Research, Design and Develop a Pipe Latching/Unlatching Device that can be used to help Automate the Pipe Tripping Process

A dissertation submitted by

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Abstract

The Oil and Gas Well Service industry is a highly competitive industry in Australia and around the world and there is a growing need to make advancements in the way of technology. One of the biggest technological advances that this industry could make would be to semi-automate the process of pulling and running tubing. This would have many benefits such as increased safety for rig personnel and decreased time needed to service a well.

The aim of this project was to research, design and develop a pipe latching/unlatching device that can be used to help automate the pulling and running of tubing process that is currently in use on rigs. To achieve this objective, analysis of existing designs on the market was conducted to gain an appreciation of pipe latching/unlatching devices and to evaluate their capability. There was not a lot of information to be found in this area but what was found assisted in conceptualising designs. The viability of the conceptual designs was investigated and a cost analysis of each design was conducted. The optimal design was chosen based on the requirements of Easternwell and the effectiveness and cost of each system. The details of the design, component selection and operation of the system were examined and preliminary finite element analysis (FEA) was carried out on the device. Recommendations for possible modifications were made by the author after consultation with professional engineers.

The prototype design that was chosen will meet all of the requirements and outlines set by the Easternwell Group. Once developed, it will make the well servicing process a safer and more efficient operation for rig personnel. Due to time and resource constraints, prototype construction and testing has been put on hold for the next six months. However, further design considerations have been outlined and will be undertaken by the author during the six month period in order for the prototype construction to run smoothly.
University of Southern Queensland

Faculty of Engineering and Surveying

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Nomenclature

**Bails**  The bails are the joining links commonly used to connect the blocks and the elevators.

**Blocks**  The blocks are basically the hook that is connected to the main winch via a set of cables. The size blocks that are normally used on service rigs range from 50T to 150T.
| **Casing** | This is the large diameter pipe that encloses a well. It is the outermost barrier to stop the well collapsing on itself. This casing is usually cemented into place. The tubing, rods and pumps are run inside of the casing. |
| **Derrick** | The derrick is the mast structure on the Rig Carrier. They range in capacities from 10 tonne to 500 tonne plus. |
| **Pulling Tubing** | Is the term used to describe the process of pulling the tubing out of a well. |
| **Running Tubing** | Is the term used to describe the process of lowering tubing into a well. |
Rods

The rods are run inside the tubing and come in a range of different diameters and lengths. They are always a solid rod with a male thread on one end and an upset collar with a female thread on the other end. The rods are used to connect the pump in the bottom of the well to the driving mechanism on the surface.

Service Rig

A service rig (also known as a work-over rig) is used for a number of purposes such as pulling and running tubing and rods, setting up new wells (pumps, etc.) and repairing/maintaining existing wells. Service rigs are usually significantly smaller and lighter than drilling rigs.
Slips  
This device sits at the top of the well and is used to clamp and hold the pipe/tubing while the rig personnel are latching and elevating the next pipe to be run into the well.
**Tubing Elevator**  This is a latching/unlatching device that is attached to the blocks on a rig and is used to grip and suspend tubing while pulling out or running in to a well.

![Standard Tubing Elevator](image)

**Tubing**  The tubing is what the oil or gas flows upwards through, out of a well. The pump and rods also run inside of the tubing. The tubing ranges in size, depending on the size and flow of the well. Most tubing varies in length from 20’ to 40’, has a male thread on one end and an upset collar with a female thread on the other end.
Chapter 1

Introduction

1.1 Introduction

The Oil and Gas Well Service industry is a highly competitive industry in Australia and around the world and there is a growing need to make advancements in the way of technology. One of the biggest technological advances that this industry could make would be to semi-automate the process of pulling and running tubing. This would have many benefits such as increased safety for rig personnel and decreased time needed to service a well. This project researches, designs and develops a pipe latching/unlatching device that can be used to help automate the pulling and running of tubing process that is currently in use on rigs. This chapter will introduce the aim, objective and reasons for the project. The methodology will be outlined and an overview of the project will also be included.

1.2 Project Sponsor

This project has been initiated by the Easternwell Group (EWG), a Toowoomba based, privately owned company that has provided a specialized and unique service to the Australian on-shore energy industry for over 18 years. EWG has accumulated the largest and most extensive rig fleet and equipment in Australia, contributing to the advancements of the well service industry through the innovative use of new technology in a safe and environmentally responsible manner. They also have the largest research and development team in Australia dedicated to the advancement of service rigs and work-over practices.
EWG has recently made advancements in pipe handling technology in the design construction and implementation of a Hydraulic Pipe Handler (HPH). The HPH ensures exact repetition of pipe position - this then opens the way for semi-automation of the pipe pulling and running process, the process of latching pipe, elevating it and lowering it in a controlled fashion. Current systems in use require manual input to control and latch the elevator, which is attached to a travelling block that is only controlled in the vertical axis. In order to automate the pulling and running process the blocks must be controlled in all axes and the pipe must be automatically latched and unlatched.

1.3 Problem Statement

The tubing elevators that are currently in use on service rigs require one or two people to catch the tubing and latch/unlatch the elevator. This is not only time consuming and costly but is also very dangerous work for the rig personnel. To stay ahead in a very competitive industry, EWG needs to semi-automate the process of pulling and running tubing. They have already started to make advances in this area with the design and development of the Hydraulic Pipe Handler. Designing and developing an automated pipe latching/unlatching device will be the next big advancement in achieving this goal.

1.4 Reasons for the Project

This project has come about due to a few factors. These are:

- An increase in safety for rig floor personnel. Rig personnel all over the world have been injured or killed in past decades from falling tubing caused by malfunctioning or incorrectly fastened elevators. Hand injuries are also very common for rig personnel who are handling the tubing elevators.

- An increase and improvement in overall operational efficiency so that the Easternwell Group can remain market leaders in a highly competitive industry.
• A need to decrease the amount of time taken to service a well.

1.5 Objectives

The objectives and aim of the project were determined by the system outline provided by the Easternwell Group (EWG). The system outline and project aim are detailed below.

1.5.1 System Outline

• The latching mechanism is to be designed for use on a service/work-over rig that has its blocks constrained in all axes. The mechanism is also to be designed to work in conjunction with EWG’s Hydraulic Pipe Handler – this ensures exact repetition of pipe position.

• The mechanism should be able to be latched and unlatched without the need for any direct physical human contact. The mechanism may be hydraulically/pneumatically/electrically controlled from a point outside of the danger zone.

• The latching mechanism should be designed to allow for a range of different tubing diameters – from 1” to 2 7/8” tubing (pipe sizes are measured in imperial units). This will be decided by EWG.

• The latching mechanism can not be accidentally undone under ANY circumstances. This could result in dropping a complete string of tubing down a well – causing hundred’s of thousands of dollars worth of damage. An even worse outcome would be injuring or even possibly killing rig personnel.

• The design should not have any protruding parts that can become tangled in the derrick/cables, etc.
• The mechanism should have a positive lock to avoid slippage of the tubing.

The system outline sets constraints for the project and from that the goals and aims of the project were set.

1.5.2 Project Aim

To research, design and develop a pipe latching/unlatching device that can be used to help automate the pulling and running of tubing process that is currently in use on rigs.

1.6 Methodology

To achieve the project objectives, the problem needs to be examined in a systematic manner. The stages of the project are outlined below.

• Conduct background research to find information relating to tubing latching/unlatching mechanisms and current methods of pulling and running tubing on existing service/work-over rigs.

• Undertake preliminary designs of some alternative methods of pipe latching/unlatching mechanisms.

• Once the most suitable design is chosen, design, develop and analyse the conceptual design.

Following the conceptual design developed in this project, EWG will undertake further work to:

• Produce detail drawings for the fabrication of the mechanism.
• Manage the construction of the first prototype.

• Conduct in field testing and evaluate design.

• Suggest changes or additions to system based on conclusions from in field testing.

1.7 Overview

The project dissertation is compiled as follows:

Chapter 1: Introduction
The aim, objectives and reasons for undertaking the project, brief overview of the dissertation.

Chapter 2: Background
Background information on work-over rigs, oil and gas well servicing and production and existing methods running/tripping tubing.

Chapter 3: Investigation into Existing Designs of Elevators
An investigation into the existing designs of elevators in use.

Chapter 4: Conceptual Designs
Covers the design details, an analysis of the four concept designs, recommendations and selection of the final design and conclusions.

Chapter 5: Final Design, Construction and Evaluation
Finalised design details, operation, selection of components, design calculations, cost analysis and conclusions.

Chapter 6: Conclusions and Further Work
Summary of objectives achieved, further design considerations, current and future development in design and final concluding remarks.

1.8 Conclusion

This chapter has introduced the aim, objective and reasons for the project. The methodology has been outlined and an overview of the project has been included. The following chapter provides further background information into oil and natural gas well servicing and production and an overview of the methods employed to pull and run tubing on rigs.
Chapter 2

Background

2.1 Introduction

To gain a proper understanding of the benefits of and need for this project, some knowledge of the well servicing process and the equipment involved, will be provided. This chapter will explain the necessity of servicing new and existing oil and gas wells, the most common processes involved and the equipment used to do so.

2.2 Well Servicing

There are two main times when a well needs servicing. These are:

2.2.1 Completion of New Wells

After drilling and casing a well, it must be 'completed'. Completion is the process in which the well is enabled to produce oil or gas. A common construction of an oil well is shown in Figure 1 below.

In a cased-hole completion, small holes called perforations are made in the portion of the casing which passed through the production zone, to provide a path for the oil to flow from the surrounding rock into the production tubing. In open hole completion, often 'sand screens' or a 'gravel pack' is installed in the last drilled, uncased reservoir section. These maintain structural integrity of the wellbore in the absence of casing, while still allowing flow from the reservoir into the wellbore. Screens also control the migration of formation sands into production tubulars and surface equipment, which can cause
washouts and other problems, particularly from unconsolidated sand formations in offshore fields.

![Figure 1: Typical Oil Well Construction](http://en.wikipedia.org/wiki/Image:Oil_Well.png#file)

After a flow path is made, acids and fracturing fluids are pumped into the well to fracture, clean, or otherwise prepare and stimulate the reservoir rock to optimally produce hydrocarbons into the well-bore. Finally, the area above the reservoir section of the well is packed off inside the casing, and connected to the surface via a smaller diameter pipe called tubing. This arrangement provides a redundant barrier to leaks of hydrocarbons as well as allowing damaged sections to be replaced. Also, the smaller diameter of the tubing produces hydrocarbons at an increased velocity in order to overcome the hydrostatic effects of heavy fluids such as water.

In many wells, the natural pressure of the subsurface reservoir is high enough for the oil or gas to flow to the surface. However, this is not always the case, especially in depleted fields where the pressures have been lowered by other producing wells, or in low
permeability oil reservoirs. Installing smaller diameter tubing may be enough to help the production, but artificial lift methods may also be needed. Common solutions include down-hole pumps (electric submersible pumps) or surface pump jacks (otherwise known as beam pumps) as can be seen in Figure 2 below.

Figure 2: EWG Rig 2 with Beam pump
2.2.2 Service of Existing Wells

Wells often need service or maintenance on surface or down-hole equipment. Well Servicing covers the maintenance, repair or stimulation of an existing well, carried out for the purpose of restoring, prolonging or enhancing oil and gas production. Working on an existing well to restore or increase oil and gas production is an important part of today’s petroleum industry, therefore, maintenance activities on existing oil and gas wells may include:

- Replacing the rods that connect the submersible pump to the driving mechanism on the surface.
- Replacing the tubing.
- Changing out the electric submersible pump.
- Removing the Horse-head off the Beam pump.

2.3 Service/Work-Over Rig

A Service or Work-over Rig is the main piece of equipment used for well servicing. These rigs are normally smaller and lighter than a drilling rig and they have the capacity to be rigged up and down a lot faster. There is a need for this ability as the average time taken to service a well is 3 days. There is a crew of five to seven men that operate these rigs and complete the service. Shown below in Figure 3 is a 3D CAD model of one of Easternwell’s service rigs.
2.4 Developments in Pipe Handling Practices

One of the most labour intensive operations involved in well servicing is handling the rods and pipes/tubulars when running into a well or pulling out of a well. The most common methods of achieving this is listed below for when they are Running In or Pulling Out.

**Running In:**

- If the rods or pipe are light enough and the work-floor isn’t too high, rig personnel will manually lift the pipe or rods up to the work-floor from the racks that they are laid out on.
- If this is not the case, the rig personnel will run a cable from a small winch on the rig over the derrick and down to the level of their racks. They will then winch a number of rods or pipes at a time up to sit on the edge of the work-floor until they are needed.

**Pulling Out:**

- If the rig is equipped with a ‘Monkey-board’ in the derrick as shown in the photos below, the pipe would be racked/stood in the derrick. This also means that one of the rig personnel (normally the Derrick-man) has to stand on the ‘Monkey-board’ in order to rack the pipe and release the elevators. This process is very dangerous as the Derrick-man is working at heights and the other rig personnel run the risk of falling pipe. This process is still widely used as it significantly speeds up the running in process after the service is completed.
- If the rig is not fitted with a ‘Monkey-board’ and they do not have a Hydraulic Pipe Handler, the rig would be fitted with a ‘V-Door’ which is basically a shallow steel trough that runs from the work-floor down to the pipe racks. Once the rod or pipe is pulled out of the well, the Floor-hand will push the bottom of the rod/pipe over the edge of the work-floor and let it slide down the V-Door to the other rig personnel waiting below on the racks. These rig personnel will then guide the rod/pipe as it lowers and position it on the racks. This operation has a high risk of hand injury.
2.4.1 Hydraulic Pipe Handler (HPH)

In order to make the above mentioned processes safer, faster and more efficient, Easternwell has recently made advancements in pipe handling technology in the design, construction and implementation of a Hydraulic Pipe Handler (HPH). There are two photos of the HPH shown in Figure 5 and Figure 6 below. There are many advantages to be gained in the use of the HPH. Some of these are given below:
• Allows for the removal of the ‘Monkey-board’ thus increasing safety because there is no longer a man working at heights or pipe standing in the derrick.
• The HPH ensures exact repetition of pipe position - this then opens the way for semi-automation of the pipe pulling and running process.
• The operator of the HPH sits in an air-conditioned cabin, therefore reducing the chance of fatigue induced accidents and heat stress.
• The use of the HPH speeds up the processes of running in and pulling out so the time to complete a service is less. This allows the rig to complete more work which means more income.
• The number of personnel can be reduced on a rig crew as the HPH makes the work less labor intensive. This also increases the profit margin.
2.5 Pulling and Running Tubing Using the HPH

The operation of *Running Tubing* into a well is as follows:

- The operator of the Hydraulic Pipe Handler would have a length of pipe/tubing loaded onto the trough of the HPH and raised to work floor height. The pipe would be positioned in the pre-set location, waiting to be latched.
- The Driller (the person operating the Rig from the operator’s console) lowers the blocks until the elevators are at a height where the Floor-hand can easily manoeuvre them onto the waiting pipe. See Figure 7.
- The Floor-hand will then close the elevator around the pipe and check to make sure that the latch has closed properly. See Figure 8.
- Once the Driller sees that the Floor-hand has finished he will increase throttle, release the brake and raise the blocks until the pipe swings to a vertical position above well centre. See Figure 9 and Figure 10.
- Once the pipe is vertical and has been elevated to the required height, it would be lowered and ‘stabbed’ into the threaded collar end of the previous pipe that is waiting in the slips. The Floor-hand will then use a hydraulic powered tong to screw the male threaded end of the elevated pipe into the female threaded end of the pipe that is held in the slips.
- Once the pipe is tightened to the required torque, the Driller will release the slips and lower the pipe until the elevators are just above the work floor. The slips will then be activated again and the elevators released.
- The rig crew will then repeat this whole process until all of the pipes are down the well.
The operation of **Pulling Tubing** out of a well is as follows:

- The Driller (the person operating the Rig from the operator’s console) lowers the blocks until the elevators are at a height where the Floor-hand can latch them onto the pipe that is protruding from the well.
- The Floor-hand will then close the elevator around the pipe and check to make sure that the latch has closed properly.
• Once the Driller sees that the Floor-hand has finished he will release the slips, increase throttle, release the brake and raise the blocks until the joint between the first and second pipe is seen. The Driller will then engage the slips again and the Floor-hand will use a hydraulic power tong to unscrew the male threaded end of the elevated pipe out of the female threaded end of the pipe that is held in the slips.

• Once this is completed the Floor-hand will push the bottom end of the elevated pipe towards the back of the work floor as shown in Figure 11 below. The operator of the Hydraulic Pipe Handler would have the trough of the HPH raised to work floor height, so that as the Driller starts to lower the pipe, the Floor-hand can slide the end of the pipe onto the trough. The Driller lowers the blocks until the elevators are at a height where the Floor-hand can release them. The HPH operator will then lower the trough and eject the pipe onto the pipe racks.

• The rig crew will then repeat this whole process until all of the pipes are out of the well and onto the pipe racks.

Figure 11: Floor-hand pushing pipe onto HPH
2.6 Conclusion

This chapter has covered the processes involved in well servicing or work-over and has also explained what a service/work-over rig is. Current practices and developments in pipe handling, including the HPH, have been discussed. This information has been found to be critical in helping to analyse the needs and requirements of the well servicing industry in order to design a useful product.

The following chapter investigates the existing designs of elevators in use today.
Chapter 3

Investigation into Existing Elevator Design

3.1 Introduction

The existing types of tubing elevators for service rigs are basically all the same bar some minor differences – mainly in the shape of the collar, door latch position and size. There are some semi-automated types of tubing elevators in use on service rigs today but they are normally a standard type elevator similar to the ‘Big D’ shown below that have been fitted with hydraulically or pneumatically operated cylinders. The elevators in use on the drilling rigs are much more advanced and most of these are semi-automated. The problem with these elevators though is that they are much too large for use on service rigs.

As the author could only find limited information on the existing designs of elevators in use on service rigs, information and specifications on the different styles of elevators in use on drilling rigs has also been added.

3.2 Petol “Big D” Tubing Elevator

The Big “D” elevator is the most common style of elevator and is shown in Figure 12 below. This style is made by many companies and they are all nearly identical. A description, feature list and operation procedures are given below.
3.2.1 Description and Features

The BDA100 Petol Big D tubing elevator hangs from the elevator links which are attached to the traveling block of the service or drilling rig. The draw-works of the rig move the elevator up and down the rig’s derrick to install and remove tubing. The elevator may also be used on or around the rig floor for handling tubing.

Each elevator is bored for one size of tubing, 2-3/8 non-upset, 2-3/8 upset, 2-7/8 non-upset, 2-7/8 upset, 3-1/2 non-upset, or 3-1/2 upset. These are stamped 238N, 238U, 278N, 278U, 312N, or 312U respectively to indicate the appropriate size. The elevator has a rated capacity of 100 tons for heavy duty use.

The BDA100 offers the following features:

- An integrated center latch mechanism consisting of a retainer, lock, retainer spring, and lock spring to provide simple, fast, and smooth operation.
• A flame hardened top surface and special heat treated alloy materials to provide long life.
• Fully compliant with API specification 8C PSL level 1.

3.2.2 Operation

To attach the elevator to the tubing, the elevator operator stands on one side of the tubing which is supported in the slips with the elevator on the opposite side of the tubing. The operator reaches around the tubing with one hand on either side of the tubing. The elevator is gripped by the handles of the elevator. The operator pulls the opened elevator to the tubing and then brings the two handles together so that the elevator is wrapped around the tubing. This action causes the retainer and lock to automatically engage the locking lug on the right body half securing the elevator to the tubing. It is important for the elevator operator to visually verify that the retainer and lock properly engages the locking lug or premature release of the tubing could occur resulting in bodily injury and/or dropping the tubing down the well requiring fishing of the dropped tubing string.

To remove the elevator from the tubing, the tubing is landed in the slips and the elevator in then lowered a few inches below the coupling. The elevator operator holds the handle on the right body half with one hand and uses the other hand to pull on the elevator lock. Pulling on the lock causes the lock to rotate free of the right body half releasing the retainer and fully opening the elevator in one smooth motion.

3.3 BX Hydraulically Actuated Elevator

The BX Hydraulically Actuated Elevator, manufactured by Varco BJ, is mainly designed for use on the heavier drilling rigs but it is useful to look at this design for the development of concepts. A simplified explanation of what Varco BJ has done is basically used a standard elevator and added hydraulic rams to operate it. This is very common in America/Canada.
3.3.1 Features and Benefits

- Purpose designed for hydraulic actuated operation
- Cost competitive with normal rig complement of air-operated, drill pipe, drill collar and casing elevators.
- The most economic way to fully actuate all elevator functions (opinion of Varco BJ).
- Double Door design for optimal balance and performance.
- The hydraulic cylinders are located the body casting for clean lines and maximum protection, and yet they are accessible for normal maintenance.
- Changeable bushings allow one elevator frame to handle all pipe size and type requirements.
- Bushings are locked into place with spring loaded pins for quick and easy removal and installation.
- Bushings can be changed within five minutes.
- No special tools are needed, no loose nuts, bolts or pins.
- Hinge journals are bushed to put major wear into replaceable components.
- One door bushing is spring loaded with a linkage connecting it to a locking pin. Any load on this bushing segment engages the pin preventing the elevator from opening. This safety lock prevents the elevator opening under load.
- The elevator is prepared for an interlock system as an option when used with a set of power slips.
- A trigger mechanism initiates the closing sequence when pipe is thrown into the elevator.
- Additionally equipped with a rotary actuator, it can be tilted to pick up pipe from the V-door, eliminating the need for single joint elevators.

Figure 13 below shows the BX Hydraulically Actuated Elevator in use on a drilling rig.
3.4 Automated Side Door (ASD) Elevator

The Automated Side Door Elevator, manufactured by Weatherford, was designed specifically to enhance safety and efficiency. Weatherford has had years of experience in Deepwater drilling where safety is paramount and every minute is critical to the operator.

3.4.1 Features and Benefits

- Double door and latch design provides 360 degree contact with the casing, allowing high tonnage without spreading the elevator body.
- Square shoulder design is compatible with numerous casing designs.
- Door and latch assembly are designed to carry the load of the casing joints picked up horizontally as illustrated.
- Hydraulic operation requires no human intervention to latch/unlatch.
- Fast cycle time means decreased run times.
- Lower connection height keeps personnel at a safe working height.
Again, this style of elevator is only used on drilling rigs at the moment and is shown in Figure 14 below.

![ASD Elevator in use](https://www.weatherford.com)

**Figure 14: ASD Elevator in use**

### 3.5 XP 1000 Extreme Performance Elevator

The XP 1000 Elevator, manufactured by Access Oil Tools, is designed to support ultra high loads associated with critical deep water and deep well operations. This is another elevator that would be primarily used on a drilling rig and is shown in Figure 15 below.

![XP 1000 Elevator](https://www.accessoiltools.com)

**Figure 15: XP 1000 Elevator**
3.5.1 Features

- Load rated at 1000 tonnes
- Uses hardened insert bushes
- Hydraulically Actuated
- Remote operation
- Compact, Versatile design

3.5.2 Benefits

- Provides safe and rapid installation
- Can be used with multiple pipe sizes and grades
- Minimizes injuries by removing personnel from the critical path area
- Can be used with 750 tonne or 1000 tonne links

3.6 VES-SD Series Elevator

This elevator, manufactured by Blohm+Voss Oil Tool Division, has the following features and benefits.

3.6.1 Features and Benefits

- Hydraulic operated Double Door Elevator System.
- Double Door design for optimal balance and performance.
- The most economical way to fully actuate all the elevator functions.
- Purpose design for actuated operation.
- The hydraulic system, including Cylinders, is located inside the body casting for clean lines and maximum protection, and for normal maintenance.
- One frame for different pipe types with easily changeable bushing system.
• Equipped with load sensor to avoid opening at the drillers console with a minimum load rate of 200 lbs.
• Integrated feed back advice.
• Emergency opening function.
• Integrated trigger system for automatically door closing.
• Hydraulic quick connections as standard.
• Suitable for B+V type elevator links 500 tonne rating.
• Hydraulic tilt actuator for ± 90° tilt operation to enable pickup from v-door.
• Hydraulic functions are speed adjustable.
• Mechanical stop pin holes at 5° intervals.
• Actuators swing out for quick and easy link removal.

A photo of the VES-SD series elevator is shown in Figure 16 below.

Figure 16: VES-SD Elevator
3.7 VES-CL Series Elevators

This elevator, manufactured by Blohm+Voss Oil Tool Division, has the following features and benefits and is shown in Figure 17 and Figure 18 below.

![Figure 17: VES-CL Elevator](www.blohmvoss-oiltools.com (2007))

![Figure 18: VES-CL Elevator - Cut](www.blohmvoss-oiltools.com (2007))

3.7.1 Features and Benefits

- World-wide, more than 250 VES-CL variable elevator systems are in operation.
- The VES-CL Elevator is the most flexible patented system in use for either manual or hydraulic operation.
- Available in load ratings of 150, 250, 350, 500 and 750 tons and manufactured to latest API-8C, PSL 1 standards.
- Each body is able to handle all pipe types and sizes by easily changeable bushings.
- Substantial savings, both in direct costs and logistics, are gained due to less maintenance, less spare parts, less freight and storage requirements.
- Depending on rig requirements, weight savings of up to 40% and initial investment cost savings of more than 20%, are possible.
- Suitable for Drill Collars, Casing and Tubing.
- The VES-CL Series of elevators are the most preferred system by many Top Drive manufacturers.
3.8 Conclusion

This chapter has investigated the existing designs of elevators in use today. It was found that there is not a lot of information available on existing designs of elevators that are in use on service rigs. It was found however that the drilling industry is much more advanced in the way of automation and technology than the well servicing industry.

The following chapter discusses the possible designs for the new latching/unlatching device and the author provides recommendations as to which design should be chosen.
Chapter 4

Conceptual Designs

4.1 Introduction

This chapter follows on from the Investigation into Existing Elevator Design chapter and discusses the possible designs for the new latching/unlatching device. The basic design process for this project involved conducting research, gaining background information and reviewing the existing designs on the market. When knowledge of this area was gained, the author conceptualised designs and came up with a number of possibilities. The viability of these designs was investigated, details were discussed with suppliers and a brief cost analysis of each design was conducted. The optimal design was chosen based on the requirements of Easternwell, its effectiveness and cost of each design.

4.2 Design Details

Based on initial research and discussions with Easternwell managers, it was decided to try and stay away from the existing styles of elevators that all use a very similar latching mechanism and design. A preferred method of latching would be one that is self locking when the device is lifted or lowered. One point that was very important to consider was the fact that under no circumstances could the device be accidentally opened while carrying a load. This would result in some cases in the entire string of pipe being dropped down the well or worse still, a length of pipe being dropped onto rig personnel. Both of these incidents have occurred in the past with multiple fatalities. After discussing this with Easternwell management it was decided that the device should also have to be remotely operated in order to keep rig personnel out of the danger zones.
As the device would be remotely operated, there are two issues that must be addressed. These are:

- Repetition of exact pipe position for pick-up and,
- Repetition of exact device position.

The first point has already been taken care of with the design and implementation of Easternwell’s Hydraulic Pipe Handler (HPH). Using the HPH the operator can position the pipe in the exact same position every time with ease.

The second point would involve constraining the blocks in all axes. This could be achieved by retrofitting a set of rails and a guide to the rig derrick. To allow pick-up of pipe off the HPH the guide would also have to be fitted with a set of hoist cylinders in order to get the correct angle of pick-up. Figure 19 below illustrates why hoist cylinders would be required as part of the automation process. To pick up pipe that is sitting on the HPH, the device has to be lifted and angled correctly, which is a job normally performed by rig personnel.

Figure 19: Picking up pipe off HPH
There are other requirements that will determine the design of the device. These are:

- The size of the device will be partly determined by the size of attaching equipment, such as the bails and the pipes that it has to latch.
- The size and type of cylinders used will be as close to a manufactures standard range as possible in order to reduce lead times and cost.
- The hydraulic pressures that will be used when designing the cylinders will be dependant on the Service Rig’s hydraulic power capacity – standard is approximately 138 bar.
- Interference checking between connecting and moving parts will be carried out on the selected concept design with the aid of the 3D CAD model.
- The device will have to clamp onto itself and not the pipe, in order for the pipe to be able to be spun when connecting to the previous pipe. This means the inside diameter of the device should be slightly larger than the outside diameter of the pipe. The standard tubing/pipe that is used in oil and gas wells always have an upset collar on one end that is approximately 20mm larger in diameter than the pipe itself. The device should be latched directly below this collar, thus transferring the load through the top of the device when the weight of the pipe string is taken off the slips.

Each conceptual design was assessed on its capability, advantages/disadvantages, cost, durability and range of application.
4.3 Concept Design 1

This first design, as shown in Figure 20 and Figure 21, is quite simple. As with all of the concept designs, this device utilizes the principle of self-locking when it is lifted – the more weight that is being lifted, the larger the clamping force on the device. The main device consists of a main body which is split into halves and a base assembly on which the main body pivots. The main device is connected to a set of specialized bails via a clevis style connection. The specialized bails have a pivot in the centre and have a hydraulic cylinder affixed to each in order to get them to ‘open’. This ‘opening’ function is how the device is opened, closed and locked.
4.3.1 Operation

The operation of this device would be as follows when running tubing and in reverse when pulling tubing:

- The operator of the Hydraulic Pipe Handler would have a length of pipe/tubing loaded onto the trough of the HPH and raised to work floor height. The pipe would be positioned in the pre-set location, waiting to be latched.
- The Driller (the person operating the Rig from the operator’s console) would open the device (via a hydraulic valve which runs the two cylinders on the side of the bails), raise the device to the required angle (via the hoist cylinders) and lower the blocks until the base assembly is cradled over the pipe.
- The driller would then close the device and start raising the blocks.
- The hoist cylinders would be single-acting so that as the blocks are raised, the pipe gently swings to a vertical position without needing input from the driller.
- Once the pipe is vertical and has been elevated to the required height, it would be lowered and ‘stabbed’ into the threaded collar end of the previous pipe that is waiting in the slips. A rig worker will then use a hydraulic power tong to screw the male threaded end of the elevated pipe into the female threaded end of the pipe that is held in the slips.
- Once the pipe is tightened to a particular torque, the driller will release the slips and lower the pipe until the device is just above the work floor. The slips will then be activated again and the device released. The driller will then repeat this whole process until all of the pipes are down the well.

4.3.2 Cost Analysis Concept Design 1

The cost of Concept design 1 is relatively high. This is mainly due to the fact that a non-standard, specialised set of bails would have to be manufactured. This design has two hydraulic cylinders used to open and close the design which also adds to the cost. Miscellaneous costs are relatively high as there would be the cost of extra pins for the
pivot in the middle of the bails and in the clevis connection to the device. The pricing for components is in Table 1.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>COST ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydraulic Cylinders x 2</td>
<td>500</td>
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<tr>
<td>Special Bails</td>
<td>15000</td>
</tr>
<tr>
<td>Main Body</td>
<td>2000</td>
</tr>
<tr>
<td>Base Assembly</td>
<td>1000</td>
</tr>
<tr>
<td>Miscellaneous Costs</td>
<td>2000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$20500</strong></td>
</tr>
</tbody>
</table>

Table 1: Cost Estimate for Concept Design 1

### 4.3.3 Advantages of Concept Design 1

The advantages of Concept Design 1 are as follows:

- Self-locking when lifted. This is because the pivot points for the halves of the main body are inside of the pick-up points; therefore this generates a clamping force when lifted.
- Relatively simple design.
- Robust design would be well suited to rig personnel and harsh environmental conditions.

### 4.3.4 Disadvantages of Concept Design 1

The disadvantages of Concept Design 1 are as follows:

- More expensive than other alternatives due to specialised bails and 2 cylinders.
- Clevis style connection from bails to device main body does not allow any tolerance for misalignment of HPH to the rear of the rig. This could also be adversely affected by uneven ground.
• If the device was to receive a hit from the bottom (i.e., by running the device down too low and hitting the slips) it would want to try and force the device open.

• Extra pivot points in the middle of the bails and in the connection to the main body provide points for seizing and would need regular maintenance to keep lubricated.

• Extra pivot points also provide more places to get fingers pinched – hand injuries being the most common type of injuries for rig personnel.

• There is a considerable amount of vertical travel up and down whilst the device is being opened and closed. This is due to the bails being rotated about a centre point and moving through an arc that opposes the arc that each half of the main body rotates through. This vertical movement may cause damage to the pipe that it is clamping.
4.4 Concept Design 2

The second design, as shown in Figure 22 and Figure 23, is very similar to the first, with the major difference being the way that the device is connected to the bails. With this design, a standard bail-type connection has been used to provide some tolerance for misalignment and uneven ground. As with all of the concept designs, this device utilizes the principle of self-locking when it is lifted. The main device consists of a main body which is split into halves and a base assembly on which the main body pivots. The main device is connected to a set of specialized bails that have a pivot in the centre and have a hydraulic cylinder affixed to each in order to get them to ‘open’. This ‘opening’ function is how the device is opened, closed and locked.
4.4.1 Operation

The operation of this device is similar to the operation of Concept Design 1.

4.4.2 Cost Analysis Concept Design 2

The cost of Concept design 2 is relatively high. This is also mainly due to the fact that a non-standard, specialised set of bails would have to be manufactured. This design has two hydraulic cylinders used to open and close the design which also adds to the cost. Miscellaneous costs are relatively high as there would be the cost of extra pins for the pivot in the middle of the bails. The pricing for components is in Table 2.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>COST ($)</th>
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<tbody>
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<td>Hydraulic Cylinders x 2</td>
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<tr>
<td>Special Bails</td>
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<tr>
<td>Main Body</td>
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<td>Base Assembly</td>
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<td>Miscellaneous Costs</td>
<td>1750</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$18250</strong></td>
</tr>
</tbody>
</table>

Table 2: Cost Estimate for Concept Design 2

4.4.3 Advantages of Concept Design 2

The advantages of Concept Design 2 are as follows:

- Self-locking when lifted. This is because the pivot points for the halves of the main body are inside of the pick-up points; therefore this generates a clamping force when lifted.
- Relatively simple design.
- Robust design would be well suited to rig personnel and harsh environmental conditions.
• Standard bail-end connection to the main body of the device allows freedom and tolerance for misalignment and uneven ground.
• Standard bail-end connection to the main body of the device takes away two of the pinch points in Concept design 1.

4.4.4 Disadvantages of Concept Design 2

The disadvantages of Concept Design 2 are as follows:

• More expensive than other alternatives due to specialised bails and 2 cylinders.
• If the device was to receive a hit from the bottom (ie, by running the device down too low and hitting the slips) it would want to try and force the device open.
• Extra pivot points in the middle of the bails provide points for seizing and would need regular maintenance to keep lubricated.
• Extra pivot points also provide more places to get fingers pinched – hand injuries being the most common type of injuries for rig personnel.
• There is a considerable amount of vertical travel up and down whilst the device is being opened and closed. This is due to the bails being rotated about a centre point and moving through an arc that opposes the arc that each half of the main body rotates through. This vertical movement may cause damage to the pipe that it is clamping.
4.5 Concept Design 3

The third design, as shown in Figure 24 and Figure 25, is quite different to the previous, with the major differences being the single standard hydraulic cylinder for opening, closing and locking and the fact that a standard set of bails may be used. As with all of the concept designs, this device utilizes the principle of self-locking when it is lifted. The main device consists of a main body which is split into halves and a base assembly on which the main body pivots. The lugs on the bails where the hoist cylinders attach would be of clamp-on style.

Figure 24: Concept Design 3 Closed

Figure 25: Concept Design 3 Open
4.5.1 Operation

The operation of this device would be as follows when *running tubing* and in reverse when *pulling tubing*:

- The operator of the Hydraulic Pipe Handler would have a length of pipe/tubing loaded onto the trough of the HPH and raised to work floor height. The pipe would be positioned in the pre-set location, waiting to be latched.

- The Driller (the person operating the Rig from the operator’s console) would open the device (via a hydraulic valve which runs the hydraulic cylinder on the device), raise the device to the required angle (via the hoist cylinders) and lower the blocks until the base assembly is cradled over the pipe.

- The driller would then close the device and start raising the blocks.

- The hoist cylinders would be single-acting so that as the blocks are raised, the pipe gently swings to a vertical position without needing input from the driller.

- Once the pipe is vertical and has been elevated to the required height, it would be lowered and ‘stabbed’ into the threaded collar end of the previous pipe that is waiting in the slips. A rig worker will then use a hydraulic power tong to screw the male threaded end of the elevated pipe into the female threaded end of the pipe that is held in the slips.

- Once the pipe is tightened to a particular torque, the driller will release the slips and lower the pipe until the device is just above the work floor. The slips will then be activated again and the device released. The driller will then repeat this whole process until all of the pipes are down the well.

4.5.2 Cost Analysis Concept Design 3

The cost of Concept design 3 is significantly less expensive than the previous two concept designs. This is due to the fact that standard set of bails can be used. This design only has one hydraulic cylinder used to open and close the design which also subtracts from the cost. Miscellaneous costs are also lower due to there only being one cylinder
(less hydraulic hose and fittings, etc) and no extra pins. The pricing for components is in Table 3.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>COST ($)</th>
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<tbody>
<tr>
<td>Hydraulic Cylinder x 1</td>
<td>250</td>
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<tr>
<td>Standard Bails</td>
<td>10000</td>
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<tr>
<td>Main Body</td>
<td>2000</td>
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<td>Base Assembly</td>
<td>1000</td>
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<tr>
<td>Miscellaneous Costs</td>
<td>1000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$14250</strong></td>
</tr>
</tbody>
</table>

Table 3: Cost Estimate for Concept Design 3

4.5.3 Advantages of Concept Design 3

The advantages of Concept Design 3 are as follows:

- Self-locking when lifted. This is because the pivot points for the halves of the main body are inside of the pick-up points; therefore this generates a clamping force when lifted.
- Relatively simple design.
- Robust design would be well suited to rig personnel and harsh environmental conditions.
- Standard bail-end connection to the main body of the device allows freedom and tolerance for misalignment and uneven ground.
- Using standard bails eliminates four of the pinch points previously mentioned.
- Considerably less expensive than the previous designs due to using a standard set of bails and only one hydraulic cylinder.
- By changing the method of opening and closing to just one cylinder, it has reduced the amount of vertical travel, thus reducing the chance of damaging pipe.
- There are less obtrusive parts than the previous two designs that may become tangled in the derrick structure.
4.5.4 Disadvantages of Concept Design 3

The disadvantages of Concept Design 3 are as follows:

- If the device was to receive a hit from the bottom (i.e., by running the device down too low and hitting the slips) it would want to try and force the device open.
- Using a standard hydraulic cylinder (one piston) to open and close the device may cause the device to operate unbalanced. This would be because the standard cylinder would tend to want to open the piston side of the main body first and similarly for closing.
4.6 Concept Design 4

The fourth and final design, as shown in Figure 26 and Figure 27, is very similar to the previous, with the major differences being the non-standard, twin piston hydraulic cylinder which is used for opening, closing and locking and the slotted pick-up points. As with all of the concept designs, this device utilizes the principle of self-locking when it is lifted but this design is also self-locking when it is hit from the bottom. The main device consists of a main body which is split into halves and a base assembly on which the main body pivots. The lugs on the bails where the hoist cylinders attach would be of clamp-on style.
4.6.1 Operation

The operation of this device is similar to the operation of Concept Design 3.

4.6.2 Cost Analysis Concept Design 4

The cost of Concept design 4 is significantly less expensive than the first two concept designs but is slightly more expensive than concept design 3. This is due to the fact that a twin piston style hydraulic cylinder has been used. The pricing for components is in Table 4.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>COST ($)</th>
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<tbody>
<tr>
<td>Hydraulic Cylinder x 1</td>
<td>350</td>
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<tr>
<td>Standard Bails</td>
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<td>Main Body</td>
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</tr>
<tr>
<td><strong>TOTAL</strong></td>
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</tbody>
</table>

Table 4: Cost Estimate for Concept Design 4

4.6.3 Advantages of Concept Design 4

The advantages of Concept Design 4 are as follows:

- Self-locking when lifted. This is because the pivot points for the two halves of the main body are inside of the pick-up points; therefore this generates a clamping force when lifted.
- Self-locking when hit from the bottom. This has been achieved by using slotted holes to connect the bails through. When the device is hit from the bottom, the bails will slip down to the bottom of the slot, thus bringing the pivot point outside of the pick-up point. This then creates a clamping force against the pipe.
• Relatively simple design.
• Robust design would be well suited to rig personnel and harsh environmental conditions.
• Standard bail-end connection to the main body of the device allows freedom and tolerance for misalignment and uneven ground.
• Using standard bails eliminates four of the pinch points previously mentioned.
• Considerably less expensive than the first two designs due to using a standard set of bails and only one hydraulic cylinder.
• By changing the method of opening and closing to just one cylinder, it has reduced the amount of vertical travel, thus reducing the chance of damaging pipe.
• There are less obtrusive parts than the previous two designs that may become tangled in the derrick structure.

4.6.4 Disadvantages of Concept Design 4

The disadvantages of Concept Design 4 are as follows:
• Concept Design 4 is slightly more expensive than the previous because of the twin-piston hydraulic cylinder.
• Fairly heavy design.
4.7 Design Recommendations and Selection

Selecting the final design involved presenting the main designs to Easternwell’s Engineering Manager and the other members of the Engineering team. The author recommended that Concept Design 4 be chosen as it covers the design criteria the best even though it is not the least expensive. The team at Easternwell agreed with this recommendation. The other feature that the Engineering Manager wanted to have included in the final design is the capacity to fit dies inside each half of the main body in order to be able to use the device on multiple pipe diameters. It was decided though, that for the first prototype this feature would not be important factor.

The most important design feature for Concept Design 4 was considered to be the slotted pick-up points in the main body as this would add an extra safety factor to the design. The fact that a standard set of bails may be used was also a major benefit as this would save time when retrofitting as well as a substantial amount of money.

4.8 Conclusion

The main designs considered for the pipe latching/unlatching device have been analysed and the advantages and disadvantages of each design have been discussed. The selection of the final design has been detailed and the reasons for selection outlined. The following chapter discusses the specifics of the final design.
Chapter 5

Final Design, Construction and Evaluation

5.1 Introduction

In the previous chapter Concept Design 4 was selected for development. This chapter follows on from that selection and covers the prototype design details and the selection and design of the critical components of the chosen design.

5.2 Prototype Design Details

This section will cover the material selection for the prototype design and also the critical dimensions. This section will also explain why the material and dimensions were chosen.

5.2.1 Material Selection

The material that was chosen for the construction of the prototype was a 700MPa grade steel. After consulting with experts and carrying out Finite Element Analysis (FEA) on the chosen concept design, it was found that a material of this grade was required due to the high loading stresses that would be imposed on the device.

One reason that 700MPa grade steel was chosen is that this grade material can be cast as well as welded. This factor is important as the first prototypes will be of welded construction, while the finalised and mass produced devices are hoped to be cast. Another
benefit of the device being easily welded is that it can be repaired rather than discarded if any cracking is picked up in routine Non-Destructive Testing (NDT), such as Magnetic Particle Testing. According to experts in this field (Carter, D. 2007, pers. comm. 18 September), this is one of the biggest problems with the existing designs of elevators that are in use today.

5.2.2 Critical Dimensions of the Design

As shown in Figure 28, the overall width of the design is 740mm and the overall height is 429mm and the overall depth is 255mm. The whole device, including the hydraulic cylinder, will weigh approximately 120kg.

As mentioned in chapter 1, there were certain constraints that played a part in determining the critical dimensions of the prototype device. One of the most important factors is obviously the size of the pipe that it is going to latch. For the prototype it was decided to design the device to latch around 2 7/8” pipe, this being the most common size that is used by Service Rigs. Future prototypes will be designed to fit multiple pipe sizes but the first prototype will be used as a proof of concept only.

Another constraint in overall size was the size of the bails used, which impacted on the diameter of the slot that the bails fit into. Easternwell’s Service Rigs use a standard size set of bails for use up to 100 tonne so this is what set the slot diameter.
5.3 Selection and Design of Critical Components

This section will cover the selection and design of the critical components of the device, such as the loadings that will be applied to the device, FEA of the main body and base assembly and the calculation and sizing of the hydraulic cylinder. The components were designed and selected based on the following criteria:

- Availability
- Suitability
- Application
- Durability

Where possible, components such as the hydraulic cylinder will be designed to use standard parts in the build. For example, hydraulic cylinder manufacturers have a standard range of bore sizes, clevises, pistons, ports and bushings.
5.3.1 Calculations of the Applied Forces on the Device

The most critical load that needs to be calculated is the maximum weight that the device will have to carry. After discussing the project with Easternwell management, it was decided to design the first prototype to carry a maximum load of 100 tonne. As the device is symmetrical about a central vertical axis, the calculations will be performed on one half of the main body. This means that 50 tonne or 50000kg will be the mass used for calculations. This mass is subject to gravity, therefore the maximum force, \( F_{\text{Max}} \), that is transmitted through each half of the device can be determined using the equation:

\[
F_{\text{Max}} = mg
\]  

(5.1)

where

\( F_{\text{Max}} \) = Maximum Force applied (N)

\( m \) = Mass (kg)

\( g \) = Gravitational Acceleration (m/s\(^2\))

\[
F_{\text{Max}} = (50000 \times 9.81) = 490500N = 490.5kN
\]

Therefore, the Maximum Force that is applied through each half of the device is 490.5kN.

The next value that needs to be determined is the Maximum Moment that will be imposed on the device. This is due to the pick-up point for the bails being offset 41mm to the pivot point of the main body and the base assembly. This will create a clamping moment that will increase linearly as the String Weight increases, as shown in Figure 29 below.
The Maximum Moment can be determined using the equation:

\[ M_{\text{Max}} = F_{\text{Max}}d \]  

where

- \( M_{\text{Max}} \) = Maximum Moment applied (N.m)
- \( F_{\text{Max}} \) = Maximum Force applied (N)
- \( d \) = The distance from the point where the force is applied (m)

\[ M_{\text{Max}} = (490500 \times 0.041) = 20110.5 \text{N.m} \]

Therefore the Maximum Moment that is applied on each half of the device is 20110.5N.m.
5.3.2 Finite Element Analysis (FEA) of the Chosen Design

The FEA completed below on the main body half and base assembly was done as a first step in calculating whether the design is close to being strong enough. Due to time and budgetary constraints, this project will only include this preliminary FEA and an evaluation of the results with possible improvements shown. The first prototype will be constructed with the recommended possible improvements and load test as a proof of concept only.

The FEA that was carried out on the main body and base assembly was done using SolidWorks Office Premium 2007 and Cosmos, which is an FEA package that can be integrated into SolidWorks.

5.3.2.1 Main Body FEA

The main body had loads applied as shown in Figure 30. A 500,000N bearing load was applied upwards through the pick-up point with an equal and opposing load applied over the top of the device where the collars of the pipes would sit when being clamped. These forces are transferred through the top of the clamping face and the pivot point of the device. Forces were applied to the back of the slotted hole to represent the connecting link that is there in normal operation. The device was restrained at three points for balance.
After consultation with FEA experts it was decided to apply a 10mm mesh to the main body half. A finer mesh may be used when further FEA is carried out. The applied mesh can be seen in Figure 31.
As can be seen in Figure 32 below, the FEA produced a maximum stress of 980.1MPa while using a Deformation Scale of 20. The highest stresses were at the top of the pick-up point as would be reasonably expected.

![Figure 32: FEA of Main Body half showing Max. Stress equals 980.1MPa](image)

The next result of the FEA is the deformation in the x-direction as shown in Figure 33. Results show that the Maximum Deformation is 2.154mm using a deformation scale of 20.

![Figure 33: FEA of Main Body half showing max deformation in the x-direction equals 2.154mm](image)
5.3.2.2 Base Assembly FEA

The base assembly had loads applied as shown in Figure 34. A 500,000N bearing load was applied through each of the two holes in the base assembly which is where the main body pivots. The base assembly was restrained with inertial relief.

After consultation with FEA experts it was decided to apply a 10mm mesh to the base assembly. A finer mesh may be used when further FEA is carried out. The applied mesh can be seen in Figure 35.
As can be seen in Figure 36 below, the FEA produced a maximum stress of 1228MPa while using a Deformation Scale of 20. The highest stresses were at the centre of the base assembly as would be reasonably expected.

Figure 36: FEA of Base Assembly showing Max. Stress equals 1228MPa

The next result of the FEA is the deformation in the x-direction as shown in Figure 37. Results show that the Maximum Deformation is 0.9673mm using a deformation scale of 20.

Figure 37: FEA of Base Assembly showing max deformation in the x-direction equals 0.9673mm
The next result of the FEA is the deformation in the y-direction as shown in Figure 38. Results show that the Maximum Deformation is 1.018mm using a deformation scale of 20.

![Figure 38: FEA of Base Assembly showing max deformation in the y-direction equals 1.018mm](image)

The final result of the FEA is the deformation in the z-direction as shown in Figure 39. Results show that the Maximum Deformation is 0.472mm using a deformation scale of 20.

![Figure 39: FEA of Base Assembly showing max deformation in the z-direction equals 0.472mm](image)
5.3.3 Evaluation of Design FEA Results

As seen from the FEA results in the previous section there were areas in the main body and base assembly that were too highly stressed. The main two sections that were too highly loaded were the top of the pick-up points at 980.1MPa and the centre of the base assembly at 1228MPa. It is common practice with Easternwell’s engineering team to design a part so that the stresses in it are no larger than 0.6 of the Yield Stress or in this case, 420MPa. After consultation with expert engineers, the changes shown below in Figure 40 were made to the design.

![Figure 40: Final Design with modifications](image-url)
It is the opinion of an expert engineer (Stangherlin, G. 2007, pers. comm. 22 October) that by adding a top flange of about 12mm in thickness to the device, it would reduce the stresses in the main body to be close to 420MPa. It is also their opinion that if the gussets on the back of the base assembly were approximately 10 to 12mm thick they would also reduce the stresses in the base assembly to be close to 420MPa. This will of course be confirmed with further FEA as well as load testing on a prototype model. The first prototype will not be used in field on a Service Rig but in a controlled testing environment to prove that the concept of this device works.

5.3.4 Hydraulic Cylinder Calculations

The twin piston hydraulic cylinder that is to be used on the device will have a number of purposes. These are:

- Opening the device.
- Closing aid for the device.
- Acting as a “back-up” lock for the device.

Out of these three purposes for having the cylinder, opening the device will require the most force as the device is designed to be self-closing and self-locking when lifted.

The first step in determining what size cylinder is needed to open this device is to calculate the mass and Centre of Gravity for each half of the main body. This was calculated using KeyCreator Version 6.52, which is a 3D CAD modelling program. This program was used to model the device and it also has a mass properties function. Using this function and inputting a density of $7.8 \times 10^6$ kg/m$^3$ a mass of 45kg was found and the Centre of Gravity is shown in Figure 41.
Figure 41: Relevant dimensions for hydraulic cylinder force calculation

With this information the force created by the weight of the main body half, \( F_{\text{Weight}} \), can be found using equation:

\[
F_{\text{Weight}} = mg
\]  

(5.3)

where

\( F_{\text{Weight}} = \) Force created by the weight of the part (N)

\( m = \) Mass (kg)

\( g = \) Gravitational Acceleration (m/s\(^2\))

\[
F_{\text{Weight}} = (45 \times 9.81) = 441.45N
\]

Therefore the downward force created from the self-weight of the main body half is equal to 441.45N.
The force, \( F_{\text{Cyl}} \), needed by the cylinder to open one side of the device can now be found using equation:

\[
\Sigma M_0 = (F_{\text{Cyl}} \times d_c) - (F_{\text{Weight}} \times d_w) = 0 \tag{5.4}
\]

where \( \Sigma M_0 \) = Sum of the Moments about the Pivot Point (N.m)

\( F_{\text{Cyl}} \) = Force needed to open one side of the device (N)

\( d_c \) = Distance from the Pivot Point to the Cylinder pin (mm)

\( F_{\text{Weight}} \) = Force from the self-weight of the main body half (N)

\( d_w \) = Distance from the Pivot Point to the COG (mm)

\[
\Sigma M_0 = (F_{\text{Cyl}} \times 56) - (441.45 \times 135) = 0
\]

\[
(F_{\text{Cyl}} \times 56) - (59595.75) = 0
\]

\[
F_{\text{Cyl}} = \frac{59595.75}{56}
\]

\[
\therefore F_{\text{Cyl}} = 1064.21N
\]

\[
\therefore F_{\text{Cyl}} = 108.5kg
\]

Therefore the force that the hydraulic cylinder would be required to push is 1064.21N or the equivalent of 108.5kg. This is not much at all for a hydraulic cylinder.

Before any calculations were done to calculate the size of cylinder needed to push 1064.21N, the author firstly looked at a reputable hydraulic cylinder manufacturer’s specification sheets in order to try and use a standard cylinder. It was found that the smallest standard cylinder has a 38.1mm bore and a 19.1mm shaft, with an extend force capacity of 1607kg at 136 Bar. This information page can be found in Appendix C. While this cylinder is much higher rated than needed, it will work out less expensive to stay with a standard cylinder bore and shaft size.

From the 3D CAD model it was found that a cylinder with the following dimensions is needed:
- 300mm closed length
- 372mm open length
- Stroke of 36mm per piston

A diagram of one possible design for this cylinder is shown in Figure 42.

![Figure 42: Twin Piston Hydraulic Cylinder for latching device](image)

Using this information and the information gained from the cylinder manufacturer, some calculations can be performed in order to make sure that the cylinder will not fail. The author has assumed that buckling in the shafts of each piston is extremely unlikely given that their length is only approximately two times their diameter. Due to the hydraulic cylinder being double-ended and its action symmetrical, the author will treat the cylinder as if it is a standard, single-ended cylinder of half the length. A conservative pressure of 136 Bar will be used and friction will be ignored.

The area of the bore is calculated by, \( A = \pi r^2 \):

\[
\begin{align*}
r &= 19.05\text{mm}, \quad A = \pi \times 19.05^2, \quad \therefore A &= 1140.09\text{mm}^2
\end{align*}
\]

The pressure in the bore by the load of the device is given by:
\[ P_{\text{bore}} = \frac{F}{A} \]  

(5.5)

where \( P_{\text{bore}} \) = Pressure in bore (MPa)  
\( F \) = Applied Force (N)  
\( A \) = Area over which force is applied (mm\(^2\))

With a force of 1064.21N and an Area of 1140.09mm\(^2\) the pressure in the bore is as follows:

\[ P_{\text{bore}} = \frac{1064.21}{1140.09} \]

\[ P_{\text{bore}} = 0.933MPa \]

Therefore, the pressure in the bore of the cylinder will only be about 0.933MPa which is miniscule compared to what the cylinder is capable of.

The shaft on the cylinder also needs checking for stress failure. With a force of 1064.21N, a shaft radius of 9.55mm and using equation 5.6, the stress in the shaft is calculated as follows.

\[ \sigma = \frac{F}{A} \]  

(5.6)

where \( \sigma \) = Stress in the shaft (MPa)  
\( F \) = Applied Force (N)  
\( A \) = Area over which force is applied (mm\(^2\))

\[ \sigma = \frac{1064.21}{286.52} \]

\[ \sigma = 3.71MPa \]
As expected, the stress in the shaft is very low at 3.71MPa, therefore the shaft in the hydraulic cylinder will not fail.

As shown by the above calculations, the cylinder is significantly over designed. This does however have a number of benefits. Apart from being less expensive than a cylinder designed using non-existing parts, this cylinder will not look out of place on this device. While aesthetics are not paramount, they do play a significant role in the oil and gas industry. If rig personnel with a non-technical background saw this device with a small, fragile looking cylinder mounted on the front of it they would raise concerns about its strength and durability. This also comes back to what exists in the industry today. Overall, even if a component is strong enough to take a large load, if it looks small or undersized, it will not be accepted nor bought.

5.4 Cost Analysis

As the first number of prototypes will be of welded construction, rather than a cast construction, the cost breakdown will differ significantly from prototype to final. Casting would initially be more expensive because of mould making costs and proofing but after the initial set up is completed, the price should drop dramatically. The price breakdown given below in Table 5 is the author’s cost estimate for fabricating the prototype. The set of standard bails will not have to be purchased as an existing set will be used.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>COST ($)</th>
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<tr>
<td>Base Assembly</td>
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<tr>
<td>Miscellaneous Costs</td>
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</tr>
<tr>
<td>TOTAL</td>
<td>$4300</td>
</tr>
</tbody>
</table>

Table 5: Cost Estimate for Prototype Construction
5.5 Conclusion

The selection and design of the critical components of the prototype has been explained and the critical design aspects examined. The design process has been detailed and the importance of aesthetics discussed. Chapter 6 will summarise the objectives that have been achieved, future design considerations and further work that needs to be done.
Chapter 6

Conclusions and Further Work

6.1 Introduction

The previous chapter discussed the selection and design of the critical components of the prototype and the critical design aspects were explained and examined. The design process was also detailed and the importance of aesthetics discussed. This chapter summarises the processes involved to achieve the project objectives, the further design considerations and what is foreseen to be the major future developments in the design.

6.2 Summary of Objectives Achieved

To achieve the project objectives, the “methodology” discussed in chapter 1 had to be undertaken.

- Background research was conducted to find information relating to pipe latching/unlatching mechanisms and current methods of pulling and running pipe on existing service rigs.
- Conceptual designs of some alternative methods of pipe latching/unlatching mechanisms were investigated considering the background research and design constraints set by Easternwell.
- The conceptual designs were developed to a stage where a cost analysis could be achieved and the advantages/disadvantages of each design reviewed.
• Concept design 4 was chosen for further development and manufacture based on the recommendations of the author and the requirements of the Easternwell Engineering team.

• The critical components of the prototype were selected and designed and the critical design aspects were explained and examined.

The overall outcome of this project was positive and all of the objectives of the project have been fully met. However, time and resource constraints at Easternwell have meant that prototype construction and testing has been put on hold for the next six months.

6.3 Further Design Considerations

There are a number of further design considerations to be taken into account before this project reaches a full production stage. As was mentioned above, construction and testing has been put on hold for the next six months. During this time however, there will be a need for further design work to be carried out before construction of the first prototype commences. This will include:

• Design of all pin sizing and bushing.

• Design of the hydraulic circuit and particular valving components. This would also include how to run the hoses from the power source to the latching device.

• Complete the design of the hydraulic cylinder and liaise with a hydraulic cylinder manufacturer to get a prototype built.

• Construction details, i.e. detail fabrication drawings and fabrication process routing.

• Design a test rig for prototype testing in a controlled environment.

• Conducting further FEA to reanalyse the design with the suggested modifications.
6.4 Future Development in Design

Future development in the design of this device will be largely dependant on the success of the prototype testing and evaluation. If the device proves successful, there will be a number of future developments in design such as listed below:

- The main components of the device, such as the main body and base assembly, will be cast.
- The material selection will be looked at further in order to try and optimise the design. For example, an alloy of different materials may be chosen to reduce weight and increase strength.
- The main body will be redesigned so that it can be fitted with dies in order to be used with multiple pipe diameters.

6.5 Conclusion

The prototype design that was chosen will meet all of the requirements and outlines set by the Easternwell Group. Once developed, it will make the well servicing process a safer and more efficient operation for rig personnel. This project has achieved all of the required objectives. Due to time and resource constraints, prototype construction and testing has been put on hold for the next six months. However, further design considerations have been outlined and will be undertaken by the author during the six month period in order for the prototype construction to run smoothly. Also discussed were the future developments in the design of the device if prototype testing proved successful.
References


Appendix A

Project Specification
University of Southern Queensland  
Faculty of Engineering & Surveying  

ENG4111/4112 Research Project  
PROJECT SPECIFICATION

FOR: STEVEN SULLIVAN, Q11215856
TOPIC: RESEARCH, DESIGN AND DEVELOPMENT OF A PIPE LATCHING/UNLATCHING DEVICE
SUPERVISOR: Dr. Selvan Pather  
Guido Stangherlin, Easternwell Group
SPONSORSHIP: Easternwell Group
BACKGROUND: Easternwell Group (EWG) is a Toowoomba based, privately owned company that has provided a specialized and unique service to the Australian on-shore energy industry for over 17 years. EWG has accumulated the largest and most extensive rig fleet and equipment in Australia, contributing to the advancements of the well service industry through the innovative use of new technology in a safe and environmentally responsible manner. We have the largest research and development team in Australia dedicated to the advancement of work over rigs and work over practices.

EWG has recently made advancements in pipe handling technology in the design construction and implementation of a hydraulic pipe handler (HPH). The HPH ensures exact repetition of pipe position - this then opens the way for semi-automation of the pipe tripping process, the process of latching pipe, elevating it and lowering it in a controlled fashion. Current systems in use require manual input to control and latch the elevator, which is attached to a travelling block that is only controlled in the vertical axis. In order to automate the tripping process the blocks must be controlled in all axes and the pipe must be automatically latched and unlatched.

PROJECT AIM: To research, design and develop a pipe latching/unlatching device that can be used to help automate the pipe tripping process that is currently in use on rigs.

PROJECT OUTLINE: (Issue A, 26 March 2007)

- Conduct a literary review to research information relating to pipe latching/unlatching mechanisms and current methods of pipe tripping on existing work-over and drilling rigs.
- Critically evaluate existing methods and designs in use.
- Undertake preliminary designs of some alternative methods of pipe latching/unlatching mechanisms.
- Once the most suitable design is chosen, develop and analyse the conceptual design.
- Complete and lodge a Provisional Patent Application for the design.
- Complete designs and produce detail drawings for the manufacture of the mechanism.

As time permits:
- Manage the construction of the first prototype.
- Conduct in field testing and evaluate design.
- Suggest changes or additions to system based on conclusions from in field testing.

AGREED:
____________________(Student) ___________________. ___________________ (Supervisor/Coexaminer)
___ / ___ / ___           ___ / ___ / ___           ___ / ___ / ___
Appendix B

String Weight VS Clamping Moment Table
## CLAMPING MOMENT VS STRING WEIGHT

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Appendix C

Hydraulic Cylinder Data Sheets
## NORDON CYLINDERS

### ROD BUCKLE LOADS

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<td>ROD DIAMETER IN INCHES - MILLIMETERS</td>
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Leverage by arms or linkages will also have to be calculated when using this data.

### TUBE YIELD PRESSURES

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### CYLINDER EXTEND FORCE

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Safety factors to use as a guide: Low pressure: Low Speed 3:1 ; Standard Working Pressure & Speed 4:1 ; High Speed High Pressure 6:1 ; Max Cylinder Speed .4 meters per sec

### BORE TO ROD STEP DOWN YIELD AT 3 TO 1 FACTOR

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Subject to change without notice.
PIN EYES

LENGTH OF EYE
OUT SIDE DIAMETER
PIN DIAMETER
First letter in number
E   = PIN EYE

LENGTH OF EYE IN mm
Base end pin eye 12mm wider than OD of tube
Rod end pin eye 12mm wider than OD of shaft

LETTER DESIGNATES DIAMETER OF EYE

OD OF PIN EYE = OD OF PIN*2 + BUSH WALL*2 ROUND TO NEAREST mm
E.g. 1" pin = (25.4*2) = 50.8 = 50mm Material IF BUSH +10mm = 60

EXCEPT WEAR THE PIN-EYE IS FITTED ON A SMELL CYLINDER E.g. 2"
WITH 1" PINS THEN THE OD MUST NOT EXCEED THE BORE

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*MARKETING/CATALOGUE 3004-2017 Part Numbering Order Code*
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<th>PISTON &amp; NUT</th>
<th>GLAND CAP</th>
<th>SHAFT DIA</th>
<th>SHAFT STAND-OFF</th>
<th>SHAFT THREAD LENGTH</th>
<th>BARE BUILD LENGTH</th>
<th>BARE BUILD LENGTH WITH ROD CLEVIS</th>
<th>ROD CLEVIS</th>
<th>BASE CLEVIS</th>
<th>END PLUS</th>
<th>TOTAL BUILD LENGTH</th>
<th>ROD EYE</th>
<th>BASE EYE</th>
<th>BUILD LENGTH WITH OPTION</th>
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NUMBER DESIGNATES BORE IN INCHES

05 = 0.5" DIA HOLE
10 = 1" DIA HOLE
12 = 1.25" DIA HOLE
15 = 1.5" DIA HOLE
17 = 1.75" DIA HOLE
20 = 2" DIA HOLE
30 = 20mm DIA HOLE
40 = 30mm DIA HOLE
50 = 40mm DIA HOLE
60 = 50mm DIA HOLE

HOLE SIZE INCLUDING TOLERANCE = PIN OD + 0.1+0.2mm UP 3"

MATERIAL: Bright mild steel up to and including 3" over 3" use black mild

PIN EYE BASE END SPACERS
ALL SPACERS ARE SP17 MATERIAL 1.75 DIA BMS

PIN EYE HARDEN BUSHES

ALL BUSHES ARE 38mm LONG
WALL THICKNESS 5mm
HB = HARDEN BUSH
ID IN mm
OD IN mm
WIDTH IN mm
MATERIAL: 4140