Automotive Floor Jack Locking Device

by

MICHAEL DELLECAVE

Submitted to the
MECHANICAL ENGINEERING TECHNOLOGY DEPARTMENT
In Partial Fulfillment of the
Requirements for the
Degree of
Bachelor of Science
In
MECHANICAL ENGINEERING TECHNOLOGY

at the
OMI College of Applied Science
University of Cincinnati
May 2002

©...Michael Dellecave

The author hereby grants to the Mechanical Engineering Technology Department permission to reproduce and distribute copies of the thesis document in whole or in part.

Signature of Author

Certified by
Janak Dave, PhD,
Thesis Advisor

Accepted by
Muthar Al-'Utaybi, PhD, Department Head
Mechanical Engineering Technology
Abstract

For the home mechanic, safety is a very important issue. This is especially true since these individuals often work alone. However, safety precautions, like jack stands are often neglected, leaving a floor jack as the only support of the vehicle. The Automotive Floor Jack Locking Device prevents a floor jack from lowering in the event of hydraulic pressure loss.

Testing confirmed the positive results of the prototype. The Locking Device functions on all vehicles weighing up to 4000 lbs, with a 6 to 10 inch specified jacking station height. It will support a load of 4000 lbs. at eight different positions. The Locking Device is compatible with the Torin Black Jack model floor jack as well as four other makes and models. The Locking Device allows the jack to retain all original functionality and conforms to the ASME PALD safety standards.

This report covers the entire design process. Using the information collected from customer surveys, three alternative designs were formed. The Weighted Objective method was used to help determine the best alternative design. This alternative was designed and drafted in greater detail and analyzed. When analysis was completed and accepted, fabrication of the Locking Device was done and the final prototype was tested. Cost analysis, for production of the Locking Device, and recommendations on improving the current design conclude the report.
Acknowledgements

Dr. Janak Dave for helping me keep on track.
Family for putting up with me and supporting me over the past 5 years.
Friends at CAS who have supported me and who I have supported.
Gary McIntosh at Reliable Castings for the price quote.
All of the faculty at CAS who helped out.
# Table of Contents

**ABSTRACT** ...................................................................................................................... II

**ACKNOWLEDGEMENTS** ........................................................................................... III

**TABLE OF CONTENTS** ............................................................................................... IV

**LIST OF FIGURES** ........................................................................................................ V

**INTRODUCTION** ........................................................................................................... 1

**RESEARCH AND SURVEYS** ....................................................................................... 3

  - Patent and Product Research ............................................................................... 3
  - Standards Research ............................................................................................... 3
  - Customer Surveys .................................................................................................... 4
  - Design Requirements ............................................................................................. 4

**TECHNICAL DISCUSSION** ............................................................................................ 5

  - Floor Jack Terminology ......................................................................................... 5
  - Alternative Designs and Selection ......................................................................... 5
  - Design and Analysis ................................................................................................ 6
  - Design for Assembly and Manufacturing .............................................................. 7
  - Fabrication and Assembly ....................................................................................... 8
  - Testing .................................................................................................................... 9
  - Time Schedule and Budget ..................................................................................... 11

**CONCLUSION** ............................................................................................................... 13

  - Accomplishments ................................................................................................. 13
  - Recommendations .................................................................................................. 13

**APPENDICES** .............................................................................................................. 14

  - Appendix ‘A’ Survey #1 ..................................................................................... 14
  - Appendix ‘B’ Patents ............................................................................................... 16
  - Appendix ‘C’ ASME PALD Safety Standards ....................................................... 19
  - Appendix ‘D’ Survey #2 ....................................................................................... 26
  - Appendix ‘E’ Proof of Design ............................................................................... 28
  - Appendix ‘F’ Selection Method ............................................................................. 30
  - Appendix ‘G’ Alternative Designs ........................................................................... 32
  - Appendix ‘H’ Calculations ...................................................................................... 36
  - Appendix ‘I’ Part Drawings .................................................................................. 41
  - Appendix ‘J’ Bill of Material .................................................................................. 55
  - Appendix ‘K’ Schedule ......................................................................................... 57
  - Appendix ‘L’ Budget ............................................................................................... 59
  - Appendix ‘M’ Cost Quote ........................................................................................ 61
  - Appendix ‘N’ Bibliography ...................................................................................... 63
List of Figures

Figure 1. Locking Device Assembled View ................................................................. 2
Figure 2. Locking Device & Floor Jack Terminology .............................................. 5
Figure 3. Raising the Vehicle ................................................................................... 9
Figure 4. Turning the Locking Screw ....................................................................... 9
Figure 5. Turning the Height Adjuster ..................................................................... 10
Figure 6. Releasing Hydraulic Pressure .................................................................... 10
Introduction

For the home mechanic, safety is a very important issue. This is especially true since these individuals often work alone. Servicing a vehicle often involves raising it off the ground for better accessibility. This requires the use of a jack and jack stands. The jack is used to raise the vehicle and the jack stands are used to support it. However, despite warnings on jacks, the jack stands are often not used. When jack stands are not used, the jack has the potential to fail and drop the vehicle down, creating a dangerous situation.

There are three major reasons why jack stands are neglected. The following three reasons were collected from Survey #1 in Appendix ‘A’. First, the work being performed does not require the vehicle to be raised to the height needed to accommodate a jack stand. Second, the placement of the jack and the jack stand often interfere with one another. Third, the use of jack stands is often considered a hassle when performing a quick task.

The design solution is a Locking Device, Figure 1, that installs on a standard hydraulic floor jack and, when engaged, will prevent the lowering of the vehicle due to hydraulic pressure loss. The Locking Device automatically engages at eight different heights and does not inhibit the functionality of the floor jack. This Locking Device can be engaged and disengaged while the operator is safely out from under the vehicle.
To ensure completion of this project, a schedule, budget, and proof of design were formed. The schedule outlined important milestones, and when these milestones should be completed. The budget helped keep material and labor in perspective, as to not make a product that is extremely expensive. The proof of design is a list of measurable objectives to which the final product was compared, to ensure the promised criteria were met.

The remaining sections of this report discuss in detail the steps that were taken to complete the prototype Locking Device. Research, on patented products and customer needs, was performed. This information led to three different design alternatives. From these three alternatives, the weighted objective selection method was used to select the best alternative. This alternative was designed and drafted in greater detail and analyzed. When analysis was completed and accepted, fabrication of the Locking Device was done and the prototype was tested. The report will close by giving insight to production costs of this prototype, as well as recommendations for further development and improvement.
Research and Surveys

Patent and Product Research

This research was performed mainly on the internet using the Delphion Patent Search Database. Only two patents were found that deal with the problems stated in the introduction. The first design uses a modified jack frame that accommodates a bar of material preventing the jack from lowering. The second design uses an adjustable linkage, much like a jack stand, to ensure the jack will not lower. The abstracts to both of these designs can be found in Appendix ‘B’. Both designs solve the problems stated previously, except that to operate these devices the operator needs to reach under the vehicle. This is a safety hazard. Other than these two patents, no products on the market were found.

Standards Research

The American Society for Mechanical Engineers has developed a set of safety standards for automotive lifting devices. This set of standards for Portable Automotive Lifting Devices, or PALD, has been conformed to. A safety factor of at least 1.5 has been maintained on all Locking Device components. The applicable sections of this set of standards can be found in Appendix C’.
Customer Surveys

A survey (Survey #2) designed to pinpoint important customer wants, to be incorporated into the design, was given to potential consumers. The results of this survey highlighted four main points. First, the customer wants a device that is easily engaged and disengaged without being under the vehicle. Second, there needs to be at least three locking positions. Third, the device must be able to be installed in under one hour. Forth, the device must not affect the functionality of the jack. An example of Survey #2 can be found in Appendix ‘D’.

Design Requirements

Certain design requirements have been laid out to prove that the Locking Device does what it is supposed to do. These requirements constitute the Proof of Design Statement. This statement consists of seven measurable objectives and information on the testing of the device. A copy of the Proof of Design Statement can be found in Appendix ‘E’.
Technical Discussion

Floor Jack Terminology

Different terms are used throughout this section to describe parts of the floor jack and the Locking Device being designed. Figure 2 shows the names of all the parts discussed in the following sections.

![Figure 2. Locking Device & Floor Jack Terminology](image)

Alternative Designs and Selection

Three alternative designs that fulfilled the customer wants were formed. These designs involved a Gear, Chain and Linkage. Two different selection methods were used. The first was the Weighted Objective Method and the second was Pugh’s Method. In both cases, the preferred design came out to be Alternative #3, the Linkage design. An
example of each of these methods can be found in Appendix ‘F’. Drawings of the three alternatives can be found in Appendix ‘G’

**Design and Analysis**

The design consists of four major components, the *Slider Linkage, Linkage Pin, Height Adjuster*, and *Latch Arm*. Calculations and drawings can be found in Appendices ‘H’ and ‘I’.

The *Slider Linkage* attaches to the lift arm by means of the *Linkage Pin*. As the lift arm is raised, the *Linkage Pin* applies a force to the *Slider Linkage* causing it to move. This design transforms the rotational movement of the lift arm to linear movement, which, in this case, is easier to deal with. The *Height Adjuster* attaches at the support pin and connects to the *Slider Linkage*. The *Height Adjuster* component enables the user to adjust the height of the *Slider Linkage* allowing easier positioning of the floor jack. It also ensures correct engagement of the sawteeth. The *Latch Arm* attaches at the piston pin and rests on the *Slider Linkage*.

When the Lift Arm is raised, the *Linkage Pin* pushes the *Slider Linkage* back. As the *Slider Linkage* moves, the *Latch Arm* swivels about the piston pin allowing the teeth to engage and disengage. Once the teeth are engaged, to lock the device, the *Locking Screw* on the *Latch Arm* is turned until it contacts the jack frame. To release the device, the *Locking Screw* is simply backed out.

Stress calculations were performed on all of the components that carry a load due to support of a vehicle. The worse case scenario, where only the very tips of the teeth are engaged, was analyzed. Bending and shear stress calculations showed the maximum stress in the *Slider Linkage* and the *Latch Arm* to be 31,090 psi. This stress occurred at
the sawteeth on both components. The maximum stress calculated due to shear in the Linkage Pin is 16,730 psi. Realistically, with the sawteeth correctly engaged, the maximum stress seen is around 7,000 psi.

Conforming to the ASME PALD-1997 safety standards, a safety factor of 1.5 must be achieved. The minimum safety factor achieved in the worse case scenario is 1.7, which exceeds the minimum standard of 1.5. Realistically, with the teeth engage properly, a safety factor of 7.7 was achieved. With these safety factors, the allowable minimum Yield Stress of all materials used is around 47,000 psi. All machined parts are made out of 1018 Cold Drawn steel with a minimum Yield Stress of 54,000 psi. The commercial parts, which include one 3/8 – 16 bolt, one cotter pin, and one ½ - 13 wing nut, will be made of the standard material commonly sold in industry. A bill of material can be found in Appendix ‘J’.

Design for Assembly and Manufacturing

The sawteeth on the Latch Arm and the Slider Linkage were originally designed with an angle of 63.4918 degrees. There is not a standard milling tool with this type of cut, but a 60 degree cut was available in the North Lab machine shop. Therefore, the design was changed to have an angle of 60 degrees to avoid the need for special tooling. The use of 1018 Cold Drawn steel is not required for all components, but to avoid complications in manufacturing, a standard material is used for all parts. This device will be installed on the floor jack by the consumer. Due to this fact, the device will not require any special tools for installation. For example, instead of using the original snap rings, which require the use of snap ring pliers, a cotter pin is used.
**Fabrication and Assembly**

The Locking Device was fabricated in the CAS North Lab facility using a mill, lathe, welder and other common shop tools. The most important aspect of the Locking Device is the sawteeth patterns on the *Latch Arm*, and the *Slider Linkage*. These components were machined with a 60 degree cut milling tool on a Cincinnati end mill. The end mill was chosen for accuracy in the spacing of the sawteeth.

The unassembled Locking Device was given to the potential customers who returned a survey. Observing these individuals proved assembly of the Locking Device can be completed with common hand tools in less than 20 minutes with absolutely no modifications to the floor jack.
Testing

To test the prototype, the Locking Device was installed on the floor jack and placed under a vehicle that meets the specifications in the proof of design. This vehicle was raised with the floor jack to a desired height where the sawteeth on the Locking Device were engaged. See Figure 3.

Figure 3. Raising the Vehicle
The Locking Screw was then turned until it contacted the frame of the jack. This creates a positive lock in that position. See Figure 4.

Figure 4. Turning the Locking Screw
With one turn of the Height Adjuster, Figure 5, correct alignment of the teeth is ensured.

**Figure 5. Turning the Height Adjuster**

Finally, the hydraulic pressure was released, Figure 6, allowing the entire load to be supported by the Locking Device. The Locking Device was left supporting the load for one half hour, which exceeds the ASME PALD standard of 10 minutes. This procedure was repeated at all 8 locking positions.

**Figure 6. Releasing Hydraulic Pressure**
Time Schedule and Budget

The time schedule generated in Senior Seminar was used. A copy of this schedule can be found in Appendix ‘K’. This schedule helped keep the large amount of tasks to be completed in perspective with the little amount of time. Without this schedule, keeping on track would have been more difficult.

Along with a schedule, a budget was also formed to help keep on track. The Torin Black Jack model floor jack was to be purchased from Walmart for no more than $20.00. The required hardware cost was approximated between $5.00 and $20.00 from Home Depot. The 1018 Cold Drawn steel was donated by the University of Cincinnati. This material was unused steel in the CAS North Lab. For a complete table of the budget for this project, refer to Appendix ‘L’.

Prototype and Production Costs

The cost to produce the Locking Device prototype stayed well under the allowable budget. The Torin Black Jack model floor jack was purchased from Walmart for $17.98. The total cost of hardware used in the prototype was $2.27. As stated above the steel was donated by the University of Cincinnati. My total cost, to build this prototype, was $20.25. However, since the machining was done in the CAS North Lab facility, there is not a labor charge in this price. About seven hours of machining was recorded in making this prototype. If the components were given to a machine shop, the total cost of the Locking Device prototype would have been around $440.25.
The Locking Device drawings were sent out to Reliable Castings, for a price quote on 10,000 units per year. The price quote is located in Appendix ‘M’. The Latch Arm would cost $3.75 a piece with a $3,000 pattern price. The Slider Linkage would also have a pattern price of $3,000, and would cost $4.00 a piece. The Height Adjuster block would cost $0.75 with a pattern price of $1,000. The total for the cast parts would then be $9.20. A price of $1.25 a unit was figured to complete the part manufacturing. Finally, the addition of the hardware purchased in bulk, totaled $0.65. The overall total to make 10,000 Locking Devices would be $111,000. This makes the total per Locking Device $11.10. This is a very acceptable price considering the cost of jack stands to exceed $50.00.
Conclusion

Accomplishments

The Locking Device met or exceeded all seven Proof of Design stipulations. The Locking Device does function on all vehicles weighing up to 4000 lbs, with a 6 to 10 inch specified jacking station height. The Locking Device is compatible with the Torin Black Jack model floor jack as well as four other makes and models. The Locking Device allows the jack to retain all original functionality and conforms to the ASME PALD safety standards. For the list of Proof of Design Accomplishments, see Appendix ‘E’.

Recommendations

In the future, to make an even better product, a few recommendations were formed. The use of a bronze bushing would greatly reduce the amount of play in the Locking Device and would allow smoother operation. The sawtooth components could be cast to reduce the machining time and material waste. Ultimately, instead of this idea being an option for the home mechanic, a Locking Device designed into the floor jack instead of being an after market add on would produce a more desirable and better product.
Appendices

Appendix ‘A’
Hydraulic Floor Jack and Jack Stand Survey #1

1. Do you ever work on or under a vehicle?
2. Do you own a floor jack?
3. Do you own a set of jack stands?
4. Do you ever use a floor jack and jack stands?
5. If yes to the previous question, how often?
6. When working under a raised vehicle, do you rely on just a floor jack, or do you use jack stands?
7. When using only a jack, do you fear the jack will fall?
8. On a scale from 1 to 10, 10 being very secure, how secure do you feel that your floor jack will not fall or creep down?
9. Do you support the entire vehicle above the ground or just the corner or side you are working under?
10. When raising a vehicle to be worked on, is it sometimes difficult placing jack stands in the correct positions for proper support?
11. Do you neglect using a jack stand when raising the vehicle only enough to get the tires off the ground?
12. Do you have any particular likes or dislikes about floor jacks?
13. Do you have any particular likes or dislikes about jack stands?
Appendix ‘B’
An adjustable mechanical device to engage the opening of a standard hydraulic floor jack to prevent said jack from lowering inadvertently in the event of hydraulic failure. Said device is installed by positioning as shown with L-clip under jack axle, and with adjustable strut extended so as to engage the upper shaft of jack. To remove the jack support, the lever is lifted wherein the pawl is disengaged, the strut lowers, and the Jack Support is removed.
A floor jack is provided with safety means to prevent arms of the jack from retracting while the arms are in a raised position. This safety means is insertable through opposing pairs of notches in the side plates of the floor jack, these notches being aligned opposite from one another.
Appendix ‘C’
SAFETY STANDARD
FOR PORTABLE AUTOMOTIVE LIFTING DEVICES

ASME PALD-1997
(Revision of ASME PALD-1993)
The 1997 edition of this Standard is being issued with an automatic addenda subscription service. The use of addenda allows revisions made in response to public review comments or committee actions to be published as necessary; revisions published in addenda will become effective 3 months after the Date of Issuance of the addenda. The next edition of this Standard is scheduled for publication in 2002.

ASME issues written replies to inquiries concerning interpretations of technical aspects of this Standard. The interpretations will be included with the above addenda service. Interpretations are not part of the addenda to the Standard.

ASME is the registered trademark of The American Society of Mechanical Engineers.

This code or standard was developed under procedures accredited as meeting the criteria for American National Standards. The Consensus Committee that approved the code or standard was balanced to assure that individuals from competent and concerned interests have had an opportunity to participate. The proposed code or standard was made available for public review and comment that provides an opportunity for additional public input from industry, academia, regulatory agencies, and the public-at-large.

ASME does not "approve," "rate," or "endorse" any item, construction, proprietary device, or activity.

ASME does not take any position with respect to the validity of any patent rights asserted in connection with any items mentioned in this document, and does not undertake to assure anyone utilizing a standard against liability for infringement of any applicable Letters Patent, nor assumes any such liability. Users of a code or standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Participation by federal agency representative(s) or personnel affiliated with industry is not to be interpreted as government or industry endorsement of this code or standard.

ASME accepts responsibility for only those interpretations issued in accordance with governing ASME procedures and policies which precludes the issuance of interpretations by individual volunteers.

No part of this document may be reproduced in any form, in an electronic retrieval system or otherwise without the prior written permission of the publisher.

The American Society of Mechanical Engineers
345 East 47th Street, New York, NY 10017

Copyright © 1997 by
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
All Rights Reserved
Printed in U.S.A.
ASME SAFETY STANDARDS COMMITTEE
Portable Automotive Lifting Devices

(The following is the roster of the Committee at the time of approval of this Standard.)

OFFICERS
D. A. Alexander, Chair
B. R. Cooper, Vice Chair
J. M. Saltarelli, Secretary

COMMITTEE PERSONNEL
D. A. Alexander, Lincoln Automotive
G. Chiang, National Highway Traffic Safety Administration
B. R. Cooper, General Motors Corp.
P. Crow, Gray Automotive Products Co.
J. J. Gray, Alternate, Gray Automotive Products Co.
B. A. Frey, General Services Administration
K. S. Guerra, Sears Roebuck & Co.
F. G. Heath, Heath & Associates
G. A. Kattelman, Sentry Insurance Co.
C. E. Naber, Hein-Werner Corp.
P. C. Reger, Reger Quality Consultants
PART 10
SERVICE JACKS

Section 10-1: Scope, Classification, and Illustrations

10-1.1 Scope

This Part applies to self-contained service jacks used for lifting, but not sustaining, a partial vehicular load.

10-1.2 Classification

Hydraulic, pneumatic, pneumatic/hydraulic, and mechanical are the four classifications for which this Part applies.

10-1.3 Illustrations

Figures 10-1 and 10-2 show typical jacks covered by this Part and are not intended to be all-inclusive.

10-1.4 Definitions

jack, hydraulic service: a device in which the lift arm is actuated by a hydraulic pump.

jack, mechanical service: a service jack in which the lift arm is actuated by mechanical means such as levers, cables, gears, screws, ratchets, and paws.

jack, pneumatic/hydraulic service: a service jack in which the lift arm is actuated by a mechanism that utilizes a relatively incompressible fluid, such as oil, as the force transmitting means, actuated by a pneumatic power source.

jack, pneumatic service: a service jack in which the lift arm is actuated by a mechanism that utilizes compressed air as the force transmitting medium.

jack, service: a self-contained device designed for lifting, but not sustaining, a partial vehicular load, consisting of a frame with wheels and/or swivel casters supporting a mechanism that actuates a pivoting lift arm equipped with a saddle.

lift arm: the main lifting member through which the force is transferred from the power unit to the saddle.

saddle periphery: the highest points of contact between the saddle and the load on the outermost edge of the saddle, including any upward protrusion such as lugs, lips, or tangs.

Section 10-2: Design

10-2.1 Operating Controls

Operating controls shall be designed in such a manner that they are readily visible and accessible to the operator and so that the operator will not be subjected to pinch points, sharp edges, or snagging hazards. The operation of controls should be clear to the operator either by position, function, labeling, or combination thereof. The release system shall require intentional positive action by the operator for release to prevent accidental lowering.

10-2.2 Travel Limits

Each jack shall be provided with a positive means to prevent the load from being raised or lowered beyond the designed limit of travel.

10-2.3 Overload Capacity

All jacks shall be designed to meet the overload capacities as stated in (a) and (b) below.

(a) Service jacks not equipped with internal load limiting devices shall be capable of performing the proof load test of para. 10-4.1.5 with a proof load of 150% of rated capacity.

(b) Service jacks equipped with internal load limiting devices shall be capable of performing the proof load test of para. 10-4.1.5 with a proof load of 125% of rated capacity.

10-2.4 Saddle Periphery

The jack shall be designed to ensure that the saddle remains 3 deg parallel to the surface that the jack is supported by throughout the entire lifting range. The saddle periphery, throughout the entire lifting range, shall not move outside the imaginary perimeter estab-
Section 10-3: Safety Markings and Messages

The following are examples of safety markings and messages.

10-3.1 Safety Markings

Safety markings shall conform to the ANSI Z535 series of standards.

(a) Study, understand, and follow all instructions before operating this device.
(b) Do not exceed rated capacity.
(c) Use only on hard level surface.
(d) Lifting device only. Immediately after lifting, support the vehicle with appropriate means.
(e) Do not move or dolly the vehicle while on the jack.
(f) Failure to heed these markings may result in personal injury and/or property damage.

10-3.2 Safety Messages

Additional safety messages include the following.

(a) Lift only on areas of the vehicle as specified by the vehicle manufacturer.
(b) No alterations shall be made to this product.
SAFETY STANDARD FOR
PORTABLE AUTOMOTIVE LIFTING DEVICES

Section 10-4: Design Qualification Testing

10-4.1 Proof Tests

For each design or design change that may affect the jack's ability to meet this Standard, sample jacks built to design specifications shall be proof tested. To conform with this Standard, the jacks shall perform to design specifications and no functional damage shall occur, nor shall operational characteristics be detrimentally affected. Prior to each test below, the jack shall be placed on a smooth, flat surface with the rear wheels or casters in contact with the surface and loaded with sufficient force to remove all vertical play in the wheels or casters.

10-4.1.1 Load Limiting Device Test. Service jacks equipped with internal load limiting devices shall be pumped against a measured load with the lift arm in the horizontal position until the load limiting device is activated. The measured load shall be no less than 80% of the rated capacity nor more than 115% of rated capacity.

10-4.1.2 Load Sustaining Test. A load not less than the rated capacity shall be applied centrally to the saddle of the jack with the lift arm in the horizontal position. The load shall not lower more than 1/4 in. (3.18 mm) in the first minute, nor a total of 0.1875 in. (4.76 mm) in 10 min.

10-4.1.3 Release Mechanism Test. A load not less than the jack's rated capacity shall be applied centrally to the saddle with the jack fully extended. The release mechanism shall be operated to control the rate of descent to no more than 1.0 in/sec [25.4 mm/s].

NOTE: In normal use, a rate of descent greater than 1.0 in/sec (25.4 mm/s) is expected.

10-4.1.4 Saddle Periphery Test. The lift point of the jack at the saddle shall be divided, using imaginary lines, into segments as shown in Fig. 10-4, sketches (a), (b), and (c). Lift point No. 1 of the saddle periphery (see Definitions in Introduction) shall be loaded to rated capacity, the load to be applied over a contact area not greater than 1.0 in² (645 mm²). The jack shall be tested with the lift arm in the horizontal position and again with the lift arm at 30% of maximum lift height or the range of the jack. The load shall be removed and the jack checked for compliance with para. 10-2.4. The procedure shall be repeated until all remaining lift points of the saddle periphery have been tested in lift point Nos. 2 through 4. The orientation of the lift points of saddles that are neither square nor circular shall be rotated for each successive test to provide the maximum distance from the saddle centerline to the load point on the segment line. If retaining lugs or upper protrusions are provided on the periphery of the saddle, all remaining lugs or protrusions shall be subjected to this test.

10-4.1.5 Proof Load Test. A proof load as defined in para. 10-2.3 shall be applied centrally to the saddle of the jack. The load shall be lifted throughout the lifting range. For purposes of this test, any internal load limiting device may be deactivated.
Appendix ‘D’
Question: The following questions concern a device that would be purchased after market and installed on a standard hydraulic floor jack. In the event of hydraulic pressure failure, this device would prevent the vehicle from falling down.

1. Should this device work through the whole lifting range?
2. How many locked positions should there be?
3. Is weight a concern?
4. Should this device be disengaged from a location out from underneath of the vehicle?
5. Is limiting the lift range acceptable?
6. Is price a major concern?
7. Is installation time of the device a concern?
8. If so, the installation should take no longer than how long?
Appendix ‘E’
Mechanical Lock for Vehicle Floor Jack
Proof of Design

This device will:

- Function on all vehicles with a 6” to 10” specified jacking station height.
- Function on all vehicles weighing up to 4000 lbs.
- Support a load in the locked position of 4000 lbs.
- Be compatible with the Torin BlackJack model floor jack.
- Install on the floor jack in less than 1 hour.
- Allow floor jack to retain all original functionality.

After installation of this device on the floor jack it will be tested. Testing will be performed by lifting one wheel of a 4000 lb vehicle with the floor jack. Once the vehicle is lifted and the device is engaged, the hydraulic pressure will be released. This will allow the load to be supported entirely by the device. The load will remain entirely supported by the device for one half hour before being released. This procedure will be performed several times in all different locking positions.

Signatures:

Student: [Signature]  Name: [Signature]  Date: 3/20/02
Advisor: [Signature]  Date: 3/20/02
Appendix ‘F’
### Weighted Objective Method

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Chain</th>
<th>Gear</th>
<th>Linkage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>0.05</td>
<td>3</td>
<td>0.15</td>
</tr>
<tr>
<td>Weight</td>
<td>0.1</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td># of Lockable Positions</td>
<td>0.2</td>
<td>3</td>
<td>0.6</td>
</tr>
<tr>
<td>Material Cost</td>
<td>0.1</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>Manufacturing Cost</td>
<td>0.1</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>Durability</td>
<td>0.25</td>
<td>1</td>
<td>0.25</td>
</tr>
<tr>
<td>Installation Time</td>
<td>0.20</td>
<td>5</td>
<td>0.1</td>
</tr>
<tr>
<td>Total</td>
<td>1.00</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>

### Pugh Method

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Chain</th>
<th>Gear</th>
<th>Linkage</th>
<th>Datum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>Datum</td>
</tr>
<tr>
<td>Weight</td>
<td>+</td>
<td>-</td>
<td>S</td>
<td>Datum</td>
</tr>
<tr>
<td># of Lockable Positions</td>
<td>S</td>
<td>+</td>
<td>S</td>
<td>Datum</td>
</tr>
<tr>
<td>Material Cost</td>
<td>+</td>
<td>-</td>
<td>S</td>
<td>Datum</td>
</tr>
<tr>
<td>Manufacturing Cost</td>
<td>+</td>
<td>-</td>
<td>S</td>
<td>Datum</td>
</tr>
<tr>
<td>Durability</td>
<td>S</td>
<td>-</td>
<td>S</td>
<td>Datum</td>
</tr>
<tr>
<td>Σ+</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>Datum</td>
</tr>
<tr>
<td>Σ-</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>Datum</td>
</tr>
<tr>
<td>ΣΣ</td>
<td>2</td>
<td>0</td>
<td>6</td>
<td>Datum</td>
</tr>
</tbody>
</table>
Appendix ‘G’
ALTERNATIVE DESIGN #1
ALTERNATIVE DESIGN #2
Appendix ‘H’
FORCE AT LINKAGE PIN

\[ M_B = F_A \cdot d_1 \]
\[ = 2000(7.4417) \]
\[ M_B = 14,885 \text{ in} \cdot \text{lb} \]

\[ F_C = \frac{M_B}{d_2} \]
\[ = \frac{14,885}{2.5623} \]
\[ F_C = 5,810 \text{ lb} \]
**SLOTTED PLATE**

\[ I = \frac{th^3}{12} \quad Q = \frac{th^2}{8} \]

\[ = \frac{(0.25)(3.85)^3}{12} = \frac{(25)(3.85)^2}{8} \]

\[ I = 1.189 \text{ in}^4 \quad Q = 0.4632 \]

\[ \tau = \frac{VQ}{I \pi} \quad \sigma = \frac{Mc}{I} \]

\[ = \frac{(5810 \cdot 0.4632)}{(1.189 \cdot 0.25)} = \frac{(5810 \cdot 2.9 \cdot 2)}{1.189} \]

\[ \tau = 9,055 \text{ psi} \quad \sigma = 28,345 \text{ psi} \]
**LINKAGE PIN**

\[ A = \frac{\pi d^2}{4} \]
\[ = \frac{\pi (0.665)^2}{4} \]
\[ A = 0.3473 \text{ in}^2 \]

\[ \tau = \frac{F}{A} \]
\[ = \frac{5810}{0.3473} \]
\[ \tau = 16,729 \text{ psi} \]

**PISTON PIN**

\[ A = \frac{\pi d^2}{4} \]
\[ = \frac{\pi (0.8)^2}{4} \]
\[ A = 0.503 \text{ in}^2 \]

\[ \tau = \frac{F}{A} \]
\[ = \frac{5810}{0.503} \]
\[ \tau = 11,550 \text{ psi} \]
## Slider Linkage and Latch Arm Sawteeth

### 5810 lb Distributed on 3 Teeth

\[ F = \frac{5810}{3} = 1940 \text{ lb} \]

\[ x = 1.5'' \quad h = 0.25'' \]

\[ I = \frac{\pi h^3}{12} \quad Q = \frac{\pi h^2}{8} \]

\[ = \frac{1.5(0.25)^3}{12} = \frac{1.5(0.25)^2}{8} \]

\[ I = 0.00195 \text{ in}^4 \quad Q = 0.01172 \]

### Distributed Load

**Mechanics of Materials**

\[ M = \frac{1}{2} wL^2 \]

\[ M = 0.5(1940)(0.25)^2 \]

\[ = 61 \]

\[ \Gamma = \frac{Mc}{I} \]

\[ = \frac{(61)(0.125)}{0.00195} \]

\[ \Gamma = 3910 \text{ psi}. \]

### Point Load at Tip of Teeth

\[ \Gamma = \frac{Mc}{I} \]

\[ = \frac{(1940)(0.25)(0.125)}{0.00195} \]

\[ \Gamma = 31090 \text{ psi}. \]

**Shear**

\[ \tau = \frac{VQ}{I\pi} \]

\[ = \frac{1940 \cdot 0.01172}{0.00195 \cdot 1.5} \]

\[ \tau = 7775 \text{ psi}. \]
Appendix ‘I’
DETAIL 'A' GUIDE WELDMENT
ONE (1) REQ'D
DETAIL 'A' SAWTOOTH SLIDER
ONE (1) REQ'D
DETAIL "A" LATCH ARM
ONE (1) REQ'D
DETAIL 'A' LINKAGE PIN
ONE (1) REQ'D
DETAIL 'A' GUIDES
ONE (2) REQ'D

LOOKING DEVICE FOR HYDRAULIC FLOORSHAFT

SCH: 0 / DATE: 03/20/02
DETAIL 'A' PLATE
ONE (1) REQ'D
DETAIL 'A' HA
ONE (1) REQ'D
Appendix ‘J’
### BILL OF MATERIAL

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>QTY.</th>
<th>DESCRIPTION</th>
<th>DWG # / DETAIL</th>
<th>MATERIAL / SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>SLOTTED PLATE</td>
<td>SD WD01 / DETAIL 'A'</td>
<td>1018 CR 1/4&quot; X 3 1/4&quot; X 4 1/2&quot;</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>SAWTOOTH SLIDER</td>
<td>SD WD02 / DETAIL 'A'</td>
<td>1018 CR 1/2&quot; X 1 1/2&quot; X 15 1/2&quot;</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>LATCH ARM</td>
<td>SD WD03 / DETAIL 'A'</td>
<td>1018 CR 1 1/2&quot; X 3&quot; X 6&quot;</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>LINKAGE PIN</td>
<td>SD WD04 / DETAIL 'A'</td>
<td>1018 CR 1&quot; ROUND 2 1/2&quot; LG</td>
</tr>
<tr>
<td>E</td>
<td>2</td>
<td>GUIDES</td>
<td>SD WD05 / DETAIL 'A'</td>
<td>1018 CR 1&quot; X 4&quot; X 1/8&quot; PLATE</td>
</tr>
<tr>
<td>F</td>
<td>1</td>
<td>PLATE</td>
<td>SD WD06 / DETAIL 'A'</td>
<td>1018 CR 1/2&quot; X 1 1/2&quot; X 1 1/2&quot; PLATE</td>
</tr>
<tr>
<td>G</td>
<td>1</td>
<td>HA</td>
<td>SD WD07 / DETAIL 'A'</td>
<td>1018 CR 5/8&quot; ROUND 2&quot; LG</td>
</tr>
<tr>
<td>H</td>
<td>1</td>
<td>TUBE</td>
<td>SD WD08 / DETAIL 'B'</td>
<td>1018 CR 1/2&quot; TUBE 1/8&quot; WT 3 1/8&quot; LG</td>
</tr>
<tr>
<td>J</td>
<td>1</td>
<td>SLIDE</td>
<td>SD WD09 / DETAIL 'B'</td>
<td>1018 CR 1/8&quot; X 1&quot; X 1&quot; PLATE</td>
</tr>
</tbody>
</table>

### COMMERCIAL PARTS LIST

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>QTY.</th>
<th>DESCRIPTION</th>
<th>VENDOR / PART #</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1/2&quot; WING NUT</td>
<td>HOME DEPOT</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>COTTER PIN 1/8&quot; X 1 1/2&quot;</td>
<td>HOME DEPOT</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>3/8-16 SHCS 2&quot; LG</td>
<td>HOME DEPOT</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>1/2&quot; SNAP RING</td>
<td>HOME DEPOT</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>9/16&quot; SNAP RING</td>
<td>HOME DEPOT</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>1/4-20 ALLTHREAD 3 1/2&quot; LG</td>
<td>HOME DEPOT</td>
</tr>
</tbody>
</table>

### TOTALS

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>MATERIAL</th>
<th>SIZE</th>
<th>TOTAL LENGTH REQ'D</th>
<th>PURCHASED</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1018 CR</td>
<td>1/4&quot; X 3 1/4&quot; X 4 1/2&quot;</td>
<td>5&quot; LG</td>
<td>6&quot; LG</td>
</tr>
<tr>
<td>B</td>
<td>1018 CR</td>
<td>1/2&quot; X 1 1/2&quot; X 15 1/2&quot;</td>
<td>15 1/2&quot; LG</td>
<td>18&quot; LG</td>
</tr>
<tr>
<td>C</td>
<td>1018 CR</td>
<td>1 1/2&quot; X 3&quot; X 6&quot;</td>
<td>6&quot; LG</td>
<td>6&quot; LG</td>
</tr>
<tr>
<td>D</td>
<td>1018 CR</td>
<td>1&quot; ROUND 2 1/2&quot; LG</td>
<td>2 1/2&quot; LG</td>
<td>3&quot; LG</td>
</tr>
<tr>
<td>E</td>
<td>1018 CR</td>
<td>1&quot; X 4&quot; X 1/8&quot; PLATE</td>
<td>4&quot; LG</td>
<td>4&quot; LG</td>
</tr>
<tr>
<td>F</td>
<td>1018 CR</td>
<td>1/2&quot; X 1 1/2&quot; X 1 1/2&quot; PLATE</td>
<td>1 1/2&quot; LG</td>
<td>2&quot; LG</td>
</tr>
<tr>
<td>G</td>
<td>1018 CR</td>
<td>5/8&quot; ROUND 2&quot; LG</td>
<td>2&quot; LG</td>
<td>2&quot; LG</td>
</tr>
<tr>
<td>H</td>
<td>1018 CR</td>
<td>1/2&quot; TUBE 1/8&quot; WT 3 1/8&quot; LG</td>
<td>3 1/8&quot; LG</td>
<td>4&quot; LG</td>
</tr>
<tr>
<td>J</td>
<td>1018 CR</td>
<td>1/8&quot; X 1&quot; X 1&quot; PLATE</td>
<td>1&quot; LG</td>
<td>1&quot; LG</td>
</tr>
</tbody>
</table>
Appendix ‘K’
<table>
<thead>
<tr>
<th></th>
<th>November</th>
<th>December</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Research</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patent Research</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standards Research</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated Budget</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proposal Due</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proof of Design</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Concepts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finished Drawings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Freeze</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oral Presentation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Order Parts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part Fabrication</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assemble</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Report</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Report</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oral Report</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tech Expo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graduation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix ‘L’
## Budget

<table>
<thead>
<tr>
<th>Item</th>
<th>Source</th>
<th>Donated</th>
<th>Loaned</th>
<th>Cost to Purchase</th>
<th>Service In Kind</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor Jack</td>
<td>Walmart</td>
<td></td>
<td></td>
<td>$20.00</td>
<td></td>
</tr>
<tr>
<td>Vehicle</td>
<td>Mike Dellecave</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel</td>
<td>U.C.</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hardware</td>
<td>Home Depot</td>
<td></td>
<td></td>
<td>$5 - $20</td>
<td></td>
</tr>
<tr>
<td>Paper Editing</td>
<td>Maria Kreppel</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Copies</td>
<td>Kinkos</td>
<td></td>
<td></td>
<td>$50</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$75 - $90</strong></td>
<td></td>
</tr>
</tbody>
</table>
Appendix ‘M’
Mike Dellecave,

Here is the quote for 10,000 units on the part drawings you sent me.

Latch Arm

Pattern Price = $3,000
Part Price = $3.75

Slider Linkage

Pattern Price = $3,000
Part Price = $4.00

Height Adjuster

Pattern Price = $1,000
Part Price = $0.75

I hope this helps out. If you have any other questions, feel free to email me.

Gary McIntosh
Reliable Castings
mcintoshg@reliablecastings.com
Appendix ‘N’
Bibliography


