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Derrick Cars and Bridge Erection; Chicago, Milwaukee & St. Paul Ry.*

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The principal requirements of a derrick car are: (1) length of boom-reach, with the necessary stability of the car; (2) strength of parts, with the required lightness for handling.

The number of uses to which a derrick car can be put are almost in proportion to its length of boom. The longer the boom and the greater its capacity, the greater must be the longitudinal and lateral stability of the car. The longitudinal stability (parallel with the track) is comparatively easily obtained by increasing the length of the car and by adding the counterweight required to the weight of the engine and rigging already in place. The lateral stability is, however, a difficult matter to provide and is a more doubtful quantity than any other feature of the car; this is due mostly to the fact that the width of base of the car available against overturning is limited to the distance c. to c. of rails, unless outriggers or guys are used.

The lateral overturning moment of the load is measured by the product of the load into its distance from the nearest rail, and this overturning is resisted by a moment which is the product of the weight of the car into one-half the distance between the rails. As this half distance between the rails, or the lever-arm of lateral moment of resistance, is only about 30 ins., it is apparent that the capacity of the car for lifts at any distance from the center line of track is limited. The exact figures for the 30-ton and 50-ton cars described below are given in the accompanying table.

To reduce the stresses in the boom tackle, and its consequent weight, it is desirable to make the height of the tower as great as possible, but the permissible height of the tower is limited by the clear headroom in through truss bridges and under telegraph wires, during transit and also when the car is at work.

30-Ton Derrick Car.

The features of a derrick car designed by Mr. W. F. Rech for the Bridge and Building Department of the Chicago, Milwaukee & St. Paul Ry. are shown in Fig. 1. This has a 50-ft. flat car of heavy construction, carrying a mast 15 ft. 3 ins. high and a boom 30 ft. long. The top of the mast is 21 ft. 3 ins. above top of rail, and the design of the connection at the top of the tower makes practically all of this height effective.

The upper part of the tower consists of an A frame, which can be removed when the car is in transit, thus bringing the total height of the car well within the overhead clearances.

The square tower is fully rigged so that when the A frame is removed the car can be used for all purposes, but, as the stresses in the top tackle are increased, the capacity of the car is reduced.

The shortest boom is made of two 15 ft. sections; additional intermediate sections of 20 ft. and 35 ft are provided, making lengths of boom of 30 ft., 50 ft., 65 ft., or 85 ft. available.

FIG. 2. ERECTION OF THE PEEDEE VIADUCT WITH 30-TON DERRICK CAR.
The Boom is Setting the Bent of a 75-ft. Span; This is Beyond Its Normal Reach, but is Effected by Outhauling, as Shown.

When heavy loads are being lifted, there is a provision for the insertion of a tight fitting hard-wood block between the body bolster of the car and the side frame of the truck. This permits part of the load to be transmitted directly from the car body bolster to the truck side frame and relieves the side bearings and springs of whatever load passes through the hard-wood block.

Fig. 1 shows the arrangement of lines, also of the clutches, brakes and throttle under the control of the engineman. These features are shown in diagram only. All winch heads and drums are provided with a ratchet and pawl.

The 30-HP. engine is of a type extensively used in bridge erection. The chief characteristic of this type (which is common to the different makes) is that all shafts, together with all gear wheels attached to same, are caused to revolve whenever steam is admitted to the cylinder. The drums run loose upon their shafts and can be made to revolve with the shafts upon which they are carried by means of friction clutches. When the friction clutch is disengaged, the drum can be held without motion by means of the brake or the ratchet and pawl, the shaft in the meantime revolving for the purpose of handling other lines.

The winch heads are also loose upon their shafts, but may be fixed to the shafts by the jaw clutches. When the jaw clutches are disengaged, the winch heads may be held in one position by means of ratchets at their ends and pawls connected to the frame of the engine. When the winch head is held against motion by the pawl, it may be used for fastening the line or holding the load, although the shaft upon which it is carried may be revolving while the engine is handling other lines.

With 110 lbs. steam pressure, the engine can exert a pull of about 8,000 lbs. on a line fastened to the drum. As this is exerted at a radius of 8 ins. from the center of the shaft, a considerable greater pull can be exerted by the winch head, which has a somewhat smaller radius.

As shown in Fig. 1, each swinging line and runner line after passing from the front of the car is given a number of wraps around the winch head and then passes into the hands of the winch head man. The pull which the winch head exerts upon the line depends upon the number of wraps which the line makes around the winch head, and also upon the pull exerted by the winch head man upon the end of the line. A very light pull, with only a few wraps around the winch head, permits the winch head to slip and revolve within the line which is wrapped around it; a greater pull and more wraps causes the winch head to grip the line with a force which can be increased up to the breaking strength of the line. The boom line and the load line are fastened to the drum, but before commencing operations, it is usual to take a few wraps around the drum, in order to reduce the stress where the line is fastened to the drum.

One engineman controls the throttle, in addition to operating the two friction drums. One winch head man operates the two swinging lines and a second winch

*Abstract of a paper read before the Western Society of Engineers and printed in full in the "Journal" of the Society.

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TABLE OF HOISTING CAPACITIES OF DERRICK CARS; C., M. & ST. P. RY.

30-Ton Derrick Car.

Length of boom ft.	Hoisting capacity tons	Swing of end of boom from center of track ft.
30	25	0
50	15	0
30	20	3¾
50	14	3¾
50	12½	5
50	7½	10
50	5	15

50-Ton Derrick Car.

		With outrigger ft.	Without outrigger ft.
80	10	26¾	12
65	20	19¼	8½
57	35	19	8¼
42	50	15½	6¾

head man operates the runner line when it is in use. This makes a total of three men in the cab, the engineman doing his own firing.

The car can propel itself with its own power in either direction by means of a chain wheel, which carries a 1⅛-in. chain; this passes around and drives a sprocket wheel keyed to the forward axle of the rear truck. The chain wheel is driven as follows:

A gear wheel is placed on each end of the front shaft, Fig 1. The gear wheel at one end of the shaft is connected by a train of gears with the chain wheel, so as to make it revolve in the direction which the engine is running and the gear wheel at the other end of the shaft is connected by a similar train of gears so as to make the chain wheel revolve in the reverse direction. The gears at the ends of the shaft run loose and can each be thrown into service (the other gear running idle) by means of a jaw clutch, feathered to the middle of the shaft. This arrangement permits the car to be propelled in either direction by a non-reversible engine.

On a structure such as the Peedee viaduct, where the material must be brought out on the track and where falsework cannot be economically used, a boom of 80-ft. reach would be required to place a single bent ahead of the portion of the structure already erected. The same result can be accomplished with a shorter boom, though not so conveniently, by outhauling the member beyond the reach of the boom, as is shown in Fig. 2. This shows the erection of a bent for a 75-ft. span ahead of the derrick car without the use of falsework; the car sets the 75-ft. girders in position. At the conclusion of this operation the structure is self-supporting and, as soon as the laterals are placed, the track ties and rails can be laid, which will permit the derrick car to move forward 75 ft. and complete the erection of the 50-ft tower.

The spans between towers of the Cow Creek viaduct, Fig. 3, are 61 ft. 8 ins. In order to place a tower bent ahead of the completed portion of the structure without outhauling, a boom of 66 ft 8 ins. reach would be required. These bents, however, were placed with the 65-ft. boom available, the small amount of outhauling being done with hand lines.

The material for this viaduct was brought out to the point where it was required by a track on the ground along the center line of viaduct, the material being delivered to the tramway from the track above by a wrecking crane, which happened to be available. This method differs from that used at the Peedee viaduct (Fig. 2), where all material was delivered above and carried to its position suspended from the boom of the derrick car. This method of bringing out the material was made possible by the level bottom of the valley which the viaduct crosses.

Fig. 2 shows also the lower story of the tower being erected by a mule traveler, running on a wide gage track and moving continuously away from the portion of the structure erected. This arrangement, which kept the derrick car continuously supplied with material without moving from its position at the end of the completed portion, greatly increased the erection speed. This viaduct (consisting of 27 spans supported by 12 towers) was erected by the company forces in 18 consecutive days.

50-Ton Derrick Car.

The general features of the 50-ton derrick car designed by Mr. W. E. Pruett are shown in Fig 4. The principal requirements of design and the difficulties encountered in satisfying them (as given in the description of the 30-ton car) are equally true as applied to the 50-ton car. But in this case the essentials of reach, stability, etc., were provided in a somewhat different manner. The longitudinal stability of the car was increased by the addition of 25 tons of counterweight; and its lateral stability by the use of outriggers.

The machine consists of a steel superstructure mounted on a steel flat car. The A-frame, which performs the work of a mast, is riveted to two transverse channels which are fitted to two circular castings resting on the plates riveted to the sides of the car. The channels form a box, into which the I-beam outrigger telescopes when not in use, and from which it can be withdrawn, when required, to either side of the car, depending upon the point from which the load is to be lifted. The outer end of the outrigger rests on blocking or a jack bearing against the ground.

To reduce the stress in the boom tackle, the A-frame is made as high as possible, being 21 ft. ¾ in. over all above the top of rail. This height is within available clear headroom, but can be materially reduced by revolving the A-frame backwards around the casting (as shown in dotted lines) when the car is in transit.

At the top of the A-frame is a forging revolving on its horizontal axis and having bearings for its ends in the A-frame and backstays. A vertical pin passes through this forging. To this vertical pin are attached two short eye-bars, which are also attached to the lower block of the top tackle. The backstays are also connected to this forging, which is about as central a connection as can be obtained in a derrick car.

The boom is in sections and has a maximum length of 80 ft. when assembled. By the removal and substitution of intermediate sections, this length can be reduced to 65 ft., 57 ft. or 42 ft. The thrust of the boom at the bottom is transmitted by a casting terminating in a spherical surface, to a bronze bushed socket forming a ball and socket joint. The 16-ft. bars shown at the end of the boom tackle are necessary to keep it clear of the boom when using long booms at high elevation. The capacities of the boom in various positions are shown in the table. In spite of instructions, greater loads than these have often been lifted in service. Fig. 5 shows the car placing a tower bent of the Blacktail Creek viaduct, which has intermediate spans of 65 ft. This was done with the 80-ft. boom, the length of which made it possible to do all this work without outhauling, as in Fig. 2.

The engine and propelling device are of the same type as on the 30-ton car, but the engine is of 50 HP. There is a locomotive air-compressor on the car, with two storage tanks under the floor. With 110-lb. boiler pressure this will supply sufficient air at 100 lbs. pressure for the operation of five riveting hammers. The compressor also furnishes air for the air brakes, and the brake equipment has proved a valuable safeguard when moving the car towards the end of a structure under erection, often on a falling grade.

The two cars described have been employed for over a year, often for duties beyond their rated capacities, and have given satisfaction to the field forces of the Bridge Department.

Traveler for Viaducts.

Where it was necessary to erect a viaduct on a new line before the track had reached that part, and where the erection of high structures had to be hurried to completion before an approaching winter in a country noted for heavy snow falls, it was necessary to design an erection machine with a capacity for the continuous and economical employment of a larger working force than would be possible with the derrick cars, the increase in working force to result in proportional increase in tonnage erected per day. Such a device is the traveler designed by Mr. H. C. Lotholz, and shown in Fig. 6. This is a combination structure of wood and iron, which spans the track, thereby permitting material to be brought to the traveler on flat cars as far as (B), and also permitting the passage of trains through the traveler immediately after completion of the structure.

This traveler has a cantilever arm of 75-ft. and two 60-ft. wooden booms, making a total reach of about 120 ft. This reach makes it possible to erect an entire tower in advance of the completed portion of the structure (as shown in Fig. 7), the tower being stable in itself without the use of temporary braces. The cantilever arm is equipped with four trolleys, each of 15 tons capacity. Each trolley is composed of a steel carriage on rollers, from which are suspended two four-sheave blocks, rove up with nine parts of 1½-in. rope.

A hook of 10 tons capacity was hung from each boom and 30 tons of rails for counterweight were placed at the rear end of the traveler. Additional anchorage was provided by anchoring the traveler to the girder with hooks. The traveler was also anchored sideways by means of three ⅝-in. hoisting cable guys, on each side, attached to top of the traveler. The machinery is of the same general type as for the 30-ton derrick car, except that the front shaft is omitted and the power is somewhat less. The following description of the equipment and operation applies to one side only, but both sides have the same equipment.

The 10-ton hook at the end of the boom is suspended from a four-part tackle of ⅝-in. hoisting cable. The fall line of this leads through the idler sheave at the top of the boom, thence through a snatch block at the foot of the mast and thence to the lower drum of the hoisting engine. The boom is raised or lowered by a seven-part tackle of ⅝-in. cable, the fall line of which leads through a snatch block at the foot of the mast and thence to the upper drum of the engine. The hook hoist and boom hoist are operated by the engineman.

The boom is swung laterally by a five-part tackle (one on each side) of 1½-in. manila rope. The fall line of this is led through a series of snatch blocks (which prevents the lines from fouling other parts of the traveler) to the outside winch head on hoisting engine. Both of these lines are operated by one winch head man.

Each of the 15-ton trolley hooks is supported by a nine-part tackle of 1½-in. manila rope. The fall line passes through a snatch block of two idlers at the forward end of the cantilever arm, and thence back through a number of deck sheaves (which keep the lines from fouling other parts) to the inside winch head of the engine. As there are two trolleys, one fall line leads to each inside winch head on the engine. This fall line is used also for traversing the trolley, there being sufficient tension in the fall line, when holding the load,

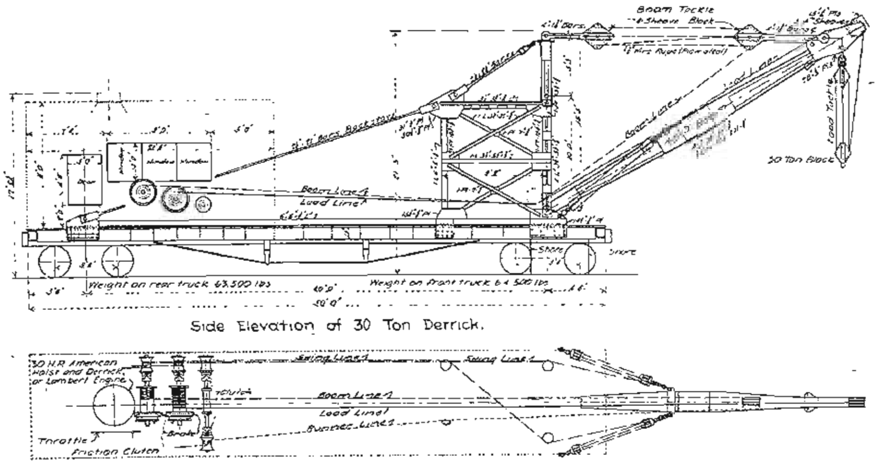
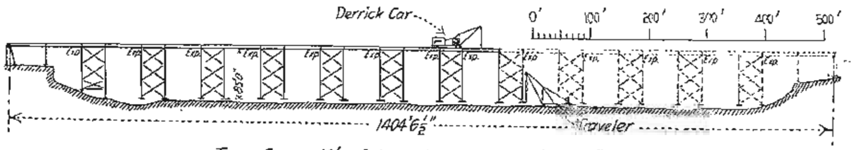


FIG. 1. 30-TON DERRICK CAR FOR BRIDGE ERECTION; CHICAGO, MILWAUKEE & ST. PAUL RY.



Tower Spans, 40' Intermediate Spans, 61' to 61'8"

FIG. 3. ERECTION OF THE COW CREEK VIADUCT BY A GROUND OR MULE TRAVELER FOR THE LOWER PORTION AND A DERRICK CAR FOR THE UPPER PORTION.

to move the trolley forward, the trolley being also under the control of the trolley tail line. One winch head man is required to operate each trolley tail line.

The trolley tail line leads from its fastening to the trolley, through two snatch blocks to a cavel on the deck of the traveler. In order to keep the trolley under control when it is being hauled forward by means of its own fall line, the tail line which is snubbed around the cavel is paid out at the required speed from the cavel. When the trolley is being hauled towards the rear of the traveler for another load, the trolley fall line and the trolley tail line are interchanged, the former being wrapped around the winch head to haul the trolley back, and the latter being snubbed around the cavel and paid out at the required speed. Each trolley tail line requires the entire attention of one man.

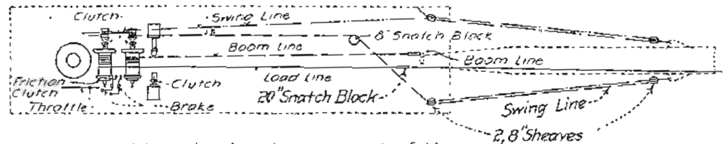
There are also two runner lines, each of which passes from the load to a snatch block fastened to a stump and leads from this block over the end of the traveler to the outside winch head of the engine, on which they are operated simultaneously with the swinging line. These lines are operated by one of the regular men on the traveler.

Six men have been enumerated in handling the lines, twelve men being required for both sides. Two of these men are available usually for handling signals, as they are not continuously engaged with their lines. A third signal man, with the assistance mentioned above, transmits all signals. This gives a total of 13 men on top of the traveler; 37 additional men were required to fill the crew for this work.

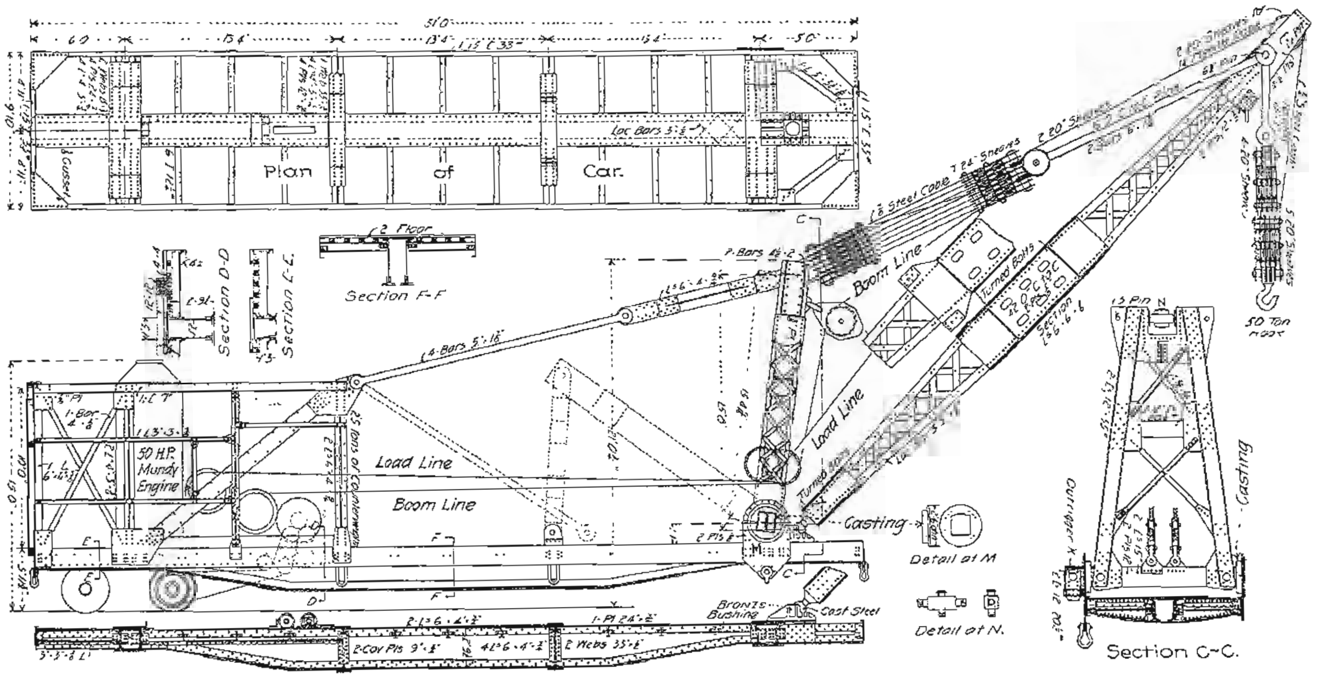
Fig. 7 shows all lines, in operation, in the erection of the 195-ft. tower of Clear Creek viaduct. The two booms are placing two columns with boom tackles No. 1 and No. 2; trolleys No. 3 and No. 4 are simultaneously placing two other columns for the same tower. Runner lines No. 1 and No. 2 are in service ready to outhaul these columns to their exact location. Trolleys No. 1 and No. 2 are lowering to the ground two loads of sway bracing, which will afterwards be picked up and placed in position by the runner lines No. 1 and No. 2, at present running to the stump and being used for outhauling. This illustration also shows a carload of columns which has been run part way through the traveler, which will be lifted from the car by the trolleys and lowered to the ground.

As shown, the traveler is employed to its maximum capacity and working 50 men. The viaduct, which is 210 ft. from base of rail to ground, partly on a 10° curve, was erected in 28 working days, by the forces of the Bridge and Building Department under the direction of Mr. F. J. Herlihy.

Fig. 7 shows also the Tekoa viaduct, on a new line, which was erected before the tracks reached its location. The material for this viaduct was delivered to the foot of an inclined tramway (25% grade), on which it was hauled up the hillside by means of hoisting engine and cable rove into a six-part tackle. Fig. 8 is a view of the erection of this viaduct by the traveler.



Plan showing Arrangement of Lines.



Elevation.

FIG. 4. 50-TON DERRICK CAR FOR BRIDGE ERECTION; CHICAGO, MILWAUKEE & ST. PAUL RY.

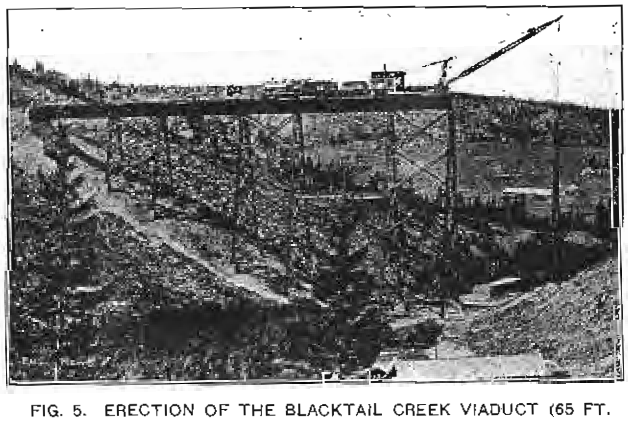


FIG. 5. ERECTION OF THE BLACKTAIL CREEK VIADUCT (65 FT. SPANS) BY A 50-TON DERRICK CAR WITH 80-FT. BOOM.

Tests of Iron Pulley Blocks.

Tests of triple-sheave blocks as used for tackle of this kind were made at the testing laboratory of the University of Wisconsin in 1908 by M. C. Withey. The blocks were furnished by manufacturers for the purpose of the test. The testing machine was a vertical hydraulic machine of 400,000 lbs. capacity. The blocks to be tested were pulled against a triple block designed in the office of Mr. C. F. Loweth, Engineer of Bridges and Buildings, and built at the railway shops at Milwaukee. Fig. 9 shows one of the test blocks and also the special or "Milwaukee" block. The construction of the test blocks differed in detail. The results of the tests are summarized in the accompanying table. This gives also the weights of the blocks. Part of the weight of the Milwaukee block was due to the use of 21-in. sheaves (instead of 13½ ins. to 16 ins. in the test blocks) to reduce the bending stress in the rope.

Block.	Weight lbs.	Breaking load lbs
1	277	148,000
2	275	151,000
3	225	86,500
4 (Fig. 8)	358	255,000
5 (Fig. 9)	350	258,000
"Milwaukee"	720	Not broken

Both blocks were rove together with ⅞-in. hoisting cable, the ends of the cable being fastened to the tail bolts of the upper and lower blocks respectively, by means of three clips at each tail bolt. The tension heads of the machine consisted of clevises with pins of large diameter, these pins passed through the clevises of the blocks to be tested. The load was applied gradually and continued until a cracking sound was heard or some indication of failure was seen or suspected. Then the load was released and the block was carefully examined for signs of failure. After several repetitions, the load was continued until the failure was complete. The "Milwaukee" block was in the upper head of the machine and in all cases the lower block failed, while the upper block remained practically intact.

Fig. 9 shows block No. 5, and Fig. 10 shows a view of block No. 5 after failure. The details of the tests of these two blocks are given below. [We omit the detailed description of test and failure of other blocks.—Ed.]:

Test of Block No. 4.—At 150,000 lbs., load was released; no sign of failure. At 170,000 lbs., load released; clearance observed below tail bolt; clevis scaling on inside; clevis pin bending. At 188,000 lbs., load released; clevis scaling all over; inside and outside straps scaling; inside strap moved down at least ⅛ in., mark seen at top of strap. At 208,000 lbs., load released; clevis pin easily seen to be bent. At 247,000 lbs., cotter sheared off on clevis pin on one side; head pin bending up. At 255,000 lbs., cotter on sheave pin sheared off on

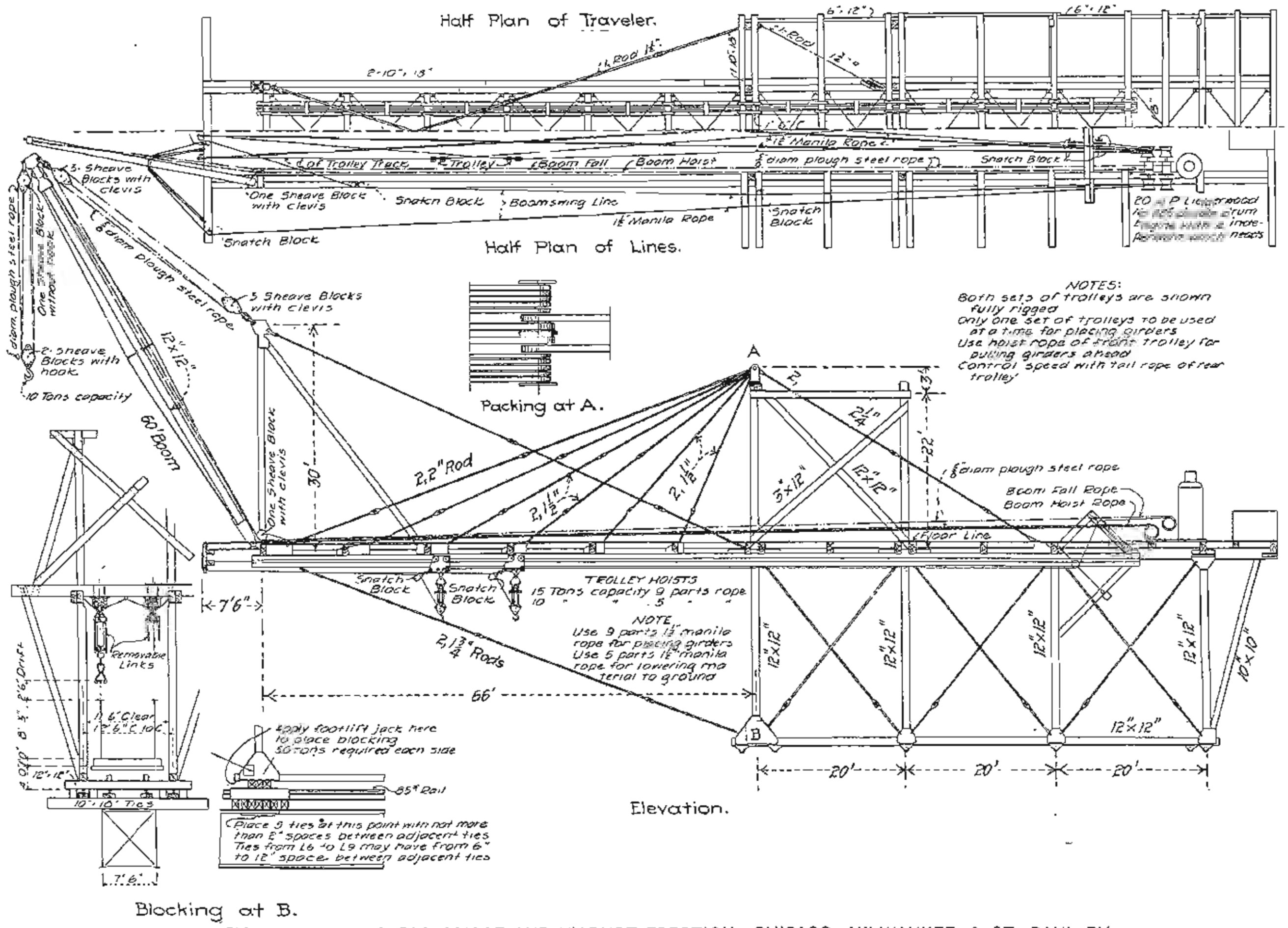


FIG. 6. TRAVELER FOR BRIDGE AND VIADUCT ERECTION; CHICAGO, MILWAUKEE & ST. PAUL RY.

one side, load dropped to 229,000 lbs. and block failed with loud report.

Test of Block No. 5.—(1) The block was pulled to 196,000 lbs., when the rigging in the testing machine broke. End of cable was fastened to outside segment of tail bolt. Tail bolt was bent in block where cable was attached. No other sign of failure noticed. (2) With cable undisturbed from first test, block was pulled again. At 235,000 lbs., clevis pin began to bend, causing block to skew upward on side where tail bolt bent. Pin hole in plates at clevis much elongated. At 255,000 lbs., ¾-in. tail bolt sheered off with a loud report. As only the tail bolt had failed where the cable was attached, it was thought advisable to put in a larger tail bolt and test the block to complete destruction.

(3) A 1-in. wrought-iron bolt was substituted, the holes being drilled larger in block. The end of cable was fastened at center segment of tail bolt. Load of 158,000 lbs. was applied and released; tail bolt was observed to be slightly bent. Maximum load applied was 258,000 lbs., after which load was released and block examined. Sheave pin badly bent, cotter broken off; both inside shell plates split; tail bolt bent upward; both inside shell bolts had moved upward ¼-in., due to bolts and sheave pin bending. Load was reapplied to get complete destruction. At 255,000 lbs. inside shell plates had raised ¾-in. and load began going back until about 178,000 lbs.; at this load block burst apart with a loud report. Just previously the inside shell plates had raised 1½ ins.

CANADA'S PORTLAND CEMENT PRODUCTION in 1908 was 3½ million barrels, an increase of a million over 1907. About 800,000 bbls. of this remained unsold, however. The average price at works was $1.39, against $1.55 in 1907. About half a million barrels was imported into Canada during the year. The production was from 23 plants, six more than were operating in 1907. However, this list includes one natural cement plant (listed as making "natural Portland cement"). One of the plants making artificial cement uses blast-furnace slag. The increasing production in Canada has reduced the imports very rapidly; five years ago more cement was imported into Canada than was made there, but since 1906 the ratio has been decreasing rapidly, until now the imports are only about 15% of the production. The import duty is 43¾ cts. per barrel (levied on gross weight, at 12½ cts. per 100 lbs.).—From figures given in a bulletin of the Department of Mines, by I. McLeish, Chief of Division of Mineral Resources and Statistics, Ottawa.

A TRAIN-FERRY between India and Ceylon has been authorized by the government of India. The South Indian Ry. has a line terminating at Pamban, on the straits, and opposite this is a series of reefs and channels known as Adams Bridge. Several projects have been proposed for a viaduct at this crossing, somewhat after the plan of the line from Florida to Key West. The present authorized project includes the extension of the railway across the Pamban Channel to Daneshkodi Island. On the Ceylon side, a railway will be built from Manar Island to the mainland of Ceylon and some point on the Ceylon Government Railways. The distance between the two islands, about 40 miles, will be served by the train ferry. This arrangement will avoid only one transfer, as the South Indian Ry. has a gage of 3 ft. 3⅜ ins., while the Ceylon Rys. have a gage of 5 ft. 6 ins., so rolling stock cannot interchange.

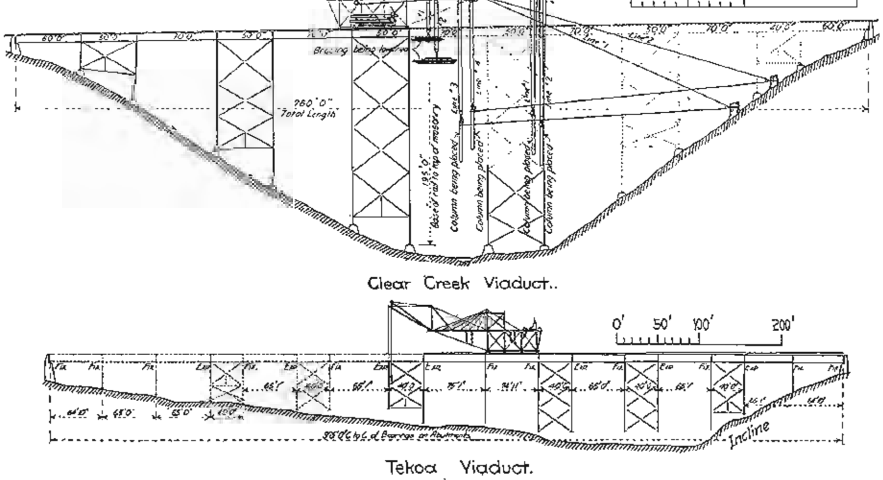


FIG. 7. METHOD OF ERECTION OF VIADUCTS BY TRAVELER.

Education for Utility and Culture.*

By DR. CALVIN M. WOODWARD.†

The early universities came into being as a part of the grand revival of learning which prevailed in Italy, Germany, France and England in the 14th and 15th centuries. They were the joint product of Protestantism and the art of printing. The former declared it the privilege of all to read the New Testament and the Fathers in the original Greek and Latin. The art of printing laid open to all the world all the treasures of ancient learning.

Oxford and Cambridge came into notice about the year 1300, and for some four centuries they were the recipients of repeated gifts and benefactions from the rulers and the nobility of England. As the universities grew the course of study slowly expanded. In the beginning they were largely Latin grammar schools for monks and priests. Even in Queen Elizabeth's time, Oxford was little more than a Divinity School. Undergraduates were 14 or 15 years of age and often younger. The "Trivium" leading to the degree of Bachelor of Arts consisted of Latin grammar, logic and rhetoric. There was no Greek until the time of Erasmus in 1511. Even a Latin version of Aristotle's Logic was used.

Having completed three years in the study and practice of dialectics, the student became a Bachelor of Arts and "incepted" or "commenced" the four years of lectics and philosophy; the quadrivium to more philosophy, perspective drawing, astronomy and Greek.

Such was the course of study that for centuries constituted the education of the youth of England who were destined to fill places in the church, to become barristers, physicians, or gentlemen of leisure. For such and such only was education supposed to be necessary.

In his famous Tractate of Education, written 24 years after the landing of the Pilgrims on Plymouth Rock, Milton wrote only for the rich and for those of noble birth. He advised the study of the poets, orators, historians and philosophers of Greece and Rome. There was little else to study. There was no science, for the speculations of Aristotle in regard to physics and the constitution of matter were unworthy of the name of science, though they blocked all scientific progress for over a thousand years. English literature did not exist. Modern mathematics is the product of the last 200 years. Milton himself followed in the track of Virgil, as Virgil had followed in the track of Homer. "Paradise Lost" was modeled after the Aeneid, and "Lycidas" closely resembles one of the "Bucolics" of Virgil.

Milton wrote and sang for the few. The great bulk of the English people, the farmers, the sailors, the miners, the tradesmen, the manufacturers, the builders of houses and ships, had no education and were supposed to need none. Popular, universal education, as we understand the term, is less than 40 years old in

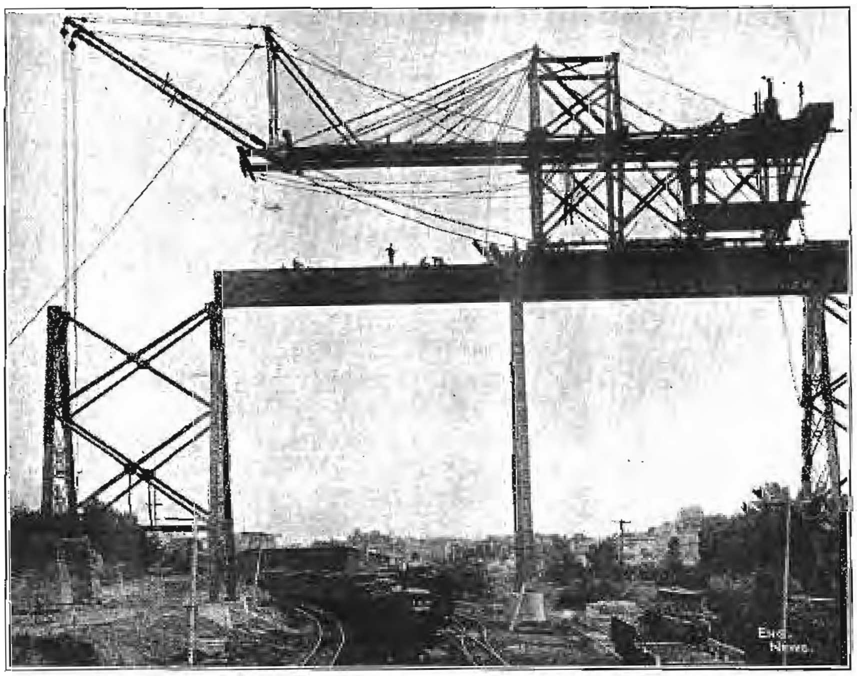


FIG. 8. ERECTION OF THE TEKOA VIADUCT BY A TRAVELER HAVING A 75-FT. CANTILEVER WITH TWO 60-FT. BOOMS (VIADUCT SPANS 70 FT.).

study of the "Quadrivium" which led to the degree of Master of Arts. The ceremony of Commencement took place naturally at the beginning of the fourth year, when the student received his first degree and entered upon the higher courses of study. The Master's degree was conferred at the end of the seventh year. You will observe that we have retained the name "Commencement" to mark the termination of the first course, and not at all to signify the beginning of the Master's course; and that the ceremony is held at the beginning of the summer vacation instead of at its end, as formerly.

The Quadrivium included: 1, arithmetic or the science of numbers (there was for 300 years afterward no algebra, no trigonometry, no analytic geometry, no calculus); 2, geometry, i. e., Euclid and maps, which included all the geography which was known; 3, music; 4, astronomy, as taught by Ptolemy.

No poets or orators were studied at Cambridge till the early part of the 16th century. Their introduction was due to Erasmus, who came to St. John's College in 1511. During the Chancellorship of Thomas Cromwell in the reign of Henry VIII., it was ordered that undergraduates should be instructed in logic, rhetoric, arithmetic, geography, music and Aristotle.

In 1549 the trivium was changed to mathematics, dia-

England. During all these years, while England was growing great, Cambridge and Oxford continued to build on the lines I have described. They had a monopoly of the education of the English ruling and property classes. No men trained differently were brought into competition with these men. Hence the claim, often made, that the greatness of England's great men is due to the fact that their training was classical rather than scientific is extremely illogical.

No one denies great intellectual value to ancient as well as to modern classics, but we have learned that men may be educated in more than one way; that the old road is a long road, a comparatively dull and uninteresting road; a road blocked up by dead issues, ancient ruins, over the graves of extinct nations, and through an atmosphere redolent with the air of antiquated myths. The classical period was a civilization of art and luxurious culture based on conquest and human slavery.

Such was the old university, and such in many institutions is the ideal to-day. But all such ideals must be classed with the ancients. It is their glory to be old, as though age in itself were a virtue.

I visited an endowed school in Manchester, England, a few years ago. It was hundreds of years old. It had its ancient halls, its ancient studies, its impassable fence, and its locked gate. But gradually its style of household furniture had become transformed. A modern kitchen, a new dinner service, carpets and chairs reminded one of modern life.

Then the craze for antiquity swept over the Board of Management and they decided to put the school back 200 years to the actual style of living in "the good old times." Out went the carpets, the cooking stove, the dining table; off went the table cloth and modern spoons and forks; modern chairs, napkins and plates. The pupils adopted again the ancient dress; they cooked on spits and behind tin ovens over open fires in huge fireplaces; they sat on benches without backs, at a rough oak table above a stone floor; and ate from pewter plates and drank from pewter mugs. Grace was said in Latin before and after meat. I assure you it seemed to me like a grand burlesque for the presentation of which a hundred little boys were being trained to act their parts.

In striking contrast with all this mockery of antiquity was a modern manual training room with the best of modern tools and appliances. This latter was the gift of an enthusiastic friend who thus redeemed and modernized the entire school.

Up to 60 years ago, the honors at Cambridge were awarded only in classics and mathematics. In 1848 two new "triposes," or honors, were established, viz., in Moral Science and in Natural Science. Then came the Law Tripos, the Historical Tripos, the Theological Tripos, the Semitic Language Tripos, the Indian Language Tripos, and finally, the Modern Language Tripos in 1886.

During the last few years, Mechanical and Electrical Engineering have gained a foothold in Cambridge and recently they have been placed on a permanent footing. A manual training shop has even secured recognition among the "modern side" people of Cambridge.

Higher education in the United States started on a somewhat different plan and it has had a very different development. When Harvard College was started, 260 years ago, it was a feeble imitation of one of the colleges of Cambridge University in England where John Harvard had been a student; but there was in every New England village a school where the rudiments of an education were accessible to all. In those days Harvard College was what would now be called a classical high school. It was pre-eminently a school for the preliminary training of clergymen and lawyers. It was Latin, Greek, mathematics, logic, rhetoric and metaphysics from first to last. The course of study had not changed in character very much when I was a student there 50 years ago, but a wonderful transformation has taken place since then.

The study of materials, the study of the laws of construction, the distribution of forces, the analysis and limits of internal stress, the transformation and utilization of energy; the study and use of exact methods and instruments of precision; the elements of drafting, shopwork, and the essential features of prime movers—all these studies have made this progress possible, and they promise yet greater progress, if the proper education is furnished.

We are at last beginning to understand that the education which is to be universal should be a very different thing from the education of a privileged few. The new education which dominates the modern colleges and universities aims to train men to high efficiency along all lines, practical and theoretical, as well as artistic and spiritual. The old procrustean bed on which all were stretched or trained to the same course of study has been banished, never to return. The characteristic features of the new university are freedom of choice and a thoroughly practical treatment of the chosen branches.

A university is a place where one should be able to study the best that has been said and done in the world. In our secondary schools one may acquire the rudiments of an education, may learn how to study, may become somewhat familiar with the breadth and scope of the object of study; but in the university he should directly attack the masterpieces of thought and achievement; should dip into the choicest and most invigorating springs and drink deeply.

From the days of John Milton, in 1608, to the end of the 18th century, university training culminated in a preparation for the professions of law, medicine and theology, and in the training of the nobility for the duties and responsibilities of government and elegant society.

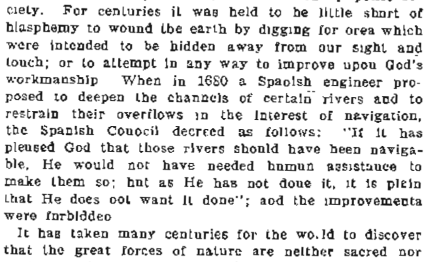
But when alchemy developed into chemistry; when physics became an experimental science, when Leibnitz and Newton elaborated the infinitesimal calculus; when Watts invented an efficient steam engine; when Fulton built a successful steamboat; when Stephenson devised the locomotive and constructed a road with smooth rails; and finally when Siemens and Gramme produced the electric motor—vast fields of fascinating and useful material were opened for study and research. Mathematical analysis and the principles of mechanics, which had previously been devoted to the problems of physical astronomy, were now directed to the study of the transformation and transmission of energy, the theory of structures, and the phenomena of electricity. The theory of evolution has given a new meaning to all vital phenomena; and the doctrine of the conservation of energy has permeated all our study of motion and force.

*An address before the graduating class of the Missouri School of Mines, at Rolla, Mo., June 8.

†Dean of Washington University Engineering Schools, St. Louis, Mo.

In the earlier days Alexander Pope voiced the popular notion that "the proper study of mankind is man." "Nature Study," which to-day is the bright attractive feature of the primary school, and equally the inspiring field of the savant, was not countenanced by polite society. For centuries it was held to be little short of blasphemy to wound the earth by digging for ores which were intended to be hidden away from our sight and touch; or to attempt in any way to improve upon God's workmanship. When in 1680 a Spanish engineer proposed to deepen the channels of certain rivers and to restrain their overflows in the interest of navigation, the Spanish Council decreed as follows: "If it has pleased God that those rivers should have been navigable, He would not have needed human assistance to make them so; but as He has not done it, it is plain that He does not want it done"; and the improvements were forbidden.

It has taken many centuries for the world to discover that the great forces of nature are neither sacred nor profane, neither kind nor cruel, that they neither love nor hate, and that they are more unchangeable than the stars, that shrines and temples, priests and priestesses, tripods and oracles have been in vain except so far as they reacted upon the human heart and satisfied



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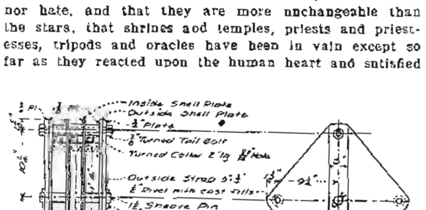

C.M. & St. P. Block.

Fig. 9. Pulley Blocks for Derrick Cars.

its natural craving for the worship of a Superior Being. Instead of building a temple to the far-darting Apollo or to Zeus the Thunderer, we now stretch over our cities a net-work for artificial lighting; and all the winds that blow and all the waters that flow are made to furnish their tribute to our comfort and pleasure. We tap the sources of endless energy and transmit it through all the ramifications of our social order, relieving mankind from heavy burdens and creating hundreds of occupations hitherto all unknown.

Out of all this vast extension of the horizon of human activities, and this multiplication of occupations, has come an imperative demand for technically educated men. In our industrial system the crying want has been and is for men who can both plan and execute. The secret of our recent success in foreign markets lies in the fact that we have put educated brains into our products and into our methods of manufacture. Hence a score of professions unthought of 100 years ago have been called into being, and the standards of these new professions are intellectually not one whit lower or less humane than the old.

Our best preparation for the future is a mastery of what has already been achieved. Our undergraduate period should be devoted to the study and mastery of established truths and accomplished facts, as embodied in language, literature, and the achievements in the arts and sciences. As Matthew Arnold put it: "The student should study the best that has been said and done in the world." I like Arnold's statement exceedingly, if I can only make it broad enough to include the wonderful results of applied science during the last hundred years. I am one of those who believe in progress, in the superiority of our own age. I regard the conquests over matter and force through intellectual processes of the highest order, as among the best things that have been done in the world, and I include what has been discovered and well established in the realm of natural history and applied art, as well as in the realm of ethnology and sociology. The world has been slow to accept the dignity of a scholarship for service. The old idea of culture was not that which enables one to accomplish something for others, but that which was valued for what it was supposed to accomplish for one's self—as Emerson puts it.

It is interesting to note how strong and enduring has been the prejudice against any scholarship that was suspected of being useful. Among the Greeks and Romans of the classic period, it was held to be not only undignified but ignoble to personally provide food, clothing and shelter for one's self or for one's family. The educated man must not build his home, nor even plan it. He must neither cultivate crops nor cook his food; neither manufacture cloth, nor make garments. All such work was for slaves, white, black or yellow.

It was the business or occupation of the gentleman (who alone received any education), to manage his family (including his slaves), fight for his country whether for conquest or for defense, cultivate art, poetry, athletics, mathematics and logic. Even Plato considered geometry as degraded by being applied to any purpose of vulgar utility. He declared that the construction of machines on mathematical principles was reducing a noble intellectual exercise to a low craft, fit only for carpenters and wheelwrights; i. e., for the white slaves of Athens. He held that the science of mechanics was unworthy of the attention of a philosopher. For nearly 2,000 years the brightest minds of Greece and Rome scorned utility, and they discouraged all studies which aimed "to add to the comfort or alleviate the calamities of the human race."

Macaulay says (in his Essay on Bacon) that Seneca was indignant because Democritus was praised for having invented the arches which supported the roof of a temple. He maintained that philosophy has nothing to do with teaching men to rear arched roofs over their heads. The true philosopher, he said, does not care whether he has an arched roof, or any roof. Philosophy has nothing to do with teaching men the use of metals. She teaches us to be independent of all material substance, of all mechanical contrivances. Instead of attempting to add to the physical comforts of his species, Seneca regretted that his lot was not cast in that golden age when the human race lived in caves and dressed only in the skins of animals. To impute to such a man any share in the invention or improvement of a plow, or a mill, is an insult. "In my time," says Seneca, "there have been inventions of this sort, transparent windows, tubes for diffusing warmth equally through all parts of a building, etc., but the invention of such things is drudgery for the lowest slaves. Philosophy lies deeper. It is not her office to teach men how to use their hands."

Bacon sets out deliberately to overthrow the influence of Greek philosophy as regards usefulness, and with unequaled force and skill proclaimed the dignity and nobility of useful studies, and of service to humanity. I feel sure that the spirit of service through the discovery and presentation of scientific truth lives and thrives, and that nevermore will it be necessary, at least in America, for a man of science to apologize to the world for making his discoveries and inventions useful to mankind.

We have been told that engineering studies and pursuits make men sordid and narrow. The statement is not true. It is true that such studies make one feel the weight of coming responsibilities, as well as the absolute necessity of mastering fundamental principles. Engineering students rarely feel at liberty to burn their old text-books. They have been thought to be somewhat lacking in reverence, and unpoetical. I must confess they are generally not given to the worship of the ancients, but they are not without poetic instincts.

Do not for one moment suppose that all knowledge is contained in books, or that all art is to be found in museums, or that all poetry is written with pens. To a mind filled with a sympathy that is born of intimate knowledge, there is in a mighty moving mechanism, and in the proportions and grandeur of a great superstructure that obeys all the laws of science, a beauty that delights the eye; a harmony and bond of thought, a rythm and rhyme of reason that falls upon the inward ear like heavenly music.

The problems of engineering are not all solved. In fact the work of solution has but just begun. There is plenty for you to do as you step from the lecture room and laboratory to take up the responsibilities of educated, well-trained men. The best thought of to-day is that the wealth of nature is not to be squandered and wasted. Our natural resources are to be conserved. We are to be not only husbandmen, but thrifty husbandmen. Is there any doubt about the worth of your product? The price of wisdom is above rubies. Solomon prayed for a "wise and understanding heart," and his prayer was granted. A wise and understanding heart means more than scholarship, more than manual skill, more than technical acumen, more than wealth, more than popularity. It may include all these, it must include several of them—it must include high character, an unspotted life, a devotion to what is true in form and in essence, a consecration to service:

. . . "I pray thee then—
Write me as one who serves his fellow men."

I wish you personal success in a very high sense, and to that end I wish to impress upon you two things. I do not mean that you should study your work, go to the bottom of every problem you have to solve. You will do that anyway, if you are made of sound material capable of intense stress and a high elastic limit. The two things I emphasize are these:

(1) An inflexible determination never to endorse what you believe to be bad engineering. Let the temptation be ever so great, the bribe ever so fascinating, stand like a rock. Let the wind blow, let the rain descend! stand your ground! Some years ago I wrote in an album as a "Maxim for Conduct":

"In matters of sentiment, go with the stream; in matters of principle stand like a rock." Carry that away with you.

(2) Cultivate the graces and refinements of really good society. Acquire (unless you have it already) a perfect mastery of your mother tongue, and in leisure hours make yourself familiar with the masterpieces of literature and art. For ten or twelve years the late Professor John B. Johnson and I were members of a Fortnightly Club that studied the books which were well worth studying and discussing, from Homer to James Russell Lowell. Professor Johnson felt, and I feel, that those hours were full of the greatest profit and the keenest pleasure. Your influence in the world and the pleasure of your life will depend partly upon your engineering skill, but more upon your manners, your speech and your breadth of culture. Too often in the past the engineer has been associated in the popular mind with a smoky chimney, greasy machinery, and bad English. Accordingly a recent writer in urging a more generous course of study for technical students, says: "It will be a sorry epitaph, that one was born a man, and died an engineer." Let your epitaph be: "Here lies one who was born a common man and who died a great engineer."

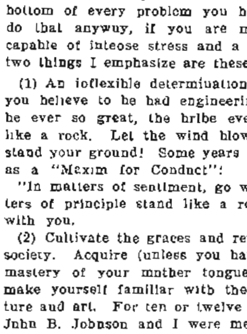

Fig. 10. Failure of a Pulley Block Tested to Destruction in a Testing Machine.

One word more. You are to be not only engineers and cultivated men—you are to be citizens. As already hinted, you are to serve your fellowmen. You are to combine Utility and Culture in Service.

We live in a new world, under the light of a new civilization. Our institutions are not founded or buttressed by human slavery, white or black; might no longer makes right; the burly robber of the Middle Ages is no longer our ideal of a good citizen. We are as certain of the Brotherhood of man as of the Fatherhood of God.

Bloody war is being relegated to the past; our ideas of heroism and manly nobility are not to be found in the prize ring or in the arena; they are to be found in the performance of the many duties of citizenship. Fellowship and not warfare should be our motto. Cooperation rather than hostile competition should be our practice. It is a glorious thing to help solve problems in such a way that every solution leads on to a higher civilization. Let us tear down the walls which separate nations one from the other, let us dismantle the forts, disband the army, and let us among ourselves lay aside warfare and adopt the methods of brotherhood. It is yours to help on the happy age when Science and

"art shall flourish,
And knowledge shall grow to more and more,
And all men shall be brothers,
And the most useful shall be the most beautiful,
And "Service" shall be the watchword,
The key that shall unlock the gates of Paradise."