Safety in Mines Research Advisory Committee

Final Project Report

Problems associated with the use of Rapid Yielding Hydraulic Props

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Executive summary

This report deals with the factors affecting the effective use of rapid yielding hydraulic props (RYHP's) in the South African gold mines. Wherever possible, such factors have been quantified in an attempt to provide guidelines for obtaining the maximum benefit from the use of hydraulic prop systems.

A literature survey indicated that a similar report was produced in the 1970's. That report dealt with the introduction of hydraulic props into the gold mining industry. This report concentrates on the new generation "20 - 40 ton" hydraulic props. Similar problems are raised in both reports which indicate that these issues have not been effectively addressed.

The entire system, from prop manufacture through the usage of the units to maintenance, has been investigated. At each step there are critical aspects which could compromise the system should they not be adequately addressed. The more pertinent aspects are discussed here.

RYHP's have very specific design and performance requirements. These requirements were developed at COMRO to address the support requirements for rockburst control. This has led to the production of a technically advanced support element with some finely engineered components. This support element is used in an extremely hostile environment. The effects of blasting, mine water, grit, toxic fumes and rough handling all have an effect on the performance of these units. It is through the understanding and control of these factors that effective utilisation of RYHP systems can be achieved.

The manufacturers produce the props to specific performance requirements. The performance is often tested on all new products via an acceptance sampling technique at CSIR Mining Technology Division. The props are then delivered to the mines where no further verification of their performance is done, irrespective of time or work done. Many units that have been in use for an extended period and have been serviced will no longer perform to their original specifications. There are no guidelines for a servicing or maintenance programme issued from the manufacturers concerning their products. All servicing and maintenance is conducted on a breakdown basis. One of the critical components of a prop is the valve. These valves are routinely replaced with little or no verification of their performance.

RYHP’s form a support system. This system comprises the prop with its footpiece, a headboard, extension pieces, setting pistols, remote release tools, high pressure hoses, couplings and pumps. The use and maintenance of all these components influence the effectiveness of the entire system. The use of “pirate” parts often compromises the system’s performance.

The implementation of a RYHP system requires a detailed plan. This will include the training of staff, the development of control and maintenance systems as well as performance objectives. The initial costs involved are high and the return on investment can only be achieved if the system is effectively utilised for a long period of time.

Prop installation contractors have proved that these systems can be cost effective and provide effective protection under some of the worst conditions in our industry.

The acceptance of RYHP systems by the workforce remains contentious. The overriding issue is that when the system becomes compromised and problematic, no one wants to have anything to do with the system. Systems that are functioning well have a very high level of support and acceptance from staff.

The costs of maintaining a prop system are often considered to be excessive. When the system fails the costs relating to maintenance, loss of props and components escalate dramatically. These costs are not well documented and are difficult to establish. Typically, the costs relating to a failed prop system are used to justify the use of an alternative support system. A reusable support system will always be more cost effective than a consumable support system. This is however dependent on the effective utilisation of that system for its expected life span.

The most suitable support system for any mine is a support system that the mine can implement and have installed on the face where it can assist with production and improve the safety to the personnel working there. Considerations for the type of support requirements will then dictate specific support elements.

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- the co-operation and assistance of the gold mines and of mining personnel in providing information
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1 Introduction

Rapid yielding hydraulic props (RYHP) were introduced into the South African mining industry in 1970. This followed a comprehensive development and testing programme which started in 1968 and was concluded by 1974. These RYHP's were designed to offer superior protection to workings and personnel in rockburst conditions. The key feature of the props was their ability to absorb energy and yield at rates of 1 m/s at 40 tons. These props rapidly gained popularity on mines which were experiencing rockbursts. By the end of 1974, 17 200 props were in use in the industry. Problems were subsequently encountered with some of the technical and practical aspects of RYHP utilisation. These problems were addressed through modifications to the design as well as guidelines to assist with implementation of prop systems.

In 1988 the specifications for hydraulic props were revised. This was based on information and experience that the functional specification of 1 m/s was, at times, inadequate. The new specification for a rapid yield capability of 3 m/s with a variable load was subsequently drawn up. A new rapid yielding hydraulic prop was developed to perform within very specific and stringent parameters. This new RYHP became known as the 3 m/s 20 - 40 ton RYHP. The functional performance parameters for this prop are shown in Figure 1.1. The development and trials for the new prop were completed in 1992. Currently some 200 000 of these props have been introduced into the industry representing an investment of approximately R 250 million.

Problems were again encountered with the implementation and effective utilisation of the props in the industry. Reliability, cost, control and acceptance by personnel are some of the key issues in this regard. The flow and use of props from the manufacturer to user is broadly shown in Figure 1.2. This will be referred to within this report when reference to various aspects of prop usage are more easily depicted within this flow chart.

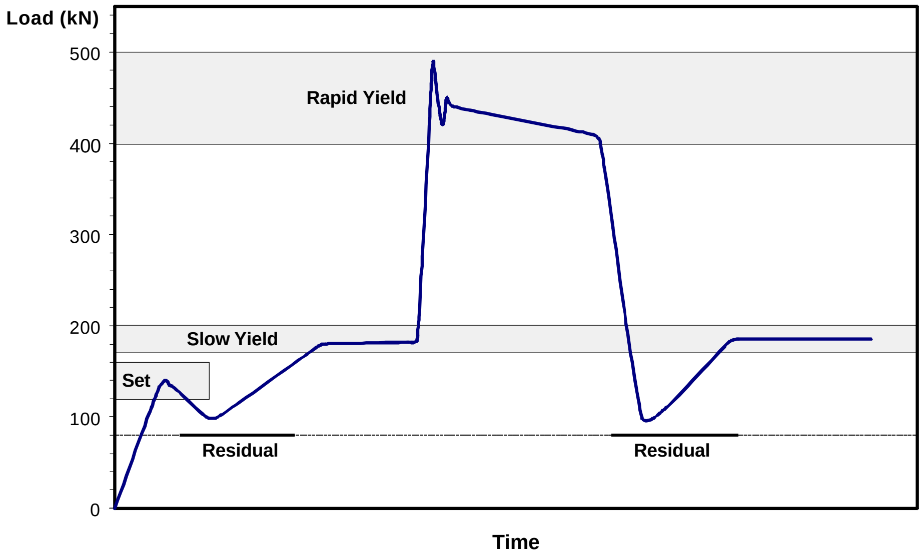

Figure 1.1 Performance specifications for 20 - 40 ton hydraulic props. (after Hojem et al. 1991)

This report attempts to review the development and progress of RYHP's in the industry with the aim of understanding the rapid decline in usage and acceptance currently being experienced. Any further reference to hydraulic props refers specifically to the new generation 20 - 40 ton RYH Props.

As agreed to at the outset of this project and reiterated in the progress report back meeting on 25 June 1997, no specific mention would be made of personnel, mines, contractors or manufacturers.

The conclusions presented to the GAPREAG committee on the 17th of October 1997 are included in the report as Appendix 3.

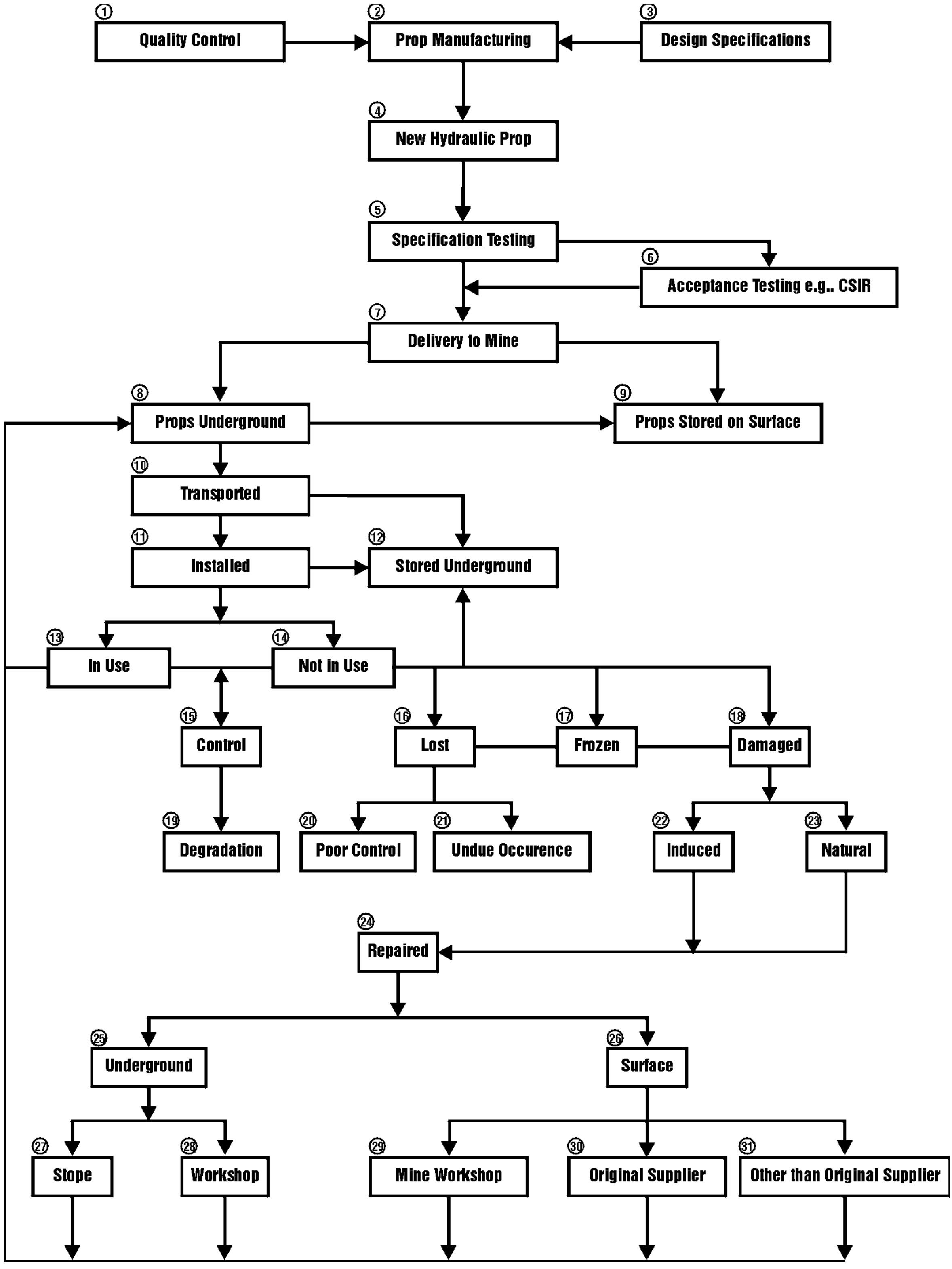

Figure 1.2 Flow chart of the life of a hydraulic prop; from assembly to usage and repair when damaged.

2 Literature survey

A comprehensive literature survey was conducted to obtain information on work previously done in this area. The most significant findings were related to the introduction of the original rockburst control hydraulic props in the mid 1970's.

More recently, many articles have appeared in mining orientated publications such as "Mining Mirror", "Mining World", "Coal Gold & Base Minerals", "SANGORM NEWS" and also from dedicated user groups like the "Elbroc Users' Club". Other references include papers written about the prop development and subsequent performance at Hartebeestfontein Gold Mine.

Extracts from a paper reads as follows: (Wagner and Lloyd 1981)

"A technical committee on rapid yielding props was formed to assist mines with the introduction of rapid yielding hydraulic props and to pool all available knowledge on the use of these props. Senior management and technical personnel of mines using these props were represented on this committee together with staff of the research organisation. Statistics relating to the operational and mechanical performance of props were kept and visits to mines in which they were used or on trial were arranged. Manufacturers were invited to attend meetings of this committee to learn about problems encountered by the industry and to be provided with the opportunity to express their views and ideas."

During this time some 20 000 props had been introduced into the industry. It was thought at the time that the implementation in the industry had been completed successfully.

"However, it was not before long that a number of serious problems were encountered. These fell into two categories, technical and organisational."

The technical problems were related to corrosion which was subsequently addressed. The organisational problems were as severe as shown in the following extract.

" - the proportion of props actually installed in stope faces dropped to as little as 50 per cent while the remainder were either in transit or on surface for repair. In addition some

mines were unable to handle large quantities of props and props damaged beyond repair reached values of more than 30 per cent per annum. These alarming figures initiated an in depth study on four gold mines into the cause of good and poor prop performances. This study revealed that on those mines showing good utilisation of props, management organisations had been set up to handle the increasing number of props. Furthermore adequate workshop facilities and a proper maintenance policy had been established on these mines. In the case of the mines having props with a poor performance rate it became evident that the size of the prop organisation had not increased with the number of props and that the maintenance policy was either inadequate or non - existent."

" - control and maintenance of hydraulic props created a problem of a magnitude which was not previously experienced by gold mines."

The report continues with this statement.

"*Guidelines based on these findings were prepared to assist gold mines with the establishment of an efficient and effective organisation for the control and maintenance of rapid yielding hydraulic props."*

The concluding comment from the report states:-

"In general the implementation of new concepts in mine design and the introduction of specialised service equipment is a less arduous process than the introduction of new production technology. However, the implementation of both new concepts and equipment deserves as much attention as their actual development."

These comments were based largely on a paper "A Review of Six Years of Operation with the Extended Use of Rapid -Yielding Hydraulic Props at the East Rand Proprietary Mines, Limited, and Experience Gained Throughout the Industry" . Included in the paper are recommendations, on the introduction of hydraulic props in a mine as well as recommended control measures. (Tyser and Wagner 1976)

What is of particular interest is that the problems associated with hydraulic props in 1976 closely mirror those experienced in 1997, some 20 years later.

3 Current situation

Rapid yielding hydraulic props are currently in use across the industry. Many mines are finding it difficult to justify the high costs and apparent unreliability of their prop systems. These costs are mainly related to the problems of effective control and utilisation of the props. For these reasons, mines are considering and implementing other systems that are more acceptable from an operational point of view. These systems have the potential to provide a similar support performance as that provided by hydraulic props. Typically, these systems would be based on some form of pre-stressed elongate with a yielding mechanism.

Hydraulic props have been designed and manufactured to perform to the criteria laid down by COMRO. In many instances, props are batch tested against an acceptance sampling standard (BS 6001 and BS 6002) before being delivered to the mines. This ensures that a certain standard is maintained for props being delivered from the hydraulic prop manufacturers (Figure 3.1).

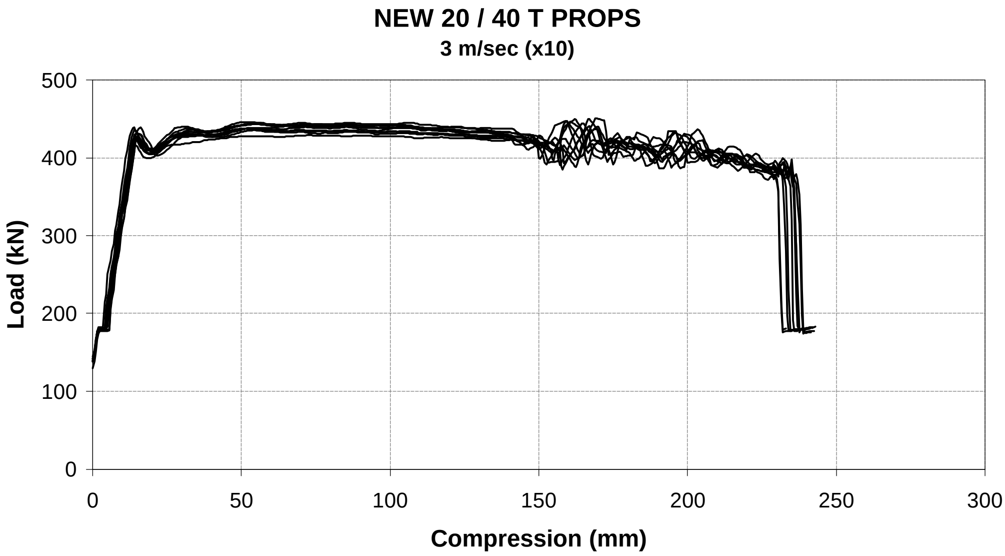

Figure 3.1 Performance of 10 hydraulic props that were batch tested prior to delivery to the customer. These props were randomly selected from a larger sample.

Pre-stressed elongates do not currently have to conform to any minimum laid down criteria. These elongates have been shown to have a variable performance during laboratory testing (Figure 3.2). This can be attributed in part to quality control and the variable nature of timber which forms the basis for the majority of the support units.

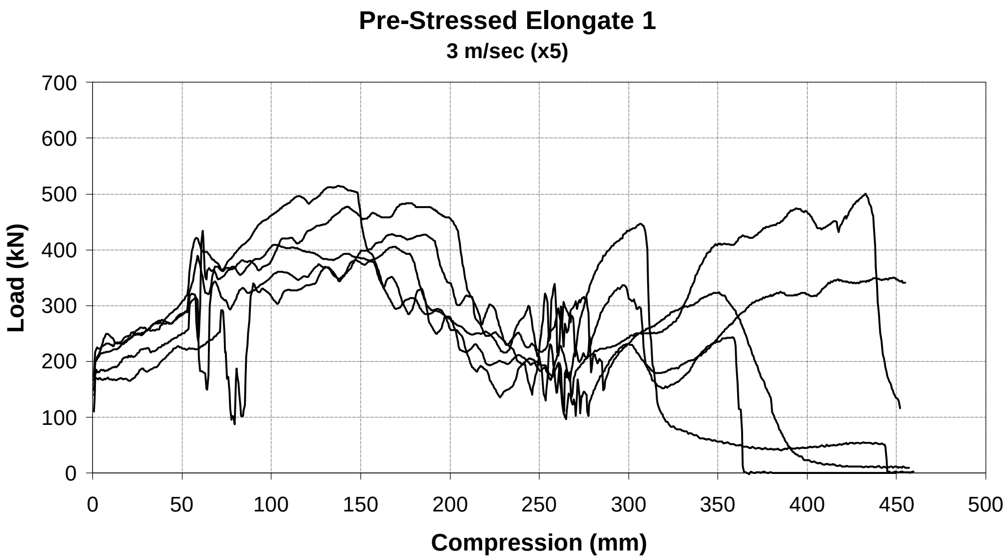

Figure 3.2 Performance of 5 units of an elongate that were tested as part of the elongate evaluation project being undertaken by CSIR Mining Technology. These units were compressed 50 mm prior to rapid displacement for 220 mm.

Concerns have been raised as to the claims made regarding the performance of pre-stressed elongate support systems. This is mainly due to the fact that these systems are being used as a replacement for hydraulic prop systems in areas of high seismic activity. An extensive study into pre-stressed elongate performance is currently being undertaken by CSIR Mining Technology.

Insufficient information currently exists as to whether or not a potential problem exists in the industry with regard to the use of pre-stressed elongate systems as a direct replacement for prop systems. The main reason for this is the lack of normalised data available with regard to the area mined on elongates.

The current utilisation of hydraulic props in the industry can generally be regarded as highly inefficient. The exception to this are a few mines which have suitable systems in place to maximise the utilisation of their prop populations. One area where hydraulic props are being used effectively is where prop installation contractors are used.

The prop contractors are attaining utilisation figures around 85 per cent with prop losses seldom exceeding 5 per cent per annum. The figures for mines controlling their own props would typically be around 25 per cent utilisation with prop losses of up to 50 per cent.

Much of the problem faced by the mines has originated from the resistance of mine personnel to installing two types of support and the substantial failures that had been experienced at the production faces. The mines' tendency towards the rejection of planned maintenance has resulted in a high incidence of in-stope prop failures, reducing user confidence in the reliability of the units. Not only do these failures arise from the lack of maintenance conducted on props, but also in deficiencies of the service when failures do occur. The use of inferior components, incomplete services and the incorrect identification of the problem all contribute towards a reduction in the reliability of the hydraulic prop support system. Performance testing of repaired props compared with new props illustrates this problem (Table 3.1).

Table 3.1 Failure rate of props when rapid displacement tested at CSIR Mining Technology.

Props	Passed Specs (%)	Failed Specs (%)	Failed Catastrophic (%)
New	97	3	<<1
Repaired	80	10	10

User confidence in the reliability of props is largely dependent on the way that the user deals with prop failures. A prop that has fallen out will likely be re-installed. If it is still standing at the end of the shift, it is no longer checked. Prop numbers would not normally be taken down. Within a few shifts it may happen again, but is it the same prop? Is there one prop continuously failing on an intermittent basis, is there a problem with several props or is there a problem in the system? Irrespective of where the problem lies, resentment towards a hydraulic prop based support system will grow.

Record keeping on prop repairs is inconsistent and on most mines almost non existent. A prop sensus may determine that a prop is in the workshop or has been in for repair, but the extent of the repair is not recorded. Repairs will range from a simple valve exchange to completely stripping a prop down and rebuilding it (with or without its original components).

Although some sort of sampling and acceptance procedure is usually adopted for new props, there is very little testing of fully assembled, repaired props. Valves may be checked by subjecting them to high water pressures and observing the pressures at which the slow and rapid yield valves open. Props may also be tested for their setting loads and installed into frames to ensure they maintain their loads for limited periods. However, only a very small proportion of repaired props are rapid displacement tested.

Functional testing of props at CSIR Mining Technology has shown that catastrophic (or functional) failure of new props occurs almost exclusively during rapid displacement testing. Valve failure is the primary cause of this functional prop failure. This is the one aspect of prop testing that a manufacturer cannot conduct at their premises.

In contrast, repaired props exhibit catastrophic failure from a number of sources. The most concerning is the fact that some props begin to leak immediately upon setting. This appears to indicate shortcomings in the assembly and testing procedure of repaired props prior to being sent into service. Valve and main seal failures account for the majority of the functional failure of repaired props. Head and valve seat failures have also occurred on occasion.

4 Manufacturer's perspective

Rapid yielding hydraulic prop manufacturers have specific concerns which can be categorised into the following areas: manufacture, quality control, reliability, liability, competition and costs.

4.1 Manufacturing and quality control

RYHP's are manufactured to comply with the recommendations laid down by CSIR Mining Technology for the 3 m/s, 20 - 40 ton RYHP's. These props are designed to provide specific support forces from setting through to dynamic loading. Quality control is applied to the products at all stages of production. Final acceptance sampling and testing is conducted to ensure that the props supplied to the mines conform to the required specifications.

Each and every component has to conform to the manufacturers specifications for the final product to perform within the required performance envelope. This involves checking every machined part for compliance with the required tolerances. All supplied parts, e.g. castings, pipes, seals, etc, require similar quality controls. This process ensures that the final product will have a certain level of quality built into it. Even in the valve assembly where conditions vary between manufacturers, the controls ensure consistency in the final product from all suppliers.

The quality control methods used are typically SABS ISO 9001 and 9002. These quality control systems have well defined procedures and record keeping systems.

The final product is a high quality, finely engineered piece of equipment designed to perform a specific function under severe conditions. Any failure in the manufacturing process will compromise the performance of the prop.

4.2 Reliability and liability

The reliability of the props is considered to be of vital importance to the manufacturers. Reliability of the props creates a positive attitude of the personnel who use these props. The quality controls and final acceptance sampling of the product ensures that fit for purpose equipment is supplied to the mines. At this point, the manufacturers relinquish control of their products. How the props are treated and used is beyond the control of the manufacturers. They have no record of what service their products have seen or the conditions under which they were used. This creates problems when prop failures occur and corrective action is required.

The lines of responsibility and accountability for a mine's prop population are not clear. Recent legislation places specific responsibilities on both the manufacturer of support equipment and the user of the equipment. This would suggest that a close co-operation between both parties is required. In practice, this does not occur with each party blaming the other for poor product performance. A constructive problem solving approach is required to ensure that the common objectives of both parties are achieved.

A critical area of controversy revolves around the servicing of the props. RYHP's are not cheap and nor is the servicing. Faulty components can be replaced relatively easily as in the case of valves. The servicing of the valve itself requires experienced personnel and specialised equipment. The different levels of competencies required for the various service requirements is not well understood or adhered to. All components have specific quality and tolerances which must be adhered to. When this is not done, the performance of the props is compromised.

The most vital component on a hydraulic prop is the yield valve. This high tech component is manufactured to very strict specifications and limited tolerances resulting in a predictable and repeatable performance (Figure 3.1). The various manufacturers assemble valves with different gassing agents and components made of different materials. As a result, the servicing of valves is not straightforward; the manufacturer's recommendations for servicing valves are quite specific. All moving parts, seals, o rings and seats must be replaced. Visual inspection and measurement of components and tolerances will not ensure the performance of the repaired valve. Valves which do not conform to these recommendations when repaired or serviced will cause problems later when the prop is used. Seals on the props have specific ratings and properties. The use of components and materials which do not conform to these requirements will, in many cases, result in prop failure or non-compliance to performance specifications.

4.3 Controls

The manufacturers have quality control systems in place to ensure that the props are produced to specification. They have acknowledged the necessity for these controls to guarantee the performance of the props. The concern raised is that this level of quality assurance is not maintained throughout the life of the props. There could be various agencies involved in the repair of a prop. This can occur where the mine has its own prop repair shop where replacement parts are fitted and any machining or valve repairs are contracted out.

Specifications regarding prop design have generally not been divulged by the manufactures thus limiting the potential for competition in the servicing and maintenance of props. However, with the potentially large market for such a service to the mines, other organisations have ‘reverse engineered’ prop components in order to ascertain these specifications and conduct repairs for users at a much lower cost than the manufacturers. Without the manufacturer’s component specifications and tolerances, repaired props do not perform as consistently as their new counterparts. Their rate of failure would also be expected to be excessive but the lack of adequate service records leaves this aspect unquantifiable.

Maintaining quality control over props with all these service operations conducted at a variety of facilities is all but impossible. The manufacturers are, however, still ultimately held responsible by the users when the props become problematic. Props that have been returned to the original manufacturer for repair often contain parts which do not conform to the required specifications. The use of “pirate” parts has long been identified as a primary cause for the failure of many props in the industry. This practice is motivated by costs and response time.

Prior to large scale product implementation on a mine, preliminary trials are usually conducted on the mine. These trials are conducted with the assistance of the prop manufacturers on a small scale. In most cases these trials have been very successful resulting in implementation of prop systems on the mine. Problems usually occur at a later stage with excessive failures of props. This would indicate that the due care and attention required for successful prop systems is not being applied. The contrast between the initial successes and the subsequent failures raises concerns about the current ability of the mines to operate large scale prop systems efficiently.

5 Mine’s perspective

The gold mines have been under severe pressure during the last five years due to a declining gold price and rapidly rising costs. The effect this has had on the industry is a 30 per cent decline in production and extensive staffing cutbacks. This has resulted in cost cutting initiatives and productivity drives across the industry. The changes in political and labour dispensations have had a significant impact requiring new strategies. Health and safety issues are now governed under new legislation. These factors combine to create an extremely challenging environment for our gold mines.

The performance of RYHP systems over this period must take these factors into account as they all impact to a lesser or greater degree on the final performance.

The use of hydraulic props systems has been problematic since their initial introduction into the mining industry. Many mines have, at one time or another, achieved considerable success with these systems (Figure 5.1). These successes have been achieved where all due consideration of the need for effective controls and maintenance have been met. In most cases, these prop systems have ultimately become problematic (Figure 5.2) or extremely costly. The corrective actions required to restore the systems are as costly as the initial implementation. The resources may not be available to restore the prop systems and the use of props is subsequently discontinued.

The mines strive to utilise the optimum support for their conditions. The type of support selected must have the following properties:

- applicable for the conditions encountered
- cost effective
- provide optimum safety for personnel
- reliability
- acceptance by personnel
- easily applied
- easily controlled

RYHP systems are acknowledged to provide superior safety for personnel in areas which are prone to rockbursts. There are documented cases where these systems have enhanced safety and productivity. (Arnold et al. 1994)

Figure 5.1 A proper prop control system will result in good working conditions with a cost effective support system.

Figure 5.2 Problems result from poor control of props such as footwall punching when props are left in back areas and the inconsistent use of headboards.

There are three major considerations for a mine wishing to utilise RYHP's. These are the high initial capital expenditure, cost effective implementation and ultimate support performance. The implementation of prop systems require money and personnel, two factors which are not readily available when considering the current situation. A mine which implements a RYHP system places additional pressures, other than those previously mentioned, upon itself to ensure that the system succeeds.

A mine which currently operates RYHP systems faces similar dilemmas with regard to costs and performance. Expansion and maintenance of the system requires considerable resources which may not be readily available.

These considerations often result in mines opting not to utilise props or the implementation of the systems being incomplete. Both of these actions do little to promote the benefits of prop systems.

The acceptance of RYHP systems by mine personnel is a contentious issue. The reaction to prop usage has generally been a " love it" or "hate it" attitude. There seems to be no middle ground where the prop system is evaluated on applicability. In general, personnel with a high regard for prop systems are involved with a prop system that is performing well. Where prop systems have been compromised, acceptance is typically negative. This performance would be judged on unit reliability and a suitable in-stope prop management system. This would include the following:

- prop handling,
- removal and installation procedures,
- availability of prop spares, accessories and replacement props in the event of prop failures and
- compliance to support standards.

One argument against the usage of hydraulic props revolves around the presence of poor, or potentially poor, ground conditions. Props are often blamed for the poor ground conditions observed with stope hangingwalls when, in reality, basic mining practices are not being adhered to. Problems such as poor marking and drilling can lead to blast damage to the hangingwall, a lack of support or a mixture of support types (hydraulic props, mechanical props and 'sticks') resulting in deteriorating ground conditions with falls of ground.

The presence of a friable hangingwall or rapid in-stope convergence have been reasons given why hydraulic props do not get issued to some working places. Proper installation procedures can however cater for these kinds of conditions.

Props issued to working places where personnel have a reluctance to use the units has lead to the problems of low population utilisation and high losses reported earlier. Props delivered to a working place (materials bay) may never be taken into the stope. Props are often buried or hidden behind or under other material.

The argument that the props are excessively heavy can only apply to the first generation of props which had a mass of 50 kilograms. The new generation props are typically 37 kilograms. A study on the effort required to work with props indicated that there was little difference for props in the 20 to 37 kilogram range. (van Rensburg et al, 1991)

The comparison between hydraulic props and pre-stressed elongates with respect to effort required is unfounded. Table 5.1 gives an indication of the average mass of each support element. All units, which cater for stoping widths up to one metre, fall within the nominal effort range for masses between 20 and 37 kilograms (Figure 5.3). The work required for installation must reflect total work required, including transportation, and as such is probably comparable for the initial installation.

Table 5.1 Average mass of various support elements.

Support type	Maximum functional length (mm)	Average mass (kg)
Loadmaster	1600	31
Loadmaster	1000	25
Ebenhauzer	1200	35
Profile prop 200 mm diameter	1000	24
Cone prop	1000	22
Rocprop	1200	29
Pencil prop	1000	20
Elbroc 750 mm 20-40 ton prop	1200	37
SMP 750 mm 20-40 ton prop	1200	37
Unique 750 mm 20-40 ton prop	1200	37.5

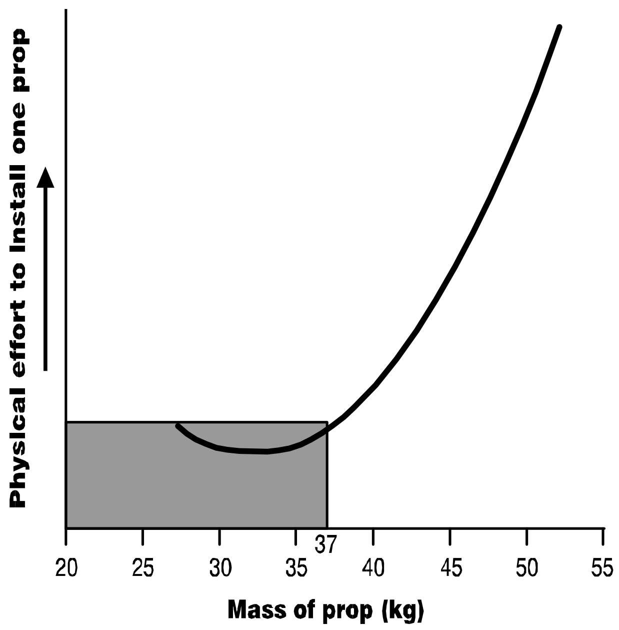

Figure 5.3 Effort required to install supports of different masses. The support elements mentioned in Table 5.1 all fall within the shaded area, indicating comparative effort required for their installation.

The argument that props require excessive work through constantly moving the system has some merit. A consumable support element is installed only once. Prop systems are installed, removed and moved for the same amount of production. This undoubtedly involves more work for the support installation crew. This must be offset against the effort required to constantly move consumable support elements from surface to the stope face. This latter operation does not cease with the introduction of RYHP's as pack timber or elongates are still transported. The effect is as such seldom quantified.

Each different make of hydraulic prop has its own specifications. This entails different setting pressures, valve configurations and general dimensions. This creates problems for mines which have a mix of props from different manufacturers. Duplication of equipment is required to operate one prop system if effective control of their distribution on the mine is not in place. The mixing of different manufacturers props in the same panel does not often occur and is not considered to be a problem.

5.1 Prop maintenance

It is difficult to check the props to ensure that they are working properly. Setting pressures are not always correct due to pump malfunction, low air pressure, etc. However, some props do have indicator pins which pop out when a nominal setting pressure is obtained and can be specified to the manufacturer as a requirement. Pressure gauges are also available for setting pumps to confirm that the required pressure is being supplied. A reduction in supply pressure is often an indicator of internal wear and in-stope maintenance is conducted or the unit is replaced.

The mines require a minimal turnaround time for prop repairs. This would allow replacement prop stock levels to be kept to a minimum and sufficient props to be available for installation in the panels. The efficiency of the repair system has a major impact on costs and system performance. Support from the manufacturers is generally considered to be poor. This is expressed as excessively high costs for repairs and unacceptably long turnaround times. Requests for manufacturers' staff to visit the mine to assist with a problem are not always attended to quickly as the cost to the manufacturer can be significant.

These factors create problems which affect the close co-operation required between supplier and customer.

Financial constraints on the mines have resulted in the development of individual cost centres and each centre has been responsible for its own profitability. Props are expected to be returned to operation in the shortest time possible at the lowest cost. In an attempt to minimise their running costs, prop shops are minimising the services being conducted on malfunctioning props by replacing or repairing only those components that appear to be worn of faulty. The onset of intermittent 'failures' of props can be devastating to the acceptance of props by the workforce. These could be very difficult to identify, even in the workshop. Intermittent failures could be the result of grit stuck in the filler or yield valves, or damage to the filler valve bearing, all of which could cause fluid leakage from the prop under specific circumstances. As a result, incomplete and inadequate servicing and the use of the cheapest, and usually inferior, parts have lead to a high degree of premature failure of props in the work place. It has been stated by both the manufacturers and users that the biggest problem with the reliability of props can be singled out as the use of pirate parts that do not meet the specifications of the manufacturers.

Most mines operate their own prop repair shops. The majority of these are on surface with only minor work being carried out underground. Work underground is kept to a minimum due to the expense that would be involved in equipping many workshops on several levels / shafts as opposed to one central shop on surface. Servicing of props underground does not often exceed the exchange of faulty valves.

The main workshops are better equipped to assess and identify the causes of prop failure. Load frames, calibrated setting pumps and high pressure water lines can be used to assess the functionality of various prop components. However, most mines do not possess the capability to conduct any yield testing of the prop and those that do have such equipment, conduct almost no testing of props. Simulated slow yield testing can be done by increasing the delivery load on the prop setting pump thus causing the slow yield valve to open.

One area that gets very little attention on the mine is the storage of props. Extended storage of props, especially on surface, may affect their performance. The effects of temperature and environment will contribute to performance and reliability problems. The seals in the props may become dry and deteriorate. This is especially problematic if the units are stored on their sides. Recent testing of hydraulic props that have been stored on surface at the mine for more than one year (having already passed standard quality assurance testing prior to delivery to the mine) had a greater than 50 per cent failure rate with several catastrophic failures. Many such props would be transported underground with the assumption that they are going to perform as if they had been recently delivered to the mine. The use of such props and subsequent failure of these units would result in resentment towards hydraulic props. Resistance towards the use of props could soon spread throughout the mine.

5.2 Geotechnical areas

Support systems must address the conditions where they are used. Consideration must be given to the geotechnical area and the support interaction with the rock. RYHP's exhibit specific performance during normal stope convergence and during dynamic stope convergence. This provides quantifiable forces that are applied to the hangingwall and footwall of a stope. The loading surfaces of the headboards and footpieces are also known. This interaction is known to be problematic in certain geotechnical areas. The factors that need to be considered include the UCS of the rock, the natural jointing and mining induced fracturing as well as the stratigraphic composition of surrounding rock.

The common effects of this are manifested by support "punching" and shattering of the hangingwall and footwall (Figure 5.4). These effects are particularly noticeable during dynamic convergence. These effects are not limited to hydraulic props but will be common for support elements with similar performance loading characteristics.

Figure 5.4 Footwall punching of prop in the course of normal stope convergence.

The current work being conducted with respect to geotechnical areas will provide more information on the applicability of RYHP's, and other support types, in specific geotechnical areas. (Schweitzer, 1997)

5.3 Safety

A question often asked is “Do hydraulic prop systems provide for a safer working environment?” The answer is not simple due to the lack of normalised data of production with respect to support systems.

The general consensus is that there are safety benefits arising from the use of hydraulic props. The best available indicators are from two different time periods. During the study conducted in the 1970’s an improvement was recorded for reportable accidents and accident rates. More recently a prop contractor has calculated that 4 million centares were produced, where their props were in use, without a single fatality.(Stopetek, 1997)

These examples give an indication of what can be achieved with hydraulic prop systems. The comparison between props and other types of support system used under similar conditions is currently unavailable.

It has been noted that conditions have improved in many cases where hydraulic props have been installed close to the stope face. This could probably be achieved by any support system which can be installed close to the face and is therefore probably not unique to hydraulic props.

6 Contractor's perspective

Hydraulic prop support installation contractors are a new service to the industry. These contractors endeavour to assist mines who wish to utilise hydraulic props. They provide a comprehensive service of prop installation, maintenance and controls for an agreed price. This enables the mine to fix their hydraulic prop support costs at a given amount.
The problems associated with hydraulic props are then passed on to the contractors. The benefits of having the props installed to standard at all times are available to the mine.

Prop installation contractors are currently operating on some 12 mines and some 22 shafts. The number of props under their control has steadily increased over the past few years to a current level of some 20 000 props. This could represent approximately 20 per cent of the total available prop population in the industry. (Stopetek, 1997 and Welprop, 1997)

6.1 Contractor's efficiencies

There are two main criteria when considering prop efficiencies, prop losses and prop utilisation. Prop losses are costly through the replacement of props before they have reached the end of their economic life. System efficiencies are compromised due to shortages of available props or excessive replacement props being available.

Prop losses are represented as a percentage of the total prop population for a period of one year. Contractors prop losses are less than five per cent per annum. This compares with an industry average of between 25 to 50 per cent.

Prop utilisation is represented as a percentage of the total prop population that is actually installed on average for a period of one year. Contractors prop utilisation is between 80 and 85 per cent. This compares with an industry average of around 25 per cent.

6.2 Operational considerations

Contractors are usually employed in problem areas where the mine requires support to conform to the highest standard. This results in contractors working under some of the worst conditions in the industry. The efficiencies attained by the contractors under these conditions indicate that hydraulic prop systems can be cost effective and utilised in most areas of our mines.

Contractors are responsible for a small part of the mining cycle. They are required to work closely with mine personnel to achieve their goals. Any disruption of the mining cycle affects the income of the prop contractors as most contracts are related to production. The margins for prop installation contractors are not great. Under these conditions contractors may decide to withdraw their services from the mine. The result will be a deterioration of support standards and safety. A broader contract of moderate to poor conditions will allow the contractors more flexibility in servicing their contracts. There could be cost advantages to the mine where cross subsidisation by the contractor occurs.

The use of contractors for one part of the support installation could be expanded to encompass all support installation. The advantages to the mine would be a fixed cost for support which would be installed to a high standard.

The prop support contractors utilise dedicated personnel and systems. The personnel have specific goals and responsibilities. The achievement of these goals is measured and rewarded. This creates a direct link between performance and reward. This system has proved to be effective and benefits all parties involved.

The quality of mining has a direct and substantial impact on support performance and subsequent safety. Shot holes drilled into the hangingwall and footwall create unnecessary problems through overbreak and dilution. Excessive burdens result in poor face advances, large rocks and unnecessary blast out of support units. The lack of effective barricades creates cleaning problems and excessive distances to the sweeping line. Support that is installed on a properly cleaned footwall has the advantage of being installed quickly and effectively. This latter situation seldom occurs as most “cleaned” stopes have excessive rock lying on the footwall. These and other practical considerations affect the ultimate mining performance and are unfortunately very common in the industry. The actual cost to the mine of the prop system is represented on an invoice each month. The mines seem hesitant to accept these high costs. This hesitancy is the result of being unable to compare the cost with what it would normally cost the mine for their own prop support systems over the same period.

7 Workforce perspective

The changes in South Africa have had a substantial impact on the workforce employed on our mines. Expectations have been raised and the poor performance of the gold mining industry has limited the ability of mines to meet these expectations. Staffing reductions are common and continue to occur. Emphasis is placed on productivity and job retention. Skills levels are generally low with job enrichment programmes being difficult to implement.

The methodology used to motivate and reward the workforce has not changed substantially in the last 20 years. Linking performance with reward continues to prove problematic. The result of these factors is low productivity and motivation.

7.1 Skills levels

The mining industry devotes significant effort into training personnel that will enable their job to be completed efficiently. However, in the past, little need was seen for providing the education required by the workforce to understand the implications of the decisions that would be made when situations occurred that did not conform to expectations. Shortage of time to complete all the required daily tasks prior to the evacuation of the stope for blasting is a common occurrence. Incorrectly spaced blast holes, inadequately supported stopes and back areas not cleaned are often the result with very definite and far reaching repercussions.

The training of personnel in the use of hydraulic prop systems revolves around the application and utilisation of the props. This involves the “how” to do it. The “why” it is done is not well understood. It is difficult to transfer knowledge about technical matters to personnel with no background on the subjects. The training provides an excellent basis for personnel to apply the system within the mining cycle. The installation and removal procedures for example are well known and generally well adhered to.

The effect of non-compliance to procedures is not well understood. This becomes evident when fault finding exercises are conducted. Faulty props are subjected to a check list of possible causes. The replacement of the valve is a typical operation which is routinely undertaken in the stope. If the problem is not with the valve, the prop may be put back into operation in a faulty condition. If this scenario is combined with poor records of what has been done to which prop, this situation may continue for some time. The end result is a lowering of confidence in the props which are seen to be continually failing.

Another area of non-conformance to procedures is where fatalities have occurred when props were not remotely released. These are avoidable accidents which occur when the correct equipment is not available or used. The understanding of why these procedures are in place is, at times, lacking. Rockfalls during prop releases are relatively uncommon which leads to complacency and disregard for procedures.

Standards and procedures are not strictly enforced. This is evident by the number of props installed with no headboards, incorrect length of the extension pieces and the amount of available travel of the legs. (Figure 7.1) Until the rationale behind the procedures is understood and the standards enforced, this situation will continue.

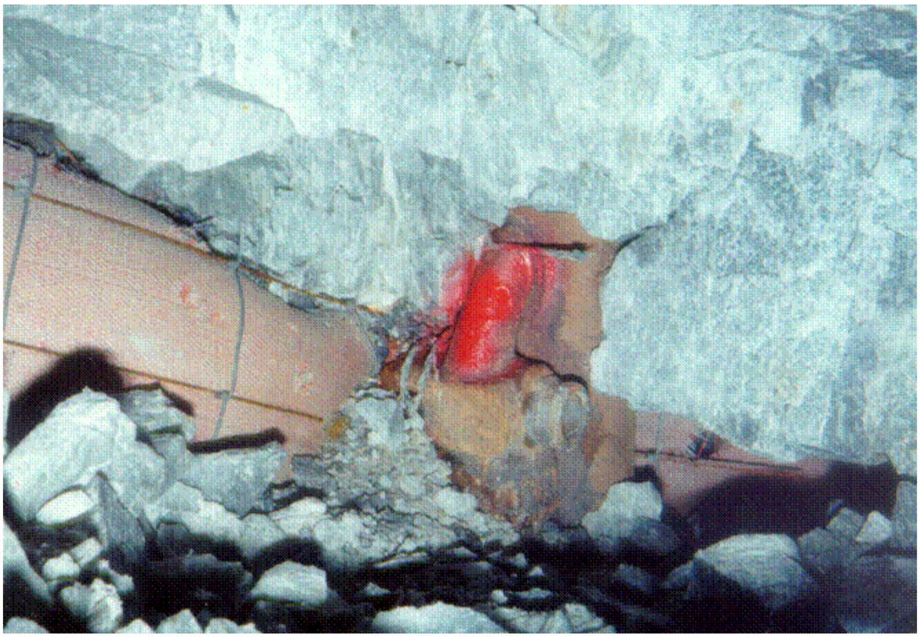

Figure 7.1 Prop installation without headboard exhibiting punching of the hangingwall following a rockburst.

Prop systems that are problematic create extensive amounts of additional work and complications. This is seen when multiple prop blast-outs occur and props and barricades are trapped in the broken rock. The cleaning operation is compromised which results in an uncleaned stope. This in turn puts pressure on the drilling shift to reinstall props on the uncleaned footwall. The additional problems of props lost down tips and unsafe conditions, where there is now no support, occur. Ancillary equipment such as headboards and extension pieces are commonly lost as a result. This creates equipment shortages and so the problem grows.

This situation of passing problems through the system is common. Systems which function correctly, typically exhibit a high level of skill, motivation and teamwork. The opposite is typical of problematic prop systems.

The motivation of personnel can best be achieved where there is a direct link between performance and reward. Many mines are having significant successes with this approach applied to production operations. Responsibility levels are generally low which has a negative impact on job commitment.

8 Cost implications

Any support system must provide the required performance at an acceptable cost. This is true for hydraulic prop systems. The major difference between props and most other systems is that the props are reusable. The difference between the costs of props and other types of support units, e.g. elongates, is high. This means that cost effectiveness for prop systems can only be obtained when the equipment is utilised over a period of time. Any problems, such as losses and ancillary equipment failure or loss, will directly affect the overall costs of the system.

Current indications are that at least 25 per cent of hydraulic props are replaced each year. This indicates that the entire prop population on a mine will be replaced every four years. The direct cost of this replacement can be easily calculated. What cannot be calculated are the losses which have occurred during this period through inefficiency.

In contrast, prop contractors will replace a maximum of 20 per cent of their prop populations every four years. This is five per cent less than what a relatively efficient mine will replace in one year. This represents an 80 per cent saving on the capital cost of the system in four years. This gives an indication of the cost differences between two prop users.

An example of this is a mine which spent R 75 million on prop systems over a six year period. A recent audit on props and ancillary equipment accounted for between R 14 million to R 16 million worth of equipment. This equates to a direct loss of some R 800 000 per month of prop equipment. For the same expenditure, a contractor would show a monthly loss of some R 52 000. The difference between these two efficiencies amounts to some R 750 000 per month.

This mine’s prop replacement percentage of 16,6 per cent compares with a contractors prop replacement of five per cent. This gives an indication of the costs involved when prop replacement percentages increase. It should be noted that this mine has an above average performance when compared with the industry average of 25 to 50 per cent.

Hydraulic prop losses occur due to operational and management factors. Mines which employ the caving method may lose props due to cave overruns as it would be considered to be to dangerous to attempt to retrieve the props. Similarly mines which have a high incidence of seismicity may lose props due to severe rockburst damage creating an unacceptable safety risk for their recovery. These types of operational problems need to be quantified and catered for. The management problems are reflected in the number of props which are lost and destroyed. Prop losses occur when props are left in the back areas, buried under backfill, unnecessarily exposed to blasting, exposed to scraper ropes and poorly handled. Other ancillary equipment losses occur due to similar mechanisms.

The true costs of hydraulic prop systems on most mines are unknown. This is the result of the many factors which can affect the cost not being controlled or monitored.

Table 8.1 indicates comparative costs for support systems. The costs of the systems have been calculated according to various assumptions as laid out in Appendix 1. The labour efficiencies are taken at 100 per cent except for the Contractors calculations which reflect actual total labour costs. This means that only the labour actually required to install the support is included and not the total labour availability. Support service labour costs are not included due to the assumption that the systems are consumable over a period of time at certain efficiencies and costs.

The results of the comparative costing are summarised below.

The cost of a pre-stressed elongate system is comparable to Contractor installed hydraulic props at 5 m face advance per month. (Table 8.1 columns 1, 2, 6 at 5 m) This may be similar to a caving system where no additional support is installed with hydraulic props.

In many instances, a simple elongate will be installed behind every hydraulic prop prior to its removal. The cost of a pre-stressed elongate system is comparable to Contractor installed hydraulic props with profile props at 8 m face advance per month. (Table 8.1 columns 1, 2, 4 and 6 at 8 m)

The cost of a pre-stressed elongate system is comparable to a mine’s hydraulic props after 34 m of face advance. (Table 8.1 columns 1, 2, and 3 at 34 m) Some mines may be able to achieve this in two months and the ‘average’ mine could achieve this in four months.

The cost of a pre-stressed elongate system is comparable to a mine's hydraulic props with profile props after 49 and 53 m of face advance for different priced elements. (Table 8.1 columns 1, 2, 3, 4 and 5 at 49 and 53 m respectively) Again, the average mine could achieve this in nearly six months.

The cost of a mine's hydraulic prop system is comparable to a profile prop system after 101 and 120 m of face advance for units costing R30 and R36 respectively. This equates to an average face advance of 8.4 and 10 m per month respectively. (Table 8.1 columns 1, 3, 4 and 5 at 101 and 120 m respectively)

Table 8.1 Cost relationships for support systems as a function of face advance expressed as Rands per centare.

1	2	3	4	5	6
Face advance	Pre-stressed elongates	Hydraulic props	Profile props	Profile props	Contractors RYHP's
Metres	@ R 110 per unit	@ R1 250 per unit	@ R 30 per unit	@ R 36 per unit	@ R 190 per month
1	68.35	2251.52	20.26	23.86	342.00
2	68.35	1126.52	20.26	23.86	171.00
3	68.35	751.52	20.26	23.86	114.00
4	68.35	564.02	20.26	23.86	85.50
*5	*68.35	451.52	20.26	23.86	*68.40
6	68.35	376.52	20.26	23.86	57.00
7	68.35	322.95	20.26	23.86	48.86
*8	*68.35	282.77	+20.26	23.86	+42.75
9	68.35	251.52	20.26	23.86	38.00
10	68.35	226.52	20.26	23.86	34.20
11	68.35	206.06	20.26	23.86	31.09
12	68.35	189.02	20.26	23.86	28.50
13	68.35	174.59	20.26	23.86	26.31
14	68.35	162.23	20.26	23.86	24.43
15	68.35	151.52	20.26	23.86	22.80
16	68.35	142.14	20.26	23.86	21.38
17	68.35	133.87	20.26	23.86	20.12

18	68.35	126.52	20.26	23.86	19.00
19	68.35	119.94	20.26	23.86	18.00
20	68.35	114.02	20.26	23.86	17.10
33	68.35	69.70	20.26	23.86	NP
*34	*68.35	*67.69	20.26	23.86	NP
35	68.35	65.80	20.26	23.86	NP
36	68.35	64.02	20.26	23.86	NP
37	68.35	62.33	20.26	23.86	NP
38	68.35	60.73	20.26	23.86	NP
39	68.35	59.21	20.26	23.86	NP
40	68.35	57.77	20.26	23.86	NP
41	68.35	56.40	20.26	23.86	NP
42	68.35	55.09	20.26	23.86	NP
43	68.35	53.84	20.26	23.86	NP
44	68.35	52.65	20.26	23.86	NP
45	68.35	51.52	20.26	23.86	NP
46	68.35	50.43	20.26	23.86	NP
47	68.35	49.39	20.26	23.86	NP
48	68.35	48.39	20.26	23.86	NP
*49	*68.35	+47.44	+20.26	23.86	NP
50	68.35	46.52	20.26	23.86	NP
51	68.35	45.64	20.26	23.86	NP
52	68.35	44.79	20.26	23.86	NP
*53	*68.35	+43.97	20.26	+23.86	NP
*101	68.35	23.80	20.26	23.86	NP
*120	*68.35	+20.27	20.26	+23.86	NP

NP Not currently practical.

* Denotes when comparisons between support systems are made.

+ Denotes that these two figures are added then compared.

Appendix 2 reflects the same calculations based on attrition rates of zero per cent to 25 per cent. This provides a basis for evaluating costs at various efficiencies.

9 Implementation requirements

The implementation of any new technology or system requires careful planning to ensure its success. The basic reasons for considering changing to a new system or methodology can be ascribed to the following reasons:

- new challenges have to be met,
- improving safety,
- improving productivity,
- cost effectiveness, and
- profitability.

These factors provide the motivation for considering the new technology. The new system may be able to provide the solutions to the problems being faced. The resolution of the problems is directly related to the degree of successful implementation of the new system.

The success or failure of the system can only be established if it can be measured. This entails having provided a list of expectations during the planning phase. These expectations can then be measured at a later stage through an audit.

The current situation needs to be clearly and accurately quantified. This provides for the basis against which the implementation will be measured.

A typical motivation for hydraulic props would be:

> **Provide rockburst and rockfall protection to workers in the stope face while improving stoping width control and dilution with the benefits of improved productivity and safety at a lower cost per unit of production than any comparable system.**

These objectives need to be defined in measurable terms. Protection and safety benefits can be measured through accident statistics and need to be quantified in monetary terms. Stoping width control and dilution can be measured and quantified in monetary terms. Improved productivity and reduction in production delays can be similarly quantified.

Once these parameters have been established, progress towards the stated objectives can be measured.

The expected efficiency of the RYHP system needs to be set. This entails setting a target for equipment replacement, refurbishment and repairs. The actual mining conditions will play an overriding part in this estimation. Mines which have a high expectancy of rockburst damage or which employ cave mining can expect to have props trapped due to dangerous conditions. The dangers associated with the props recovery may result in decisions to abandon these props.

The prop system will benefit from these provisions as actual attrition can then be quantified for operational losses or management deficiencies.

The transition from one support type to another can result in unsafe working conditions if the transition is not done smoothly. Insufficient available support is a common problem.

The implementation planning will need to provide for the support structure required by the operational RYHP's. This involves the personnel who will monitor, install, transport and repair the props.

Current indications are that dedicated prop personnel achieve greater successes than when prop responsibilities are combined with existing line functions.

One area of concern is that the implementation of the props does not exceed the available capacity. The capacity of repair facilities, the training prop personnel and staffing levels must keep pace with the actual numbers of props being introduced. Suitable monitoring and reporting systems are required to provide accurate management information.

The ultimate success of the system will depend on combining all these factors into an implementation plan which is then effectively managed.

10 Control requirements

The evaluation of any system requires information of the critical aspects of the system. The key aspects with regard to hydraulic prop systems are costs and performance. If the total costs of the system are known, these costs can be related to factors such as production, stoping width and safety.

Control systems provide the framework within which the system will operate. The critical aspects of the system can then be monitored and reported on. The location of every prop on a mine is not information that a manager needs to know. What can be reported if the locations are known are prop losses, installed prop efficiencies and prop repair rates.

The control measures should enable the mine to measure the performance against the established goals. The reporting on the different aspects will enable management decisions to be taken to ensure that prop system performance conforms to the accepted goals.

The quality of the base information supplied by the control system is critical in identifying precise problem areas which require attention. Information which has a limited base will only identify problem areas in general terms. Corrective action to address the problem will in all probability only address the symptoms and not the causes.

The primary difference in the performance of prop systems run by the mines and those run by contractors can be directly attributed to the control systems employed. The controls employed by the contractors may seem to be exhaustive but have proved their worth. The majority of the information required is obtained in the stopes where the props are installed. This can be attained at a relatively low cost with properly trained personnel and the use of modern equipment.

The reporting should be done at each level of the organisational structure. The information should enable the responsible person at each level to take informed decisions to ensure the effective application of the prop system.

11 Service requirements

The service requirements for hydraulic props will be different for each mine and for different types of props. The requirements will depend on the conditions under which the props are used. The critical aspects need to be evaluated in each case to ensure that the system will operate efficiently. These critical aspects revolve around the attrition rate of the prop or components of the prop.

This can be best explained by a number of examples.

- Props which are regularly installed 1,5 m from the face will have a higher blast attrition rate than props installed 2,5 m from the face. The use of blasting barricades can prevent damage to the props from blasting. This could mean that the props installed close to the face, with a blast barricade, exhibit less damage from blasting than props installed at 2,5 m without barricades.
- The quality of mine service water is not consistent throughout the industry. This water is required to pass through the setting pumps and prop valves to set the props. Acidity levels and suspended solids can have a major influence on these components. Acidity levels can accelerate corrosion of components. Fine grit particles increase wear on components. This latter case could become critical when the setting pump can load the prop beyond its slow release pressure. This will cause the grit in the water to pass through the valve. This effect is not as critical during normal operation as the grit would have had time to settle within the prop. The effect on the rapid yielding valve during a rockburst or repeated rockbursts is unknown.
- Flushing of the valve prior to setting can remove the grit from the valve. Where this is not done or not done properly, the effect of grit passing across the valve seats is experienced. This alone could cause a slow leak of the valve, either the filler or yield valves.

The effects of such factors need to be established in order to determine a suitable preventative maintenance programme for props. This may require that, at regular intervals, such as six monthly, several props are to be removed from an area of known conditions of usage and stripped for evaluation of wear and tear. Items that would need to be assessed could include the following evaluations:

  - water inside the prop (e.g. acidity, corrosiveness, etc.)
  - solids inside cylinder (size, shape, material, etc.)

- condition of all external parts (cylinder, ram, head, footpieces, etc.)
- dimensions of all wear parts (‘o’ rings, seals, full valve assemblies)

If sufficient information is collected regarding the wear of parts under specific conditions, then a preventative maintenance plan can be drawn up to ensure that in-stope failures are kept to a minimum. Such an evaluation may best be conducted with the co-operation of a prop contractor who could provide better records on the conditions of use and of the failures and services that were conducted on props.

The current requirements for maintaining props should adhere to the manufacturers recommendations. The use of parts and services not recommended or approved by the manufacturers will continue to create problems with the prop systems.

The performance of a repaired prop is critical when it is required to conform to its original performance specifications (Figures 1.1 and 11.1). The indications are that this cannot be guaranteed with the current repair systems (Figure 11.2). New props are required to conform to the specifications and repaired props are assumed to conform to the specifications. This lowers the confidence levels of the prop system being able to perform at its designed level. (Figure 11.3)

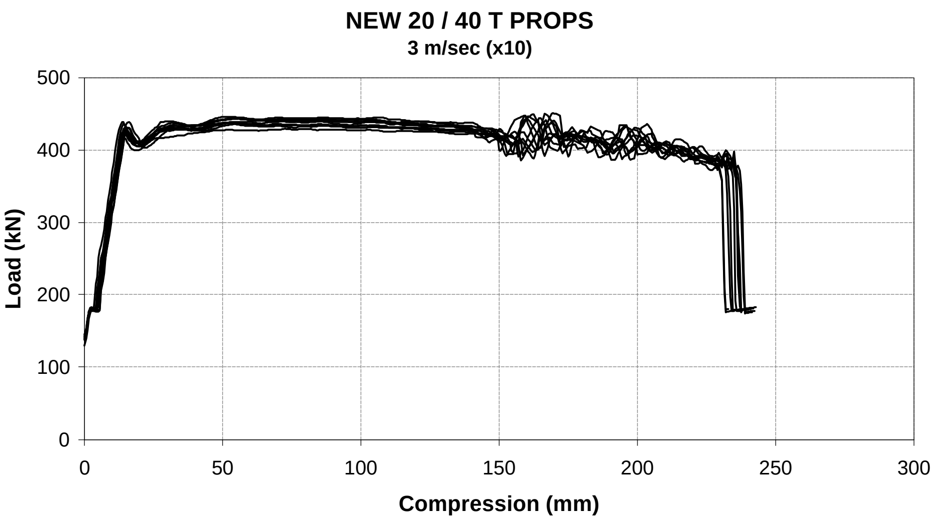

Figure 11.1 Performance during rapid displacement of 10 randomly selected new props.

A system of random sampling and testing will allow an informed decision to be made about the effectiveness of current repair practices.

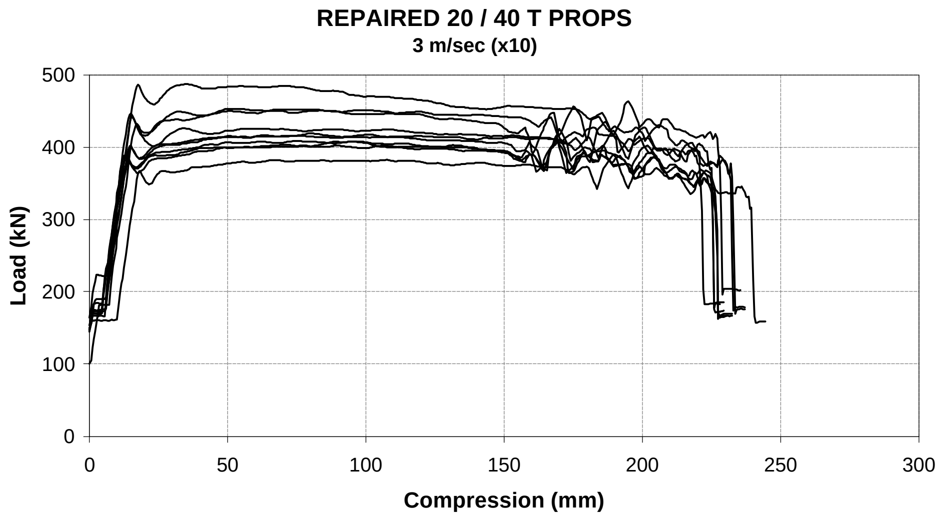

Figure 11.2 Performance during rapid displacement of 10 randomly selected repaired props.

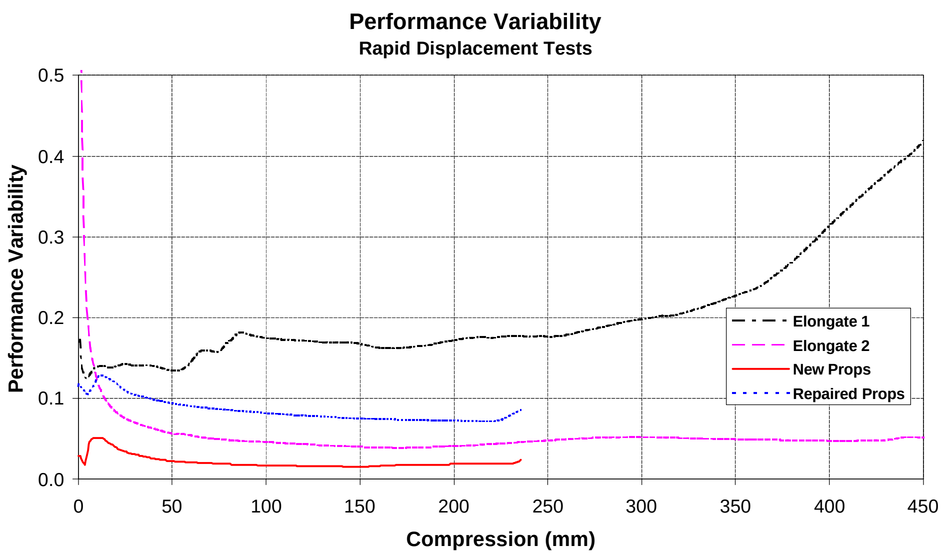

Figure 11.3 Performance variation of new and repaired props compared with that of two types of pre-stressed elongates. The performance variation is determined as a ratio of the standard deviation to the mean evaluated at regular intervals.

Repair records for props are, in most instances, incomplete or completely non existent. If problem areas are to be identified, a complete record must be maintained of the following:

- reported problems from the user,
- problems determined at the repair facility,
- type of service performed, and
- a complete list of all components replaced.

The old components should be inspected for any unusual wear and this should be reported and cross-referenced to the type of environment and usage that this prop has been subjected to since its last service. All replaced parts should be bagged and stored in a systematic manner for future reference in an effort to identify potential problems with the usage of props, repair process or faulty components.

Surface storage of props can result in rapid deterioration of prop performance if this is not dealt with appropriately. Props must be stored in a neutral environment in an upright position. Prop turnaround should be handled on a first in, first out basis to minimise excessive storage time of some units - ideally, less than one month. Seals and ‘o’ rings can dry out and deteriorate with prolonged storage.

All props that have been in storage for longer than one month should be cycled to their full ram extension at least once per month to reduce the potential deterioration of seals and ‘O’ rings. Any prop that is scheduled to be sent underground after storage for a period exceeding one month should be tested to ensure functionality. This could involve pressurising the prop in a test / load frame with a pump set to deliver a pressure high enough to force open the slow yield valve. Provided that the valve opens within the acceptable load range (170 to 200 kN) and that the prop is able to maintain load for at least one hour, then the prop may be sent underground. Prop movements underground should also be co-ordinated to minimise the time that they spend waiting to be taken into and installed in the stope. Any extra props should be rotated with props in use to prevent excessive storage time.

Prop setting pumps and hoses are also susceptible to a great variety of conditions under which their performance can be affected. This could typically include the following:

- total use; compare one panel with 20 props advancing four metres per month to one with 60 props advancing 16 metres per month (12 fold increase in use)
- subjected to falls of ground

- subjected to fly rock from a face blast
- dragged by a scraper while cleaning in back areas
- condition of the water supplying the pump

The lack of reliability of such equipment is generally the result of abuse in their handling, usually due to carelessness. The wear on pumps and associated parts (even in areas of extensive use) is often much less significant that that due to abuse. If a pump is handled within the limits of its design (as they are designed to take the harsh conditions encountered in deep-level stopes), the sudden failure of components should be relatively infrequent. A reduction in the pressure supplied by the pump is an indication that a service is required. Through normal wear and tear of a pump, signs of reduced performance would allow time to exchange units without fear of pump failure. This time period would vary depending on the conditions encountered. The use of a pump pressure gauge to ensure optimum performance is therefore recommended at the beginning and end of each prop installation cycle.

11.1 Service responsibilities

With the extensive problems that have been, and are currently being, experienced on the mines with the reliability of hydraulic props, stricter control measures need to be in place to ensure their reliability after they have been serviced. A service agreement would need to be negotiated between the manufacturer and user to ensure that the division of responsibility for the servicing and maintenance of these units can be adhered to by all involved. This will ensure that the optimum performance can be maintained at all times.

The most critical component on the prop is the valve and this is also the most difficult to service. Dimension specifications, tolerances and materials are critical to the functioning of the valve, and therefore the prop. The controls in place to ensure that the assembly of the valves is conducted to exacting specifications cannot be easily duplicated elsewhere and certainly not at a mine workshop. Third party repairs and services of valves are currently being conducted at a much lower cost to the mine because these specifications are not being met. For these reasons, it must therefore be recommended that valve servicing and repair be conducted only by the original manufacturer and preferably on a service exchange basis to minimise downtime of the prop. The product can then be guaranteed to the mine as functioning to the required specification.

All other, low tech, service and repairs should be the responsibility of the user or a designated agent. This work is then to be conducted in accordance to the manufacturer's recommended procedures using only accepted parts. This may include the replacement of all moving and wearing parts.

The failure of a hydraulic prop and subsequent service required can be divided into two key areas: 1) yield valve only and 2) all remaining small component failures and large scale damage. Provided that the yield valve is externally accessible, if a valve failure is suspected, valves can be easily replaced and the prop can be back in use in a short period of time. However, each prop should still be checked (or closely monitored while initially back in use) to ensure that the failure / problem has, in fact, been properly diagnosed and dealt with. The misdiagnosis of a prop failure can easily occur in the confines and difficult working conditions of the stope face. Provided that the problem has been solved, no formalised standard testing should be required as the stock valves should already have been tested.

Any other failure would result in the prop having to be brought to the workshop to be stripped and repaired. If the failure has been identified, all aspects of the prop surrounding the failed component should be inspected for the cause of failure. The repaired prop amongst the other repaired props would then be batch tested in order to evaluate the quality of the maintenance process.

In terms of prop accessories, only the setting pump is considered a serviceable item. Pump servicing / repair has generally been conducted on a breakdown basis by both mines and contractors. Delay problems have been minimised with an ample supply of spare pumps. Spare pumps would have to be available in case of failure whether a maintenance scheme was introduced or not. The users do not appear to have a problem with this approach. The routine use of a pump pressure gauge is recommended to ensure the correct setting load of the props. A drop in delivery pressure is likely to be the first sign of a problem with the pump and the unit can be replaced before failure.

Headboards and extensions are a consumable item, but still need to be cared for to maximise the life expectancy of every unit. These accessories are reusable as long as they appear intact, without deformation, and that they can be separated from one another or a prop with no more than a stiff blow from a four-pound hammer. Any attempt to repair a deformed or cracked headboard or extension would result in a support element of inferior strength resulting in further failure in the near future with potentially catastrophic consequences. Damaged units need to be discarded immediately.

11.2 Testing programme

All repaired props need to undergo some sort of testing, ranging from just pressurisation to full rapid displacement testing. Since full functional testing of each prop would be impractical and uneconomical, batch testing using some sort of sampling routine would appear to be the best option to ensure that the optimum performance is being maintained. Some sort of testing would even be desirable for props currently in operation in order to gain information on their performance with the possibility of identifying potential problems prior to the unit's failure.

The sampling procedure that is used to determine the sample size of props for testing from each batch varies from one user to another. Most (but not all) new hydraulic props are batch tested prior to delivery and acceptance by the user. Batch testing, in most instances, involves testing between five and 10 per cent of a batch of props to obtain slow and rapid displacement performance. As stated previously, very few repaired props are tested in this manner and the failure rate of these is unacceptably high (in the order of 20 per cent, Table 3.1).

If a prop is changed or repaired in any manner, there must be some sort of minimum testing to which the unit is subjected to ensure functionality (Table 11.1). In the case of new props, testing will continue as currently being done. The extent of testing of repaired props will vary depending on the extent and location of the repair. For example, if valves are exchanged in-stope, then setting the prop in the back area and observing its behaviour may be the only test that can be conducted without bringing it to a workshop, resulting in the loss of use of a prop for a certain period. In the case of a rebuilt prop, more extensive testing would be desirable to ensure that re-assembly has been adequately completed.

Since the valves are the most critical component of a hydraulic prop and the vast majority of prop failures that occur during testing is related to the valves, all valves supplied to the user individually (without a prop) should be tested with the sampling and acceptance criteria as a complete prop for full functionality testing (Table 11.2). Prop repairs that only require a valve exchange should not require full testing as long as the problem has been correctly identified and that by all appearances, the prop should be otherwise operational. Due to general wear and deterioration, props that have had to be stripped for repair, should be fully tested at least to the same extent as new props if the specified performance is to be maintained.

Table 11.1 Minimum functionality testing requirements for all 20 - 40 ton RYH Props prior to their installation underground, determined by their state of repair.

Prop Condition	Minimum Testing for Each Unit
new props	no leaks, slow and rapid yield portions of valves functional, complete extension and contraction of ram in cylinder, prop maintains setting load
repaired valves	no leaks, slow and rapid yield portions of valves functional
valve exchange only	no leaks, prop remains installed if setting load cannot be checked
prop repairs	no leaks, complete extension and contraction of ram in cylinder, prop maintains setting load

Table 11.2 Recommended sample sizes for full functionality (slow and rapid displacement) testing.

Product Tested	Sampling Size	Comments
new props	5 - 10 %	as currently
new / repaired valves	5 - 10 %	same as new props
valve exchange only	0	valves already tested
prop repairs	10 %	at least as new prop
props in use	1 % annually	retrieved during move

It would be useful to test props which are currently in use and assumed to be in good working order. A sample of props could be taken from a stope or panel as the props are being moved from one working place into another. A small sample of approximately one per cent of props could be taken over a one year period to get some indication of the actual performance of these units. Although one per cent is a very small sample when considering a limited number of panels, across the industry, this could be around 500 prop tests. Although props installed at the face may appear to behave as designed, slow stope convergence and lack of operation of the rapid yield valve for an extended period may lead to a false sense of security regarding its functionality.

Each prop pump should be equipped with a pump pressure gauge used to ensure that the pump can deliver the required pressures to set the prop. This should be done at the beginning of every shift. Failure to achieve a minimum prop load (stated to be approximately 120 kN) could result in the blasting out of props. One or two prop load cells should also be present to allow for quick and easy testing of props that are suspected of inadequate performance. Following a valve exchange, the prop may be tested in-stope to ensure that the setting load can be maintained. (Table 11.1)

12 Conclusions

Literature survey

1. Similar problems as to those experienced today have existed since the introduction of hydraulic props over 20 years ago.

Current situation

1. Generally, the mines do not obtain the maximum benefit from hydraulic props.
2. Many alternative support systems have a variable and non-repeatable performance.
3. Hydraulic prop systems are seen to be excessively expensive. This is only the case where the prop control and maintenance systems have failed.

Manufacturer’s perspective

1. Manufacturers are concerned that they are competing with inferior products which claim to have similar performance characteristics.
2. Manufacturers have no control of their products once they are delivered to the mines. This is particularly relevant to usage, servicing, replacement parts and overall performance.
3. Manufacturers are concerned about the stringent performance requirements for their products when no such requirements apply to competitive products.
4. Proper servicing of hydraulic props requires that many components are replaced with new components. The old components may not show any signs of wear but failure to replace some of these components will result in a compromise of prop performance.
5. Servicing of hydraulic props by any agent, mine or even prop manufacturer is no guarantee that all the props will perform to their original specifications.

Mine’s perspective

1. Mines typically encounter problems with the reliability, cost and worker acceptance of hydraulic prop systems.
2. The support, training, maintenance and implementation of hydraulic prop systems have proved to be problematic on most mines. This normally follows a phase when the prop systems performed very well. Some mines do have efficient prop systems currently in use.

3. Service requirements for hydraulic props and ancillary equipment is largely on a breakdown basis. No comprehensive recommendations on service requirements exist to assist the mines with their planning.
4. Hydraulic prop workshop capacity, training and skills is usually overwhelmed when prop implementation exceeds a specific number of props.
5. Certain geotechnical areas are problematic with regard to hydraulic prop utilisation. This is specifically where “punching” is known to occur. Incompetent and weak hangingwall or footwall conditions could be further compromised by the forces exerted by hydraulic props.
6. Inefficient hydraulic prop systems are expensive, unreliable, disliked by mine personnel and a liability to the safe production of a mine.
7. Hydraulic props are treated as consumables on many mines. This reflects poor management of capital equipment.
8. Hydraulic props require correct setting and functional releasing equipment, pumps, etc, the correct procedures for setting and releasing, the use of footpieces and headboards combined with an effective management system are required. The management system includes monitoring, training, servicing and providing sufficient equipment when and where it is required. Any break in the system will compromise the overall performance of the props which will in turn cause the entire system to fail.

Contractor’s perspective

1. Contractors have a high percentage prop utilisation when compared with most mines. The quality of prop installation with respect to the mines standards is extremely good. This is usually achieved in the most arduous conditions.
2. Contractors have an efficient control system which is reflected by their minimal prop losses .
3. Contractors can offer a prop installation service to most mines at a lower cost than the mines themselves can achieve.
4. The margins for hydraulic prop contractors are not great. This, combined with their reliance on mine production personnel in the mining cycle in arduous conditions, may see a cessation of such support installation services in the future.
5. Contractors generally obtain a higher level of worker motivation and commitment when compared to the mines support labour.

Workforce perspective

1. Support installation problems often occur due to the practice of not cleaning the footwall of all broken rock (incomplete or poor cleaning).
2. The most suitable support system for any mine is a support system that the specific mine can implement and have installed on the face where it can assist the production and provide a measure of safety to the personnel working there. Considerations for the type of support requirements will then dictate specific support elements. Any support in the face is worth far more than the best support in the mine's standards.

Cost implications

1. There is no standardised methodology for costing support systems, which makes comparative costing between systems difficult.
2. RYHP systems are reusable and as such have considerable cost saving advantages. Generally RYHP systems compare favourably with any other support system for rockfall control where the face advances exceed 10 m per month. In rockburst prone areas RYHP systems are most cost effective where face advances exceed 4 m per month.
3. Mines often compare their RYHP systems costs with those of alternative support systems and claim cost and productivity advantages from using these alternatives. Where their RYHP's have failed as a functional system, costs are out of control and the installed props become more of a problem than a support system. In such, alternative support systems compare favourably from a cost and an ease of installation viewpoint.

Implementation requirements

1. Effective prop utilisation on mines depends on the emphasis placed on ensuring that the system has all the necessary support and control mechanisms in place.
2. The inability of the industry, as a whole, to implement and utilise hydraulic props, reflects poorly on any future technological advances being implemented successfully.

Control requirements

1. Many RYHP's across the industry are installed without headboards. This creates point loading and results in a loss of areal coverage.

2. The incorrect usage of extension pieces results in insufficient leg extension left to absorb normal stope convergence and any dynamic convergence during a rockburst.

Service requirements

1. The use of non - standard parts, e.g. headboards, extensions, valve components and seals, compromises the prop’s performance.

13 Recommendations

The manufacturers need to have more involvement on the mines. With the introduction of hydraulic props to cater for rockbursts and meeting the requirements for rapid stope convergence, prop manufacturers were becoming relaxed regarding their involvement on the mines as no other product could provide the face support performance requirements. Interaction with mine personnel and involvement with the mining problems has given the manufacturers of alternative support systems a very strong position in the support market.

Many of the aspects of hydraulic props are well known and understood. There are areas where accurate predictions of expected performance and failures need to be defined. Information of this nature will assist the prop users in their planning and day to day operations. The requirements of hydraulic prop systems are well known but still create problems.

Close co-operation between suppliers and customers is essential for the effective utilisation of prop systems. The needs and responsibilities of each need to be clearly defined.

A model for the implementation and usage of hydraulic prop systems needs to be established. A team of experts should be available to assist a mine through the various phases of implementation.

13.1 Best practice

The usage of props in the industry has diminished significantly in the last few years. Although many mines still make use of props in the most hazardous areas, the prop control structure that was in place ten / twenty years ago, has all but disappeared. To re-establish this structure in mines currently using props or those wishing to introduce props for the first time, requires a commitment from management (and labour) that props will be used and that the systems will be in place to ensure a functional, cost effective support system.

If the logistics behind the establishment of such an infrastructure appears beyond the capabilities of mines given their existing structure, prop contractors should seriously be considered as a viable alternative. The mine must then be committed to the use of contractors and allow them to operate in a manner that is economically viable to them. They should not be seen as people that come in and operate in conditions that the mines have lost control over. If only the most difficult of working areas are turned over to contractors, they must be adequately compensated.

If a functional prop system is to be established, the drafting of implementable mine standards and training of personnel should be done in conjunction with technical representatives from the manufactures involved. The lack of involvement by suppliers in the running of prop systems on the mines cannot be overlooked as an influence in the collapse of prop systems on the mines (certainly one of the reasons that pre-stressed elongates have achieved so much success recently in replacing props). The commitment by suppliers is essential in maintaining a cost effective prop system.

All assembly lines can experience problems, either with the parts supplied or labour related issues (attitude of personnel, staff turnover, skill levels, etc.). Routine, quality assurance testing conducted in-house during manufacture and on completion needs to be conducted to guarantee a consistent, functional product. Full functional testing then needs to be conducted at CSIR, Mining Technology (as this is the only facility capable of conducting controlled rapid displacement testing) prior to delivery to the user. The recommended testing at various stages has been discussed earlier in some detail for props and accessories. The sampling procedure for this testing could be established (as part of the purchase contract) by individual mines or mining houses. The use of British standards BS 6001 and BS 6002 by some mines is recommended as it allows for increased or reduced sampling depending on product consistency.

The servicing of props has been the main source of problems regarding performance and reliability. A service agreement between user and supplier needs to be established to clearly define the responsibilities of each party. This agreement should also include training of mine personnel in service procedures. Only the manufacturer should deal with high tech or high precision components. All other areas could be the responsibility of the mine prop shop personnel or a manufacturer recognised third party. All components must be supplied or approved by the original manufacturer to ensure compatibility with the system.

The testing of serviced / repaired props has been limited in extent. Full functional testing has been almost completely non-existent and yet significant problems in prop performance have been identified (10 per cent non-compliance to specs with an additional 10 per cent complete functional failure following rapid displacement testing). The test requirements have been discussed previously in some detail.

14 References

Arnold, D.A., Legg, E.W. & Roberts, M.K.C. 1994 Reducing the unsupported stope span at Hartebeestfontein Gold Mine. XV'th CMMI Congress, Johannesburg, SAIMM, Vol. 1,159-165.

Elbroc Strata Control. 1997 Personal Communication on hydraulic prop usage and maintenance. Boksburg North, 1460

Hojem, JPM, Taggart, PN & Roberts, MKC. 1991 Functional requirements for prop based support systems for use in rockburst-prone stopes, Project GR1P, Reference Report 45/90 (Amended), Chamber of Mines of South Africa, Carlow Road, Auckland Park, Johannesburg, 2000

Schweitzer, J. 1997 Personal communication on geotechnical areas. CSIR: Division of Mining Technology, Carlow Road, Auckland Park, Johannesburg, 2000

Steinmuller Mining and Piping. 1997 Personal Communication on hydraulic prop usage and maintenance. Heidelberg, 2400

Stopetek 1997 Personal Communication on hydraulic prop usage, Primrose, 1416

Tyser, J.A. & Wagner, H. 1976 A Review of Six Years of Operations with the Extended Use of Rapid-yielding Hydraulic Props at the East Rand Proprietary Mines, Limited, and Experience Gained Throughout the Industry, Association of Mine Managers of South Africa, 321-347.

Unique Engineering. 1997 Personal Communication on hydraulic prop usage and maintenance. Lilianton, Boksburg, 1467

Van Rensburg et al. 1991 "Physiological demands associated with handling props underground." Reference Report No. 6 / 91, Chamber of Mines of South Africa, Johannesburg, South Africa. 2000

Wagner, H. & Lloyd P.J.D. 1981 Implementing Advances in the Mining Industry, Symposium on Management in Research Establishments, Randburg, 23-26.

Welprop Support Systems 1997 Personal Communication on hydraulic prop usage, Eva Park, Cresta

Appendix 1

Costing of relative support systems

The following cost estimations are based on various assumptions. These assumptions are used to enable a direct comparison of the actual cost per centare for different support systems.

1.1 Pre-stressed elongate support systems

The following assumptions have been made.

The panel is 30 m long
The face advance is 1 m per blast using 1,2 m drill steel
The stoping width is 1 m
Elongates are 1.2 m long
Support spacing is 1.0 m on strike and 1.5 m on dip
Support is installed 2.5 m from the face before the blast
A longwall layout with follow behind gullies is used
Packs are 1.5 m by 1.1 m long axis on dip spaced at 2.0 m on strike 3.5 m from the face before the blast
The number of elongates installed per blast = 18
The square metres mined per blast = 30
It is assumed that a secondary shaft system is used and the depth of mining is 2 500 m
Elongates are bundled and loaded by forklift into material cars on surface
Material cars are transported 250 m to the bank
Material cars are transported 500 m to the secondary shaft bank
Material cars are transported 2000 m to the crosscut or stope access
The sweeping line is 5.5 m from the face before the blast

Cost Calculation

Number of elongates required per blast	= 18
Cost of 30 elongates @ R 110.00	= R 1 980
Time taken to install one elongate	= 12.14 man minutes
Time taken to install 18 elongates	= 218.52 man minutes
Total installation costs @ R 0.23 per minute	= R 50.26
Transportation and hoisting @ R 1.13 per elongate	= R 20.34
Total cost to install 18 elongates per blast	= R 2 050.60
Total m^2 broken per blast	= 30 m^2
Total cost for elongate support	= R 68.35 per m^2

1.2 Profile prop support systems

The following assumptions have been made.

The panel is 30 m long
The face advance is 1 m per blast using 1,2 m drill steel
The stoping width is 1 m
Profile props are 1.2 m long
Support spacing is 1.0 m on strike and 1.5 m on dip
Support is installed between the last line of hydraulic props
A longwall layout with follow behind gullies is used
Packs are 1.5 m by 1.1 m long axis on dip spaced at 2.0 m on strike 3.5 m from the face before the blast
The number of profile props installed per blast = 18
The square metres mined per blast = 30
It is assumed that a secondary shaft system is used and the depth of mining is 2 500 m
Profile props are bundled and loaded by forklift into material cars on surface
Material cars are transported 250 m to the bank
Material cars are transported 500 m to the secondary shaft bank
Material cars are transported 2000 m to the crosscut or stope access
The sweeping line is 5.5 m from the face before the blast

Cost Calculation

Number of profile props required per blast	= 18
Cost of 18 profile props @ R 36.00	= R 648
Time taken to install one profile props	= 11.46 man minutes
Time taken to install 18 profile props	= 206.28 man minutes
Total installation costs @ R 0.23 per minute	= R 47.44
Transportation and hoisting @ R 1.13 per profile	= R 20.34
Total cost to install 18 elongates per blast	= R 715.78
Total m^2 broken per blast	= 30 m^2
Total cost for elongate support	= R 23.86 per m^2

1.3 Rapid Yielding Hydraulic Prop support system

The following assumptions have been made.

The panel is 30 m long
The face advance is 1 m per blast using 1,2 m drill steel
The stoping width is 1 m
Hydraulic props are 750 mm long
Support spacing is 1.0 m on strike and 1.5 m on dip
Support is installed 2.5 m from the face before the blast
A longwall layout with follow behind gullies is used
Packs are 1.5 m by 1.1 m long axis on dip spaced at 2.0 m on strike 3.5 m from the face before the blast
The number of hydraulic props installed per blast = 18
The square metres mined per blast = 30
It is assumed that a secondary shaft system is used and the depth of mining is 2 500 m
Hydraulic props are manually loaded into material cars on surface
Material cars are transported 250 m to the bank
Material cars are transported 500 m to the secondary shaft bank
Material cars are transported 2000 m to the crosscut or stope access
The sweeping line is 5.5 m from the face before the blast
Total cost for pumps, hoses, props, headboards, extensions etc = R 1 250 per prop
Three lines of hydraulic props are installed
The support system is installed over three blasts
This cost calculation assumes no maintenance costs and no equipment attrition

Cost Calculation

Number of hydraulic props required per blast	=	18
Number of hydraulic props required for the system	=	54
Cost of 54 hydraulic props @ R 1 250	=	R 67 500
Time taken to move and install one hydraulic prop	=	11.00 man minutes
Time taken to install 54 hydraulic props	=	594 man minutes
Total installation costs @ R 0.23 per minute	=	R 136.62
Total installation costs per blast	=	R 45.54
Transportation and hoisting @ R 2.26 per prop	=	R 122.04

Total cost to install 54 hydraulic props for first 3 blasts	=	R 67 758.66
Total m^2 broken per blast	=	30 m^2
Total cost for hydraulic prop support for the first blast	=	R 2 255.59 per m^2
Total cost for hydraulic prop support for the second blast	=	R 1 128.55 per m^2
Total cost for hydraulic prop support for the third blast	=	R 752.87 per m^2

1.4 Contractors hydraulic prop installation costs

Cost per prop installed per month	=	R 170
Maintenance costs per prop per month	=	R 20

Total cost per prop installed per month	=	R 190
Total cost for 54 props installed per month	=	R 10 260

Assume a face advance of 8 metres

Assume 30 m^2 per blast

Cost calculation

Total production per month 8 x 30	=	240 m^2
Total costs	=	R 10 260
Cost per centare	=	R 42.75 per m^2

1.5 Existing cost structure for a mine operating hydraulic props

Total maintenance cost per prop per month	=	R 170

Assume a face advance of 8 metres

Assume 30 m^2 per blast

Assume 54 props

Cost calculation

Total production per month 8 x 30 m^2	=	240 m^2
Total costs	=	R 9 180
Cost per centare	=	R 38.25 per m^2

Appendix 2

Costing of hydraulic prop support systems at various percentage attrition rates as a cost per square metre mined

These costs assume that the system is being replaced at a certain percentage of initial cost, due to attrition, each year.

Number of blasts	Costs at 0 %	Costs at 5 %	Costs at 10 %	Costs at 15 %	Costs at 20 %	Costs at 25 %
1	2251.52	2364.02	2476.52	2589.02	2701.52	2814.02
2	1126.52	1182.77	1239.02	1295.27	1351.52	1407.77
3	751.52	789.02	826.52	864.02	901.52	939.02
4	564.02	592.14	620.27	648.39	676.52	704.64
5	451.52	474.02	496.52	519.02	541.52	564.02
6	376.52	395.27	414.02	432.77	451.52	470.27
7	322.95	339.02	355.09	371.16	387.23	403.30
8	282.77	296.83	310.89	324.96	339.02	353.08
9	251.52	264.02	276.52	289.02	301.52	314.02
10	226.52	237.77	249.02	260.27	271.52	282.77
11	206.06	216.29	226.52	236.75	246.97	257.20
12	189.02	198.39	207.77	217.14	226.52	235.89
13	174.59	183.25	191.90	200.56	209.21	217.86
14	162.23	170.27	178.30	186.34	194.38	202.41
15	151.52	159.02	166.52	174.02	181.52	189.02
16	142.14	149.17	156.21	163.24	170.27	177.30
17	133.87	140.49	147.11	153.72	160.34	166.96
18	126.52	132.77	139.02	145.27	151.52	157.77
19	119.94	125.86	131.78	137.70	143.62	149.54
20	114.02	119.64	125.27	130.89	136.52	142.14
21	108.66	114.02	119.38	124.73	130.09	135.45
22	103.79	108.90	114.02	119.13	124.25	129.36

23	99.34	104.24	109.13	114.02	118.91	123.80
24	95.27	99.96	104.64	109.33	114.02	118.71
25	91.52	96.02	100.52	105.02	109.52	114.02
26	88.06	92.38	96.71	101.04	105.36	109.69
27	84.85	89.02	93.18	97.35	101.52	105.68
28	81.88	85.89	89.91	93.93	97.95	101.96
29	79.10	82.98	86.86	90.74	94.62	98.50
30	76.52	80.27	84.02	87.77	91.52	95.27
31	74.10	77.73	81.36	84.99	88.61	92.24
32	71.83	75.35	78.86	82.38	85.89	89.41
33	69.70	73.11	76.52	79.93	83.34	86.75
34	67.69	71.00	74.31	77.62	80.93	84.24
35	65.80	69.02	72.23	75.45	78.66	81.88
36	64.02	67.14	70.27	73.39	76.52	79.64
37	62.33	65.37	68.41	71.45	74.49	77.53
38	60.73	63.69	66.65	69.61	72.57	75.53
39	59.21	62.09	64.98	67.86	70.75	73.63
40	57.77	60.58	63.39	66.21	69.02	71.83
41	56.40	59.14	61.88	64.63	67.37	70.12
42	55.09	57.77	60.45	63.13	65.80	68.48
43	53.84	56.46	59.08	61.69	64.31	66.92
44	52.65	55.21	57.77	60.32	62.88	65.44
45	51.52	54.02	56.52	59.02	61.52	64.02
46	50.43	52.88	55.32	57.77	60.21	62.66
47	49.39	51.78	54.18	56.57	58.96	61.36
48	48.39	50.74	53.08	55.42	57.77	60.11
49	47.44	49.73	52.03	54.32	56.62	58.92
50	46.52	48.77	51.02	53.27	55.52	57.77
51	45.64	47.84	50.05	52.25	54.46	56.67
52	44.79	46.95	49.11	51.28	53.44	55.60
53	43.97	46.09	48.22	50.34	52.46	54.58
54	43.18	45.27	47.35	49.43	51.52	53.60
55	42.43	44.47	46.52	48.56	50.61	52.65

56	41.70	43.71	45.71	47.72	49.73	51.74
57	40.99	42.97	44.94	46.91	48.89	50.86
58	40.31	42.25	44.19	46.13	48.07	50.01
59	39.65	41.56	43.47	45.37	47.28	49.19
60	39.02	40.89	42.77	44.64	46.52	48.39
61	38.40	40.25	42.09	43.94	45.78	47.62
62	37.81	39.62	41.44	43.25	45.07	46.88
63	37.23	39.02	40.80	42.59	44.38	46.16
64	36.67	38.43	40.19	41.95	43.71	45.46
65	36.13	37.86	39.59	41.33	43.06	44.79
66	35.61	37.31	39.02	40.72	42.43	44.13
67	35.10	36.78	38.46	40.14	41.82	43.50
68	34.61	36.26	37.92	39.57	41.22	42.88
69	34.13	35.76	37.39	39.02	40.65	42.28
70	33.66	35.27	36.88	38.48	40.09	41.70
71	33.21	34.79	36.38	37.96	39.55	41.13
72	32.77	34.33	35.89	37.46	39.02	40.58
73	32.34	33.88	35.42	36.96	38.50	40.05
74	31.92	33.44	34.96	36.48	38.00	39.52
75	31.52	33.02	34.52	36.02	37.52	39.02
76	31.12	32.60	34.08	35.56	37.04	38.52
77	30.74	32.20	33.66	35.12	36.58	38.04
78	30.36	31.81	33.25	34.69	36.13	37.58
79	30.00	31.42	32.85	34.27	35.70	37.12
80	29.64	31.05	32.46	33.86	35.27	36.67
81	29.30	30.68	32.07	33.46	34.85	36.24
82	28.96	30.33	31.70	33.07	34.44	35.82
83	28.63	29.98	31.34	32.69	34.05	35.40
84	28.30	29.64	30.98	32.32	33.66	35.00
85	27.99	29.31	30.64	31.96	33.28	34.61
86	27.68	29.99	30.30	31.61	32.91	34.22
87	27.38	28.67	29.97	31.26	32.55	33.85
88	27.09	28.36	29.64	30.92	32.20	33.48

89	26.80	28.06	29.33	30.59	31.86	33.12
90	26.52	27.77	29.02	30.27	31.52	32.77
91	26.24	27.48	28.72	29.95	31.19	32.42
92	25.97	27.20	28.42	29.64	30.87	32.09
93	25.71	26.92	28.13	29.34	30.55	31.76
94	25.45	26.65	27.85	29.04	30.24	31.44
95	25.20	26.39	27.57	28.75	29.94	31.12
96	24.96	26.13	27.30	28.47	29.64	30.81
97	24.71	25.87	27.03	28.19	29.35	30.51
98	24.48	25.63	26.77	27.92	29.07	30.22
99	24.25	25.38	26.52	27.65	28.79	29.93
100	24.02	25.14	26.27	27.39	28.52	29.64
101	23.80	24.91	26.02	27.14	28.25	29.36
102	23.58	24.68	25.78	26.89	27.99	29.09
103	23.36	24.45	25.55	26.64	27.73	28.82
104	23.15	24.23	25.32	26.40	27.48	28.56
105	22.95	24.02	25.09	26.16	27.23	28.30
106	22.74	23.81	24.87	25.93	26.99	28.05
107	22.55	23.60	24.65	25.70	26.75	27.80
108	22.35	23.39	24.43	25.48	26.52	27.56
109	22.16	23.19	24.22	25.26	26.29	27.32
110	21.97	23.00	24.02	25.04	26.06	27.09
111	21.79	22.80	23.82	24.83	25.84	26.86
112	21.61	22.61	23.62	24.62	25.63	26.63
113	21.43	22.43	23.42	24.42	25.41	26.41
114	21.25	22.24	23.23	24.22	25.20	26.19
115	21.08	22.06	23.04	24.02	25.00	25.97
116	20.91	21.88	22.85	23.82	24.79	25.76
117	20.75	21.71	22.67	23.63	24.59	25.56
118	20.59	21.54	22.49	23.45	24.40	25.35
119	20.43	21.37	22.32	23.26	24.21	25.15
120	20.27	21.21	22.14	23.08	24.02	24.96
121	20.11	21.04	21.97	22.90	23.83	24.76

122	19.96	20.88	21.80	22.73	23.65	24.57
123	19.81	20.73	21.64	22.55	23.47	24.38
124	19.66	20.57	21.48	22.38	23.29	24.20
125	19.52	20.42	21.32	22.22	23.12	24.02
126	19.38	20.27	21.16	22.05	22.95	23.84
127	19.23	20.12	21.01	21.89	22.78	23.66
128	19.10	19.98	20.85	21.73	22.61	23.49
129	18.96	19.83	20.70	21.58	22.45	23.32
130	18.83	19.69	20.56	21.42	22.29	23.15
131	18.69	19.55	20.41	21.27	22.13	22.99
132	18.56	19.42	20.27	21.12	21.97	22.82
133	18.44	19.28	20.13	20.97	21.82	22.66
134	18.31	19.15	19.99	20.83	21.67	22.51
135	18.18	19.02	19.85	20.68	21.52	22.35
136	18.06	18.89	19.72	20.54	21.37	22.20
137	17.94	18.76	19.58	20.40	21.23	22.05
138	17.82	18.64	19.45	20.27	21.08	21.90
139	17.71	18.51	19.32	20.13	20.94	21.75
140	17.59	18.39	19.20	20.00	20.80	21.61
141	17.48	18.27	19.07	19.87	20.67	21.46
142	17.36	18.16	18.95	19.74	20.53	21.32
143	17.25	18.04	18.83	19.61	20.40	21.19
144	17.14	17.92	18.71	19.49	20.27	21.05
145	17.04	17.81	18.59	19.36	20.14	20.91
146	16.93	17.70	18.47	19.24	20.01	20.78
147	16.82	17.59	18.35	19.12	19.89	20.65
148	16.72	17.48	18.24	19.00	19.76	20.52
149	16.62	17.37	18.13	18.88	19.64	20.39
150	16.52	17.27	18.02	18.77	19.52	20.27

Appendix 3

Conclusions as presented to GAPREAG on 17 October 1997

1. The future of rapid yielding hydraulic props in the South African Gold mining industry is presently uncertain.

2. Generally the mines have the inability to obtain the maximum benefit from hydraulic props.

3. Manufacturers are concerned that they are competing with inferior products which claim to have similar performance characteristics.

4. Manufacturers have no control of their products once they are delivered to the mines. This is particularly relevant to usage, servicing, replacement parts and overall performance.

5. Hydraulic prop systems are seen to be excessively expensive. This is only the case where the prop control and maintenance systems have failed.

6. Manufacturers are concerned about the stringent performance requirements for their products when no such requirements apply to competitive products.

7. Mines typically encounter problems with the reliability, cost and worker acceptance of hydraulic prop systems.

8. The support, training, maintenance and implementation of hydraulic prop systems has proved to be problematic on most mines. This normally follows a phase when the prop systems performed very well. Some mines do have efficient prop systems currently in use.

9. Service requirements of hydraulic props and ancillary equipment is largely on a breakdown basis. No comprehensive service requirements or recommendations exist to assist the mines with their planning.

10. Hydraulic prop workshop capacity, training and skills are usually overwhelmed when prop implementation exceeds a specific number of props.

11. Inefficient hydraulic prop systems are expensive, unreliable, disliked by mine personnel and a liability to the safe production of a mine.

12. Proper servicing of hydraulic props requires that many components are replaced with new components. The old components may not show any signs of wear but non-exclusion of those components will result in a compromise of prop performance.

13. Servicing of hydraulic props by any agent, mine or even prop manufacture is no guarantee that all the props will perform to their original specifications.

14. Hydraulic props are treated as consumables on many mines. This reflects poor management of capital equipment.

15. Certain geotechnical areas are problematic with regard to hydraulic prop utilisation. This is specifically where “punching” is known to occur. Incompetent and weak hangingwall conditions could be further compromised by the forces exerted by hydraulic props.

16. Hydraulic props are a system comprising correct setting and releasing equipment, pumps etc, the correct procedures for setting and releasing, the use of foot pieces and headboards combined with an effective management system. The management system includes monitoring, training, servicing and providing sufficient equipment when and where it is required. Any break in the system will compromise the overall performance of the props which will in turn cause the entire system to fail.

17. Contractors have a high percentage prop utilisation when compared with most mines. The quality of prop installation with respect to the mines standards is extremely good. This is usually achieved in the most arduous conditions.

18. Contractors have an efficient control system which is reflected by their minimal prop losses.

19. Contractors can offer a prop installation service to most mines at a lower cost than the mines themselves can achieve.

20. The margins for hydraulic prop contractors are not great. Combined with their reliance on mine production personnel in the mining cycle in arduous conditions may see a cession of such support installation services in the future.

21. Contractors generally obtain a high level of worker motivation and commitment when compared to the mines support labour.

22. Support installation problems often occur due to the practice of not cleaning the footwall of all broken rock. (Incomplete or poor cleaning).

23. Dedicated RYPH support teams, which function in conjunction with, but as a separate entity from production personnel, obtain the best results from the prop systems.

24. RYPH’s have proved to assist with stoping width control. This is more a function of the installation distance to face and the use of suitable and effective load spreaders than the support type. Any support type that can be installed close to the face with an effective headboard and withstand the blast will provide this benefit.

25. Worker safety is enhanced by the use of suitable and correctly spaced support close to the stope face. RYHP’s are one form of support that can provide this benefit reliability.

26. Support unit for support unit RYPH’s provide the best personnel protection in seismically active stopes.

27. Many RYPH's across the industry are installed without headboards. This creates point loading and results in a loss of areal coverage.

28. The incorrect usage of extension pieces results in insufficient leg extension left to absorb normal stope closure and any dynamic closure during a rockburst.

29. The use of non-standard parts e.g. headboards, extensions, valve components and seals compromise the prop's performance.

30. RYPH systems are re-usable and as such have considerable cost saving advantages. Generally RYPH systems can compare favourably with any other support system for rockfall control where the face advances exceed ten metres per month. In rockburst prone areas RYPH systems are the most cost effective where face advances exceed four metres per month when compared with pre-stressed elongate support systems.

31. Mines often compare their RYHP systems costs with those of pre-stressed elongate support systems and claim cost and productivity advantages from using the elongate systems. This is valid where their RYHP's have failed as a functional system. In this case the RYHP systems costs are out of control and the installed props are more of a problem than a support system. Pre-stressed elongate systems then compare favourably from a cost and an ease of installation viewpoint.

32. Effective prop utilisation on mines depends on he emphasis placed on ensuring that the system has all the necessary support and control mechanisms in place.

33. There is no standardised methodology for costing support systems. This makes comparative costing between systems difficult.

34. The most suitable support system for any mine is a support system that the specific mine can implement and have installed on the face where it can assist the production and provide a measure of safety to the personnel working there. Considerations for the type of support requirements will then dictate specific support elements. Any support in the face is worth far more than the best support in the mines standards.