THE SUN A SOURCE OF POWER.

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When we watch a gentle summer rain, does it ever occur to us that this familiar sight involves the previous expenditure of almost incredible quantities of energy, or do we think of a drizzly day as perhaps calling for a greater exertion of Nature's power than an earthquake? Probably not; but these suppositions are both reasonable.

Take Manhattan Island, for instance, which contains 20 square miles, and on which one year with another over 30 inches of rain falls. (To be within the mark we will call the area 20 miles, and the annual rainfall 30 inches.) One square mile contains 640 acres, and each acre 43,560 square feet. Multiplying by 640 and dividing by 12 we have 2,323,200 as the number of cubic feet of water on 1 mile in a rainfall of 1 inch, and as a cubic foot of water weighs $997\frac{137}{1000}$ oz. avoirdupois, and there are 35,840 oz. to the ton, this weighs $\frac{2{,}323{,}200 \times 997\cdot137}{35{,}840}$, or, in round numbers, 64,636 tons (to 1 mile and 1 inch of rain). As there are 20 miles and 30 inches, the annual rainfall on this little island is 1,393,920,000 cubic feet, or 38,781,600 tons. The amount of this may be better appreciated by comparison. Thus, the pyramid of Cheops contains less than 100,000,000 cubic feet and weighs less than 7,000,000 tons, and this water, then, in the form of ice, would many times replace the largest pyramids of Egypt. If we had to cart it away, it would require 3,231,800 cars carrying 12 tons each to remove it, and these, at an average length of 30 feet to the car, would make 6 trains, each reaching in one continuous line of cars across the continent, so that the leading locomotive of each train would be at San Francisco before the rear had left New York—a result which appears at first so incredible that it seems best to give the figures on which we rest the statement.

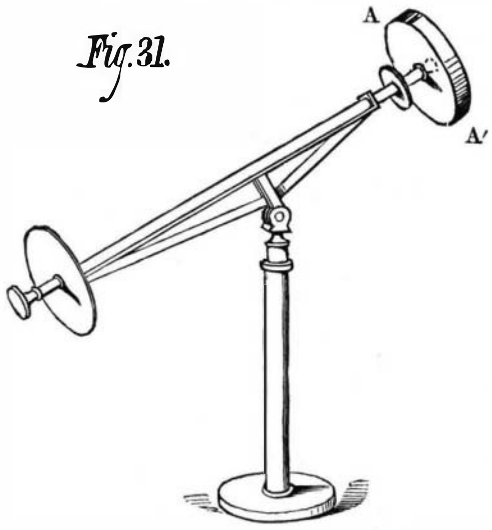
Now this is for a very small part of a single year's work of the sun in raising water to produce rain on the little spot of Manhattan Island alone—a spot, geographically speaking, hardly visible on the map of the country. Again, $\frac{1}{10}$ of an inch of rain spread over the whole area of the United States is not an extraordinary day's rainfall throughout its territory, but it will be found by any one who wishes to make the computation that such a day's rain represents a good deal over the round sum of ten thousand of millions of tons, and that all the pumping engines which supply Philadelphia, Chicago, and our other large cities, dependent more or less on steam for their water supply, working day and night for a century, would not put it back to the height to which it was raised by the sun before it fell. Every ton was lifted by the silent working solar engine, at the expense of a fixed amount of heat, as clearly as in the case of any steam pump, and this is the result of an almost infinitesimal fraction of the heat daily poured out from the sun! Now heat is something men have only in quite modern times learned to think of as a measurable quantity, and we must remember that we cannot even begin to have accurate knowledge of any form of force till we can answer the question, "how much" about it, not vaguely, but in figures.

When we hold the right hand in warm water, the other in cold, for a few moments, and then plunge both in the same basin of tepid water, the two hands will give different reports; to the right the fluid is cold, to the left it will feel warm, though it is the same really to both, and we might vary the experiment by trying it with shade and sunshine. In either case the experiment would convince us that our sensations were very untrustworthy, and that if we were going to measure the sun's heat we must depend on some sort of instrument and not on anything that can feel. The first thing we have to do about the sun's heat is to measure it, not to guess at it; to measure it as accurately as we would anything which we could try with a foot rule or put in a pair of scales. When we have done this we have a solid foundation to work on, and the doing this has been thought a worthy occupation of a considerable part of their lives by many able men.

One of the first of these was Pouillet; others, such as Saussure and Herschel, had been at the problem before him, but his results were the most accurate until very recently, and even recent work has not materially affected his conclusions.

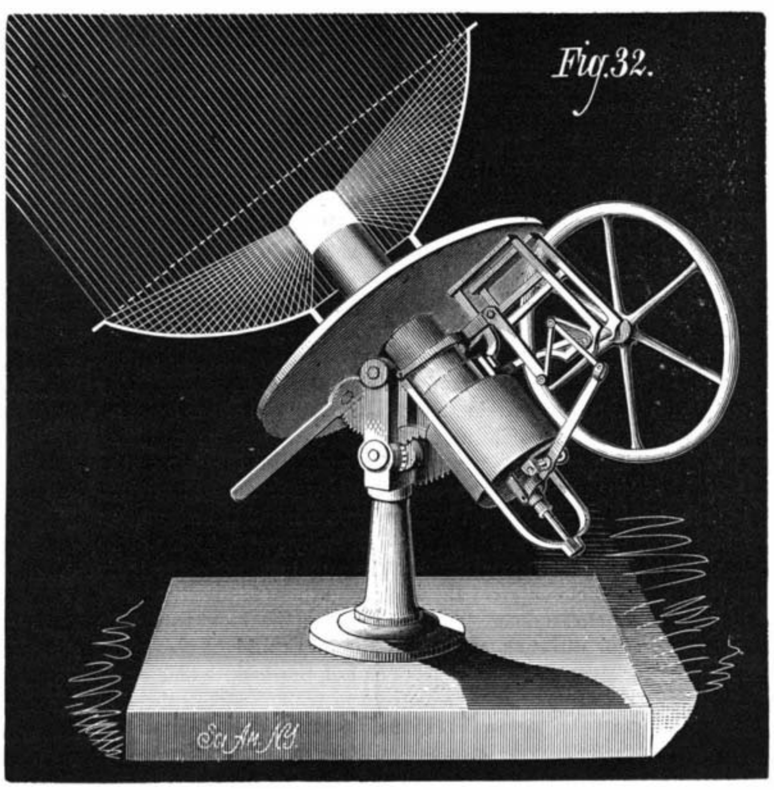
His instrument is easily understood with a little attention. We have it represented in Fig 31. Let us first remark, that what we want to get is the sun's direct or radiant heat, quite irrespective of that of the atmosphere around us, and that to get definite results, by our present method, we want to know how much of this radiant heat falls on a given surface of one square foot or yard. We may reckon it by any one of the numerous effects heat produces; practically it is convenient to let it warm water, and to see how much it heats, through how many degrees, and in how many minutes.

Pouillet's pyrheliometer is substantially nothing but a very shallow cylindrical box, A A', filled with a measured quantity of water. It is mounted on the end of a hollow rod, having at its other extremity a metal disk of the same size as the water box. When the shadow of the box exactly covers the disk the instrument is pointed true on the sun. Held in the hollow rod is an inverted thermometer, whose bulb is within the water box, A A'. This enables us to read the temperature of the water from moment to moment. It is not enough to expose it for a time to the sun and read the thermometer—this would give too small a result, because the instrument as soon as it is warmed commences to radiate the heat away again, like any other hot body; and we would

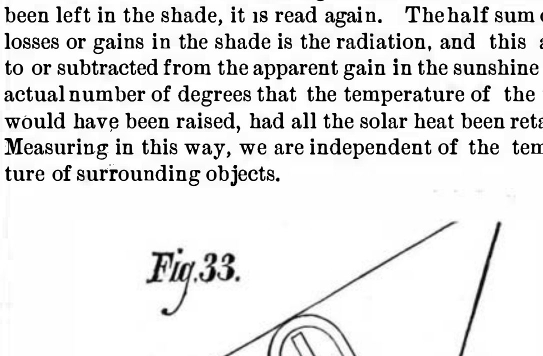


THE PYRHELIOMETER.

like, if we could, to keep all this heat in it to measure. As we cannot, we reach the same result by finding how much is lost, and allowing for it. Thus, the observer first leaves the apparatus in the shade (for instance) five minutes, and notices whether it loses or gains from its own radiation to surrounding objects. Then he leaves it directed to the sun, which shines full on it for five minutes more, the thermometer being read at the end of this exposure; and finally, at the end of another five minutes, during which the instrument has been left in the shade, it is read again. The half sum of the losses or gains in the shade is the radiation, and this added to or subtracted from the apparent gain in the sunshine is the actual number of degrees that the temperature of the water would have been raised, had all the solar heat been retained. Measuring in this way, we are independent of the temperature of surrounding objects.



ERICSSON'S SOLAR CALORIC ENGINE.



Mr. Ericsson, the celebrated engineer, who has improved on Pouillet's apparatus, has in fact shown that we do in accurate experimenting always get more heat (other things being equal) on a day in winter than in summer, as we should, if it is the direct solar radiation alone we are after; for that will be the greatest when the sun is nearest, as it is in our northern winter. Again, measuring when the sun is high, and at all altitudes down to the horizon, we find less and less heat, as the rays go through more of our atmosphere, and hence we can make a table showing how much this absorbs for every altitude, and consequently how much we should gain if it were taken away altogether. When this is done we find, according to Mr. Ericsson's late determinations (which we substitute for Pouillet's), that the direct heat of the sun on 1 square foot in March is competent to raise 7·11 pounds of water 1° Fah. in one minute. This is what it would do if we got outside of our atmosphere; but owing to the absorbing action of this, the radiation which actually reaches us, under a vertical sun, will so heat only about 5·6 pounds. According to the mechanical theory of heat this effect is that which would be required to drive an engine of $\frac{5\cdot6 \times 772}{33000} =$ 0·131 horse power. In other words, the heat of a vertical sun after absorption by our atmosphere represents rather over one horse power to each square yard. It is true that we cannot always have a vertical sun, nor clear sky, nor can we realize in actual work this whole effect by any form of engine, but when we have made the largest deductions, the statement of the sun's power, in this form, is calculated to excite astonishment. We have here, since there are 5,280 linear feet in a mile, $5280^2 \times 0.131 = 3{,}650{,}000$ horse power to the square mile (in round numbers); so that if we suppose in actual practice one horse power realizable to ten square yards the efficient working power of sunlight on an area much smaller than such a region, for instance, as the Adirondacks, is much greater than that of the computed actual steam power of the whole world. Upon the surface of the whole earth the heat at any time must be equal to that falling vertically on one of its great circles, which contain, roughly, about 50,000,000 square miles. Here, when we come to multiply the number of miles by the power per mile, we reach figures bewildering in their magnitude, but which are demonstrably correct. The only way this heat is utilized by conversion into power at present (steam power being dependent on coal made by the sun in past times) is by windmills and water wheels, both supplied by the sun, as in fact is every form of power, unless we except the insignificant one of tide mills, a kind only in a very remote degree dependent on solar action.

The student must be referred for the more indirect but equally certain action of the sun in providing the coal by which our engines are driven to special treatises (the popular one on "Heat" by Tyndall is a good introduction to the subject for the general reader), but this stock of coal is by no means unlimited, and in the course of a few centuries at most it will be exhausted in Great Britain, for instance, at the present rate of consumption. We may depend that long ere that time her engineers will with those of other countries, be turning to the immense source of power in the sun's direct rays, and that regions now barren under a tropical sun, where there is no fuel, water, or scarcely human life, will rise into new importance as the proper seats of industry, fed by the new power.

Engineers have hitherto done little for this, but we may be sure they will in the future do more. We are not writing a historical article, and, merely mentioning the curious fact that Solomon de Caus, the unhappy man of genius whose connection with the history of the steam engine is so well known, was one of the first to invent a solar engine, we pass over much that is historically interesting, to come to the present. Mr. Ericsson, whose work we have already quoted, is understood to have given a large part of his life, and particularly of his late years, to the problem. Fig. 32 is a drawing of a solar hot air engine of his invention, which is said to make 400 revolutions per minute. This is probably to be considered rather as an illustration of the feasibility of the instantaneous conversion of solar heat into power than as a useful form in practice, the circular mirror not being adapted for work on a large scale. The inventor, however, at present has not published the dispositions he is understood to have made for concentrating the heat in a larger working engine.

In France, M. Mouchot has, for many years, been pursuing similar studies; a section of one of his machines is shown in Fig. 33. This has the inconvenience of a very large heat reflector in a form which is expensive and liable to injury, but it must be remembered we are now feeling our way in the first steps of invention in his new field. Such things are, in one sense, but mechanical toys at present; but it was such toys as Hero's æolipile which preceded the steam engine. These are already more than mere toys, however, and in their promise, if not in actual performance, worth attention. If the reader wishes to know what is the best so far realized, or at least so far made public, we may refer to the *Comptes Rendus* of the French Academy of Sciences for October 4, 1875, where M. Mouchot states that he now employs a metallic mirror with a linear focus, in which focus is the elongated boiler he uses, and that he also makes use of a glass cover to let the solar radiation pass, but to retain the obscure heat re-radiated from the boiler. In the largest machine actually built, he employs, however, a mirror in the form of a truncated cone, Fig. 33, about 10 feet in diameter at its large, and 40 inches at its small section, looking like a mammoth lamp shade, with its concavity directed skyward. The material is copper, coated inside with silver leaf. A large bell glass covers the boiler, which is about 32 inches long. The whole apparatus can be made to follow the sun. On May 20, in ordinary weather, 20 liters of water at 20° C. were let into the boiler at 8 : 30 h., and rose to 121° (two atmospheres) in 40 minutes, and then rapidly to 5 atmospheres, beyond which, owing to the slight nature of the apparatus, it was not thought safe to go. On the 22d July, at about 1 o'clock, under uncommon heat, the apparatus vaporized 5 liters of water per hour. The inventor claims that under favoring circumstances, he actually realizes about 10 calories per minute per meter, which is a trifle less than one horse power to ten feet square. Something exceeding this might probably be reached with the same apparatus in a drier air; upon the whole we are justified in speaking of one horse power to the square of ten feet on the side, as actually realized; one horse power to one square yard being about the limit of that which is theoretically realisable.

It must be remembered that, according to what has been stated, the sun offers us a source of power which is practically infinite both in amount and duration. According to what we believe we know with assurance, we can say that the sun is not a fire, fed by any fuel, but a glowing gas ball, maintained at an enormous temperature, and radiating enormous heat from a fund of energy maintained by the contraction of its volume, and by the impact of meteoric bodies. We can reckon with confidence that there will be no material diminution of its supply from these sources for a duration only to be reckoned by hundreds of thousands of years. As to the amount of heat supplied, it is inconceivable. The writer has made a computation of the time all the coal of the world would suffice to maintain the sun's radiation, were the actual source of it to fail, and were our whole supply of coal transported to its surface and burned there in its place. The result, otherwise stated, is that in any one second the sun radiates into space an amount greater than could be made good by totally consuming all the known coal beds of the world!

Something like 300 years separates the England of to-day, with her countless furnaces and engines, from the England of Elizabeth, in whose reign the spinning wheel was almost the most intricate piece of machinery on the island. Something like 300 years more, it is said, is all that separates the England of to-day from the future England whose furnace fires will have died out with the flame of the last bushel of coal under her surface; whose harbors send out only sailing craft; whose manufacturing population has gone to other lands, and whose "black country" is growing green again as Nature covers the ashes of her burnt-out mineral wealth with new verdure for the few who remain on the soil. We do not pretend ourselves to join in such pessimist views, or try to look into the future so far, though this is a very little way compared with what we know of the rise of man to civilization. To us, in this country, such a time, if it is ever to come, is immensely distant. But what is certain is that if some such change do not take place it will be through the discovery of a new source of power, for of the old, the coal, when our underground supply is used up we cannot get any more. Let us remember, then, in time, that though the stock be great there is no renewal.

For a journal counting among its readers so many interested in the applications of power as the SCIENTIFIC AMERICAN, I have thought, elementary as this presentation of the sun's claim to interest, merely as a source of mechanical power, is, it is better to offer it. We are, in closing, led back to the suggestion with which these articles began, of the sun's influence in altering the conditions of existence for the human race.

Future ages, it has been truly enough observed, may see the seat of empire transferred to regions of the earth now barren and desolated under intense solar heat—countries which, for that very cause, will not improbably become the seat of mechanical and thence of political power. Whoever finds the way to make industrially useful the vast sun power now wasted on the deserts of North Africa, or the shores of the Red Sea, will effect a greater change in men's affairs than any conqueror in history has done, for he will once more people those waste places with the life that swarmed there in the best days of Carthage and of old Egypt, but under another civilization, where man no longer worships the sun as his god, but has learned to make it his servant.

A SHIP RAILWAY AT PANAMA.

In a letter to the *Tribune*, Capt. Jas. B. Eads proposes a ship railway instead of the contemplated ship canal across the Isthmus of Panama. He says:

The Isthmus Canal Congress, recently held in the city of Paris, has presented to the civilized world all the results of the various surveys and estimates which have been thus far made. I believe in the effort to overcome the great barrier interposed by the American Isthmus to interoceanic navigation.

The fact that the congress comprised among its members many of the most able and distinguished engineers and scientists in Christendom is at once an assurance that its estimates and opinions are entitled to the highest respect. From these it appears that the most economic solution of this great question by means of a canal must involve the expenditure of at least $140,000,000, and possibly much more, and that the execution of the work will occupy from fifteen to twenty-five years from the time the work is commenced. These facts justify the conclusion: 1st, That the amount of capital required is so vast that it will not pay to execute the work with private means alone. 2d, That the amount cannot probably be obtained unless the governments of the several maritime nations directly interested in the work can be induced to contribute liberally in aid of the enterprise. 3d, That the time required for consummating the work is so great that the enjoyment of the completed canal must necessarily be reserved to the next generation.

In view of these facts, is it not wise to carefully consider other engineering expedients which have been or which may be suggested for the transportation of ships and their cargoes across the Isthmus? It is, as I am informed, recommended by the Paris Congress that the Isthmus be cut down below the level of the two seas to such a depth as is needed for the passage of ships from sea to sea, and thus avoid the use of locks in the canal. To do this involves the construction of a tunnel four miles long through the Cordilleras, of such dimensions that the one under Mont Cenis dwindles into insignificance when compared with it. This method has been justly termed "the heroic treatment." The term, however, is not limited in its application, and suggests similar treatment to the Panama Railroad, or to some other road which may be constructed for transportation of the largest ships with their entire cargoes overland from ocean to ocean.

My own studies have satisfied me of the entire feasibility of such transportation by railroad, and I have no hesitation in saying that for a sum not exceeding one-third of the estimated cost of the canal, namely, about $50,000,000, the largest ships which enter the port of New York can be transferred, when fully loaded, with absolute safety across the Isthmus on a railway constructed for the purpose, within twenty-four hours from the moment they are taken in charge in one sea until they are delivered into the other, ready to depart on their journey.

HOW SPEED MAY BE RAISED.

On such a railway across the Isthmus there need be no grades steeper than those on our chief lines of railroads, and the road bed need not be over forty feet wide, nor have more than eight or ten rails laid upon it to sustain the car or cradle upon which the ship is placed. The vessel should be lifted from the sea to the level of the road by a lock or by other well known hydraulic devices, and placed upon a car or cradle of ample strength to sustain the vessel with her cargo without the possibility of injury. The lock should be twice the length of the ship, and only one-half of its length should be deep enough to receive the ship from the sea. The bottom of the other half of the lock should be at the sea level, and on this the railway should commence. Into this upper part of the lock the cradle to carry the ship should be run, and the gates at the land end should then be closed. The ship should then be floated into the deep end of the lock and the sea gates closed, after which water should be admitted to fill the lock to a height sufficient to float the ship on the car in the upper lift, after which the water should be drawn off and the gates of the land end opened, and the car and its burden be then started on its journey by rail. At the other end of the road the car should be run into a similar lock, the gates closed over the track, and those at the sea end of the lock closed also. This being done the lock would be ready for filling, after which the ship could be floated off the car and moved to the deep end of the lock. The water would then be allowed to escape from the lock, the ship lowered to the ocean level, the sea gates opened, and the vessel would then be ready to resume her voyage in the other sea.

Another method of transfer between the sea and the railway, equally practicable and perhaps less expensive, would be to have a platform of iron of sufficient strength to support—first, a portion of the railway; second, the car or cradle to receive the ship; and third, the ship itself. This platform should be supported on each side by a row of large iron columns sunk into the bottom of the harbor and extending up above water to receive the hydrostatic cylinders with which the platform would be raised and lowered. By this hydraulic apparatus the platform should be lowered to a depth sufficient to permit the ship to be floated in over the railway car on the platform, after which the hydrostatic presses would lift platform, car, and ship, until the railway track on the platform would correspond in height with and form an integral part of the railway extending across the Isthmus. The platform I have thus briefly endeavored to explain would simply be a huge elevator on which the terminus of the railway would be laid. Of course such an elevator would be constructed in a harbor at each end of the railway. The purpose of such elevators would be to lift the ship out of the sea at one end of the route, and lower it into the sea at the other, and thus avoid using a steep grade into the sea like the marine railways which are seen in almost every navy yard. Many ships are very long, and any change of grade would have a tendency to strain them. Any perceptible change of grade must, therefore, involve devices to prevent such straining, and these devices it is desirable to avoid. For the same reason, curves in such a railway should be avoided. If a change of direction be absolutely necessary, it can be managed by a turn-table at the locality where a change of alignment is desirable. The avoidance of curves would greatly simplify the construction of the car on which the ship is to be transported. This car would probably be formed by joining several separate sections together, according to the length of the ship. Each separate section would probably be 100 feet long and be supported by about 200 wheels, some of which should be drivers, actuated by propelling engines. Rubber or steel springs should be interposed between the axles of the wheels and the car. Each section of the car or cradle that carried the ship would really constitute a locomotive. The propelling engines would be placed on each side, and at such a height as to prevent submergence when the car would be sunk on the elevators or in the locks. The weight of the largest merchant steamers and their cargoes would not exceed 10,000 tons, and such a one would be carried on a cradle composed of five such locomotives. These would have about 1,000 wheels, bearing on eight or ten rails with a pressure of about twelve tons to each wheel. This is only twice as much as the pressure on the rails under the driving wheels of the locomotive of an express train. The total weight of ship, cargo and cradle would be distributed over an area of road bed 40 feet wide by 500 feet long, and would be only 1,200 pounds per square foot, allowing 2,000 tons for the weight of the car. This is not half the pressure on the earth under each tie when each pair of the driving wheels of an ordinary locomotive passes over it.

GREATER SPEED THAN IN A CANAL.

On moderate grades an ordinary freight locomotive will pull about fifty loaded cars from fifteen to twenty miles per hour. The weight of the cars and their load is about 1,000 tons, and this is carried on about 400 wheels. Hence the largest ship and her entire cargo should not require more than the power of a dozen such locomotives to move it at the same speed over similar grades. From this it must be evident that the ship once safely placed on a properly constructed car, adjusted to the railway of a substantial and well-ballasted road-bed, can be moved with certainty and ease at a much higher rate of speed than would be safe in the very best canal that has been proposed. I would, however, not expect to use a higher rate of speed on a ship railway than eight miles per hour.

The practicability of lifting the heaviest ships out of water with perfect safety on cradles adjusted to receive them is illustrated in every dock-yard in the country, and one of the methods I have referred to as being a huge hydraulic elevator, has been put to a practical test. A dry-dock was constructed upon this principle in England a few years ago, and sent to the East Indies, by which ships placed over a platform sunk to receive them are lifted vertically out of water by hydraulic pumps.

Of course, the works and devices required for the successful operation of a ship railway should be of the most substantial character, and the elevating machinery should be of such strength and power as to make the transfer of the ship from the railway to the sea, and from the sea to the railway, a matter of perfect safety and dispatch.

The actual cost of operating such a railway would be, I think, considerably less in proportion to the tonnage moved over it than that of the most successful railway line in this country, for the reason that the tonnage carried would be handled by machinery exclusively, and the ratio of paying cargo to non-paying weight would be much greater. The cost of maintenance in proportion to the tonnage carried should be much less also. This result may be safely anticipated, because the railway would be very substantial and durable, and very short compared with the magnitude of the tonnage carried; the machinery would also be very simple in character, and the ratio of cost of maintenance to gross receipts would therefore be proportionately reduced. But even if we assume that the operating expenses and maintenance be equal to one-half of the gross receipts, it will be seen that a ship railway will be a much more profitable investment than a canal, even if it cost half the price of the canal, whereas it should not cost more than a quarter as much. The gross receipts must be the same in either case, and the railway can be completed in three or four years, while it is safe to assume that the canal will require five times as long. The interest on the canal investment before completion would therefore be enormously greater than that on the railway. A single track railway, with provision for side tracks to enable the cars to pass each other at proper points on the road, would, I think, be ample to meet the demands of commerce at the Isthmus for many years to come.

The California Codfish Trade.

The following facts and figures with regard to the codfish trade of the Pacific Coast are given by the San Francisco *Alta*. The four firms engaged in this industry employ nine vessels. An ordinary catch for this number of vessels is 1,000 tons, and they carry from San Francisco 800 tons of salt to pack the fish for the return voyage. The season commences about March 1 and closes October 1. The fish are caught off the Alaska coast and Choumagin Islands on the American side, and in the Ochotsk Sea on the Asiatic side, where the fish are taken with hand lines, while trawls are exclusively used on the banks near the Alaska shore. Each fisherman has a dory to himself, and tries hard to make the best catch in the fleet. The hand line fishing is quite exciting, and the men take to it like sport. When the fish are hauled on board from the boats they are at once cleaned and packed in frames in the vessel's hold, a thick layer of salt on each layer of fish. At the close of the season sail is made for San Francisco, and here the fish are washed, soaked in brine, and dried for market.

U. S. FISH COMMISSION.—The headquarters of the U. S. Fish Commission for their summer work this year on the Atlantic coast is at Provincetown, Mass. Work was begun there about the middle of July.