the angle of thread is 45deg., that is, when the pitch equals the circumference. The purchase gained by such a screw, as I remarked before, is nil, but there is much less work lost in friction, and therefore less wear of threads of screw and nut than with a fine pitch—hence the advantage of using coarse pitched screws for driving planing machines and lathe motions. A screw of 45deg. would work equally well both ways, that is, both to convert rotary motion into rectilinear, and vice versa. In a screw-jack, of course, the first only is our object, and the angle of thread with the horizon should be less than the angle of repose of the surfaces, considering the thread friction only, or less than about twice that angle if the cap friction is also taken, as it usually must be. With the above screw-jack, if the lubrication was so effective as to reduce the co-efficient of friction to 1/25 (corresponding to an angle of repose of 2deg. 18min.), the efficiency would be just about 50 per cent., or the loss equal to the useful work, and the load would be on the point of running down when the pressure was taken off the turning bar, but unless the gear was floating in oil, so to speak, such a contingency would not arise. If the cap was furnished with ball bearings it might, however. If an exhaustive series of careful experiments was made on screw-jacks, it would probably be found that the general law of friction being proportional to load does not exactly apply, but that the formula would include a constant number to be added, whatever the quotient might be, so that at low loads the work would be more than the above theory gives, and again at high loads the lubrication would be found so defective and uncertain as to upset all attempts at formulating.

A great variety of screw tackle is used in the workshop and engine-room, but the above functions are common to all. A double-ended screw with right and left handed thread is used often for a lifting or stretching screw; its use presents some conveniences, but its efficiency is no more than that of a single-ended screw with a well-designed end-bearing, and of double the pitch.

Screw-lifting gear is handy and neat, but often wofully inefficient. It is usually impossible to oil the bearing surfaces when the load is on them. To have to lift, say, a 4-ton marine engine cylinder cover with the screw tackle usually applied, if the rubbing surfaces are about dry and the friction possibly aggravated by the emery and brick dust left behind by a careless fireman when polishing "the tops," is an education in itself. Screw gear is occasionally fitted in shaft tunnels of steamers for handling the intermediate and tail-shafts when "drawing" the latter, but I have never seen any really well designed for the purpose. The time, money, and patience wasted in handling such shafts in confined tunnels, with dock dues mounting up all the time, perhaps, is appalling, and could be much reduced if owners would supply proper tackle and engineers make up their minds as to what they want. A screw arrangement for handling a 5 or 7 ton shaft in a tunnel should be much better than merely good enough to hang the dead weight. There should be no question as to its ability to bear all the cross stresses and twisting moments that may come on it; the rubbing surfaces should be ample and oilable, the threads designed to minimise friction, and a ratchet arrangement for turning he screws would pay well. The suspension collar of these lifting screws might be on roller or ball bearings. Ball bearings are used in many machines now-a-days, from mangles and mowers to machine tools and thrust blocks, and if they have not quite effected a revolution in machine design yet, they at least make revolutions much easier. The bearing should at least have two or three loose washers interposed, so that if one pair of rubbing surfaces seize another pair can take up the running.

Another useful screw tackle is the chain block worked by worm gearing. There are many types of chain tackle in use, but for heavy lifts, that in which the chain wheel is driven by a worm is perhaps the best. The friction on the thrust bearing is most important in this type of block, and should be minimised as much as possible by proper design; sufficient bearing surface, facilities for lubrication, and loose washers to give alternative rubbing surfaces being most desirable. The screw is set tangentially to a worm wheel, and driven by a light sprocket wheel on which is a hand chain; another wheel on the same axis as the worm wheel or cast along with it carries the lifting chain, and has deep, well-fitting sprockets, so that the latter, which is simply passed over it, with a hook on either end to carry the weight, cannot slip. The pressure on the screw not being axial, is not equally distributed on the thread or thrust, and the bearing of the thread on the wheel, being necessarily much less than it would have been in a nut, makes the pressure there intense, and the oil is squeezed out, so the friction is more than with a screw-jack, while the frictional resistance to motion of the interlacing links of the chains is very considerable, but the thrust pressure on the screw, being theoretically less than the load lifted in the proportion of radius of lifting chain wheel to that of worm wheel, the effect of the main chain friction is probably to make the end pressure on the screw about equal to the weight with ordinary ratios of worm and gipsy wheels. The **theoretical "purchase" of this gear is = circumference of hand chain wheel × radius of worm wheel ÷ pitch of screw × radius of chain wheel, hence to get a good** purchase we want to keep the factors in the numerator as large as possible. In order to keep the friction and, therefore, the counter-efficiency low, the factors in the denominator must not be reduced too much, and these conditions militate against the handiness of the arrangement, especially as we want the block to occupy as little vertical space as possible usually. The best arrangement is to have the worm under the block, and then we can use a large diameter of hand chain wheel without its projecting above the top suspension hook of the tackle. The mechanical efficiency, if we want the gear to be self-sustaining, must be low, probably never over 20 per cent., but that is really good for this class of mechanism. Twenty per cent. means that five times the calculated effort must be applied to the hand chain. If the screw is made with a coarse pitch there is a greater efficiency, but it can no longer be relied on not to run down, and, of course, the "purchase" is less. A self-acting friction brake may be fitted to the hand chain wheel, which prevents this running back of the weight. The hand wheel is not keyed on to its spindle, but put on with a thread, so that when heaving up it is screwed hard against a loose ratchet wheel, which it binds against a collar and so jambs it and itself, and communicates its motion to the spindle; a pawl on the ratchet prevents it running back until the chain is pulled the reverse way, which screws back the wheel and allows the spindle to revolve in the ratchet wheel. If this arrangement proves reliable and durable, it must constitute a great improvement. The simplest and most universal chain tackle is Weston's differential. Here an endless chain is reeved from opposite sides over two chain wheels of slightly different radii, secured adjacent on the same spindle, so as to hang down in two bights, one of which carries a single movable block with hook for carrying the weight; the other hangs free, and may be used to haul on to raise or lower, or this may be done by a light chain driving a wheel of larger diameter on the same spindle as the differentials. The velocity ratio of this gear (when no driving hand chain is used) equals the circumference of the larger pulley: half the difference of the two circumferences, and may be very great, giving a high theoretical purchase, which, however, is very disappointing in practice This is due to the loaded chain running at the full velocity of the effort while the tension on it is never less than half the weight lifted, consequently the work lost in friction among the links as they work over the three sheaves is very great, and produces a greatly increased strain on the chain, so that the pull on the lifting side of the movable block may be nearly equal to the whole weight, and the strength of chain must be increased accordingly. Moreover, this straining of the chain may permanently elongate the links, and when they no longer fit the wheels, slipping and surging occur, which are dangerous and detrimental. In the worm-driven chain pulley, the chain, though under heavy tension, travels at the same slow rate as the weight lifted, and the work lost here is comparatively small. In differential tackle it travels at the speed of the effort, and the work lost is enormous. The frictional resistance may even render it impossible to move the chain with any effort less than what would break down the gear, hence the necessity of keeping the chain well greased, which makes it unpleasant to handle and lubricates the operator's hands also, making it difficult to secure a grip of it. Evidently this chain friction is of uncertain amount, and does not easily lend itself to calculation. The differential principle for getting a high velocity ratio is a very elegant one, but is liable to this defect, that the moving parts must run at high speeds while carrying the weight, so that the efficiency is very low. Hunter's differential screw is an instance. We ought to get an enormous mechanical advantage with it, but the friction, when loaded, annuls it, and the motion is only useful for micrometers, and such where we are concerned with motion only, and not with work.

Geared blocks are used sometimes in which the velocity ratio is let down by a train of toothed wheels, and if these are well designed the sliding of the teeth on each other should produce but a moderate amount of friction. It is impossible, however, to have a great difference between the diameters of spur wheel and pinion, and have at the same time easy working teeth without making the pinion tooth too weak and thin at the flank for practical work; if made strong, or the number of pairs increased, the tackle gets too heavy for ordinary work. Epicyclic trains are used in some chain tackles, but the same considerations hold there also—the pitch circles roll on each other with great velocity compared with actual speed of lifting; there is a great and uncertain loss in sliding friction; the teeth and spindles are enclosed and difficult to lubricate, and if made strong are heavy and unhandy. This gear is usually of a differential nature, and high velocity ratios may be obtained by it, but with great friction among the teeth. He had known hydraulic capstans employed on steamers' decks for warping purposes, etc., some of the most beautiful and ingenious pieces of mechanism possible, discarded, because the slow-speed drum driven off the fast running one by a sort of differential sun and planet motion of the epicyclic type, and which theoretically ought to have put a stress of at least 10 tons on the rope it hauled on, would pull up before there was enough strain on—in the words of the deck-hands using it—to break a rope-yarn.

The rope block and tackle for moderate weights can hardly be excelled for handiness, adaptability, and length of drift, as the rope used can be of any reasonable length, and the mechanism is of the simplest, but the purchase gained is not great. Rope, however, is perishable and of uncertain strength, and has peculiarities of its own that bring down the efficiency. The sheaves of rope blocks are often made with ingenious roller bearings, which effect a saving, but often again run on rough, unturned pins, which should not be. The friction of the sheaves on their pins, however, is but a small part of the loss. The work necessary to bend the taut rope over the multitude of sheaves is what tells, and the only way to lessen that is to increase the sheaves' diameter; this evidently lessens the amount of curvature in each unit length of rope, and as it is the initial bending as the rope enters on the pulley, and its straightening again when it leaves it, that absorb the work, the greater the radius, the less work is needed. This lost work must also increase with the cross section, or with the square of the rope's diameter, and depends on the consistency or nature of the fibre also. Consequently this co-efficient of rigidity can only be arrived at experimentally, even for a turn over a single pulley, much more for a series of turns over a set of sheaves, for evidently the pull on the rope must alter at every pulley it passes over. Suppose a pair of blocks with 3 sheaves in each, giving a 6-fold purchase, carrying a weight of 1200lbs.—with an effort or pull of 200lbs. on the fall or free end the arrangement would be in equilibrium, and the stress on each part of the rope equal. Let the co-efficient of rigidity be $\frac{1}{10}$, that is, let it need a pull of 220lbs. to lift a weight of 200lbs. by the rope passing over a single pulley. Then, to put the system in motion and raise the weight, the tension on the rope must increase from 200lbs. on the standing and by 10 per cent. compound interest every time it goes round a sheave, and the pull on the fall must be 200 × (1.16=1.77) or 354 lbs., and the efficiency would be, if the weight was lifted by a steady pull, $\frac{1200}{354 \times 6} =$ 57 per cent. This is assuming a somewhat high co-efficient but neglecting the work done in stretching the rope, and assuming the rigidity is proportional to tension, which is not strictly true, but it is probably near what occurs with Manilla rope in such a tackle. The work, however, is seldom done by a steady pull, but by a series of tugs, a turn of the fall being taken round a belaying pin and the slack taken up and retained by a man whose duty is to "keep all he gets." But there is inevitably some slackening of the rope every time a new grip is taken; the lost ground has to be recovered and more work put into the elastic rope to stretch it, so that the loss of efficiency is really much greater. The pull on the rope increasing by a compound interest law, mounts up rapidly as the number of sheaves is increased. At the rate instanced above the pull on the fall would be equal to the whole weight lifted if the rope passed over a series of 38 pulleys; the theoretical purchase would be 38, but the 38th power of 1.1 is also 38, consequently the counter-efficiency would equal the theoretical saving and annul it. Hence, if a great purchase is wanted with rope blocks, we cannot get it by multiplying the sheaves in the main tackle, but may do something by applying a "luff" tackle to the fall of it. Suppose such a tackle applied to our three sheaves blocks, the sheaves same number and diameter as in the main tackle, and rope of same quality, but 2/5 the diameter, ½in. instead of 1¼in., then the rigidity of the small rope is less than that of the large as 2^2 is to 2^2, or is less than $\frac{1}{6}$ that of the other, and the ratio 1.016 instead of 1.1. The weight on our small tatckle is 354lbs., and the pull on the fall of it will be $\frac{354}{6} \times 1.016^6 = 59 \times 1.1 =$ 65 lbs.—with which we get a volicity ratio and theoretical purchase of 36, and the efficiency of the system, neglecting elastic stretching at every pull and spindle friction, will be about 51 per cent. The efficiency is not much lowered, while the purchase is increased proportionately to the product, not the sum, of the two sets of sheaves employed. Of course, if the slack is not all taken up at every change of hands, the elasticity of the rope makes it contract when the pull is relieved, and a lot of extra work has to be done stretching it again at every surge, so that the foot lbs. lost depend much on the position and efficiency of the belaying pin, which should be as near the effort, or hands of those pulling, as possible, and in line with its direction of motion. As so many variables affect the efficiency of rope tackle, a general formula can hardly be laid down, and for any particular case, even, it would be hard to determine it with much exactness. Enough has been said, however, to show that when a great purchase is employed it is associated with a great frictional loss, notably so with differential chain blocks. A great desideratum in a shop or engine-room is a chain tackle which will lift a crank, shaft, or propeller without this enormous counter-efficiency. Compounding the tackle by the use of something analogous to a "luff" tackle is the true solution, he thought, a differential chain block with a greater difference in the sheaves than usually obtains, and the purchase brought up by driving them with a light chain through a pinion and spur wheel would be advantageous.

Hydraulic jacks are much more efficient than any screw gear, since the liquid friction in the chambers and ports is quite different from solid friction, but leakage at the pump valves is a variable quantity and affects the result. This opens, however, quite another chapter, which time prevents us from entering on.

In conclusion, he had only to repeat that the loss of efficiency in the use of the so-called "mechanical powers" is much greater than most people imagine, and that the ordinary way of stating problems dealing with them, "neglesting the effect of friction," and without giving some idea as to what that effect is, is very much like performing the tragedy of Hamlet with the part of the Prince of Denmark left out.