Research Association (Inc.), P.O. Box 147, Rotorua, New Zealand.

- A C K N O W L E D G E M E N T S -

LIRA acknowledges the assistance provided by the many logging industry sources who supplied information for this project. Particular thanks are due to loader owners for supplying details about their machines and assisting wit visits to their operations. Thanks also to equipment suppliers for information on machine specifications and pricing.

TABLE OF CONTENTS

INDEX TO FIGURES

Page No.

SUMMARY

There is an increasing use of hydraulic excavators as log loaders. This study reviews their application in New Zealand.

There are some 20 excavator log loaders in operation. Most are in the 18-20 tonne size range and have had only minor changes for logging. Buckets have been replaced by rotating grapples, with the excavator hydraulics modified to suit. Cab guarding has usually been added. The loaders are typically used with small contract gangs producing around 20,000 m^3 annually. Machines are usually purchased second hand and commissioned at a cost of $50,000 to $100,000.

There are 10 excavator log loaders in each of North and South Islands. Main areas of use are Southland and Otago, with groups of machines also in the Wairarapa, Coromandel and North Auckland. These areas all have difficult winter ground conditions where tracked crane loaders are better suited to loading operations than rubber tyred front end loaders. Mobile loaders cut up skidsites and require heavily metalled surfaces on which to operate while excavator loaders are able to work on smaller skidsites and are competitive in terms of capital and operating costs. Fuel use is approximately half that of front end loaders of similar capacity. Operation of excavator loaders is easy and operator comfort good. The large population of excavators means the choice of new and used machines is wide, and parts and service back up good.

The grapple is the key to successful operation of excavator loaders. Choice in N.Z. is limited. Many users have experienced problems with grapple design and reliability but most are obtaining satisfactory results after modifications. It was found that the grapple types normally used on cranes on self loading trucks are too light for use on excavator loaders.

It is foreseen that demand for excavator loaders will increase and that potential for improved performance exists through availability of a wider range of grapples and greater excavator modification for log loading. Likely modifications include raised cabs, purpose built logging booms and the use of live heel attachments.

INTRODUCTION

Log loading operations are a vital link between extraction and transportation, contributing up to 25% of the harvest cost before transportation.

A previous LIRA report by Gordon (Ref. 1) outlines the loader options commonly available in New Zealand and identifies the factors influencing selection and application. Gordon's report identifies a trend from tracked, rope operated cranes to rubber tyred front end loaders. (RTFEL). In 1978, 61% of log loaders were RTFEL, and the log loader population (excluding self loaders) was estimated at 250 (Ref. 1). By the year 2000, the loader population is expected to be over 500 (from Ref. 2).

A predicted three-fold increase in harvesting activity by 2015 and dispersal of logging activity from the relatively easy pumice plateau region will have major effects on log loading requirements, and costs. Many regions where increased harvest activity will occur are notable for steep terrain and difficult ground conditions. This may require smaller landings and an increased use of crane type loaders, which suit small landings and cause less ground disturbance than mobile loaders.

Hydraulic excavators modified for log loading have gained popularity, particularly in the last 5 years and this type of machine may find wider application. Excavators are readily available, easily converted to log loading and cost competitive against RTFEL type. The objective of this study was to review the equipment in use, to detail applications, specifications and performance. Emphasis was placed on the machine performance, modifications required and grapple type.

Specifications of excavators on the market were compiled and analysed with emphasis on lift and reach capacities. An indication of machine cost by size range, for both new and used machines was obtained.

Enquiries were made to identify owners and locations of excavator loaders and visits were then made to most operations, to obtain details of machine specifications and performance. Discussions were held with users and other industry sources, to determine key factors in machine selection, modification and application.

Ref 1. 'Log Loaders, Criteria for Machine Selection and Application' by R.D. Gordon, PR15, 1981

Ref 2. 'Prediction of Machinery Requirements', V.F. Donovan 1982 LIRA Seminar Proceedings

1. EARLY EXPERIENCE WITH HYDRAULIC LOG LOADERS 1970-1980

1.1 Machines in Regular Use

From 1971 to 1975 N.Z. Forest Products Limited operated two Koehring Bantam log loaders. These were purpose built loaders, mounted on rubber tyred carriers. Mechanical reliability was poor and the machines were not considered successful.

Two contractors for the Dunedin City Council logging operations used Massey Fergusson MF450S excavators converted to log loaders for some years. These were 15 tonne tracked machines, fitted with Hiab type pulpwood grapples. More details are available in a LIRA report (Ref. 3). These machines operated from 1973 and 1976 until about 1980, but were limited by machine size, and lightweight grapples.

Two contractors in the Invercargill area were also using excavator log loaders from the mid 1970's onwards. Peter Keenan operated Ruston Bucyrus 20H and Priestman 120 loaders. Mike Carran operated a Hymac 580. Generally the converted excavator loaders used by these South Island contractors proved suitable for muddy ground conditions and low volume loading situations. Machines of this type are still used in these areas.

1.2 Machines on Demonstration

Around 1975 there was a surge of interest from industry and machinery distributors in trialling hydraulic excavator type log loaders. Four major machinery distributors equipped excavators as loaders and demonstrated them to potential customers. The following machines were trialled :

- Poclain LY80-2P (1976)

  This was an 18 tonne rubber tyred excavator fitted with a Poclain live heel and grapple. The grapple had full 360° rotation.

- Hitachi UH09 (1976)

  The Hitachi was a 21 tonne machine fitted with a Barko 160 grapple, having 280° rotation. It was briefly demonstrated in the Kaingaroa Forest.

Ref 3. LIRA Machinery Evaluation Report, Vol 4, No 1, 1979

- Bucyrus Erie 20H (1977)

  This loader was a 22 tonne tracked machine fitted with a Mar live heel and grapple. The grapple had full 360° rotation.

- Caterpillar 235 (1977)

  This was the largest machine demonstrated, at 40 tonnes. It was equipped with a Harricana grapple with 270° rotation. Further details of this machine are given in Ref. 4.

1.3 Trial Results

Generally the trials produced industry interest but no sales. The potential of this type of machine was recognised. They were capable of high production, easily operated and comfortable. The machines were faster and in many ways more efficient than the 30RB rope cranes commonly used, but also more expensive. Hydraulics were at the time viewed with distrust, and this was reinforced by unreliable or unsuitable grapples fitted to some of the machines. Reach of these hydraulic machines was considerably less than with rope cranes and there was resistance to changing traditional methods to suit a new type of loader. Thus sales were not made because of price, difficulties in fitting into landing systems, and maintenance problems, particularly of grapples.

The machines were converted back to excavators, but several grapples and live heel attachments from these trials are now in use on other excavator log loaders.

Ref 4. LIRA Machinery Evaluation Vol. 3, No. 4, 1978.

2. APPLICATION OF EXCAVATOR LOG LOADERS IN NEW ZEALAND

There are some 20 excavator based log loaders in New Zealand, with 10 in each of the North and South Islands. A typical excavator based log loader is shown in Figure 1. Table 1 shows the brands of excavators and grapples in use, and their locations. Main areas of use are Southland and Otago with pockets of machines around about Wairarapa, Coromandel and North Auckland. These are all areas with difficult winter ground conditions, and the ability of tracked cranes to work where RTFEL type machines cannot, has been a major reason for selecting excavator loaders. Low maintenance, and fuel economy are further reasons.

Most loaders in use are in the 18-20 tonne size range, and only minor alterations have been made for logging. These include cab guarding, fitting of a grapple, and hydraulic system changes to suit grapple operation. Two machines are fitted with live heel attachments. Machines in the 18-20 tonne range are popular because this size excavator is commonly available, and a convenient size for transportation (not requiring overweight permits).

Table 1 Excavator Log Loaders in New Zealand

Excavator	Mass (tonnes)	Grapple	Area
JSW Nikko RH6	17.5	-	North Auckland
Kobelco K907B	18.9	'Cashmore'	North Auckland
Hitachi UH07	18.3	Mar	Coromandel
Warner & Swasey	37.0	Harricana	Coromandel
JSW Nikko 45	12.0	-	Rotorua
JCB 8D	23.5	Poclain*	Rotorua
Hitachi UH07	18.3	Bell*	Taranaki
Hitachi UH083	18.5	'Havard'	Wairarapa
IHI IS 190	18.8	Hiab	Wairarapa
Kato HD750	20.0	Palfinger	Wellington
Mitsubishi 110	11.0	Hiab	Otago
Hitachi UH063	12.0	C & R 1000	Otago
Hitachi UH07	18.3	Hiab	Otago
JSW Nikko RH4	12.0	Hiab	Otago
Caterpillar 225	21.5	C & R 1500	Southland
Massey Fergusson 450S	15.6	Grab	Southland
Komatsu PC200	18.8	C & R 1500	Southland
Hitachi UH081	18.5	C & R 1000	Southland
Hitachi UH081	18.5	C & R 1000	Southland
JSW Nikko RH6	17.5	'Carran'	Southland

* Denotes live heel grapple attachment

Figure 1 Hydraulic Excavator Based Log Loader

Generally the machines are owned by logging contractors and used with gangs of 3 to 6 men. Production targets are relatively low, typically 20,000 m^3 annually so that low capital cost equipment is favoured. Most loaders in use have been purchased in used condition and commissioned at a cost (1985 equivalent) of between $50,000 and $100,000. Modification and grapple costs account for $10,000 to $25,000 of this total.

Seven loaders are used in gangs operated by companies, to supply their own timber requirements. Four loaders operate in gangs contracted to companies and most of the remainder operate in gangs on Forest Service contracts. Two operators have loading only contracts (hot deck). In many cases contracts call for tracked crane type loaders as this suits the management requirements of the forest. Smaller landings are possible, and less metal is required than with RTFEL machines, so cost is reduced. Non productive land area is decreased with small landings.

In a typical operation loaders clear timber from the landing area, sort and stack, and load trucks as required. Excavator loaders of 18-20 tonne are often capable of unloading three axle trailers of around 5 tonne. However the machines are at the limit of their capacity to do this, both in terms of lift height, and stability, so unloading is often avoided. Production is most often loaded out in short lengths and is transported by truck and 3 axle shorts trailer, or 'bailey bridge' trailer.

Five of the loaders operate with hauler extraction crews while the remaining gangs use crawler tractors or skidders for extraction. Four operations are in indigenous forest while the remainder are in exotic forest.

The most popular excavator brand used for log loading is Hitachi. Most brands in use were reported to be very reliable, with most maintenance and downtime attributed to the grapple and hoses. A wide range of grapple variants are in use but most fall into two class types, discussed in a later section.

3. Equipment Options and Modifications

This section deals with modifications to machines in use in New Zealand and also looks at modifications carried out in the U.S.A. and their potential here.

Excavator type log loaders are widely used in the Pacific North West of the U.S.A. (Fig. 2). Machines in this area are heavily modified for log loading and a wide range of equipment options are offered, both by excavator manufacturers, and firms specialising in logging attachments. Machine size and application is considerably different to that in New Zealand, but some ideas for modifications may be applicable here.

While most excavator log loaders in New Zealand have minimum changes for logging, i.e. guarding and grapple fitting, some have modifications to give better stability, greater lift height, and extended reach.

Figure 2 - Excavator Log Loader in U.S.A.

3.1 Basic Excavator

3.1.1 Undercarriage

Lifting capacity is usually determined by machine stability rather than hydraulic lift capacity. For this reason choice of excavator undercarriage for a loader is important. Most brands of excavators are available with either standard or long track frames, and track shoes of various widths. Most loaders in use have standard track frames. On a machine of 18-20 tonne size, standard track length is typically 4 m while the long crawler (LC) undercarriage is typically 4.3 metres long. On some machines track centres (width) is also increased for LC machines. Machine weight is increased by over a tonne with long crawlers while ground pressure is reduced, due to a larger bearing area. Machine stability is improved by increases in undercarriage width, length and weight.

The effect of undercarriage size on performance is covered further in a later section, but typically an LC machine has 15% extra lift capacity over both front and side compared to a loader with standard undercarriage. On new machines, the L.C. option may add 10-15% to purchase cost.

Track shoes are available in a range of sizes from 500 mm to 900 mm. On excavators in N.Z., 600 mm and 800 mm appear to be the preferred sizes on mid range excavators. Wider shoes give better flotation in muddy conditions, and also increase stability and thus lift capacity. Consideration should be given to transportation when increasing machine width. The maximum legal width on the road is 2.5 m. Many transporter low loaders are wider than this and operate on permanent overwidth permits. However, above 3.1 m overall width restrictions on movement become more severe, and often an MOT pilot vehicle is required. Track width usually determines overall width of a machine. Excavators of 18-20 tonne size on 800 mm track shoes are normally below 3.1 m wide, while excavators in the next size range (22-24 tonne) are normally above 3.1 m.

In the U.S.A. track 'gauge extenders' are commonly fitted to increase width and thus lifting capacity. Most U.S. excavator manufacturers offer an expanding width track, and about 30 to 40% of loaders on crawlers have this feature. Additional guarding is also sometimes fitted in the form of track recoil guards, and track guiding guards. Track counterweights may also be added, typically 1 tonne per side on a 40 tonne machine. An additional rear counterweight of 3 tonnes would also be common on this size machine, giving around 1.5 tonne extra lift at 6 m radius. Costs in N.Z. for such modifications are estimated at $6,000 for 1.0 m width extension, and $2,000/tonne for counterweighting.

3.1.2 Operators Cab

Main options for loader cabs are; a cab riser to improve visibility, and cab guarding. Most excavator loaders are equipped with cab guarding and in some cases this is extended to the rear of the excavator to protect the machinery.

Cab guarding is important particularly where used in conjunction with a hauler, where overhead guarding should also be included. When loading trucks loaders must approach closely because of limited reach and this increases the risk of being hit by a log. Department of Labour Bush Inspectors recommend or insist upon guarding. Several near miss situations are known of were logs have damaged the cab. Figure 3 shows a typical guarding installation.

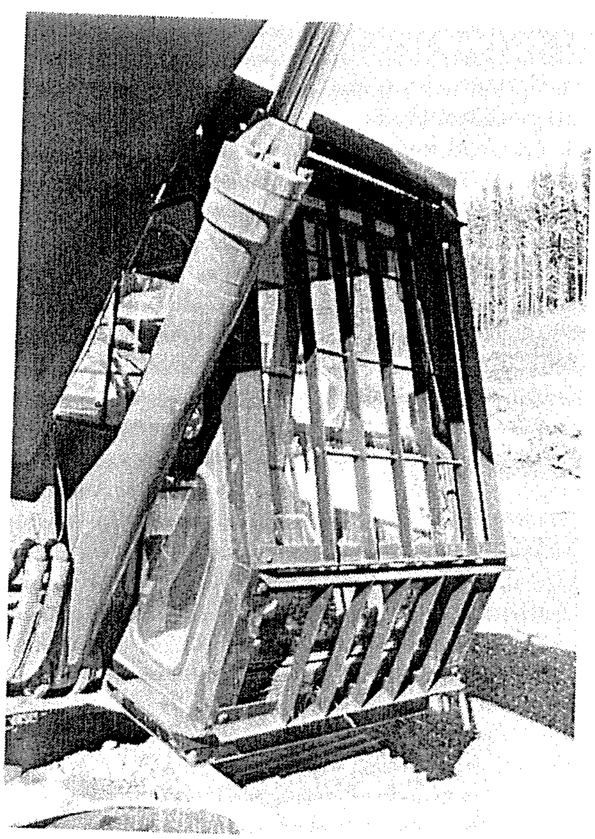

Figure 3 - Loader with Cab Guarding

None of the excavator loaders in use in New Zealand have raised cabs, but many operators felt there would be some benefit in having this feature. Cabs on excavators are quite low, with operator's eye level around 2.7 m above ground. Height to the top of a log load may be 4.0 m, and seeing to position top logs is frequently difficult. Many operators load off a bank to overcome this problem.

An increase in cab height of around 1 m greatly improves visibility and many excavators used as loaders in the U.S.A. have cab risers fitted. Estimated cost to raise a cab 1.0 m is around $6,000. Consideration should be given to transportation, before raising cabs. Height to top of cab is generally around 3.0 m and low loader deck height 1.0 m. Maximum legal height is 4.25 m. A 1.0 m cab riser would make the overall load height 5.0 m. A hinged top section to the raised cab would allow the loader to be more readily transported with permits.

3.2 Boom and Dipper Arm

Most excavators on the market have single piece main booms curved in a 'banana' shape. Some machines are equipped with variable position, two-piece booms. Due to boom shape and the height of grapples, lift height is reduced. A modification carried out by several users is to alter the main boom to give greater lift height. On the single piece boom this has been done by altering the attachment point of the boom cylinders. These normally attach to the boom centreline, but have been relocated to the underside of the boom. This gives increased lift at the grapple of about 1.5 m. One manufacturer offers this option on excavators used for clamshell operation. Care with boom stresses is necessary and bracing back to the original location point to utilise internal bracing is recommended as shown in Figure 4.

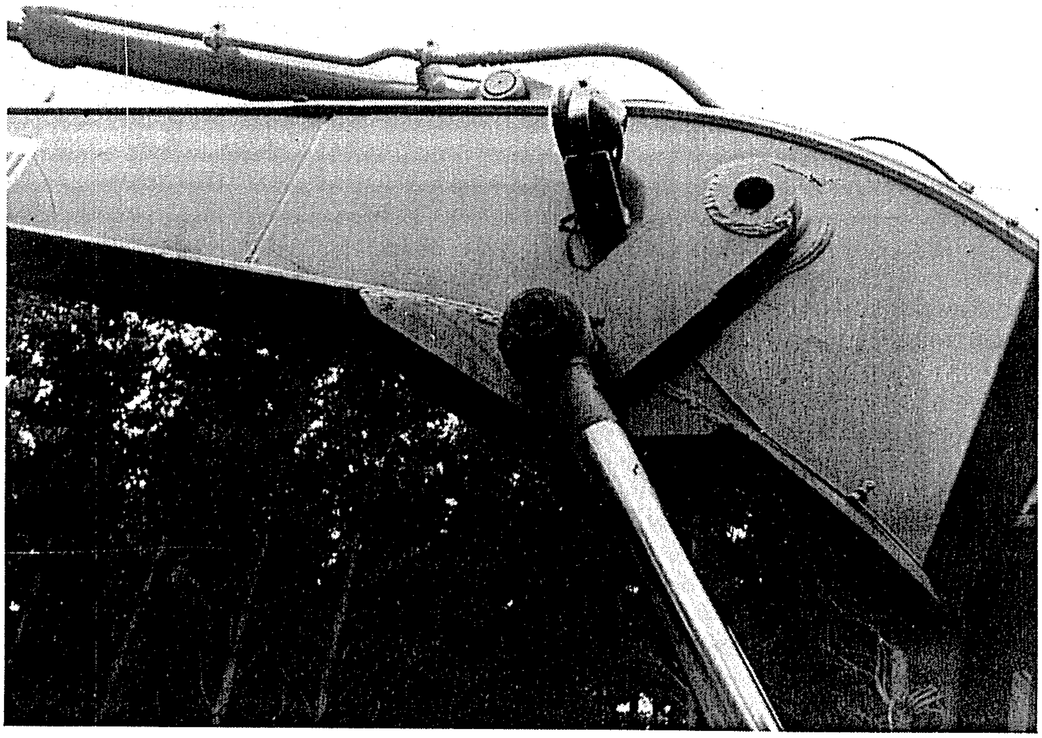

Figure 4 - Modification to Increase Lift Height

A method of increasing lift height on a two piece boom is to add a bracket between the first and second boom stages to remove the bend from the boom. This option is also offered by an excavator manufacturer for clamshell and crane application. This method is illustrated in Figure 5.

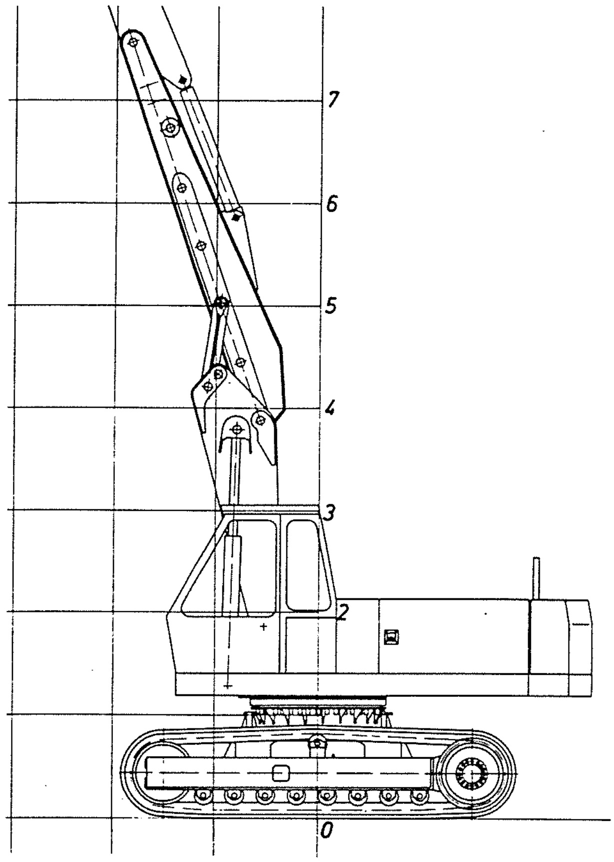

Figure 5 - Increased Lift Height, 2 Piece Boom

A range of dipper arms is offered with most excavators, e.g. short, standard and long. On an 18-20 tonne machine these are typically 2.2 m, 2.9 m and 3.5 m. Long dipper arms have generally proved most popular for log loading. A short dipper may be extended by a pinned, slip on extension. Over long dipper arms may cause high stresses and should be avoided.

A hydraulic cylinder is mounted to the top of the dipper arm to operate the excavator bucket. This cylinder is not required for log loading, but is often left in position so that the machine can be converted to earthmoving when required. Weight of cylinder and bucket linkage is approximately 250 kg and lift capacity is increased this amount if the cylinder is removed.

Most excavators used for log loading in the U.S.A. are fitted with booms and dipper arms especially designed for logging, as shown in Figure 2. Features of these are that the main boom is straight and the cylinder to operate the dipper arm is usually bottom mounted, which gives increased lifting power. When used without live heel attachments, dipper arms are generally longer than fitted to excavators. The cost of a purpose built logging boom with live heel and grapple to suit a 20 tonne machine is estimated at

$60,000 (N.Z. manufacture).

3.3 Grapples and Heeling Attachments

The grapple on a hydraulic loader is one of the most important influences on loading rate and machine availability. Because of past small demand for heavy duty grapples to suit excavator type machines, there are very few suitable grapples on the market. As a result many owners have started operation with unsuitable grapples and spent much time and money to obtain suitable shape and reliability. One New Zealand manufacturer, C. & R. Equipment Ltd of Christchurch, produces two sizes of grapple designed for large hydraulic loaders, such as excavator loaders.

In most cases in New Zealand, no heeling attachment is fitted to the boom. The excavator bucket is removed, and a grapple fitted via a clevis bracket. Grapples generally have 360° rotation. Many grapple variations are in use but most can be classified as one of two types. These are the three tine type, with side mounted rams, similar to the C. & R. type, or the wider pulpwood design with single horizontal ram, similar to the Hiab type.

Figures 6 and 7 illustrate grapples of the two types.

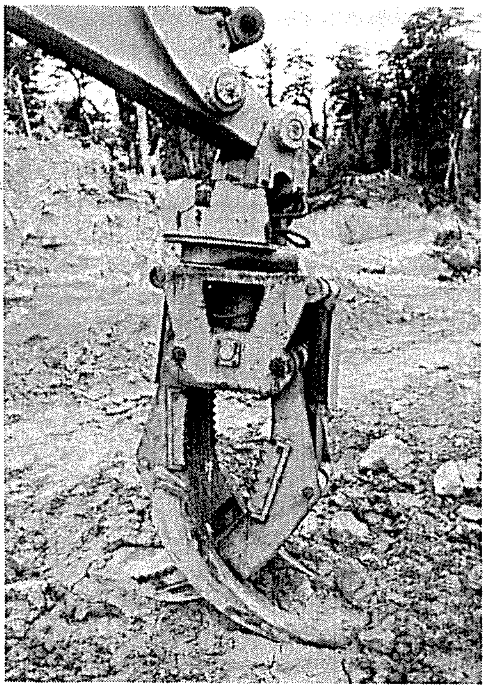

Fig 6 C & R '3 tine' type grapple

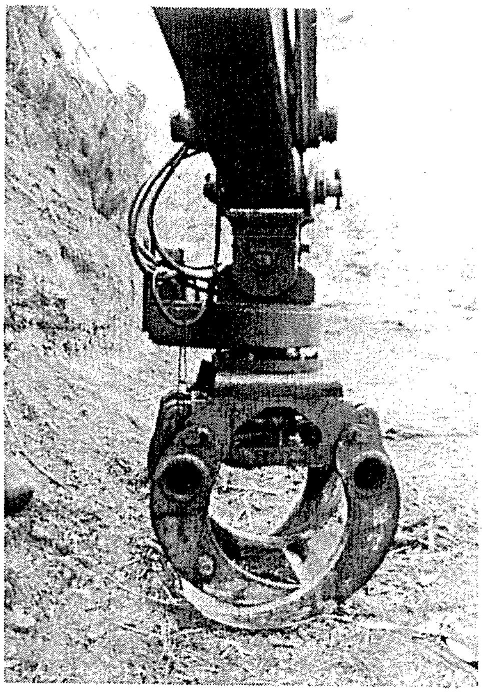

Fig 7 Hiab 'pulpwood' type grapple

The C & R type grapples are purpose built for excavator type loaders, while the Hiab type are designed for use on hydraulic cranes normally found on self loading trucks. Grapples on excavators generally experience higher loadings than on truck cranes and most pulpwood type grapples in use have been strengthened or modified. They are generally lighter in weight and less expensive than the three tine type. The latter is generally better suited to large single stems, while the pulpwood grapple handles multiple shorter stems better.

Most operations involve a mixture of log diameters and one grapple may be required to handle posts and large sawlogs. Many grapples have been modified to compromise. When handling multiple stems in a 3 tine grapple, logs tend to tip and become untidy. Some operators add short outriggers parallel to log direction to limit the amount that logs can tilt. The wider pulpwood grapple reduces the twisting effect of multiple stems due to its wider jaws and also its shape, which draws the logs upwards against the frame. The rounded jaw shape is however a disadvantage when attempting to select individual logs from a stockpile. To assist in this task some operators have welded tips on the bottom corners of each jaw. Logs are then picked up using grapple tips only.

A third type of grapple is the non rotating grab type. Only one is used in New Zealand, but they are popular in Australia, known as the 'Crab Grab'. The lower jaw is braced back to the dipper arm while the top jaw is pivotted by the dipper cylinder. A grab attachment is shown in Figure 8.

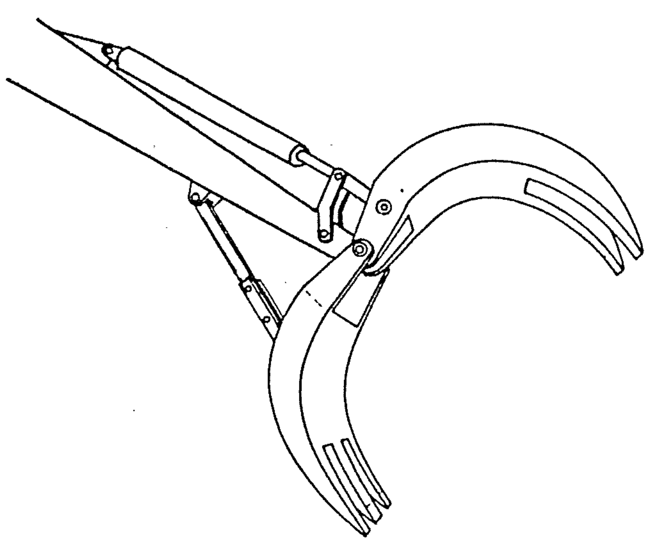

Figure 8 - Log Grab Attachment

Cost of log grabs is much less than rotating types and as is the maintenance, but operational versatility is lost.

A common problem with grapples is excessive oscillation. This makes it hard to accurately locate the grapple quickly and increases handling time. Excessive movement about the pin in the dipper arm may result in the grapple striking the underside of the arm, and damage in this area was observed on several loaders. Suitable stops, and oscillation dampers or 'snubbers' assist in overcoming these problems.

3.3.1 Heeling Attachments

Live heel attachments fit to the loader dipper arm and are pivoted by a hydraulic cylinder. The grapple is suspended from the front while a heeling rack is attached to the rear. Figure 2 shows a live heel. Most medium and large loaders used in the U.S.A. are fitted with live heels. In New Zealand only two operators use them. The major advantage of a heeling attachment is that logs may be picked up off-centre which effectively extends machine reach, and allows very long logs to be handled. Log control is enhanced and the option given of loading from front or rear of the truck as well as from the side.

Heel loading has the disadvantage that a heavier loader is required to load the same size timber compared to balance loading. This is because the centre of gravity of the log is further from the loader. Use of heel loading is particularly suited to large, long length timber. Most local hydraulic machines load short length timber and often handle multiple stems.

Another type of heeling attachment is the fixed heel. This is permanently fixed to the dipper arm. Normally a fixed (or 'dead') heel extends a metre or more below the dipper, several metres behind the grapple. As logs are lifted off centre they pivot until the inner end hits the heel rack and are then controlled. Fixed heels are sometimes pinned to allow stowing parallel to the dipper when not required.

3.4 Hydraulics for Grapple Operation

Fitting a rotating grapple requires one extra circuit (2 hoses) compared to bucket operation, while fitting a live heel and grapple requires two additional circuits. Most excavators are equipped with a spare implement circuit, but if not, or if two circuits are required then an additional pump and control system may be needed. It is recommended that hydraulic modifications be carried out by a company specialising in hydraulics and approved by the agents for the excavator.

3.4.1 Spare Circuit Available

In the case where only one extra circuit is required and the machine has one spare, conversion of excavator to log loader is relatively simple and inexpensive, costing $3,000 - $5,000. The hoses to the bucket cylinder are extended to the grapple and used for the closing circuit. Additional pipes and hoses are run from the control valve bank up the boom and dipper arm and used to operate the rotator. An extra control is fitted in the cab and connected to the valve bank. The control is usually a pivotting foot pedal, or a switch on one of the two main operating levers.

Extra valving is required to give the correct pressure and flow to the grapple. A schematic of a typical circuit for grapple adaption to an excavator implement circuit is shown in Figure 9.

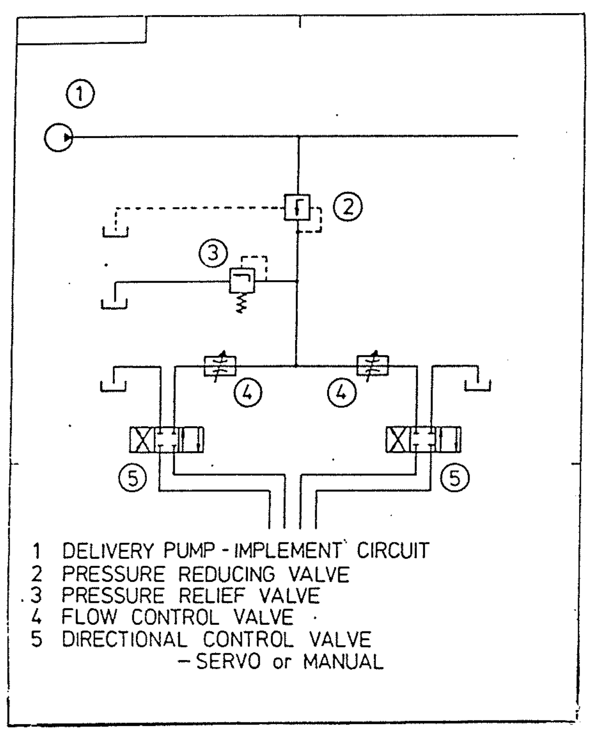

Figure 9 - Log Grapple Adaption Circuit

In addition a crossover relief valve (or cushion valve) should be fitted in the rotation circuit, (if not incorporated in the grapple rotator design). This valve prevents shock loads when a rotating load is brought to rest. Figure 10 shows a log grapple hydraulic circuit, including crossover relief for the rotator circuit. The figure also shows check valves on the grapple jaws to prevent them opening if hydraulic power is lost, a good safety feature.

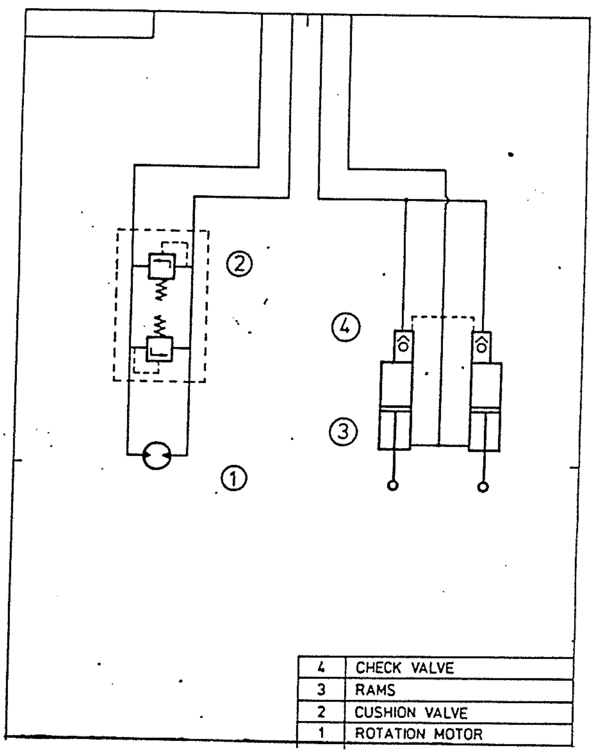

Figure 10 - Log Grapple Hydraulic Circuit

3.4.2 Insufficient Circuits

Where more circuits are required than are supplied on the excavator, additional circuits must be provided. This requires the supply of an extra pump, control valving, hoses and fittings. The modification then becomes more expensive and may cost in excess of $10,000. Selection of an excavator with a spare implement circuit is recommended.

3.5 Summary of Equipment Options

3.5.1 Excavator Options

When selecting an excavator for conversion to log loading the following basic machine options should be considered (ignoring considerations of machine size and brand).

(a) Undercarriage type :

Long track frames and wide track shoes are advantageous due to reduced ground disturbance and better stability, thus greater lift capacity. Machine weight is increased.

(b) Boom :

Single or two-piece booms are available. Modification for greater lift height is easier for a two-piece boom. The need for greater height is not common and more single piece booms are available.

(c) Dipper Arm :

A range of lengths are available. The longer length options are best suited to log loading.

(d) Hydraulic System

Hydraulic modifications for grapple operation are reduced in cost if the excavator chosen has a spare hydraulic circuit.

3.5.2 Grapple Options

The grapple is the key to efficient loader operation, but the choice available is limited. Four categories are available, the first two most commonly used in N.Z.

(a) Hiab type : Wide jaws, horizontal ram. Generally designed for truck cranes and only the heavier, strongest models may be suitable for excavator use. Particularly good for multiple small stems.

(b) C & R type : Narrow three tine type, side mounted rams. Generally designed for use on large loaders such as excavators. Tend to be heavier and more expensive than Hiab type. Particularly good for large single stems. Most common type used in U.S.A.

(c) Grab type : Non rotating. Low weight, low cost. Less loss of lift height than rotating type. Simple, but not as versatile as rotating type. One in use in N.Z., more in Australia.

(d) Vertical central ram type : Not commonly used.

3.5.3 Modification Options

In New Zealand grapple fitting and cab guarding are often the only changes made for log loading. In the U.S.A. a wide range of machine modifications are commonly carried out on excavators used for log loading. Many options are offered by manufacturers and dealers. Loader applications differ in the U.S.A. from New Zealand and generally high capital cost loaders are justified by high production situations. Larger log size and heel loading mean larger more heavily modified machines are used for loading.

A listing of some typical U.S.A. modifications follows :

(i) Undercarriage guarding
(ii) Track frame counterweights
(iii) Track width extension
(iv) Additional rear counterweights
(v) Raised cab
(vi) Cab guarding
(vii) Fit live heel attachment
(viii) Fit special logging boom and attachments

In New Zealand, modification options include :

(i) Raised cab
(ii) Cab guarding
(iii) Boom modification to increase lift height
(iv) Removal of bucket cylinder
(v) Fit sleeve to extend dipper arm
(vi) Fit grapple oscillation damper, or snubber.

4. Performance of Excavator Loaders

4.1 Lift and Reach Capacity

Specifications for five size ranges of excavator, from 10 to 30 tonnes, are summarised in Table 2, which provides typical lift and reach capacities for each size of machine.

Size Range	Horizontal[1] Reach (m)	Lift[1] Height (m)	Front[2] Lift (tonnes)	Side[2] Lift (tonnes)	Power (kw)
10-12 tonne	7.5	5.5	1.8	1.5	60
14-16 tonne	7.9	5.7	3.3	2.3	68
18-20 tonne	8.7	6.5	4.6	3.1	79
22-24 tonne	9.3	6.8	6.5	4.4	98
28-30 tonne	10.4	7.3	7.3	5.4	136

Notes : (1) Figures are for long dipper arm
(2) Figures do not exceed 75% tipping or 87% hydraulic lift. Figures are at 6m radius, ground level, with bucket fitted.

Table 2 - Lift and Reach by Size Range

Heights shown are maximum dump heights, which approximate height to bottom of grapple (i.e. 1.25 to 2.0 metres below dipper pivot pin). Reach figures are to the point of grapple suspension, i.e. the dipper pivot pin. Lift capacities are for machines fitted with buckets. Weight of bucket and hydraulic cylinder closely approximate grapple weight, (both range between 0.5 and 1.0 tonne), so that figures show approximate log lift capacity. The figures are based on 75% static tipping load, i.e. slightly greater lifts can be achieved.

Figure 11 shows lifting capacity for a 19 tonne excavator. This illustrates how capacity varies with working radius. The leading figures are for 360° rotation, and those in brackets for over the front of the machine. Capacities are shown in tonnes.

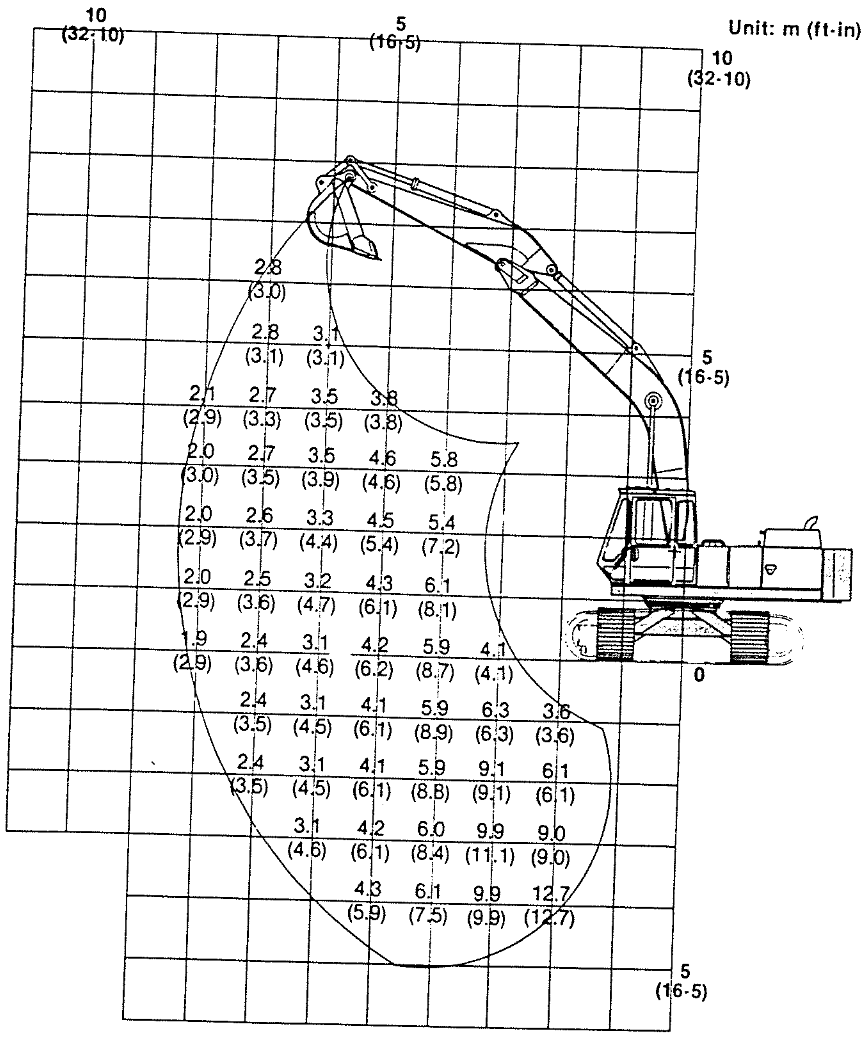

Figure 11 - 19 Tonne Excavator Lift Chart

The lift chart shows that while lift capacity over the front at 6 m radius is 4.6 tonnes, at 4 m radius this increases to 8.7 tonnes. However lift height at this radius reduces to below 4 m. This is why lifting 5 tonne trailers off trucks presents difficulties. Sufficient height cannot be obtained at small working radius. Lifting from a bank would allow trailers to be unloaded more easily. The chart also illustrates the relatively small useful working radius, i.e. from 3 to 8 metres from the machine centre line. This range increases when longer dipper arms are fitted. When long crawlers are fitted to the same machine, lift capacities are increased as follows :

	Side (tonnes)	Front (tonnes)
Standard crawler	3.1	4.6
Long crawler	3.5	5.3

This represents an increase of about 15% in lift. Similarly 800 mm track shoes fitted in place of 600 mm shoes increase lift by about 7%.

The increase in lift capacity between the 18-20 tonne size and 22-24 tonne size is dramatic and makes the larger machine suitable for heel loading applications in small timber sizes. For large second crop radiata the 28-30 tonne size machine would probably be required for heel loading.

4.2 Grapple Performance

As previously discussed, there are two general types of grapple in use. These are the side ram, 3 tine type (similar to C & R) and the horizontal ram, wide jaw pulpwood type (similar to Hiab). Table 3 lists some specifications for three models of grapples.

Grapple Detail	C & R 1000	C & R 1500	Hiab .4 m^2 (3406113)
Load Capacity	3500 kg[1]	5000 kg[1]	4000 kg
Grapple Weight	450 kg	1000 kg	350 kg
Max. Opening	1100 mm	1500 mm	1610 mm
Min. Opening	200 mm	300 mm	155 mm
Oil Pressure	17 MPa	17 MPa	16 MPa
Flow, Close	35-45 l/min	45-55 l/min	60 l/min
Flow, Rotate	5-10 l/min	5-10 l/min	35 l/min
Overall Height	1350 mm	2000 mm	1108[2]
Jaw Width	300 mm	300 mm	580 mm
Slew Speed	6 rpm	6 rpm	25 rpm
Approx. Price	$12,500	$19,000	$6,500

Note : (1) C & R capacities are for continous use. Maximum ratings are 5000 kg and 7500 kg respectively.

(2) With external rotator, height increases to 1350 mm approx.

Table 3 - Typical Grapple Data

The C &R 1000 and Hiab grapples are normally used for exotic timber, while the larger C & R 1500 grapples are used to handle large diameter indigenous timber. The Hiab model listed has an integral rotator, within the frame. Many Hiabs in use on excavator loaders have separate top mounted rotators and overall height is increased to around 1300 mm.

In operation, the three tine type are best suited to large single stems and the wide pulpwood type is best suited for smaller diameter multiple stems, and is significantly better at handling post material. Both types are successfully used to handle a wide range of log sizes, but have advantages in particular applications. Points added to the jaw corners of the pulpwood type allow single logs to be more easily picked out of stockpiles, while side extensions on 3 tine type limit log tilt when lifted off centre. Reliability of the three tine type was generally reported to be good. In contrast, many of the pulpwood grapples in use were reported to have experienced frequent problems, and some dramatic failures. Cracking of the grapple jaws and frame was common, and rotator problems were also reported. Two grapples had been fitted with heavier rotators, in both cases after dramatic failures. The addition of plating to the jaws and frame were normal. The pulpwood type are generally designed for machines less powerful than excavators, which can impose higher loadings while handling the same log size.

The routing of hoses to the grapple is important. Hose breakage between dipper and grapple is the cause of most grapple and loader downtime. Sufficient slack is required in the hoses to allow for grapple oscillation, but untidy routing leads to damage through catching on obstructions. Hose rubbing also creates flat spots where the hose may burst. On machines from which bucket cylinders have been removed, hoses are normally routed along the top of the dipper arm to the grapple. This makes for a neat installation, in which hoses are led over the end of the dipper to the grapple. Increased lift capacity is also gained by removal of bucket cylinder and linkage. If operations with both bucket and grapple are to be undertaken, hose routing down the side of the dipper arm is usual, which makes hoses vulnerable. Top routing is still possible and should be considered. Note should also be taken of oil heating. During grapple operation fluid may not return to the reservoir to be cooled and the use of steel tube down the boom and dipper arm may be advisable to avoid premature hose failure due to heat.

4.3 Log Loading Performance

The main productive duties carried out by log loading machines are :

- Clearing landed logs from extraction machine
- Sorting and stacking logs
- Unloading trailers from trucks
- Loading trucks

4.3.1 Clearing Logs, Sorting and Stacking

These functions are closely associated. Logs are removed from the landing and processing area and sorted into various log types which are then stacked in heaps for loadout. The variables affecting the processing and stacking functions are :

(a) Cycle time of extraction unit
(b) Volume of wood per extraction cycle
(c) The number of log sorts

The extraction machine determines haul cycle time and volume. Generally hauler cycle times are quicker than ground based machines, but drag size is smaller. The time available for processing is reduced, and if the loader is busy with a truck a pile-up can accumulate, whereas a tractor can normally fleet processed logs to one side.

The number of log sorts varies depending on employer but there is a trend to cutting more special log types, to maximise value. More log sorts require a greater area for stacking and more travel by the loader. It is common for up to 8 sorts to be required and in the case of a crane type loader this generally requires travel with load to some stacks. Crane type loaders are most effective when able to remain static, and with 5 sorts or less this is possible. Even with 8-10 sorts up to 75% of production may be in only 3-4 sorts, and loader shifts may be minimised by accummulating logs of lesser sorts before moving them to stacks. When loading out, the loader can position by a stack and need not travel. Excavator loaders are able to travel loaded more readily than most crane types at up to 4 km/hr. Older rope cranes can often travel at only 2 km/hr, cannot swing while travelling, and cannot counter- rotate tracks. Truck mounted cranes are not readily moved, as outriggers must be lifted, and the operator may have to change from crane cab to truck cab.

Operators of excavator loaders generally arrange stacks alongside the roadways so as to occupy minimum area. Rubber tyred loaders in contrast usually arrange piles around the landing edge with processing and loading areas in the centre. This layout is necessary to allow manoeuvring with logs, and requires a greater skid area. While on the pumice plateau skidsite preparation costs are of minor importance, this is not the case in steeper, wetter terrain with difficult soil types. Site preparation will be expensive and skids will need to be kept small. Also the cost of metalling skids will be significant as much metal will be required to allow rubber tyred loaders to operate, and metal may not be readily available. Small skidsites also mean less productive land is lost. The conflicting requirements of more log sorts and smaller landing size favour the use of excavator loaders which are space-efficient and able to work on smaller, less metalled skid sites.

4.3.2 Loading Trucks

Many logging trucks carry their empty trailers and require the log loader to offload the trailers. This takes little time but is often the heaviest mass the loader is required to lift. Two-axle trailers weight from 3 to 4 tonnes and three-axle trailers from 4 to 5 tonnes. The trailer unloading ability of excavator loaders is as follows :

10 - 12 tonne	unable to unload trailers
14 - 16 tonne	able to unload 2-axle trailers
18 - 20 tonne	able to unload 2 and 3-axle trailers

While the 18-20 tonne loaders can unload 3-axle trailers, they are at the limit of their lift capacity to do so, as to get sufficient height they must lift at about 6 m radius. If the excavator is raised, e.g. on a bank, then lift height can be obtained at a reduced radius, where lift capacity is greater.

When loading trucks, excavator loaders normally position beside a stockpile so that tracks are perpendicular to the truck, and slew angle when loading is 90°. In some cases 180° slew is necessary depending on stack location. Speed of loading is generally comparable to a rubber tyred front end loader, and 10 to 20 minutes to load a truck and shorts trailer is typical. Loading time depends largely on log diameter handled, being quicker for larger piece sizes. Operator skill is also significant. The time required to train an operator on an excavator loader is much less than for a rope crane, and also less than for rubber tyred loaders. The main skills involved are in grapple operation, log selection from stockpiles, and in building a good load. Due to restricted visibility operators normally try to build the far side of the load first, and sometimes load off a bank to improve vision. Grapple shape and amount of oscillation have a large effect on loading time. Excessive swing slows grapple positioning, and incorrect shape makes picking logs from a pile difficult. Shape also determines how many logs can be gripped at once, and whether logs splay apart when lifting slightly off centre.

Because excavator loaders are able to carry out loading operations with minimum machine movement they do not churn up skid sites in wet conditions. However where frequent loader shifting between skids is required the mobility of the rubber tyred loader is desirable, as transportation costs and delays affect profitability. Excavator loaders are well suited to operation with hauler gangs which tend to remain in one place longer, and where skid size is often limited. The ability of crane loaders to clear drags away from in front of the hauler to a processing area is also useful. Logs not fully landed on the skid can be pulled on, and congestion under the ropes avoided. The ready ability to rotate logs makes building tidy loads, with correct weight distribution, much easier than with rubber tyred loaders, where log rotation is an awkward manoeuvre.

5. COST OF EXCAVATOR LOADERS

There are a wide range of excavators available on the new and second hand markets. There are over 20 brands to choose from, and the market has been very competitive. The market for new machines has stabilised with several major brands handled by established distributors making most sales, and some brands disappearing from the market. An indication of typical excavator prices, new and second hand, is shown in Table 4 below. For use as log loaders no sales tax is payable so new prices shown are retail, less 9% sales tax. Prices are approximate only.

Size Range (tonnes)	New Excavator Price (less sales tax) $	Used Excavator Price 4000 hrs $
10 - 12	99,000	60,000
14 - 16	115,000	69,000
18 - 20	129,000	78,000
22 - 24	156,000	99,000
28 - 30	206,000	124,000

Table 4 - Typical Excavator Prices (March 1985)

Additional costs of equipping a machine for log loading include cab guarding, hydraulic modifications and grapple purchase. Indicative costs for these extra items are shown below.

Item	Estimated Cost
Cab guarding	$1,500
Hydraulic Modifications for Grapple	
a) using spare circuit	$5,000
b) adding one extra circuit	$10,000
Grapple Purchase	
i) Pulpwood type	$7,000
ii) Small 3 tine type (1.0m opening, 3 tonne lift)	$12,500
iii) Large 3 tine type (1.5m opening, 5 tonne lift)	$19,000
Live heel attachment (assuming use of bucket cylinder)	$6,000
Cab raised 1.0 m	$6,000

Typical conversion costs from an excavator to a log loader would be from $13,000 to $19,000 depending on grapple chosen, and assuming a spare hyraulic circuit was available for grapple rotation. At the other extreme, a machine fitted with raised cab, live heel and large grapple could cost $43,500 to convert.

The figures below compare the cost of an excavator log loader with a rubber tyred front end loader (RTFEL) or purpose built hydraulic loader (e.g. Barko, Prentice). Machines of U.S. origin have been chosen to avoid distortion due to currency values. Prices are as at March 1985 and include sales tax which is reclaimable. Machines are generally comparable in ability to carry out log loading functions. Two size ranges are shown.

Machine	Basic Cost $	Grapple & Hydraulics $	Total $
Caterpillar 215 Excavator (18T)	141,000	19,000	160,000
Caterpillar 950 RTFEL	211,000	18,500	229,500
Prentice 210 Log Loader	160,000	50,000 (truck)	210,000
Caterpillar 225 Excavator (22T)	183,000	19,000	202,000
Caterpillar 966 RTFEL	288,000	25,000	313,000
Prentice 410 Log Loader	220,000	50,000 (truck)	270,000

In the case of the Prentice, a nominal figure of $50,000 has been used to cover truck purchase and loader mounting ($5,000 approx.). As can be seen excavator loaders are the cheaper option.

In terms of operating costs, the crane type loaders are considerably more efficient in having to move a much smaller mass on each cycle. The RTFEL must transport its own weight plus the log weight over some distance, where the crane rotates the log weight only. The cranes therefore have smaller power requirements and are able to operate at part throttle, constant engine speed. Fuel consumption for excavator loaders is reported to be less than half that for an equivalent RTFEL by owners who have operated both. This is a factor of increasing importance. The crane type loader with less rigorous duty cycle can be expected to have a longer service life. On average crane loaders are kept twice as long as RTFELs, and this may apply with excavator loaders. The excavator loader (or any tracked machine) suffers transportation costs and delays when moving skid sites and this is a major factor in favour of the RTFEL, or truck mounted loader. A typical excavator loader shift by transporter costs $150-$200 depending on distance, whereas over shorter distance RTFELs can readily transport themselves.

With a trend towards limited scale logging and small contract size (20-30,000 m^3 annually) the cost of new equipment for small contractors can be difficult to finance. Here the ready availability of second hand excavators at relatively low prices is a major reason for their selection. Price of similar capacity RTFEL and excavator loaders at 5000 hours would be in similar ratio to new price, e.g. $115,000 for Cat. 950 and $80,000 for Cat. 215. As yet there are no purpose built hydraulic log loaders on the second hand market. Two Prentice 410 truck mounted loaders have recently commenced work in the Kinleith forests, used mainly for the cold deck loadout of thinnings. These machines are very competitive with excavator loaders in terms of performance, having better visibility, reach and operating envelopes. However price may rule out this type of loader except in high production situations where the logging system can be organised to suit the loader. In adverse ground conditions more expensive rubber tyred all-terrain type carriers or tracked carriers may be required for purpose built loaders. Truck mounted carriers are at a disadvantage where sorting and stacking more than 5 log sorts is required, as this necessitates loader shifts, with load. Tracked front end loaders are another option, but these also must travel with load, and cut up skid sites in adverse conditions, as do RTFELs. In adverse ground conditions, cost of skid formation and metalling can be kept to a minimum where excavator loaders are chosen. RTFELs require larger skids, and large supplies of metal. Loss of productive land to large skid sites can also be significant.

Thus for small contracts and for operations in adverse conditions excavator loaders have economic and operational benefits. For handling multiple sorts, in good ground conditions on unrestricted landings, the RTFEL has some advantages. For high production operations, with limited sorts to handle on firm, restricted size landings (e.g. with haulers) purpose built truck mount loaders are competitive with other options. Details of maintenance costs for excavator loaders are not available as most operators of these machines do not keep good records. However no significant problems of undercarriages, revolving frame or booms were reported. Most maintenance was related to hydraulic leaks and hose breakage particularly in the grapple area. The need to carry spare hoses and to have a machine operator prepared to fit these was emphasised. Generally R & M costs were reported as low and machine availability as high. This may not be the case if a mechanic has to be called out over long distances to change hydraulic hoses.

6. CONCLUSIONS ON EXCAVATOR LOADER SELECTION AND APPLICATION

6.1 Selection

A very good reference on selection and application of log loaders is a short LIRA report by Gordon (Ref 5). This recommends a systematic approach to selection and details items to consider at each of three stages, which are :

(a) identify the most suitable type of loader
(b) establish the size of loader necessary
(c) select brand of loader, or specific machine.

The following notes summarise information relevant to the three stages of the selection process.

(a) Type of Loader

Some advantages of the excavator loader type are as follows :

- i) ability to work in adverse ground conditions
- ii) ability to work on skid sites with little metal
- iii) ability to work on skids of restricted size
- iv) ability to work from roadsides
- v) low fuel usage
- vi) low R & M (with possible exception of grapple and hoses)
- vii) low (relative) capital cost new
- viii) ready availability of low cost, used excavators
- ix) ready resale as excavators
- x) ease of operation
- xi) large excavator population means good parts and service back up
- xii) operator comfort
- xiii) ability to be used as excavator, for roading, skid formation etc.

(b) Size of Machine

- i) The smallest excavator loaders in use are in the 10-12 tonne size range. Machines of this size cannot unload trailers but readily load small to medium diameter logs in short length. Reach and lift are restricted.

Ref 5. 'Loader Selection and Application' LIRA Report Vol. 5, No 5, 1980

ii) The most popular size of excavator loader is the 18-20 tonne range. This size is readily available, readily transported, able to handle most log sizes and length and just able to unload 3 axle trailers. This size is probably too small for successful heel boom loading of larger, long length second crop timber.

iii) For heel loading, machines in the 22-24 tonne size range are probably a minimum size. Price is not drastically different to the 18-20 tonne range (20% higher), but lift capacity is much improved (41%). There are some good arguments for using this size of machine in preference to the 18-20 tonne range for general loading also. Reach and lift height is improved, and with less strain on equipment, less maintenance and longer life could be expected. Trailer off loading could be carried out more easily.

(c) <u>Selection of Brand and Specification</u>

Points for consideration when making a final selection include:

i) long undercarriage and wide track shoes make for a more stable machine with greater lift capacity.

ii) A long dipper arm is favoured for log loading.

iii) Cost of hydraulic modifications to fit a grapple will be reduced if a machine with a spare implement circuit is chosen.

iv) Service back up and parts availability in the user's locality are important.

v) Financial considerations such as trade in offered, resale value and expected operating costs also need consideration.

vi) Choice of log grapple is critical to successful operation. The three tine type appear most reliable but cost more than the lighter pulpwood type. Pulpwood type are best for multiple small diameter logs. Grab type jaws are another option.

6.2 Application

The objectives in any loader application is to get the job done in a way that results in least over-all cost to the logging operation. Efficient application depends on the loader and logging system being modified to the benefit of both. Changes in items such as landing layout, log sorts being handled, truck scheduling, loader lift capacity, reach and visibility, grapple suitability etc can all enhance efficiency.

Some options to enhance excavator loader performance are as follows :

i) Raised cab for better visibility

ii) boom modification to increase lift height (either by altering lift cylinder attachment points on one piece booms, or adding a bracket to remove bend from two piece booms.

iii) dipper arm extension to give increased reach.

iv) grapple modification to prevent excess swing (fitting stops, and snubbers).

v) Cab guarding

vi) Remove bucket cylinder and linkage to decrease weight and increase lift capacity.

vii) Use of live heel attachment to extend reach and give better log control.

viii) Fit purpose built log loading boom complete with live heel.

ix) Fit extra machine counterweights to increase lift capacity.

BIBLIOGRAPHY

1. Log Loaders - Criteria for machine selection and application
R.D. Gordon, LIRA Project Report 15, 1981.

2. Market Study of Hydraulic Log Loaders in the Pacific Northwest
Martech Associates, Inc., Portland, Oregon, 1981

3. Hydraulic Knuckle-boom cranes for log loading
I.S. MacDonald, University of Canterbury, Project Report 39, 1979.