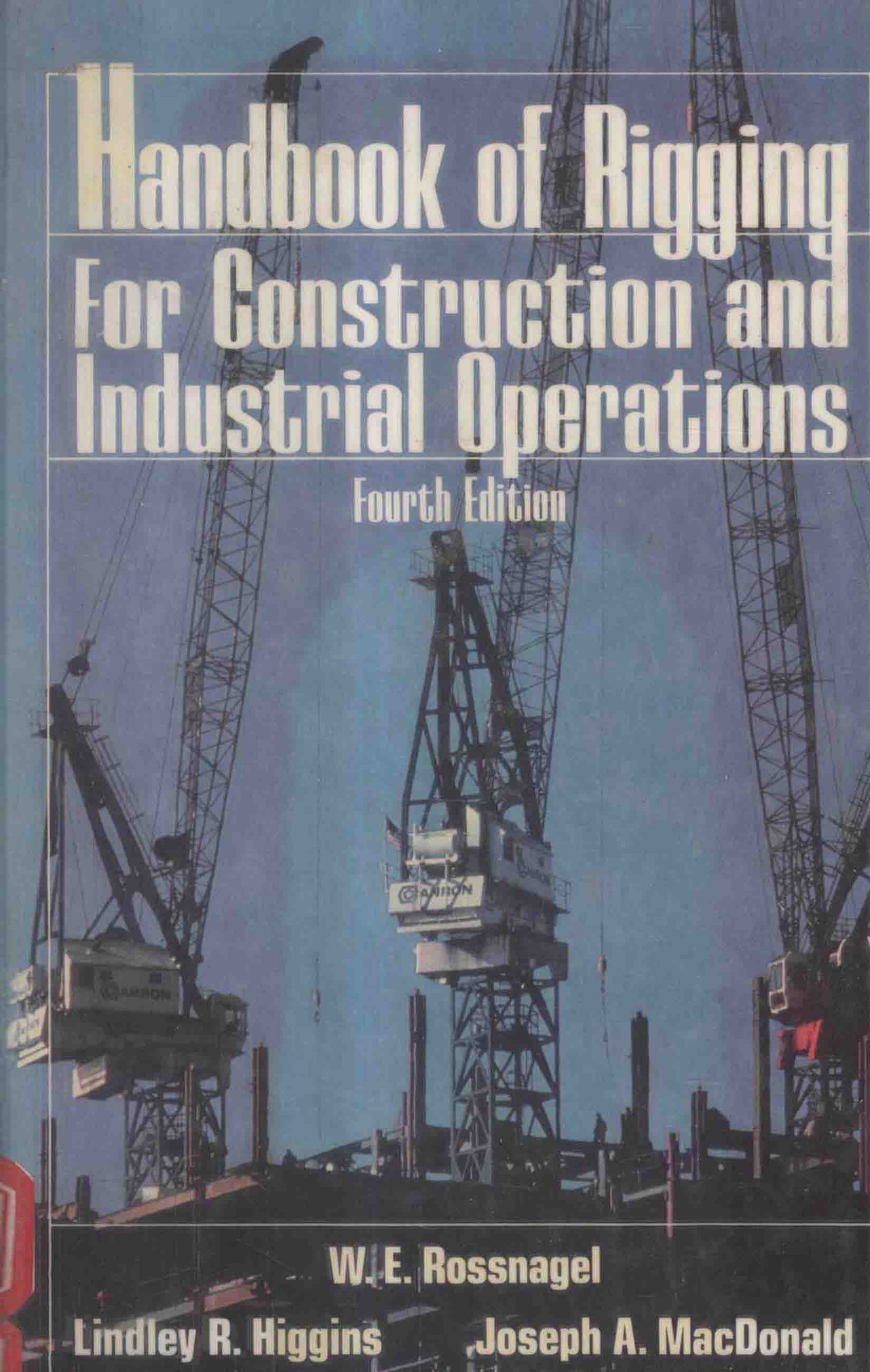
Handbook of Rigging For Construction and Industrial Operations

Fourth Edition



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For Construction and Industrial Operations

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Preface

This fourth edition of the acknowledged standard rigging reference—*The Handbook of Rigging*—has been revised, expanded, and updated to incorporate not only the advances in methods and technologies of rigging and scaffolding that have occurred since publication of the first edition in 1957, but also the regulations governing the safe practices and procedures for using rigging equipment and materials on projects that have been prescribed and enforced by OSHA since 1970.

The handbook is intended to be a ready reference and guide for expert riggers engaged in full-time rigging operations; erectors of buildings and other structures; maintenance mechanics in industrial plants and electric generating stations having less frequent rigging jobs to perform; operators of all types of hoists, derricks, and cranes; and other workers engaged in the erection of scaffolds or signage, or in climbing tall structures for repair or maintenance work.

Proper training can significantly improve accident prevention. The handbook attempts to identify the elements of safe rigging practice and expand upon the minimum safety regulations promulgated by the various standards organizations and by OSHA. It should be used as a guide in conjunction with the applicable safety regulations by contractors, supervisors, riggers, equipment operators, and managers concerned with or responsible for the safety of employees at work on a project, as well as for the general public and surrounding structures.

The information contained in specific chapters such as "Derricks and Cranes" or "Scaffolds and Ladders," and so forth can provide the basis for developing instructional material used in the training of personnel engaged in rigging operations. It can also be included in standard instructions issued to employees for the safe use of rigging equipment and materials.

Safe practices recommendations in the handbook, of necessity, are framed in general terms to accommodate the many variations in rigging practices and the different ways in which rigging is used. Because these recommendations are only advisory in nature, they must be supplemented by strict observance of specific relevant regulations as well as manufacturers' recommendations and requirements.

The authors are grateful to the many technical and trade associations, government agencies, equipment manufacturers, and materials producers cited in the text and illustrations, that assisted in the preparation of this handbook. Special thanks go to: Catherine M. Barth for her conscientious assistance in collecting and cataloging reference material solicited from equipment manufacturers, technical associations, and government agencies; Eugenie L. Gray for her critical review of editorial material to ensure grammatical consistency and technical accuracy of both manuscript and page proofs; Ingeborg M. Stochmal and Rita Margolies for their patient and thorough review of the finished manuscript and guidance through the editing and production stages.

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Introduction

The art of rigging may be traced to prehistoric times. Levers were used then, as now, to pry stones, roll logs, and move objects that were too heavy to be moved by hand. The inclined plane, or natural ramp, was in use even then to help move heavy objects up to higher elevations.

The first major rigging job, of which there is not only a record but also indisputable evidence, was in the construction of the three pyramids at Gizeh, near Cairo, Egypt, about 2700 B.C. It's estimated that preparation work must have taken almost 10 years; and construction about 20 years.

As it stands today, the large pyramid—built to contain the remains of Pharaoh Cheops (Khufu)—is 746 ft square at the base and 451 ft high. Originally, the structure was encased in a fine grain limestone. But at some unknown time during the past 4,600 years this sheath was removed.

The large pyramid contains about 2.3 million stones weighing from 2 to 30 tons each; a total of about 5.75 million tons (nearly 20 times the weight of the masonry in the 102-story Empire State Building in New York City). These huge blocks of stone had to be moved from the quarries to the bank of the Nile River, ferried across during the annual three-month period when the river was at its flood stage, and then dragged to the construction site.

Records indicate that a sand ramp, requiring nearly one million tons of sand transported from the desert, was built up one side as the pyramid rose in height. Another million tons of sand were then required to backfill the interior of the pyramid. And when the job was completed, the ramp had to be removed.

The construction crews had no mechanical equipment. Instead they used levers, rollers, crude ropes, sledges, plumb lines, and string sightings to get the massive job done. The huge stones were hauled up the ramp on rollers, for an average lift of 100 ft, by the brute strength of 100,000 slaves in teams of 50 men each, driven by the slave master's whips.

The pyramid remains today as indisputable proof of the ingenuity of the Egyptians. To fully appreciate the enormity of this undertaking, consider the power one man can develop:

> Turning a crank, such as on a winch, a man may exert 15 to 18 lb force continuously. Intermittently, he may exert 25 to 40 lb.
>
> Pulling downward on a rope or on the hand chain of a chain hoist, he may be able to exert a 40-lb pull for a long time; but for a short period, his pull may approach his weight.
>
> In lifting a few inches off the ground (assuming that he does it in a proper manner), he may lift up to 300 lb.
>
> Pushing or pulling an object, such as a vehicle, he may (with good footing) exert a force of 100 to 300 lb.

Now, considering the amount of work that a man may be expected to accomplish in an 8-h day, compare his effort with the cost of doing the job electrically.

Assume that electric power costs about $0.10 per kilowatt-hour and that electrically driven machinery is 50% efficient. Further, for continuous work, a man may be expected to deliver about 0.10 hp, while for a very short time he may exert from 0.4 to 0.5 hp. Then the cost equivalent of a man's labor may approximate the following calculations:

> A strong man can lift 86 tons (such as bags of cement) from the ground to a height of 4 ft in an 8-h work day, averaging 0.045 hp. The cost of doing this with electric power would be about $27 per day.
>
> A man can carry 22.3 tons up a ramp or stair to a height of 12 ft in an 8-h workday, averaging 0.034 hp. The equivalent electric power would cost about $20 per day.
>
> Pushing a wheelbarrow, he can move 40.7 tons up a 3-ft ramp in 8 h and average 0.015 hp. With electric power this would cost approximately $9.00 each working day. Shoveling loose earth, he can raise 20 tons to shoulder height in 8 h, exerting 0.013 hp. Using electric power, he can do this for about $7.00.

Thus, it can be shown that man is a very inefficient machine, and it is easy to understand why 100,000 men were required to transport material for the Great Pyramid.

The art of rigging has developed to the degree that today manufacturers build 200- to 400-ton traveling cranes for power plants; hammerhead cranes of even greater capacity for shipyards; and mobile cranes and derricks capable of handling trusses and girders weighing up to 200 tons for buildings or bridges.

However, this book is not intended to deal with rigging operations of this magnitude. Rather it covers conventional rigging operations in industrial plants, factories, and power plants; in transporting and handling heavy machinery; in mines and port facilities; and on construction sites for erection and demolition of structures.

Chapters include rigging equipment, materials, accessories, procedures, and precautions used in the practice of rigging. Included also is a section on the erection of temporary scaffolding for painting, repairing, construction or demolition of structures, and supporting heavy loads.

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Section
1

Engineering Principles

Chapter

1

Basic Machines

The first and most important step in any rigging operation is to determine the forces that will affect the job, and then to select and arrange the equipment that will move the loads safely, both horizontally and vertically.

Too often, though, the load-bearing parts of a rigging system are stressed to a point dangerously close to the breaking point without the rigger realizing it. This element of chance can be reduced to a minimum by a simple knowledge of how to determine the loads that must be moved and the capacity of the equipment being used.

The forces involved in rigging will vary with the method of connection, the direction of support in reference to the load, and the effects of motion. Thus the rigger must know something about mechanical laws, the determination of stresses, the effect of motion, the weight of loads, the centers of gravity, and factors of safety. Also essential is a basic knowledge about the strength of materials, which is covered in succeeding chapters.

Mechanical Laws

Machinery offers a mechanical advantage in moving loads. The elementary machines from which all machinery is constructed are the inclined plane, the lever, the wheel and axle (gear or pulley and shaft), the screw (derived from the inclined plane), and the block and fall.

Riggers frequently make use of the inclined plane when hauling a load on rollers up a ramp or on skids onto a truck.

To estimate roughly the pull required to haul a load of 15,000 lb on rollers up an incline of 4 ft in 20 ft, draw a diagram *ABC* representing

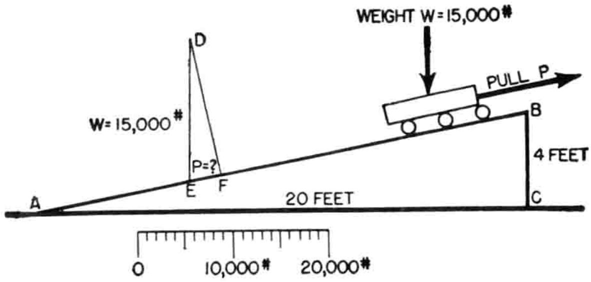

Figure 1.1 Calculating the force required to move an object up an inclined plane or ramp.

the incline. Then draw to any suitable scale a vertical line *DE* representing the weight of the load (see Fig. 1.1).

Assume a scale of 1 in. = 10,000 lb so that a line 1½ in. long will represent 1½ × 10,000 lb, or 15,000 lb. From *D* draw a line *DF* at a right angle to the slope of the incline *AB*.

Using the same scale of 1 in. = 10,000 lb, measure the distance *EF*, which will be the theoretical pull required. This scales to about 0.3 in., or 3,000 lb, which is the pull if frictionless rollers were used. To this value the resistance to friction must be added to determine the actual pulling force.

Another simple application of the mechanical advantage is through leverage, in which one point (the fulcrum) of a rigid bar is fixed, another point is connected with the force (the load) to be acted upon, and a third point is connected with the force (the power) applied. The crowbar is a typical lever.

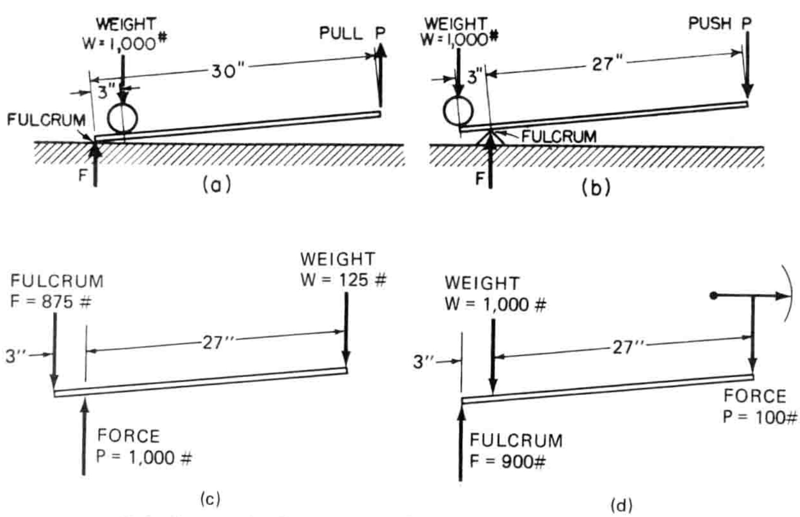

Figure 1.2 Calculating the force required to lift or move a load by means of levers.

As commonly used, there are two arrangements of the fulcrum. Figure 1.2*a* shows how an upward pull P on the handle lifts the weight W because gravity acts as a downward force. The toe of the crowbar pivots about the fulcrum F and, in effect, the floor or ground exerts an upward force to resist the downward pressure.

Assume a weight W of 1,000 lb acting at a distance of 3 in. from the fulcrum F and a person lifting up on the lever at a distance 30 in. from the fulcrum. The force P times the force distance (30 in.) always equals the weight W (1,000 lb) times the weight distance (3 in.). Thus $P \times 30$ in. = 1,000 lb × 3 in., or the force required is $P = 100$ lb. In other words, if the force distance is 10 times the weight distance, then the force is one-tenth the weight, and the lever is said to provide a mechanical advantage of 10. This rule holds true for other ratios of distances also.

However, if the crowbar is used as shown in Fig. 1.2*b*, where the fulcrum is between the force and the load, the force then is a push P in the downward direction. Using the same 30 in., the force P times the force distance (27 in.) equals the weight W (1,000 lb) times the weight distance (3 in.). Thus $P \times 27$ in. = 1,000 lb × 3 in., or the force required is $P = 111$ lb.

By observation, then, the crowbar is most efficient, or requires less force, when used as shown in Fig. 1.2*a* although sometimes it may be necessary to limit the pressure on the fulcrum, as in Fig. 1.2*b*. In this latter application, the pressure is always the sum of the weight W and the force P.

A third form of leverage, with fulcrum and load at the ends of a rigid member and the applied force at an intermediate point, produces a mechanical disadvantage, as illustrated in Fig. 1.2*c*. However, this arrangement is important in a fishing rod, where a relatively light weight at the end of the rod must be lifted quickly by a relatively heavy pull of small travel above the butt end.

In construction work, a heavy load of a very small travel, on a scale used for weighing loads on trucks, is balanced by a small force with considerable travel on the indicator end, as shown in Fig. 1.2*d*.

Yet another application of the basic lever is in the use of a pulley, where the block-and-tackle arrangement acts as the lever, with the fulcrum at the side of the block and the rope fixed to the ceiling (see Fig. 1.3). The mechanical advantage obtained with the block-and-fall arrangement is explained in detail in Chapter 10.

Just as the block and tackle, or hoisting derrick, can be considered as a form of lever, so almost every other tool becomes some form of the same simple device. Even the simple twisting of two lines with a pipe to pull a load is merely the application of a lever with a long driving arm and a short resisting arm.

An important adaptation of the lever principle is the wheel and axle. Although the movement of the lever is limited, the motion of the wheel may continue indefinitely. For the wheel-and-axle arrangement with belts and pulleys, the belt pulls, or tensions, are inversely proportional