Ergonomics and Reach Truck Applications

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A wealth of ergonomic knowledge specific to the design of electric narrow aisle forklift trucks has been developed and accumulated by The Raymond Corporation. The author gratefully acknowledges the contributions of those listed above to this body of knowledge, from which much of the content of this article was derived. The author, however, assumes full responsibility for the analysis and interpretation of the data as presented herein.

The application of ergonomics to the lift truck environment presents unique opportunities to impact the design and configuration of the reach truck. Due to input from OSHA and other agencies, and the heightened awareness of workers in the form of safety committees, lift truck manufacturers are especially interested in ergonomic analysis. Certain approaches to lift truck design may seem reasonable on first blush, but in many cases they have been created without the benefit of quantified, specific ergonomic research and analysis. When subjected to research and analysis, these seemingly reasonable designs are found to be ergonomically inappropriate for certain uses.

Good ergonomic design may be applied to the specific design and location of hand and foot controls, operator space and comfort features, the method of controlling reach truck functions (sequential or simultaneous), the nature and order of information presented on truck control panel displays, and the stance of the operator within the truck. The scope of this article will be limited to examining the stance issue and, in particular, comparing the sidestance orientation to the fore/aft orientation for certain applications.

Good ergonomic design begins with an analysis of tasking; we must understand the job the operator/truck combination is expected to do, what performance is expected and at what level of comfort.

The Connection Between Ergonomics and Reach Truck Performance

Reach truck performance is generally measured in terms of cycles per hour, travel speed, lift height, turning radius, and so on. The ergonomic challenge, then, is to position the operator relative to the truck to safely take advantage of this performance, yet avoid the musculoskeletal extremes of posture that lead to soft tissue damage and repetitive motion disorders.

To analyze and then design this operator/truck system, we must ask these questions: What is this merged man-machine system required to do? What are its tasks? To get the answers we must conduct a task analysis that consists of an examination of how the truck is used in the warehouse, and then analyze how the operator relates to both the tasking and to the truck to accomplish this tasking (see Figure 1).

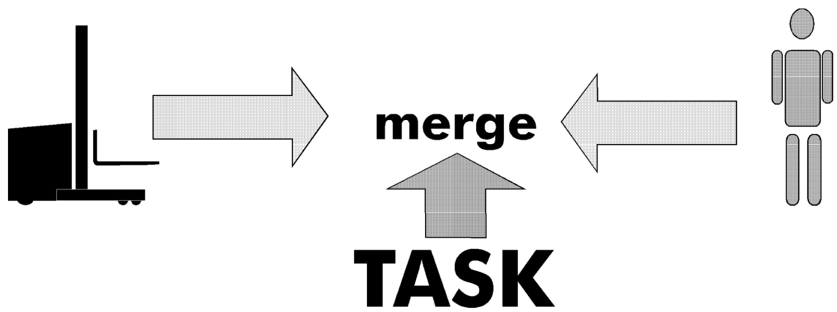

Figure 1. Task Analysis is the First Step in Ergonomic Design

Today's Tasking for a Reach Truck in the Warehouse, from an Ergonomics Viewpoint

Reach trucks perform many functions and services. However, for the purposes of ergonomic task analysis, we can say that the truck operates within two basic environments: 1. RACK WORK to include lifting, inserting, extracting, and lowering pallets, and 2. TRAVELING. Each of these two environments has its own unique ergonomic characteristics. The two key parameters that define these environments are: 1. Height – often up to 400 inches, and 2. Travel distance – which can average 300 feet (see Figure 2.) This paper examines the ergonomics of the reach truck in this typical environment.

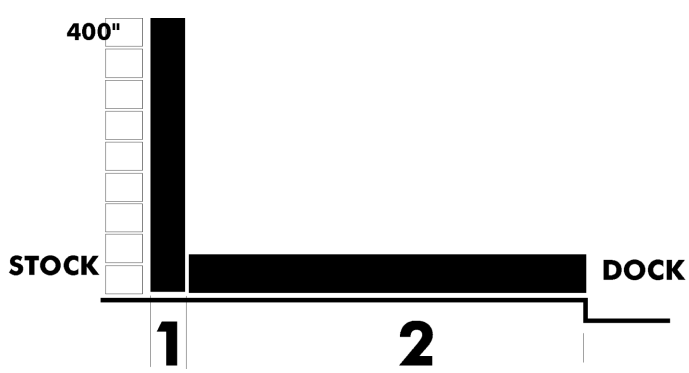

Figure 2. Reach Truck Environment: 1. RACK WORK, and 2. TRAVELING

Trends in Warehouse Design

The design of high productivity warehouses and the trend to high cubic efficiency has driven warehouse design to higher heights, narrower aisles, and to some extent larger square footage. Twenty years ago, the average lift height in narrow aisle warehouses was below 200 inches, maximum truck travel speeds were 5 miles per hour, and productivity averaged 12 to 14 cycles per hour. Today's warehouse is significantly different.

In response to these trends, we must assure and improve the ergonomic fit-to-the task of our reach trucks to include the following considerations.

1. What are the implications of looking up higher to maneuver pallets into racks? What will higher sightlines do to the neck? What is the best torso position to support the visual tasking of lift/lower and insert/extract?

2. In today's fast-moving, busy, traffic-filled warehouse, how can we optimize driving safety and ergonomics within long, complex travel routes?

3. In narrower aisles, what is the optimum ergonomic configuration for pallet handling?

Let's look at each of these questions, in the context of both the RACK and the TRAVELING environments.

Rack Environment and Pallet Handling

Right angle stacking of pallets in racks is the task for which the reach truck was specifically designed. In this environment, the fore/aft stance is superior to the sidestance.

The *first* significant ergonomic consideration here is the NECK.

The operator must look up at high angles to manipulate loads. The goal is to reduce deviations from ergonomic neutral to the extent possible, and to place the operator in such a posture as to reduce the impact on the musculoskeletal system to the extent feasible when looking up.

Both head and body should be facing the work such that the neck is in ergonomic neutral in the horizontal plane. This will eliminate the potential for a compound axis twist to the neck when looking up. If the operator were forced to stand side-facing the work, the neck is already rotated to the maximum. To then ask the operator to look up 300 to 400 inches to manipulate the load puts the neck at risk for soft tissue, tendon, and cervical spine damage.

Indeed, the biomechanics of the neck limit the tilt angle of the head when the neck is also rotated. Turned sideways to the load, the maximum look-up angle without strain is 60 degrees, which equates to about 200 inches in height. Standing facing the load, the maximum look-up angle without strain is 80 degrees, which equates to just over 400 inches in height (see Figure 3).

In a strict sideways stance, operators will tend to over-tilt the neck. This problem is compounded by the design of some sidestance units that place the head behind the mast, forcing the operator to lean forward, or, more seriously, lean backward out of the protective compartment of the truck to see loads high up.

High angle load sighting activity is characterized by quick cycles of looking up to the forks and down to see the position of the baselegs relative to the rack as the driver moves into the pallet. With three or four of these movements per load putaway, within the larger full shift of perhaps 200 to 300 pallet move cycles, the at-risk situation could occur 1200 times per shift.

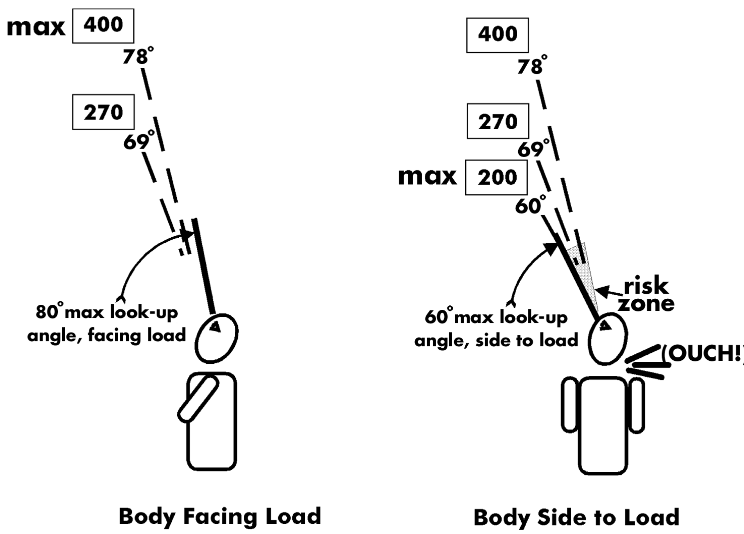

Figure 3. Standing facing load, maximum no-strain look up angle is 80 degrees, or over 400 inches. Standing body side-to-load, maximum no-strain look up angle is 60 degrees, or 200 inches.

The *second* significant ergonomic consideration is the TORSO.

With narrow aisles, half of the “backing up” in a pallet putaway is accomplished by the retract feature of the forks. Subsequent initial tractor movement, because of the location of the steer tire under the driver, is for the most part MORE than 45 degrees away from the direct aft position (see Figure 4). The operator needs to pay particular attention to objects up and down the aisle, rather than to the direct rear. The operator has a good sense of where the rack is to the rear without actually focusing on it. The rack is a fixed, known obstacle, whereas in-aisle objects, such as pedestrians or other trucks, are transitory/temporary.

The forward facing posture allows visual clearing of potential unknown objects both up and down the aisle with no more than a look 90 degrees left and right from ergonomic neutral; the operator may comfortably look in either direction. Although sidestance allows one-way visual clearing down the aisle with no twist, the operator must fully rotate head/torso 180 degrees to look in the other direction. Assuming that the operator needs to depart the rack in this direction at least half of the time, full torso twisting for aisle clearing behind the operator would occur 100 to 150 times during a typical shift of 200 to 300 pallet move cycles.

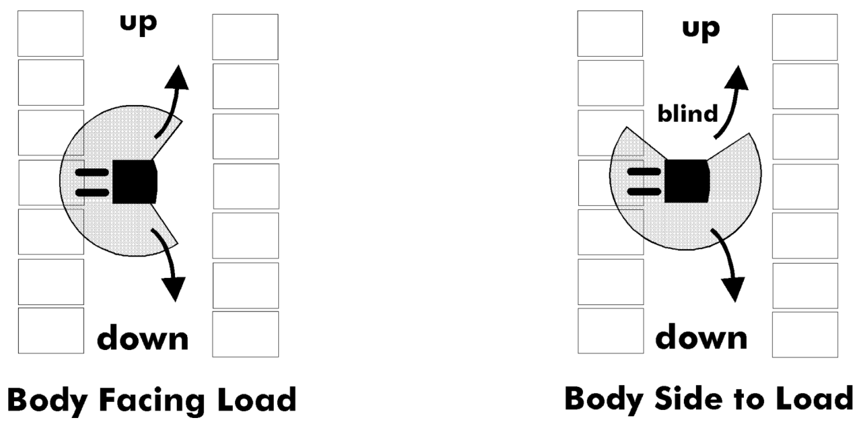

Figure 4. Post-retraction Tractor Movement and Visual Clearing Requirement

Travel Environment

Within this task environment, two distinctly unique circumstances prevail: 1. Long distance fast travel through a high risk, variable threat environment, and 2. Short distance slow travel within a low risk, known, stable environment.

Let us first look at LONG DISTANCE TRAVEL

Today's large, high-cube warehouse may be characterized by the term TRAFFIC GRID with many storage aisles, crossing aisles, and walls and doorways; in other words, a lot of intersections. Add to this the high amount of fast moving lift truck, walkie, and pedestrian traffic on this grid, and the potential for mishap is significant. The operator's task, then, is to visually clear not only the direction of travel but also the entire front hemisphere of travel, left and right of center.

Let us clarify some terms here. All relevant safety documents, including ASME, OSHA, and government agency specifications require operators to "keep a clear view." Does this mean that putting your face only in the direction of travel will suffice? For long distance travel we must interpret this as meaning FACE AND TORSO, such that the full hemisphere is visible in the direction of travel (see Figure 5). With side-to-travel, full visibility to one side of the direction of travel is biomechanically limited.

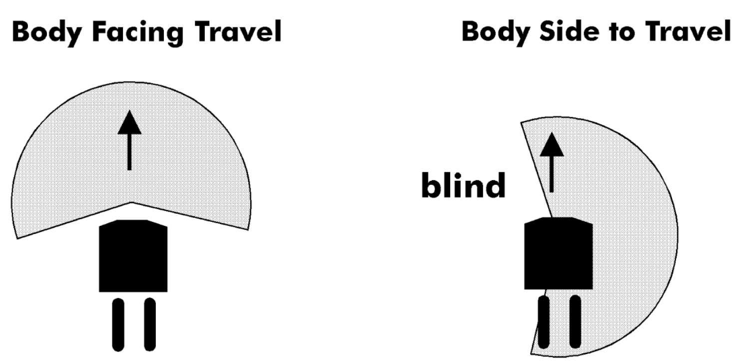

Figure 5. Body Facing Travel Allows Full Visibility of Front Hemisphere

RISK is another term. In this case, we mean unexpected objects as we pass through intersections. The operator is traveling through a series of changing environments where only clear, instantaneous visibility of that whole frontal hemisphere environment will suffice. The preferred posture, then, is face AND torso in the direction of travel.

Let us now look at SHORT DISTANCE TRAVEL.

The tasking within short distance occurs in a stable, known risk environment due to the limited space involved. A quick visual snapshot of the location of racks and other obstructions, either by focal vision or peripheral vision, may be all that is needed. This "snapshot" has a temporal quality in that the operator has a sense of where he/she is within the environment, and how long it would take a moving threat to enter the environment, reducing his need to continually check for "pop-up" traffic. No blind corners exist within this environment and truck speed is far less than when on the open grid. The operator has an ingrained map of fixed object spacing, or fixed threats (racks, columns, and so on), through experience.

An operator may thus work in this environment with quick looks in both directions for short clearing checks, either moving forks forward working with the load, or moving backwards for short distances. The total tasking in this environment suggests that the best stance is fore/aft.

Measuring the Frequency of At-Risk Bodily Postures

We have used a method of analysis similar to traditional time and motion study to see all of the operator's actions and movements throughout an entire shift, combining activities in both the RACK and TRAVELING environments. Our goal, in this case, involved determining the frequency of *at-risk bodily postures* throughout the shift, and not timing.

The task analysis indicates that facing the task, with both head and torso, reduces or eliminates the frequency of at-risk bodily postures. This is accomplished by facing the load in the rack environment, and fully facing the direction of travel when transporting loads in the warehouse grid.

The body at rest (standing) is in a posture we call ergonomic neutral; hands and arms are down at the sides, the eyes are forward and slightly down, the head is forward and level, and the torso is facing forward and upright. What we searched for was a method of measuring both the *frequency* and *degree of movement* of these body parts from ergonomic neutral during a full work shift.

In developing this analytical tool, we asked one question: What causes an operator to deviate his posture from ergonomic neutral? The answer is a question: *What is the operator looking at?* (See Figure 6).

Specifically, what environmental EVENTS occur that cause the operator to FOCUS his/her eyes? Where are these events relative to the truck, how frequently do they occur, and how should we thus position our operator to minimize the frequency and degree of deviation from ergonomic neutral? We will now talk about VISUAL FOCAL EVENTS.

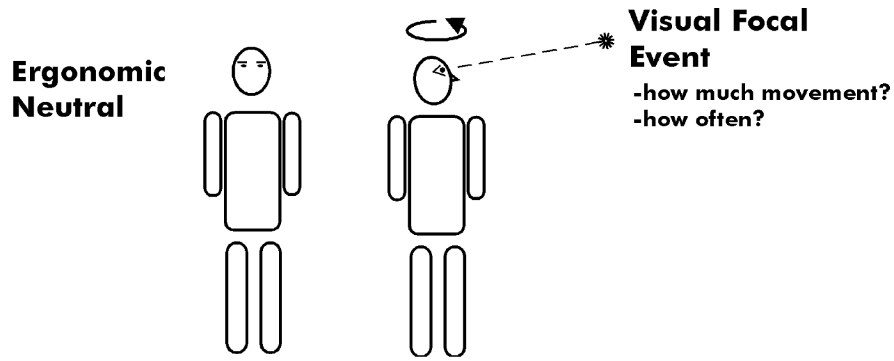

Figure 6. Visual Tasking Determines Frequency and Degree of At-Risk Postures

The Integrated Focal Vision Task Analysis

The analytical process involved both direct observation and review of video files of reach truck operators at work. A sequence of truck tasking was then constructed for an entire shift, including 200 putaways and 200 letdowns. One pallet cycle consisted of some 25 discrete truck tasks with 50 discrete visual focal events, generating some 20,000 visual focal events over the course of a full shift. The full shift study allowed a percentage of error movements to be introduced to the data, such as missing a rack location and backing up to correct the error. Some of the cycles included the removal of covering pallets before the desired pallet could be accessed.

The analytical format involved identifying first the reach truck events, then the associated visual events and their frequency, and last the location of the event around the truck.

Figure 7 illustrates the results as a percentage of the total full shift events, distributed around the truck in 30 degree quadrants indicated by clock position.

The 12 o'clock quadrant indicates the most activity, since the operation of the forks is, as we would expect, the busiest task for both the truck and the operator. This is, of course, ergonomic neutral in the horizontal plane for the driver of a fore-and-aft stance truck.

Very little occurs at 9 o'clock – ergonomic neutral for the sidestance operator. Indeed, the sidestance operator must hold his/her neck in extreme positions, interspersed with periods of rapid cycling between the extreme left and right positions.

Much of the activity at 7 and 5 o'clock represents visual clearing while traveling in the forks trailing mode.

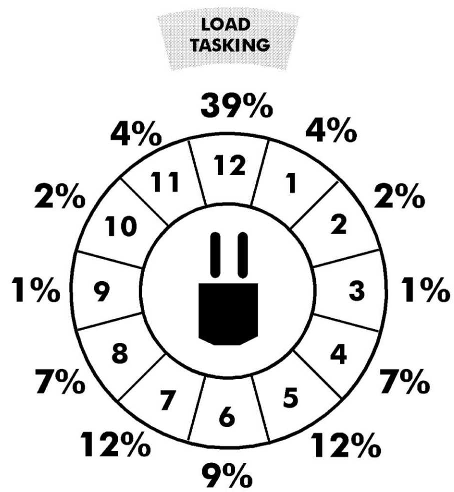

Figure 7. Occurrence of Visual Focal Events Around the Truck

As shown in Figure 8, the operator can use focal vision by turning his/her eyes, then eyes and neck, then eyes, neck, and torso up to 125 degrees left and right of ergonomic neutral. The operator can detect obstructions in the rear quadrant when fully rotated to 125 degrees through peripheral vision.

How should we therefore design the truck? Place ARROW "A" in the direction of the most focal vision activity, which by Figure 7 is either forks forward or forks trailing.

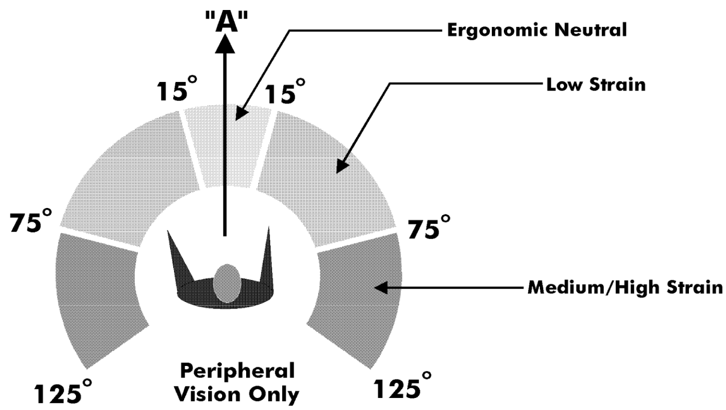

Figure 8. Operator Visual Focal Capability

Conclusion:

Combining Visual Focal Events, Figure 7, with Operator Visual Focal Capability, Figure 8, plus our upward neck restrictions from Figure 3, we would conclude that a fore-and-aft stance is preferable for reach truck applications. 48% OF THE VISUAL EVENTS OCCUR IN THE ERGONOMIC NEUTRAL ZONE (39% at 12 o'clock, plus 9% at 6 o'clock in the travel stance), compared to sidestance with 1%.

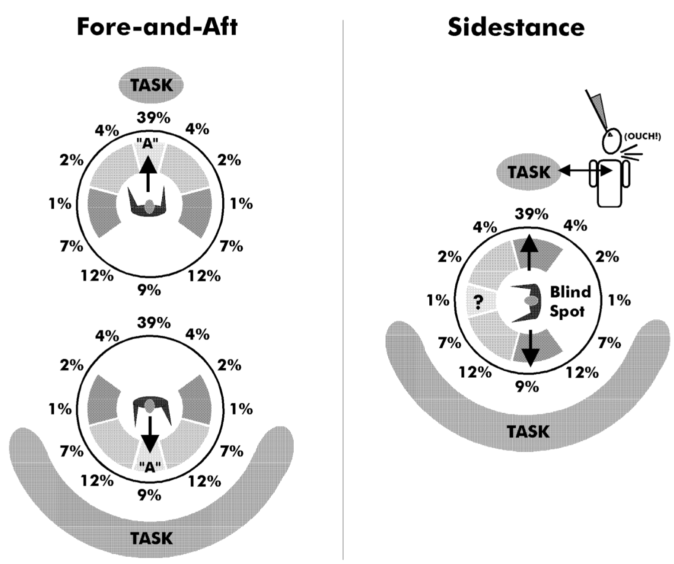

Figure 9. Merging Truck Tasking with Operator Capability puts TASKING in the Operator ERGONOMIC NEUTRAL ZONE

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