SAFETY BRIEF

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Triodyne Inc.

Consulting Scientists - Safety Philosophy & Technology

3054 North Lake Terrace
Glenview, IL 60026
(847)-677-4730
FAX: (847) 647-2047

Officers:
Ralph L. Barnett
Dolores Gildin

e-mail: infoserv@triodyne.com
website: triodyne.com

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Standard Chain Lever Load Binder

Ralph L. Barnett and Theodore Liber

ABSTRACT

The standard chain lever load binder that is used for truck cargo securement operates on an over-center principle that has been used for over a century on suitcases, tool boxes and camera cases. The safety hazards associated with the uses and misuses of the load binder were identified decades ago and various inventors patented innovations that eliminated or mitigated the safety shortcomings. Furthermore, their ideas were not only effective, they were economical, versatile, and efficient. These patents are now in the public domain and many companies manufacture and/or distribute entire lines of securement that include not only the standard chain lever load binder but most of the alternative designs as well. This case study takes the position that the standard chain lever load binder should be banished. Since the appropriate bodies, after all these years, have not arranged for its demise, this paper appeals to the product liability system for safety relief. Engineering analysis and tests are provided to the legal profession to help them protect us by making the cost advantage of the standard binder too expensive. This paper explores some of the remarkable properties of the standard load binder, e.g.,

- Load binders develop very large chain tensions and very high levels of recoverable energy. The standard chain lever load binder does not enable the tension and energy levels to be safely maintained or released.
- The handle slack on the standard load binder cannot be fine-tuned; consequently, a scenario is frequently encountered where the chain is either too loose or too tight to secure with the binder handle. This is the major motivation for resorting to a "cheater bar."
- A complete analysis of the securement forces acting on the cargo and load binder is seldom possible because the system is a "moving target." The handle loading is randomly applied by human exertion which changes with handle orientation. The boundary conditions depend not only on the cargo and securement strategy, but on the loading itself. Unknown friction characteristics of the loading affect the distribution of chain forces.
- On one side of the load binder the chain tension can always be predicted using only the handle torque. This cable tension is independent of the boundary conditions and any axial handle force components.
- When the load binder system is rigid, it gives rise to three singularities. The mechanical advantage is unbounded at the two extreme handle orientations. When the binder is suspended in a taut condition, any lateral force on the binder develops infinite cable forces.
- Handle slack has a profound effect on the handle resistance, the resilience, the chain tension, and the latching capability.

INTRODUCTION

When a winch is used to secure cargo to a flatbed truck the tension load in the strap is almost proportional to the length of the winch bar used to operate the winch and the force applied to it by the operator's weight or strength. This clamping force is an independent variable that is limited by anthropometric considerations. The strap tension is not effected by the stiffness of the lading; the large strap elongation is a dependent variable that allows the strap to follow the cargo as it bounces and shifts. In short, the truck driver imposes a load on the cargo which is maintained by the strap flexibility.

By contrast, the chain lever load binder shown in Fig. 1 does not impose a load on the chain; it introduces a fixed stretch. This fixed chain elongation is an independent variable; it draws the two ends of the chain together by a predetermined amount. The cargo doesn't like being constricted by the chain; it resists in the same way that your torso resists when you tighten your belt another notch. This resistance gives rise to chain tension which is a dependent variable. In the load binder case, chain tension depends directly

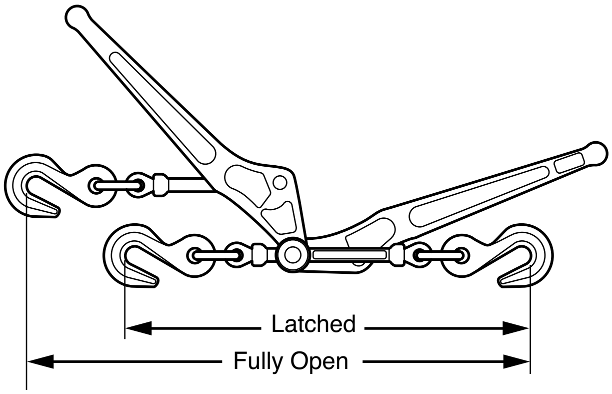

Figure 1. Standard Chain Lever Load Binder

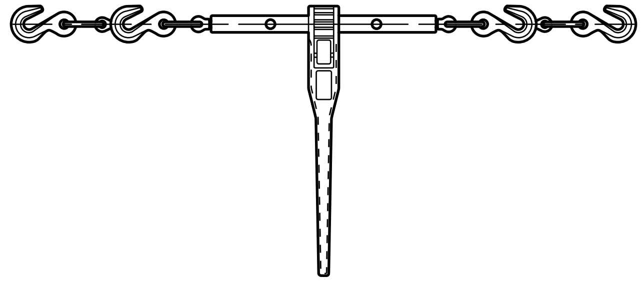

Figure 2. Ratchet Chain Binder

on the system stiffness, i.e., the flexibility of the chain, the load binder, and the cargo. When securing a large bundle of feathers with a chain, a five inch cinch produces negligible chain tension; the cargo has very low stiffness. On the other hand, with very stiff loads such as pipe, coiled steel, or large punch presses, a five inch cinch could overload the chain and give rise to an enormous handle force that defies latching the binder even with assistance of handle extension bars.

The standard chain lever load binder is fabricated with grab hooks on both ends. These hooks securely hold a single link of chain in their narrow opening. Typically, when pulling on a chain the grab hook is attached to a chain link and the load binder is latched over-center. If this procedure results in a chain that is "too loose," the grab hook is reattached to an adjacent link that places more tension on the chain when the binder is latched. Often with a stiff cargo, this second grip develops an extremely high handle resistance that precludes latching. Because of the coarseness of the chain (large inside link size), a condition is encountered where the chain is either "too loose or too tight." This condition motivates truck drivers to use an extension handle to close the load binder in the "too tight" domain.

One of the alternative designs to the standard load binder is called the ratchet type binder. As shown in Fig. 2 this device is merely a turnbuckle with a ratchet lever. Once again the binder imposes a contraction of a chain about the cargo. The distance between the hooks is an independent variable; the resistance to the contraction is the dependent variable. With the continuous adjustability of the screws, the condition "too loose/too tight" does not exist. Retightening a loose chain mid-trip is really simple; retightening of a standard load binder is not straight forward and may lead truck driver to imprudent behavior.

The Federal Motor Carrier Safety Administration (FMCSA), which is part of the Department of Transportation (DOT), developed their first safety regulations for cargo securement more than 70 years ago. Their new cargo securement rules were published on September 27, 2002 [1]. The Federal Register describes contributions from over two dozen organizations on securement issues.

It is especially vexing that neither the old nor the new rules "prohibit the use of tiedowns or cargo securement devices currently in use [2]." The rules are silent on the design and operation of securement hardware. A few of the rules provide guidance for hardware designers; to wit,

> **§393.102 What are the minimum performance criteria for cargo securement devices and systems?**
>
> (a) ***Performance criteria***. Cargo securement devices and systems must be capable of withstanding the following three forces, applied separately:
>
> 1 (i) 0.8 g deceleration in the forward direction;
>
> 2 (ii) 0.5 g acceleration in the rearward direction; and
>
> 3 (iii) 0.5 g acceleration in a lateral direction
>
> (b) ***Performance criteria for devices to prevent vertical movement of loads that are not contained within the structure of the vehicle.*** Securement systems must provide a downward force equivalent to at least 20 percent of the weight of the article of cargo if the article is not fully contained within the structure of the vehicle. If the article is fully contained within the structure of the vehicle, it may be secured in accordance with §393.108(b).

(c) ***Prohibition on exceeding working load limits.*** Cargo securement devices and systems must be designed, installed, and maintained to ensure that the maximum forces acting on the devices or systems do not exceed the working load limit for the devices under the conditions listed in paragraphs (a) and (b) of this section.

(d) ***Equivalent means of securement***. Cargo that is immobilized, or secured in accordance with the applicable requirements of §393.104 through 393.138, is considered as meeting the performance criteria of this section.

§393.104 What standards must cargo securement devices and systems meet in order to satisfy the requirements of this subpart?

(f) ***Use of tiedowns.***

(3) Each tiedown must be attached and secured in a manner that prevents it from becoming loose, unfastening, opening or releasing while the vehicle is in transit.

FORCE ANALYSIS

A. Chain Lever Load Binder

An idealized version of the operation of a chain lever load binder is depicted in Fig. 3 where an equivalent virtual handle is introduced to replace the actual load binder handle. This substitution enables us to extend our analysis to include an entire family of latches found on suitcases, tackle boxes, camera cases, and tool boxes. The handle force P has an upward component at the beginning of the binding cycle ($\alpha < 90°$); this is also true during the unlatching phase ($180° < \alpha \le \alpha_f$) shown in Fig. 3c. At all other handle orientations P has a downward component. During the entire tightening phase the handle is being pushed to the right.

The load binder provides the greatest chain shortening and chain tension when $\alpha = 180°$ as illustrated in Fig. 3b; this is called the center position. The over-center position is shown in Fig. 3c; the handle is designed to limit the maximum over-center orientation α_f (typically, $\alpha_f = 187°$). It can be seen in Fig. 3c that the chain

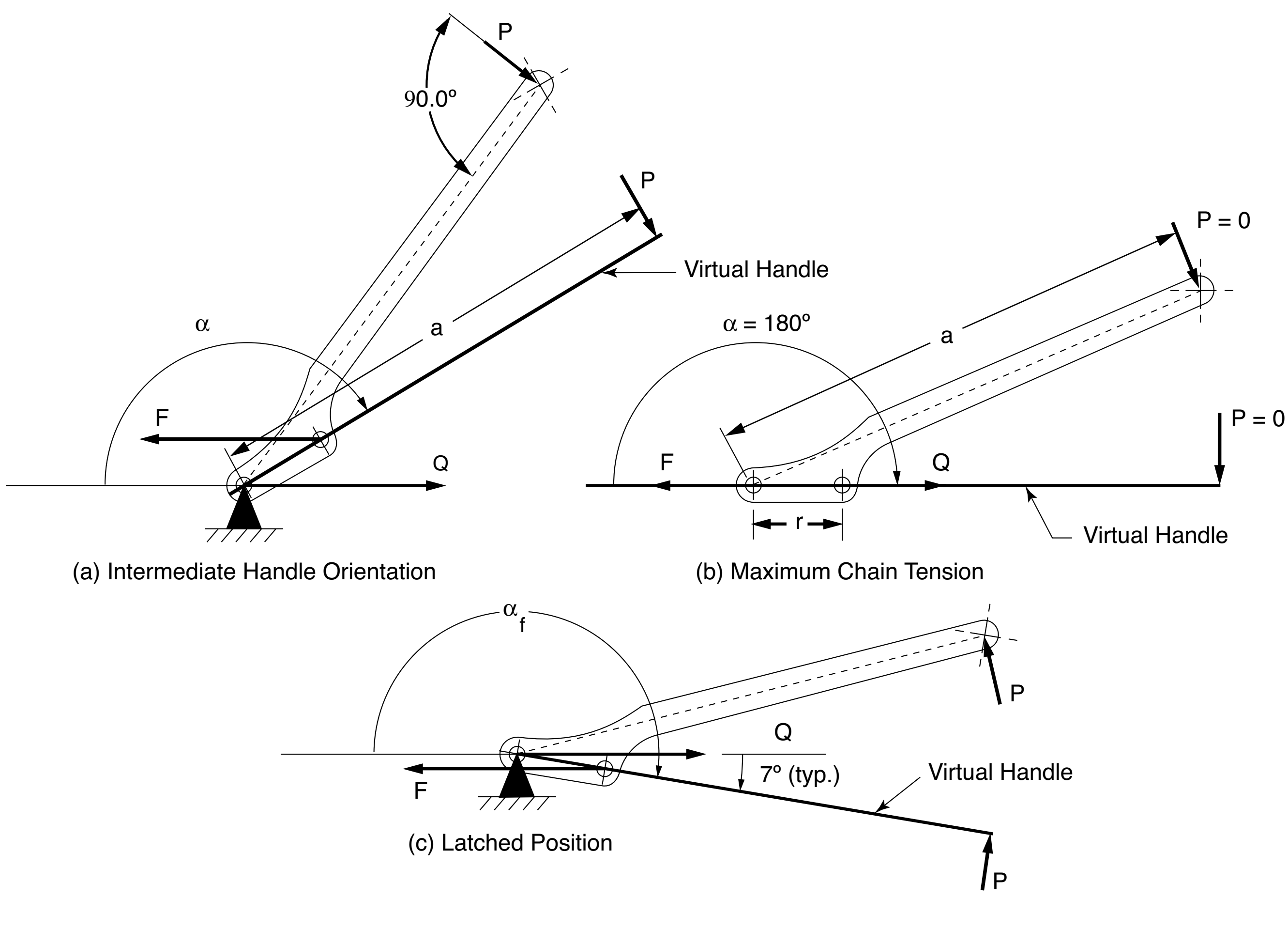

Figure 3. Diagrams Of Binder Handle at Various Orientations

tension F applies a moment (couple) to the handle to force it into the latching region. When the load binder is in the open position shown in Fig. 1, a slack chain (F = 0) is inserted into the hooks. When the handle is rotated clockwise in the tightening phase there is an orientation where the chain just becomes taut, this is defined as the slack angle α_o.

B. Mathematical Models

Figure 3b is a free body diagram of the load binder at $\alpha = 180°$ where the chains achieve maximum stretch and maximum tension. The binder is supported only at the hooked ends. The chains are collinear, horizontal, and equally loaded. In this orientation the binder is a two-force member [3]. The state of the load binder at its centered position is unique. At every other loaded handle orientation multiple conditions may be encountered that must be characterized by different mathematical models. The status of the binder system may be influenced by the geometry and structural behavior of the cargo; the handle force magnitude, location, and direction; the securement strategy; the slopes of the chains; and the boundary conditions.

A typical free body diagram of a chain lever load binder is shown in Fig. 4 where various possible boundary conditions are indicated for the lower binder pin. If the left and right chains are horizontal (β...small) all of the important characteristics of the binder may be derived from this model in a very simple form. The model indicates that the handle force P exerts an upward force component (P cos α) on the binder for $\alpha < 90°$ and a downward force component when $90° < \alpha < 180°$. The cable tensions F and Q will resist any vertical displacement of the binder by pulling in the opposite direction [4]. Downward acting forces may also be resisted by pushing the binder against the cargo. The horizontal handle force component (P sin α) exerts a force on the binder that may be resisted by cargo/chain friction; frequently the left and right chains are attached at one end to the truck bed.

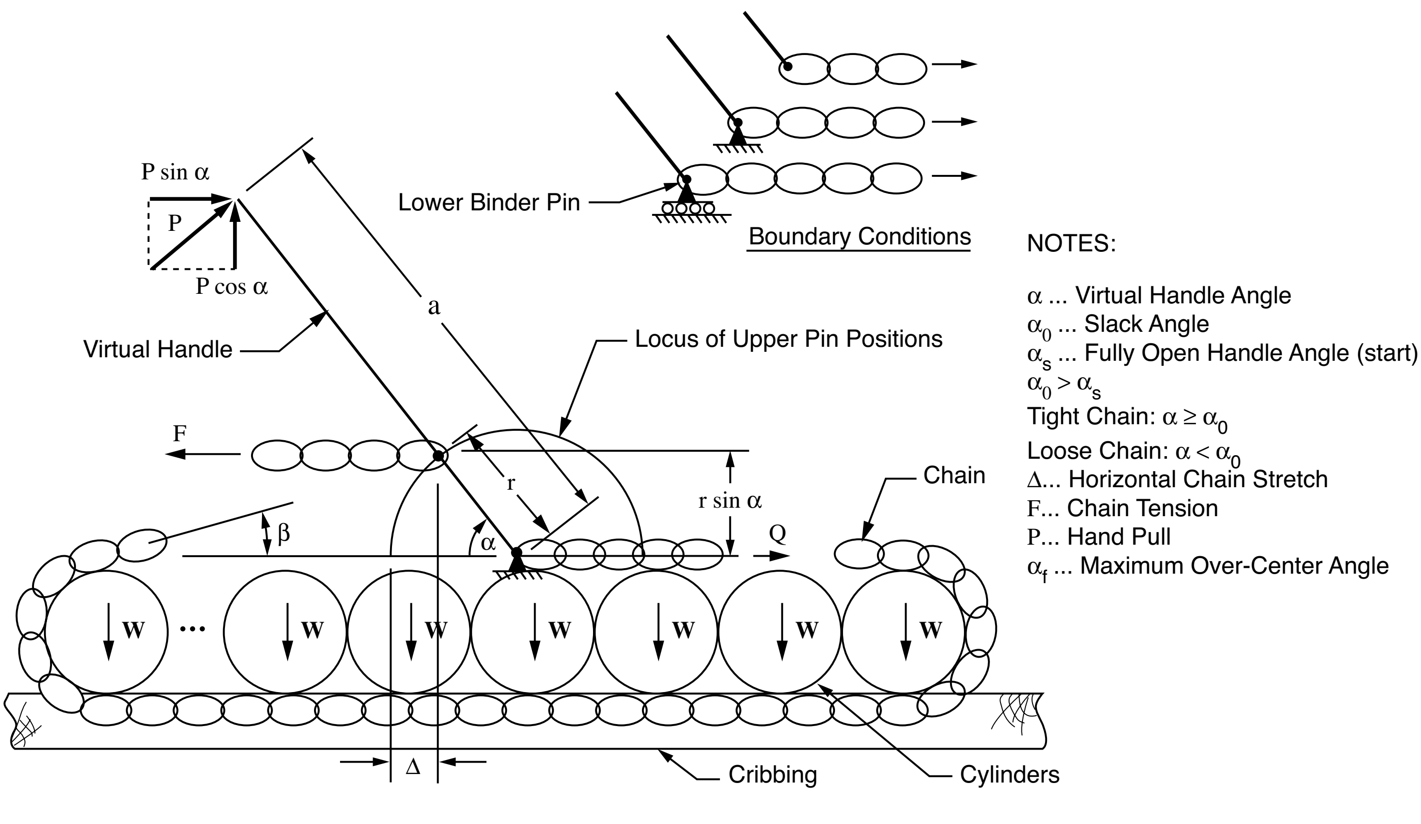

Figure 4. Free Body Diagram - Load Binder

The chain tensions F and Q are equal, as previously noted, when $\alpha = 180°$. They are also equal when the binder handle is twisted by a couple, say Pa, as opposed to the handle force P; there are no net forces in any direction. Normally, when the binder is being closed by the handle force P, horizontal equilibrium requires that $F - Q = P \sin \alpha$. Thus, the difference between the multi-thousand pound chain forces is never greater than the strength or weight of an operator.

C. Chain Force, F

The load binder system consisting of the binder, chain, and cargo is assumed to form an elastic system with a stiffness k; i.e., when the chain is stretched one inch, the chain tension is F = (1)k. If the chain stretch is Δ then the slope of the F vs. Δ diagram is k. With reference to Fig. 4, the chain just becomes taut at $\alpha = \alpha_o$. At this orientation of the virtual handle, the two hooks have contracted Δ_o. Continued rotation of the handle will stretch the chain $(\Delta - \Delta_o)$. Geometry provides,

$$\Delta = r\,(1 - \cos \alpha) \qquad \text{Eq. 1}$$

$$\Delta_o = r\,(1 - \cos \alpha_o) \qquad \text{Eq. 2}$$

The chain tension F is given by $k\,(\Delta - \Delta_o)$; thus,

$$F = rk\,(\cos \alpha_o - \cos \alpha) \qquad \text{Eq. 3}$$

The maximum contraction of the hooks occurs at $\alpha = 180°$ and the associated chain tension F_{max} becomes,

$$F_{max} = rk\,(\cos \alpha_o + 1) \qquad \text{Eq. 4}$$

When the fully open virtual handle is restricted to $\alpha \geq \alpha_s$, the largest F_{max} is kr $(\cos \alpha_s + 1)$. (For typical chain lever load binders, $\alpha_s = 80°$). Many suitcase type over-center latches are designed with unrestricted handles where $\alpha_s = 0$; here, $F_{max} = 2rk$ which is the theoretical limit for an over-center device. To achieve large binding loads Eq. 4 indicates that one should strive for high stiffness cargo and small slack angles.

When the load binder is centered, $\alpha = 180°$, the left and right chains are colinear. Rotation of the handle beyond $\alpha = 180°$ is called over-center and in this region the upper binder pin moves to the left and begins to unload the chain. Binders are designed to limit the over-center angle to $\alpha = \alpha_f$. (Typically α_f is about 187°) The chain tension at $\alpha = \alpha_f$, F_f, is given by Eq. 3, thus,

$$F_f = rk\,(\cos \alpha_o - \cos \alpha_f) \qquad \text{Eq. 5}$$

Consequently, the maximum chain tension F_{max} drops down to F_f when the handle moves completely over-center. The percentage drop-off in the chain tension is,

$$\%\ \text{Drop-Off Force} = \frac{F_{max} - F_f}{F_{max}} \times 100$$

$$= \frac{\cos \alpha_f + 1}{\cos \alpha_o + 1} \times 100 \qquad \text{Eq. 6}$$

For a vertical slack angle $\alpha_o = 90°$ and a latch angle $\alpha_f = 187°$, the % Droff-Off in the maximum chain tension is only 0.75%. For a working load limit, WLL = 5400 lb., the drop-off is 40.5 lb.

Equation 3 is presented in non-dimensional form, F/(rk), in Fig. 5 for various slack angles. These curves reflect all of the information provided in Eqs. 3, 4 and 5.

D. Hand or Handle Force, P

The relationship between the handle force P and the chain tension F is established by equilibrating the moments about the lower binder pin,

$$P\,a = F\,r \sin \alpha$$

$$P = \frac{F}{a/r} \sin\alpha \qquad \text{Eq. 7}$$

Observe that Eq. 7 is independent of the boundary conditions. Further, if the lever moment Pa is applied as a couple Eq. 7 remains unchanged; only Q is different. Finally, axial forces applied to the handle do not produce moments about the lower handle pin; Eq. 7 remains valid.

Using Eq. 3, the handle force becomes,

$$\begin{aligned} P &= \frac{r^2 k}{a} \sin\alpha(\cos\alpha_0 - \cos\alpha) \quad && \alpha \geq \alpha_0 \\ &= 0 && \alpha \leq \alpha_0 \end{aligned} \qquad \text{Eq. 8}$$

Note that,

P = 0 when $\alpha = 0$ ... theoretical binder, fully open
P = 0 when $\alpha < \alpha_o$ ... slack chain
P = 0 when $\alpha = \alpha_o$ ... begin binding
P = 0 when $\alpha = 180°$ ... fully stretched chain

Equation 8 is plotted in non-dimensional form, $P/(r^2k/a)$, in Fig. 6 for various slack angles. Observe that the handle force reaches a peak before the handle completely closes. This maximum handle force P* occurs at an angle α^* where the slopes of the curves are zero. Thus,

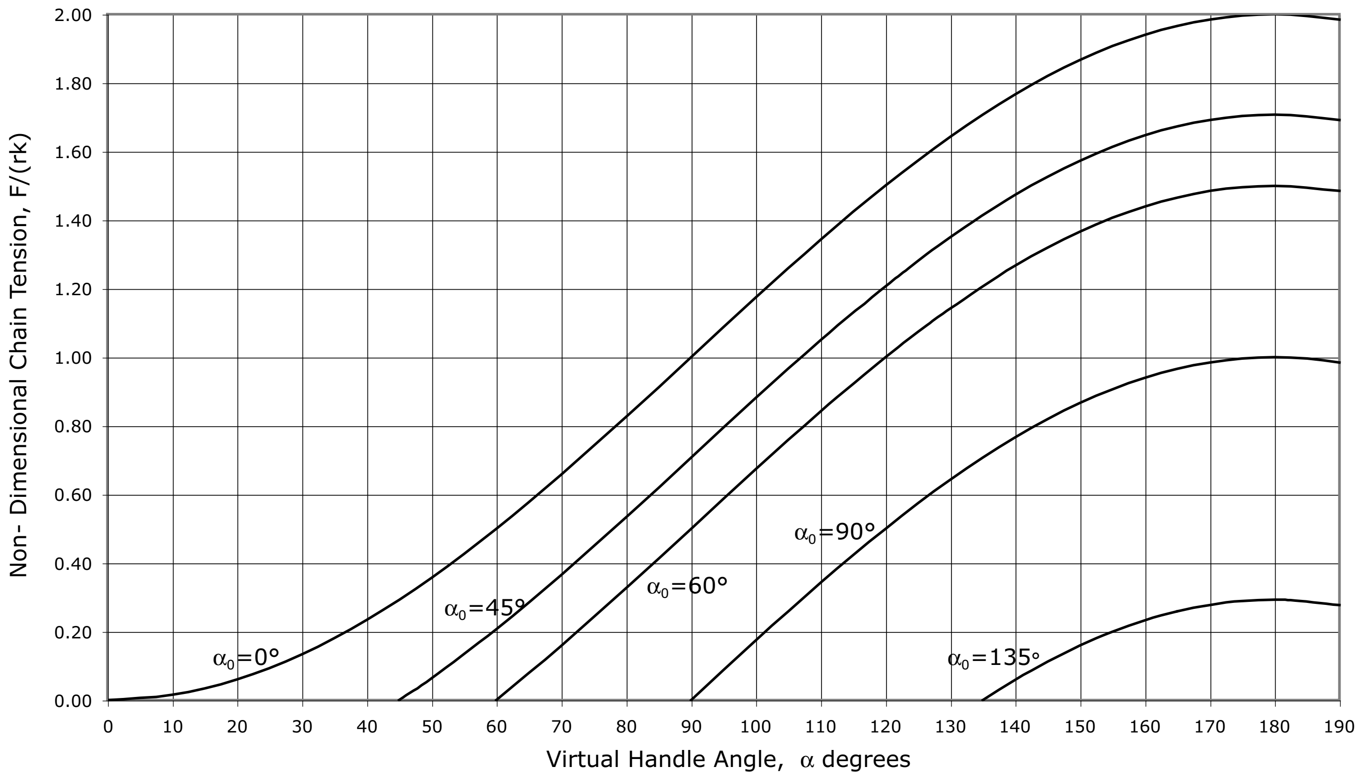

Figure 5. Chain Force vs Virtual Handle Angle for Various Slack Angles

$$\left.\frac{dP}{d\alpha}\right|\alpha=\alpha^*=\frac{r^2k}{\alpha}\left[\cos\alpha^*(\cos\alpha_0-\cos\alpha^*)+\sin^2\alpha^*\right]=0$$

$$\alpha^*=\cos^{-1}\left[\frac{\cos\alpha_0-\sqrt{\cos^2\alpha_0+8}}{4}\right] \qquad \text{Eq. 9}$$

$$P^*\equiv P_{\max}(\alpha_0)=P(\alpha^*) \qquad \text{Eq. 10}$$

The coordinates of the peak handle forces (α^*, P^*) are indicated in Fig. 6. Equation 9 indicates that the peak handle force always occurs at virtual handle angles between $\alpha = 120°$ and $\alpha = 180°$, i.e., on the backside of the stroke where the operator can press down on the handle with his weight.

E. Mechanical Advantage: MA

The binder magnifies a trucker's hand strength to provide very large chain tension. This so called mechanical advantage MA is the ratio F/P which is different for every handle orientation α. Using Eq. 7, we obtain

$$MA=\frac{(a/r)}{\sin\alpha} \qquad \text{Eq. 11}$$

When the virtual handle is "straight up", $\alpha = 90°$, the handle is a simple lever with a mechanical advantage MA = (a/r). Typically, for small load binders with a working load limit WLL = 5400 lb. a = 15.1 in. and r = 2.75 in.; MA = 5.49. Notice that regardless of the classic lever mechanical advantage (a/r), the MA becomes unbounded as the handle approaches either zero or 180°. The non-dimensional mechanical advantage curve, MA/(a/r), is the cosecant curve shown in Fig. 7 where the smallest MA/(a/r), occurs at $\alpha = 90°$. This curve illustrates that at the beginning of the loading cycle where the chain forces are small, the MA in the neighborhood $50° \le \alpha \le 65°$ is not much greater than (a/r).

It is very common for truck drivers to extend the handle length (a) by using a cheater bar (three foot pipe) or a combination bar extension. Typically, the effective handle length is increased from a = 15.1 to a = 50.6 then MA = (a/r) increases from 5.49 to 50.6/2.75 = 18.4.

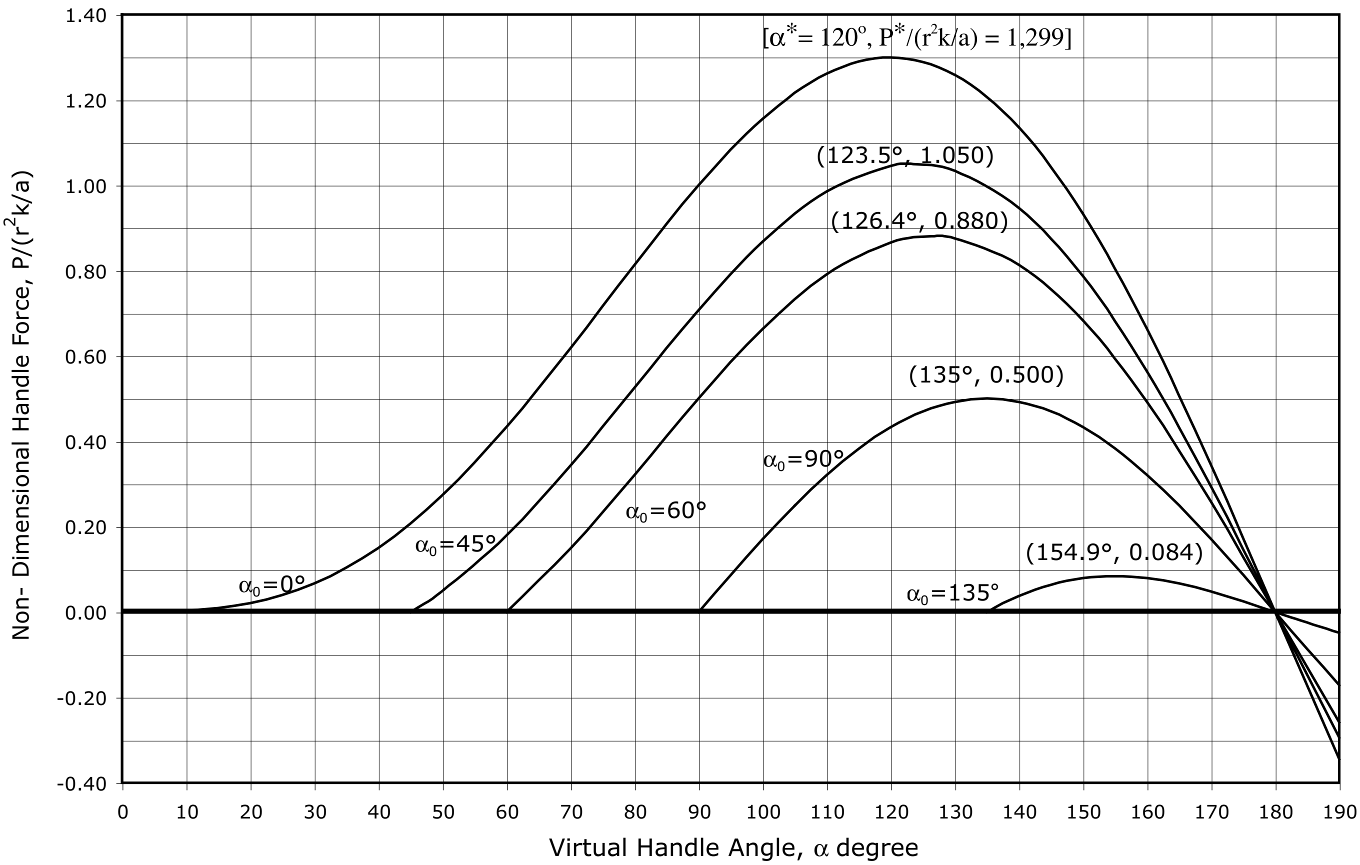

Figure 6. Handle Force vs Virtual Handle Angle for Various Slack Angles

F. Latching Integrity

The latched position of the virtual handle is depicted in Fig. 3c; $\alpha = \alpha_f$ (A typical maximum over-center angle is $\alpha_f = 187°$). In this orientation the chain tension F_f is given by Eq. 3,

$$F_f = rk\,(\cos\alpha_0 - \cos\alpha_f) \qquad \text{Eq. 12}$$

This force acts through a moment arm $r \sin \alpha_f$ to produce a clockwise latching moment

$$\begin{aligned} M_f &= F_f r \sin\alpha_f \\ &= r^2 k \sin\alpha_f (\cos\alpha_0 - \cos\alpha_f) \end{aligned} \qquad \text{Eq. 13}$$

The latching moment M_f can be overcome by an unlatching force P_f acting on the binder handle to produce a counterclockwise moment, thus, $aP_f = M_f$. The unlatching force becomes,

$$P_f = \frac{r^2 k}{a} \sin\alpha_f (\cos\alpha_0 - \cos\alpha_f) \qquad \text{Eq. 14}$$

Example 1. Latch Integrity

The stiffness k was measured on a cargo consisting of a linear array of well casing pipe cut down to three foot lengths. The pipes were six inches in outside diameter with a 0.25 inch wall thickness. The assembly was circumnavigated by a 3/8 inch Grade 70 chain that was linked to a load binder and a load-cell. A one inch chain stretch gave rise to a load-cell reading of 2,028 lb/in. Assume

k = 2,028 lb/in ... cargo stiffness
a = 15.1 in ... handle length
$\alpha_f = 187°$ ... latching angle
r = 2.75 in ... pin spacing

Then,

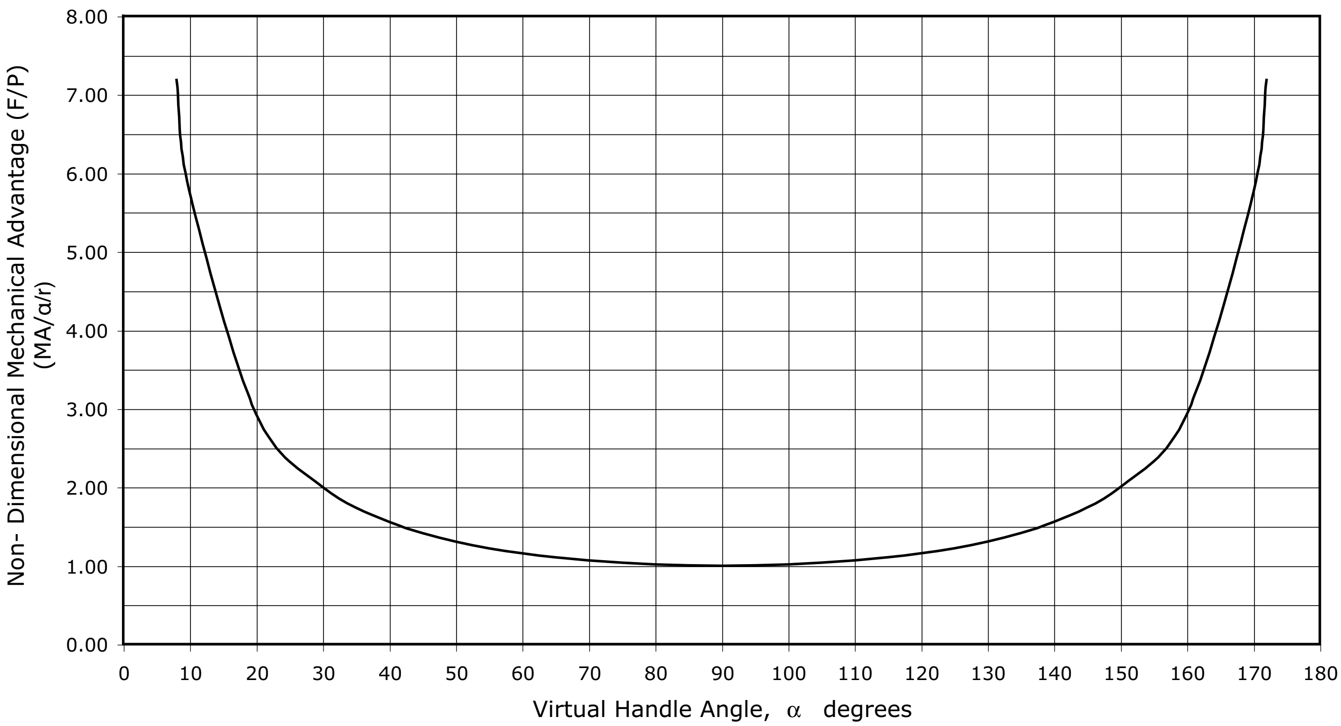

Figure 7. Mechanical Advantage

$$P_f = \frac{(2.75)^2\,(2{,}028)}{15.1}\sin 187(\cos\alpha_0 - \cos 187)$$
$$= -122.86 - 123.78\cos\alpha_0$$

At $\alpha_o = 0$, P_f = -246.6 lb. (negative sign implies
At $\alpha_o = 90°$, P_f = -122.9 lb. counterclockwise
At $\alpha_o = 160°$, P_f = -6.5 lb. acting force)

This example demonstrates that the latching resistance may range from very high handle loads that must be pried open to very small loads that cannot resist ordinary trailer vibrations. It should be pointed out that stiff lading (high k) can be randomly unclamped by small shifts in position.

Loss of latching integrity was recognized as a safety problem for decades. In 1976, Patent 3,954,252 [5] introduced a padlock into the handle of a load binder to lock it in the over-center position. Some manufacturers placed a hole at the end of the binder handle to aid in tying it down. Trucking companies have adopted protocols for securing handles with bungee cords. A number of load binders are designed to accommodate an external lock pin for securing the handles. The standard chain lever load binder has not incorporated a single idea into its design; some include a warning, "Secure handle to chain".

G. Spring Back

When a load binder tightens a chain around a truck's lading, strain energy U is stored as its handle is rotated between $\alpha = \alpha_o$ and $\alpha = 180°$. This energy, called resilience, is available to cause a handle to spring backward; to urge a combination bar to recoil; to whip a broken chain; to throw a cheater bar, or to launch a load binder. As the handle torque (Pa) rotates through the angle $(\alpha - \alpha_0)$ it does work. The area under a (Pa) vs.α diagram is a measure of this work or energy. From Eq. 8

$$Pa = r^2 k \sin\alpha\,(\cos\alpha_0 - \cos\alpha)$$

By definition,

$$U = \int_{\alpha_0}^{\alpha=\pi} (P\alpha)\,d\alpha$$

$$U/(r^2 k) = \int_{\alpha_0}^{\pi} \sin\alpha(\cos\alpha_0 - \cos\alpha)\,d\alpha \qquad \text{Eq. 15}$$

$$U/(r^2 k) = \cos\alpha_0\,(1+\cos\alpha_0) + \frac{1}{4}\,(1-\cos 2\alpha_0) \qquad \text{Eq. 16}$$

This non-dimensional equation is plotted in Fig. 8 where we observe that the available rebound energy gets smaller as the slack angle α_0 gets larger.

Example 2: Rebound Energy

Assume that k = 2,028 lb/in for a horizontal array of fourteen well casing pipes. When r = 2.75 in., r^2k = 15,337 in-lb and U = 2,556 ft-lb. Release of the stored energy can throw a 6-1/2 lb. combination bar extension handle forty stories into the air.

FAILURE MODES AND EFFECTS ANALYSIS

A. Hand Strength-Chain Tension Relationship

For a given hand strength, how much tension does the load binder impose on the chain? During a binding cycle the maximum hand resistance encountered is given by Eq. 10; it has various names, $P^* = P_{max} = P(\alpha^*)$. Figure 9 presents the non-dimensional curve, $P_{max}/(r^2k/a)$, which is a function of the slack angle. To develop this curve values of α_o are inserted into Eq. 9 and the resulting α^*'s are in turn substituted into Eq. 8. Every cargo/chain accommodation provides a slack angle α_o. The maximum chain tension F_{max}, given by Eq. 4, is likewise a function of α_o. Its non-dimensional representation, $[F_{max}/(rk)]$, is also presented in Fig. 9 where we observe that for every value of α_o there is a required hand strength P^* and an associated maximum chain tension F_{max}.

Example 3

Assume a system with the parameters a = 15.1 in., r = 2.75 in., and k = 2,028 lb/in. Equation 10 can be plotted against the slack angle α_o as depicted in Fig. 10. For each slack angle the maximum chain tension F_{max} is marked on the P_{max} vs. α_o curve. Observe that large slack angles favor low hand resistance and small slack angles favor high chain tension.

Based on the foregoing technology the following observations are pertinent:

1. Static handle forces of 50 to 100 lb. provide chain tensions of about 1300 to 2000 lb. This is approximately 1/3 of the working load limit, 5400 lb.

2. To achieve the working load limit, a static handle force of about 500 lb. is required.

3. The Ancra winch bar and similar box end handle extensions extend the lever arm from 15.1 in. to 50.6 in. This provides a proportional increase in the mechanical advantage; the applied handle torque goes from P(15.1) to P(50.6). When entering Fig. 10 using a winch bar, the handle load P should be increased to 3.35P. The hundred pound pull that gave a

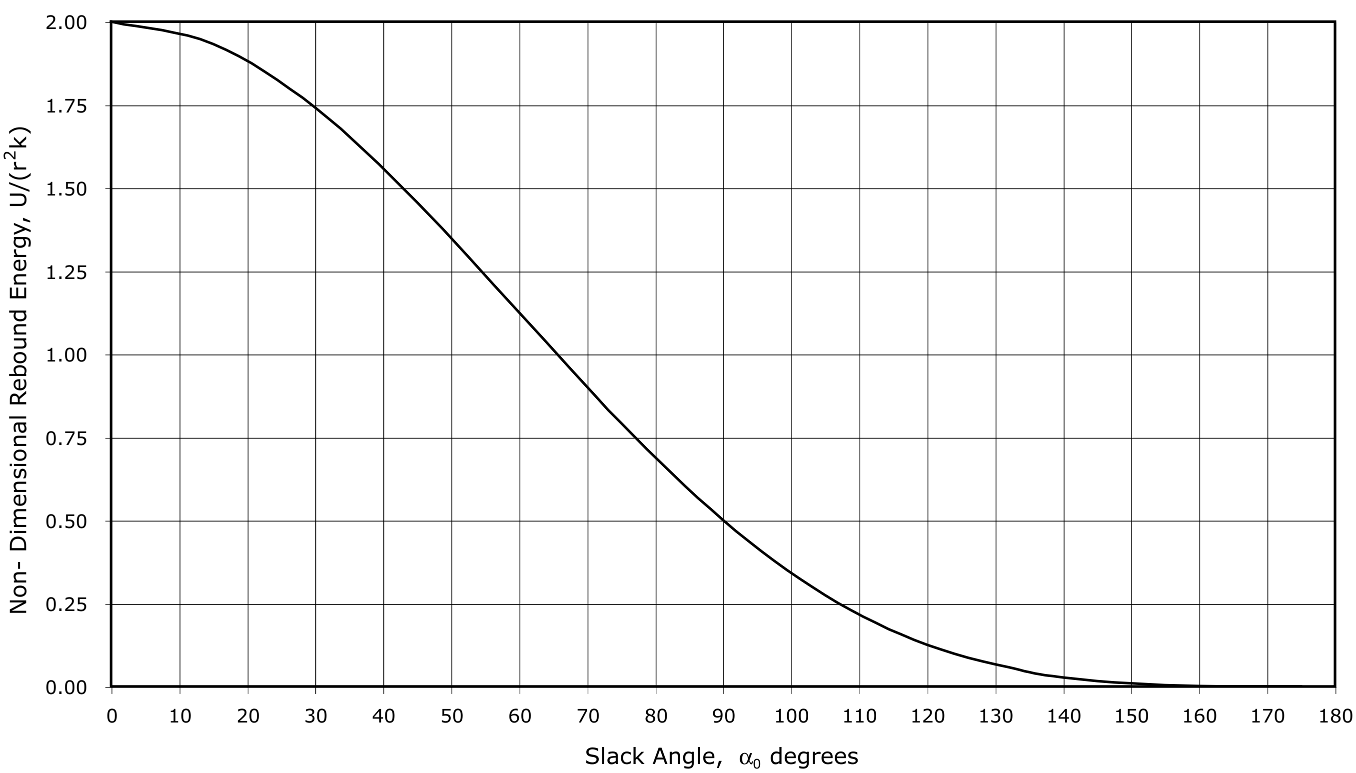

Figure 8. Stored Strain Energy As a Function of the Slack Angle

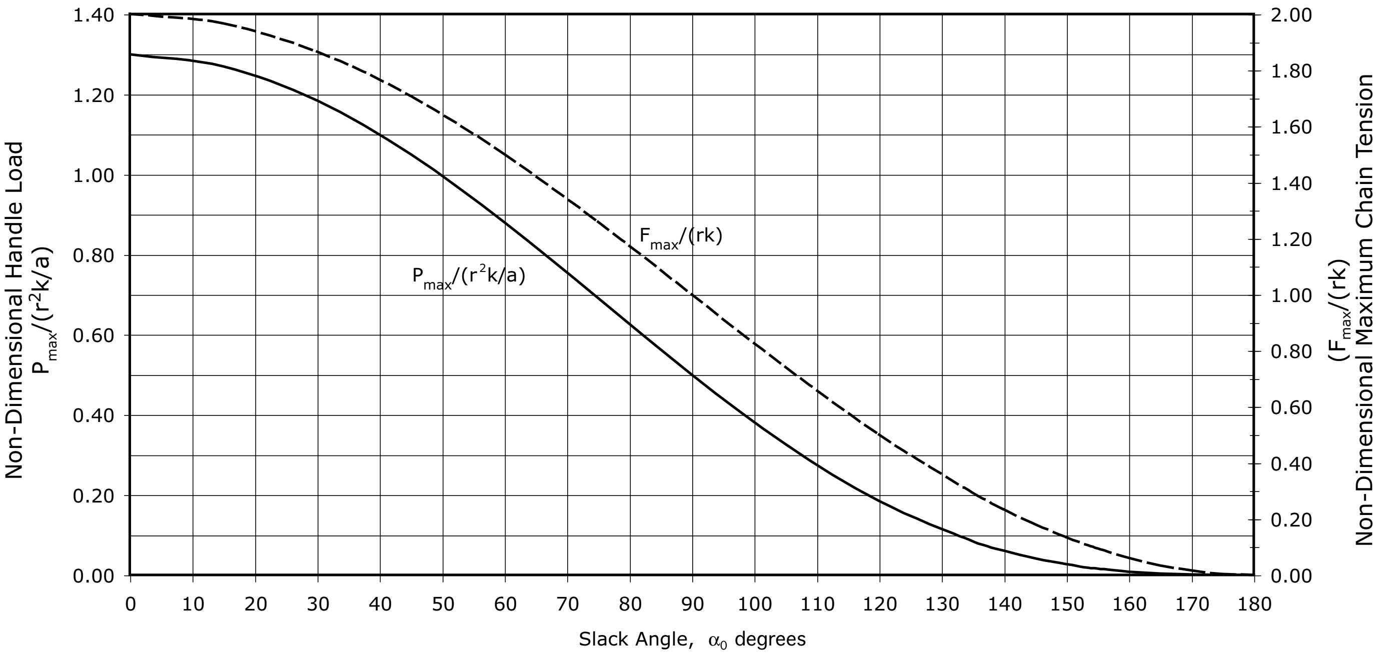

Figure 9. Non-Dimensional Handle Loading and Chain Tensions As a Function of the Slack Angle

chain tension of about 2000 lb. now becomes an effective 335 pound handle pull which produces a chain tension of over 4100 lb. This is about 76% of the WLL.

4. If an operator hangs his weight on the end of a winch bar, a seven fold increase in the effective handle pull is achieved. An effective pull of 700 lb. in Fig. 10 corresponds to a Chain tension of over 7000 lb. This is greater than the working load limit but less than the proof test load of 10,800 lb.

5. Large slack angles provide free-play in the load binder handle which enables a truck driver to close the handle dynamically. Hammering through the peak hand resistant mountain tops shown in Fig. 6 allows an operator to effectively increase his hand strength; doubling his strength is easy. When a winch bar is used together with the operator's weight bouncing on the end of the bar, an effective handle load of 1400 lb. can be achieved; this produces chain loads over 10,000 lb. which challenges the proof load which is 10,800 lb.

6. With stiff lading such as well-casings, hooking onto adjacent chain links can lead to condition where the chain tension is either "too loose or too tight." Too loose is unacceptable for truck securement; too tight is an invitation to use a cheater bar or a combination bar which will overload the chain and binder. This problem has been solved by load binders designed to permit fine adjustments, such as an "Adjustable Lever Binder." These units provide a continuous lengthening and shortening capability.

7. Hand tightening the subject load binder cannot result in over-tensioning the binder or chain.

8. The use of a cheater bar or combination bar may easily overstress the binder or chain.

B. Force Reversal

The unloading of a load binder is not the reverse of loading it. Figure 6 demonstrates that there is no force reversal in the loading cycle of the binder. After $\alpha = 183°$ the handle is pulled into the latch position ($\alpha = 187°$). When unloading, the binder handle is first pulled upward. This counter clockwise action continues until $\alpha = 177°$; our testing showed that friction restrained the binder handle for 3° on either side of the centered position ($\alpha = 180°$). After the handle moves into the range $\alpha < 177°$, the handle is pulled into the open position. To keep the handle under control so that it does not violently accelerate like a "bear trap", the operator must reverse his handle force. First time users cannot deal with this surprise reversal; its too fast for the normal control protocol - perception, processing, and execution.

There is another kind of reversal surprise that can affect even experienced operators. In a worst case scenario the load binder is tightened with the aid of a handle extension, the operator's weight, and dynamic handle action. Then, unloading is initiated by another party using only the regular binder handle which will immediately overcome anyone grasping the handle.

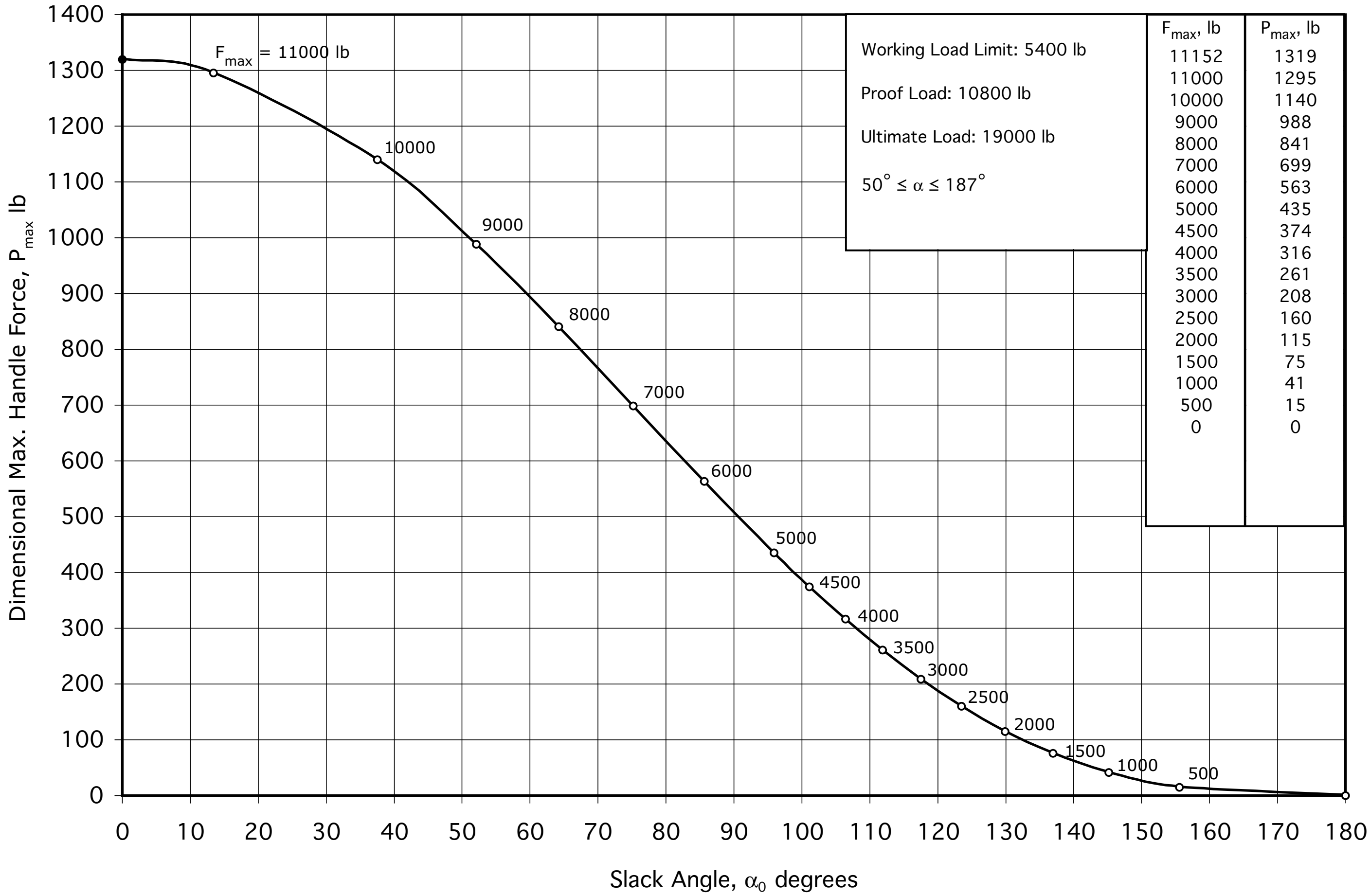

Figure 10. Dimensional Maximum Handle Force

C. Handle Design

1. Hand Grip: During loading or unloading, the load binder handle may swing through an arc of about 130°. For some operator positions it is impossible to maintain a power grip where the fingers tightly encircle the handle.

2. Cheater Bars: Every manufacturer and distributor of load binders admonishes users not to use cheater bars.

3. Out-of-Plane: The orthogonal nature of adjacent chain links occasionally cause load binders to lay in a horizontal plane on top of the cargo. Laboratory set-ups at the working load limit required as much as 80 ft-lb to rotate the binder into the vertical operating plane. Operators are often compelled to use combination bars when they cannot insinuate their fingers beneath a horizontally disposed handle.

4. T-Handle: All of the handle shortcomings are eliminated with the adoption of a T-Handle such as shown in Fig. 11. The hands rotate about the T-Handle without losing a power grip; a cheater pipe cannot slide over the wide handle profile; and the T-Handle precludes a horizontal disposition of the binder. In addition, the T-Handle offers the following features:

- Extends the effective handle length by 16.8%.
- Prevents hands slipping off the original handle in an axial direction.
- Precludes the use of currently available combination bars and handle extension bars.

The securement industry currently use T-Handles on some of their ratchet type binders.

D. Spring Back

The standard chain lever load binder can suddenly release large amounts of stored strain energy with concomitant whip-

Figure 11. T-Handle Load Binder

ping, missile, and impact hazards. These well known hazards can be mitigated or eliminated by the recoilless chain load binders sold by all major distributors of securement hardware. Patents on recoilless load binders have been forthcoming for forty years, e.g.,

- July 6, 1971: 3,591,141 [5]
- Jan 4, 1983: 4,366,607 [6]
- Dec. 18, 1990: 4,977,646 [7]

Instead of attacking the root cause of the spring back hazards, sudden energy release, various solutions have been promulgated to treat symptoms; e.g.

- Extension handles that remain linked to the load binder handle.
- Warning and instructions prohibiting the use of extension handles.
- Breakaway combination bars that decouple from the original handle during the release.
- Admonitions to stay away from the handle trajectory.

E. Handle Disengagement

Latching integrity is an extremely important safety topic because accidental opening of a load binder may drop a truck's lading onto a highway or onto unloading personnel. This safety problem has been known for decades. In 1976, Patent No. 3,954,252 [8] introduced a padlock into the handle of a load binder to lock it in the over-center position. Some manufacturers placed a hole at the end of the binder handle to aid in tying it down. Trucking companies have adopted protocols for securing handles with bungee cords. A number of load binders are designed to accommodate an external lock pin for securing the handles. The standard chain lever load binder has not incorporated a single idea into its design; some include a warning, "Secure handle to chain".

CLOSING REMARKS

1. Load binders develop very large chain tensions and very high levels of recoverable energy. The standard chain lever load binder does not allow the tension and energy levels to be safely maintained or released. Widely available alternative designs not only provide the requisite safety controls, they are economical, efficient and versatile.

2. Unlike alternate designs, the standard load binder cannot be adjusted to control the slack angle α_o; consequently, a scenario is frequently encountered where the chain tension is either too loose or too tight to secure with the binder handle. Operators typically resort to handle extensions which can overstress the chain.

3. The standard chain lever load binder is ubiquitous and unsafe; it should be retired.

4. A complete analysis of the securement forces acting on the cargo and load binder is seldom possible because the system is a "moving target". The handle loading is randomly applied by human excursion which changes with handle orientation. The boundary conditions depend not only on the cargo and securement strategy but on the loading itself. Unknown friction characteristics of the lading affect the dis-

tribution of chain forces.

5. In the neighborhood of the load binder, the left hand chain tension can be accurately predicted from the moment of the handle forces about the lower binder pin. This cable tension is independent of the boundary conditions and any axial handle force components.

6. When the load binder system is rigid ($k = \infty$), it gives rise to three singularities. The mechanical advantage is unbounded at $\alpha = 0$ when this is achievable and at $\alpha = 180°$. When the binder is suspended in a taut condition, any lateral forces on the binder leads to infinite forces in the cable.

7. It is not uncommon for a chain load binder to twist into a horizontal plane. This problem is not addressed in the trade literature.

8. The slack angle α_o has a profound effect on the hand force P, the resilience U, the chain tension F, and the latching resistance.

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