INGOLD

The Development & Present Trend
Of Traffic on the Great Lakes

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# THE DEVELOPMENT AND PRESENT TREND OF TRAFFIC ON THE GREAT LAKES

BY

ERNEST THOMPSON INGOLD

THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE

IN MECHANICAL ENGINEERING

IN THE

COLLEGE OF ENGINEERING

OF THE

UNIVERSITY OF ILLINOIS

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# UNIVERSITY OF ILLINOIS

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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ENTITLED THE DEVELOPMENT AND PRESENT TREND OF TRAFFIC ON THE GREAT LAKES

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of
# Traffic on the Great Lakes

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THESIS

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PART 1.

INTRODUCTION

The Great Lakes, Superior, Michigan, Huron, Erie, and Ontario with their navigable streams constitute by far the largest, the most important and commercially the most valuable natural series of waterways in the world. They are primarily an asset of the United States rather than of Canada for had they been located by the hand of man they could not have been better placed relative to the commercial interests of any country than they are to those of the United States. On their waters float a fleet of vessels of iron, steel, and wood aggregating a total tonnage of over 2,000,000 and representing an investment of capital amounting to over $1,000,000,000. On their shores there are docks, warehouses, and freight handling

machinery representing an additional investment of another billion dollars.

The commercial interests of the United States are practically concentrated in the north-east states or those north of the Ohio river and east of the Mississippi river. Of these states the Great Lakes wash the shores of Minnesota, Illinois, Indiana, Michigan, Ohio, Pennsylvania, and New York. They have located on them the cities of Chicago, Duluth, Superior, Green Bay, Detroit, Toledo, Cleveland, and Buffalo.

By their waters may be reached the large iron ore, coal, copper, and lumber districts as well as the large manufacturing states New York, Illinois, Pennsylvania and Ohio. The states leading in overland transportation facilities are also tapped, they being Illinois, Ohio and Pennsylvania. The length of the Great Lake route from Duluth at the head of Lake Superior to the foot of Lake Erie is 1050 odd miles and Lake Michigan adds a route to the south of some 410 miles additional. This route is unobstructed except at NiagaraFalls and between the lakes Superior and Michigan. Both these obstructions how-

ever are passed by canals, at the former by the Canadian Welland Canal and at the latter by both American and Canadian canals.

The Great Lakes posess very few obstructions to navigation and such as there are are not serious. Practically the entire area of each of the lakes is open to navigation. They are open to ocean going vessels through the Erie Canal and through the St. Lawrence river and if present plans are carried out they will be connected to the waters of the Mississippi system and thence to the gulf by a canal from Chicago to the Mississippi river.

So it may be seen that the Great Lakes are of priceless value to this country in particular if the advantages they offer for transportation are developed. This is being done. An enormous lake fleet is being built, harbors are being developed, ore and coal handling machinery is being perfected and new waterways are continually being laid out by engineers.

This thesis will point out the steps leading to and the present condition of the developmentof the lake traffic and the

the lake fleet,dealing more especially with the structural and the mechanical features of the vessels, the mechanical development of their engines, and the development of the accompanying loading and unloading machinery.

The Great Lakes tap the richest of the coal and ore producing regions of the United States. Since the manufacture of steel and steel goods is this countries greatest industry and the production of coal reaches a total of 480,000,000 tons a year, the lakes furnish a cheap and ready means for the transportation of the greater part of this material. These two commodities have given rise to the present peculiar type of freight vessel. This type will be discussed later. Of the total coal production,the states bordering on the lakes produce annually 336,000,000 tons or in the neighborhood of 70% of the total output. Coal, especially the hard or anthracite coal lends itself readily to mechanical handling. The hard coal is of fairly uniform size and is not readily broken in handling. Care must be used however in designing and operating machinery for handling soft coal as it

crumbles and therefore loses a part of its market value if handled roughly.

The shipments of iron ore by the Great Lake route vary from 18,000,000 to 28,000,000 net tons annually. At present approximately two thirds of the iron ore consumed by the furnaces of this country annually is carried during some portion of its journey from the mine to the furnace over the Great Lake route. Iron ore is widely distributed through the United States, every state and territory containing it with the exception of three. There are three principal ore producing areas. The eastern region consisting of New Jersey, New York, Pennsylvania and Ohio have contributed most of the eastern production. The northern Wisconsin and Michigan or more properly the Superior region is the second great ore producing region. The third is in Tennessee and therefore away from the lake route.The output of iron ore reached by the lake routes is about 22,500,000 tons annually.

To the vast extent of territory about the Great Lakes but especially to the country west and north of the lakes Michigan and Superior, lake transportation means cheap

coal. This reduction in the price of coal means much to the people of the northwest where fires must be maintained at least six months out of twelve each year. To the lake carriers coal means west bound cargos and the neccessity of returning ore vessels to the Superior region "light" is done away with. The west bound coal shipments,being in the direction of the least traffic movement,gives rise to a healthy competition between the railroads and the lake carriers, for the bulk of the railroad traffic is also eastward and cars as well as vessels are not returned"light"if a shipment can be found.

The demand for coal by the manufacturers of the cities on the Great Lakes and the need for iron ore by the steel plants located on the lakes, coupled with the fact that the lakes tapped the richest of the countries ore and coal producing regions gave rise to two spontaneous and paralell mechanical developments which will now be treated at considerable length. They gave rise, first to an entirely new type of lake vessel a ship radically different in all the main features of ship construction from any of

its predecessors and particularly suited to the needs and requirements of the coal and iron ore hauling business. Secondly, they gave rise to the perfection of dock and loading and unloading facilities. Up to the time of the new type of vessel these were not developed to any great extent but immediately after the coal and ore ship had been given a fair trial the possibilities of a more automatic piece of ore and coal handling machinery as well as the need for special and adequate dock accomodation was realized. So we have developed side by side the loading and unloading machinery and the modern dock.

The development of the marine engine for the use on the Great Lakes has kept apace with the development of its vessel. The tendencies in the engine development are identical with those of the marine engine for ocean use.

## PART II.

## THE LAKE VESSEL.

A very interesting and important part of this thesis will now be taken up. It is the development of the constructive features and the present tendencies in the design of the Great Lake vessel, especially the freighter.

The early lake boats were all made of wood. Their engines were always located in the most roomy part of the ship or in the amidship section. The first and foremost point in the construction of a ship was to give the engines and the coal bunkers, not only the choicest location in the entire vessel but to give them all the room they needed and then a liberal allowance of additional working space fore and aft of the engine and boiler rooms. The cargo accomodations were in this way made a more or less secondary consideration. The wooden hull lacked the neccessary stiffness and strength which is called for in a ship with anything other than a centrally located engine plant so the need of locating the engines in the body of the boats was not all the fault of the

design.

The year 1888 marks possibly the most important year in the development of ship construction for it was this year that saw the modern steel lake boat tried out and the era of steel vessel construction on the Great Lakes ushered in. From the report of the traffic authorities of the Sault St. Marie canal for 1908 we find that of the total tonnage passing through that canal in that year 86.4% of it was steam tonnage and iron vessels. The average size of these vessels was 2157 registered tons and the length of them had practically doubled in less than ten years. The demand for reduced rates and the institution of a definate and comprehensive program of harbor improvement, canal building, and dock lengthening and widening gave rise to the increase in vessel size and tonnage. This development bears a direct relation to the marked reduction of lake freight rates. Unless a further improvement of the waterways permits a continuing growth in the size of the lake vessel the improvement of the past ten years cannot

go on indefinately. The need at present is for deeper harbor and dock approaches as it is the depth of the vessels which has now reached a maximum.

Before entering into the details and characteristics of the lake vessels in general it may be well to point out a few facts concerning the type of vessel which is now being built for the largest lake fleet ever handled under one management. This fleet is a series of vessels now built or building for the United States Steel Corporation, George A. Tomlinson, and A. B. Wolvin. They vary in detail slightly but the object of the designers in each ship was to utilize to the utmost the improved loading and unloading devices as well as to put forth a ship of the maximum size now possible. The ships are all 10,000 ton boats and each is capable of carrying a gross cargo equal approximately to its own tonnage.

The United States Steel Corporation fleet consists of four vessels, duplicates, all of them 569 feet long over all, 549 feet keel, 56 feet beam, and 31 feet deep. They draw when loaded 18 feet of water. The decks

of these ships are pierced by 33 cargo hatches each hatch 9 feet square and spaced 12 feet from center to center so there is but 3 feet between the openings. This makes the deck negligible as a constructive feature for stability. In order to utilize to the utmost the unloading devices it is neccessary that there be a minimum of cross beams and stanchions between decks and these have been eliminated entirely in these vessels. The strength lost in the decks is made up for by employing extra heavy construction below, by heavier plates at the decks and by the use of heavier girders across the ships between the hatches. The cargo hold is a departure from anything now on the Great Lakes. It descends in a straight line from the deck to within 9 feet of the tank bottom where an inner hold, or hopper, is constructed placed 9 feet from the sides of the vessel and 5 feet above the bottom Between the outer and the inner skins and up the sides of the vessel is room for 8500 tons of water ballast, making the ships navigable, large as they are, in any

weather, even though running without a cargo.

The vessels are fitted with the latest appliances for removing the hatch covers and two men can either take off or replace the entire 33 in 20 minutes.

The Tomlinson ships differ from those already described or from any others ever built. Four of them are 524 feet long over all, 54 feet beam, and 30 feet deep. One of these will be built with a series of hoppers in its hold each hopper being built to permit rapid unloading from its own hatch. The hoppers extend athwartship, from side to side and therefore add materially to the strength of the vessel. There are no double sides but the water ballast is carried,as it usually is, between the two bottom skins and the hoppers.

The Wolvin vessel is similar to several now owned by the Acme Steamship Company and it has a clear space of hold. There is an arch construction of the deck girders running athwartship, fore and aft. This gives ample room for an unloading machine to swing above the cargo and the hopper of the inner hold in which the cargo is carried,

thus permitting the machine to take up all of the cargo without the assistance of an ore shoveler.

The development of the lake vessel has been largely characterized by ecomony; economy of building material,space, time of loading and unloading, of operation, and in initial cost. The type of vessel now built may be divided into three parts, the hold or hopper, the engine rooms and the crew accomodations. Of these three the first occupies from 9/10 to 15/16 the cubical contents of the vessel.

The use of an inner skin and a cellular bottom in the hull construction was deduced originally from wrought iron bridge structural practice and first introduced in the Great Eastern, an ocean going vessel. The adoption of this system is justified by the increased longitudinal strength it gives as well as the convenience it offers for satisfactory ballasting. Broadly and briefly described the cellular system consists of in the fitting in a thoroughly watertight manner and sufficiently high as

to be accessible for repairs, inspection and painting, of a double or inner skin, extending across the vessel to the outer skin at the turn of the bilge. A series of longitudinal plates are worked fore and aft vertically between the outer and inner bottom plating, and connected to both by continuous angles. Between these longitudinals are traverse floor plates at every frame or at every second frame, lightened by oval man holes and connected like the longitudinals by angles to the outer and inner plating.

In cargo vessels the use of the system is justified if only for the convenience it offers to ballasting. With the long expanse of cargo hold in the vessels as now designed exceptional structural strength is called for and the construction also furnishes this.

Another indispensible feature, expensive and inconvenient, but almost a neccessity is the subdivision of the hull by watertight bulk heads. Their object is to limit the space to which water can find access in case of leakage and to reduce this space so that if water should enter one of

these compartments, its weight will not exceed the surplus buoyancy of the vessel. Shipowners objected to bulkheads at first because the minute subdivision of a vessels hold impaired the boats usefulness as a cargo carrier and reduced the space formerly used for the storage of miscellaneous freight. These objections still exist but owners are not as willing to risk on the lakes the large investment now called for in the construction of a lake freighter for the sake of a few thousand extra cubic feet of cargo hold. Ships now so subdivided are proving as efficient and quite as economical as the more scantily divided ones.

The bulkheads are always carried higher than the water level on the outside of the ship. A finely subdivided ship would be unsinkable, however the question of convenience and the necessity of getting about the boat and from one compartment to another interposes itself. Doors although a convenience are largely a risk. Patented doors for bulkheads , hydraulically operated or operated by electricity either singly or

collectively are on the market and have found wide adoption. A lever touched by a ship officer when danger is near closes and seals every door in less than half a minute. They may be opened by the same lever or opened independently at each door.

The growth in the size of the lake vessel shown later on by a series of curves, restricted as it was by the comparatively slow progress evinced by the iron manufacturers in producing larger and stronger structural items, within requisite limits as to weight as well as the uncertain quality of these materials drew attention to the claims of mild steel. The use of this is now practically universal, it contributing handsomely to the increased strength and safety of the lake vessel. Designers of iron and steel sea going boats paved the way for the makers of lake vessels as it was the ocean going ship builder who overcame the opposition to the use of steel. The opposition contended that once pierced a steel hull would sink and that steel corroded easily, fouled, and interfered with the ships compas.

Doubt existed at first as to the economical advantage of adopting steel and there was a hesitancy on the part of ship owners to adopt it. Upon its introduction into vessel construction, insurance rates were dropped 18% and as the weight of the vessels was more the net saving amounted to about 13 or 14%. The first cost of the steel ship was for four or five years considerably more than that of an iron or wooden one,even considering the reduction in the weight of materials which the use of steel permitted of. The increased sources of supply of iron ore and improved steel mill methods led to a reduction in the cost of mild steel and today a steel vessel costs no more than a well built one of wood.

Doubt existed as to the durability of the steel ship, such doubts being aggrevated by the thinness of the steel plating and by numerless unnacountable bad plates which were found in vessels already built. With a larger experience in the making of steel and the protecting of it after it has been placed in the boat these objections

do not appear to be justified and steel seems to have established itself permarantly as the great structural material ,not only for lake boats but for ships of all classes. Tonnage or mere bulk is not a measure of importance in shipbuilding productions but they are desirable and economical results of improved building methods, improved design and an improvement in structural materials.

The Lake freighters have seemingly reached a point in their development where all resemble in essential particulars a single design. They are all divided , as has allready been stated in an earlier paragraph , into three parts, the cargo hold, the space for the machinery, and the crew accomodations. From a distance the entire central stretch of the vessels have a "bare" appearance In the bow are grouped the captains bridge, officers accomodations, mast, crew quarters, mess rooms, galleys, etc. while at the extreme stern are placed the engines, boilers and coal bunkers. This arrangement admits of the good use of a rather undesirable space in the vessel, namely the bow and stern

leaving the vast bulk of hold ready to receive freight.

Side by side with this tendency to build free holds comes the reduction in net register tonnage relative to the size or carrying capacity of the vessel. The whaleback type is self-explanatory. In it the designers sought to evolve a steamer with decks clear of all erections so that the sea might sweep over them without doing damage. This type of vessel has found its field on the Great Lakes only and has not been developed or tried for sea use. Their carrying capacity was large but not as great as the steel vessels now built. They were in a way a freak development of the steel vessel, the first being built in 1888 the year steel was introduced extensively into lake vessel construction.

The introduction of steel then has brought about many radical and noteworthy results in the design of the lake boat. They are larger, and have a greater carrying capacity relative to their registered tonnage. They are safe in all respects. They are built

more easily and more rapidly. They admit of easy repair and easy cleaning. They are faster. They permit a very easy handling of their cargoes. They offer every possible incentive for a low freight rate. They have come to stay and developments toward economy of building and upkeep may be looked for rather than an increase in size, this being limited now by the depth of the lake channels. As stronger steel is manufactured an increase in the tonnage for any given capacity may be expected.

# PART III.

## THE MARINE ENGINE.

The development of the marine engine has been fully as rapid as the development of the ships themselves. The table on the following page has been prepared from the best of the available data and it will summarize the results of the progress made during the four decades beginning with 1872.

The success of a boat is reckoned according to the expense of the boat in doing its work, viz in carrying its passengers or freight for a given distance. The engineers part is considerable,being associated with the first cost, fuel economy and the cost of repairs. The coal consumption per I. H. P. hour in 1872 was 2.11 pounds and in 1901 we find it to be only 1.48 pounds. In compiling the table only the results of actual performances are taken not the results of trial trips.However for the data in the 1872 column trial trip results are taken for want of better data.

Comparison of Marine Engines.

Average Results.

| | 1872 | 1882 | 1892 | 1902 |
|---|---|---|---|---|
| Boiler pressure lb.sq.in. | 52.4 | 77.4 | 158.5 | 197 |
| Heating Surface sq.ft.per sq. ft.of grate. | -- | 30.4 | 31.0 | 38 |
| Heting surface per I.H.P. | 4.41 | 3.91 | 3.27 | 3.0 |
| Coal per sq.ft. grate, lb. | -- | 13.8 | 15.0 | 18-28 |
| R. P. M. | 55.67 | 59.76 | 63.75 | 87 |
| Piston Speed ft. min. | 376 | 467 | 529 | 654 |
| Coal per I.H.P. hour. | 2.11 | 1.83 | 1.53 | 1.48 |
| Average Consumption for long trip. lb. per I.H.P. hour. | -- | 2.0 | 1.76 | 1.55 |

The incresing economy may largely, in fuel consumption, be laid to the increased steam pressures now in use. In 1891 the average was about double that of 1881. As a result of the use of higher steam pressures and more economical engines more power is obtained from the boilers per square foot of heating surface, the average per I. H. P. having decreased from 3.27 to 3.00 square feet in three years. At the same time the piston speed has increased considerably. It was 528 feet per minute for the ten years previous to 1901. Since then the average has increased to 654 feet per minute and in certain vessels has reached as high a speed as 880 feet per minute.

Improved economy in overlake transport of commerce is also being sought for in the greater size of cargo steamers, the fuel consumption of which does not increase in the same ratio as the cargo capacity. A ship to carry 5000 tons requires machinery of about 3475 I.H.P. to propel her at 13 knots, while a ship of trebel the capacity the power

is scarcely doubled. In other words the consumption of coal per hundred ton miles in a now relatively small ship taking 5000 tons of cargo is 8 pounds, while in a vessel taking 16000 tons it is only 4.4 pounds per hundred ton miles. Not only is the fuel consumption less but the first cost per ton mile carried need not be any greater, the working expenses are generally lower owing to the introduction of mechanical means, and the personnel of the boat does not increase pro rata with the size.

There has come within the life of the steel vessel some uniform degree of practice as regards marine boilers. There is a preferance for the single ended type although convenience often requires the installation of the double ended type. The through combustion chamber is a thing of the past. The maximum pressure in lake marine boiler practice is 267 pounds although in naval vessels it sometimes reaches as high as 300.

The thickness of the boiler shell plates remains about the same varying from 1 7/16 inches to 1 19/32 inches and in diameter the boilers measure frequently as much

as 17 feet. The tensile test for steel boiler plate is 27 to 32 tons per square inch. This is however a very carefully conducted test for the same test was used fifteen years ago notwithstanding the fact that boiler pressures have doubled.

In most of the newer vessels the draft is heated by the waste gases before it reaches the furnace. With this hot draft more coal may be burned per square foot of grate area and a higher rate of evaporation per square foot of heating surface may be obtained.

Very little progress has been made in the general application of oil fuel although it has advantages in easy and uniform stoking. The disadvantage of the greater cost of oil is diminishing owing to the increasing cost of coal and the more plentiful supply of oil, but apart from this there is a greater prime cost of the ship with its more carefully built bunkers to store the oil. Even if the oil is carried in the double bottom the added cost to a ship of moderate size would be $10,000. A high

degree of perfection has been reached in burner appliances but there is still a difference of opinion as to whether the mechanical spray, the steam or air propelled jet , or the voltallized system proves most efficient. The first requires a brick lining to maintain the initial furnace temperature, the steam spray involves a loss of fresh water which has to be made up by the evaporators, while with the air the steam pressures neccessary to run the compressors involves a serious fuel consumption.

The use of voltallized oil seems to offer great advantages. It is vaporized by first being heated and subsequently distilled in the presence of superheated steam within a retort burner. But after all it seems that it is only a question of the relative cost per B. T. U. of oil and coal which enters into the problem. The maximum results of tests run in New York with oil and coal show that less than half the heating value is obtained from the oil on the same cost basis. Oil when burning beyond a certain rate forms dense volumes of smoke which are objectionable.

Oil may yet be used together with coal, being sprayed on the fire or in some way fired with the coal.

Mechanical stokers have been largely adopted in connection with land boilers but there are scarcely more than five cases where a similar system has been adopted on board ship although there seems to be a wide field for them, especially so if the water tube boiler with its large grate area comes into favor for marine use. The system fitted in one or two lake steamers has stokers of the chain grate type and they differ but little from the run of stokers under land boilers. On official trials the marine stokers gave very satisfactory results, the consumption being 33.64 pounds of coal per square foot of grate area and the rate was 1.998 pounds per H. P. hour. At 20.62 pounds of coal per square foot of grate the rate was 1.56 pounds per H. P. hour. Tests are now being made on a new model of the Barrow stoker for marine use.

There seem to be great possibilities for the use of superheated steam in marine work, thus utilizing more of the waste gases. On short trials vessels fitted with the super-

heating steam devices the rate of fuel consumption worked out at 1.00 pound per horse power hour, the superheat being 57 1/2 deg. F. and the pressure 267 pounds. It must be remembered however that superheaters only add additional parts to the engine room equipment and multiplication of parts must be avoided, especially if of difficult access when the vessel is under way.

It may be said that as far as high speed machinery is concerned the universal practice is to fit a four crank engine operating from four cylinders, usually on the three stage compound system and occasionally for a quadruple expansion. Experience has shown the enormous importance of ballancing forces in the reduction of vibration and in doing this the third or fourth stage cylinders are divided and the tandem cylinders are arranged in couples to balance each other. Diameters of cylinders run as high as 113 inches and even larger but the larger diameters do not seem desirable. There is no reason why with the higher steam pressures

a larger number of expansions should not be adopted with multiple cylinders. Vibration is decreased by any increase in the number of cylinders.

The average ratio of low pressure to high pressure cylinders has increased. These ratics ten years ago for a pressure of 160 pounds were

$$\frac{L.\ P.}{H.\ P.} = 6.77 \qquad \frac{I.P.}{H.P.} = 2.56$$

$$\frac{L.P.}{I.P.} = 2.64$$

The average now for a pressure of 180 pounds is,

$$\frac{L.P.}{H.P.} = 7.55 \qquad \frac{I.P.}{H.P.} = 2.74$$

$$\frac{L.P.}{I.P.} = 2.76$$

There is a variation in practice of within one decimal place of the average values as given above. In freight vessels when coal economy is of vital importance the ratios are changed slightly but the view that a large ratio of expansion is neccessary is not endorsed by the practice. It is not even helpful to high propulsive effiency when everything from the fire bars to the propellors is

considered. It is interesting to note that in fast cruisers the ratio $\frac{L. P.}{H. P.}$ reaches as high as 10.25.

With the prevailing high steam pressures the neccessity for steam jacketing is not as great as it was formerly but there are no good engines now in the lake boats which are not jacketed, even in slow running vessels having early cut off. Present developments seem to indicate that the steam jacket may be dispensed with at some time in the near future.

The increase in piston speeds has already been mentioned. The speed per minute on the average lake vessel is about 550 feet per minute on a four foot stroke. High piston speeds call for more attention to lubrication of the large parts, especially of the lower parts of the crank and main bearing brasses. No accidents are tracable directly to high speed of rotation and accidents will only be laid to this when care in selecting material is overlooked and carelessness enters into the design of the working parts.

The shafting often fails especially the tail end shafts. This has been overcome to a certain extent by the use of shafts of

greater diameter. For instance in 1890 when a shaft having a diameter of 11 3/4 inches was considered sufficient one of 13 inches diameter is now required. This increase in size means an increase in strength of 36%.

The engines in lake freight steamers are not as heavy as in the case of naval vessels. In a comparison of a cargo steamer of 3750 I. H. P. 80 R. P. M. 7500 I. H. P. (combined) and a torpedo boat of 3000 I. H. P. 390 R. P. M. and 6000 I. H. P. (combined) the following table has been prepared. The torpedo boat represents a very highly developed piece of marine mechanism and the stresses in its engine parts are as high if not higher than those of any other type of boat. Only the main working parts or or those most liable to break are taken account of in the table.

Comparison of Engine Stresses

Lb. sq. in.

| Part. | Freighter | Torpedo |
|---|---|---|
| Crank shaft | 3200 | 6700 |
| Piston rod body (tens) | 2370 | 5275 |
| Connecting rod bolts | 5200 | 8875 |
| Piston rod screw | 4150 | 9150 |
| High Pressure barrel at test pressure | 4175 | 4400 |
| Ditto, Low pressure | 2580 | 2230 |
| Ditto, Intermediate pressure | 3230 | 4700 |
| Factor of safety | | |
| Connecting rod bolts | 12 | 7.575 |
| Piston rod body | 26.4 | 12.75 |
| Piston rod screw | 13.2 | 7.35 |

Turning now to the question of ship propulsion and speed it is noted that design favors the twin screws because of the guarentee they give against complete breakdown

and because of their ready adoption to vessels of moderate draft. They also offer a very easy solution of the disposal of space in the engine room. The ship propeller seems to have reached a standard design and it is doubtful if a very much more efficient piece of propulsive mechanism will ever be found or the standard designs ever improved upon.

Vessel speed has increased. With almost perfect machinery to depend upon, carried in steel vessels with easy lines this has been a natural outcome. Moreover the increased speels have made possible a regular schedule even on the freight lines.

With the increase in steam pressures the whole question of auxillary machinery comes up. Troubles have been found in securing a suitable packing for auxillary and main engines through piston and slide rod glands Asbestos proved unreliable and a packing consisting of powdered white metal, black lead, and mineral grease mixed together and held in position by several vulcanite rings inserted at top and bottom was tested

and found very reliable. It has been found more recently that under usual circumstances a metallic packing was unneccessary for the piston and slide valves of the low pressure cylinders.

By compounding many of the engines the coal consumption of the auxillary machinery was reduced. Flat slide valves are replacing piston slide valves. It has been suggested that much of the auxillary machinery be operated by electricity and the possibilities along this line are good, especially in the driving of fans and other gear situated at a considerable distance from the main leads. Care must be used that the electrical system is not applied to machines requiring great initial impulse such as anchor hoists.

The steam turbine has not as yet been used in lake boats and there is no reason at all why developments in this line should not be forthcoming immediately. It has been most successfully tried in a number of ocean boats although these vessels are for the most part in the fast mail or passen-

ger service. Their efficiency is satisfactory especially the turbines of the Parsons type. The tendency has been for the builders of lake vessels to abstain from the use of the turbine until it has been thoroughly tried out in ocean traffic, both on fast boats and on those of more moderate speeds.

## PART IV.

### IRON AND COAL HANDLING MACHINERY.

The extent to which the Great Lakes and their navigable streams tap the manufacturing centers and the iron and coal producing areas has already been pointed out. It is altogether natural that the iron and coal carrying vessel should have been developed as it has. Iron ore and coal both are materials which may be readily handled on conveyors, by bucket machinery and by the use of chutes. The problem in lake transportation is to first find a ready means of loading the vessel and then a means of unloading it. Of the two the former is the most readily solved of the two and satisfactory means for loading a vessel was found first.

Several striking facts concerning the character of lake transportation are brought out by traffic statistics. Probably the first to arrest attention is the celerity with which cargoes are unloaded and loaded. Instead of being days in taking on and dis-

charging cargoes as was once the case only hours are lost now. Perhaps this statement is not strong enough for if averages could be obtained it would probably be found that it does not now require as many hours to load and unload as it required days some years ago. Vessels loose almost no time at the docks. It is almost literally true that they are constantly going or coming, or that they are continuously engaged in the transport of goods. This is of course the object for which they were designed.

The labor saving methods for loading iron ore and coal are characteristically American and peculiar to the commerce of the Great Lakes. The ore or coal when it comes from the mine is put into cars which are made up into trains of forty or fifty cars and hauled to the docks. Upon arrival there each car is weighed carefully and they are switched over the pockets of the docks, the openings to which are spaced so as to come directly under the drop bottoms of the cars. The ore is dumped into these pockets each

of which will hold from four to six carloads or an average of twenty tons apiece.

The lake iron ore docks are all of essentially the same design. They consist of a giagantic pier extending from the main-land out far enough to reach water of the required depth. When this depth has been reached a superstructure of timber is built carrying on its top as many as four standard gage railroad tracks. Below these tracks are located V shaped pockets also built of wood although now generally lined with metal at least partially. These pockets are spaced so they come directly under the ore cars used for the dock. The lower end of the pockets terminate in spouts made of steel and spaced so as to drop when lowered directly into the hatches of the vessels.

A boat upon reaching the dock takes her place directly beside the pockets from which her cargo is to be taken, and the spouts of such pockets as are to be opened are dropped into the hatchways. The spouts are usually raised or lowered by a counter-weight or by a series of gearing. Winches are being introduced to do this, a single winch operating a series of spouts. With

the spouts in the vessels hatchways the dock laborers remove the pins from the doors at the foot of each pocket and the ore is released and drops into the vessels hold. In case the pockets are not filled when the boat arrives the vessels cargo may be dumped directly from the cars into the hold by way of the pockets. Careful manipulation of the spout enables a ship to be loaded evenly and very little if any trimming need be done afterward.

One of the largest of the existing ore docks is that of the Chicago Milwaukee & St. Paul Railroad located at Escanaba Michigan. In both capacity and in respect to the engineering work involved it takes rank with the most noted structures of this class in the world. It was built as a terminal for the Escanaba & Lake Superior Railway from Channing to Escanaba. The dock proper is 750 feet long, 52 feet wide on top and 59 feet wide at the bottom. It stands 66 feet above the water. It has 120 pockets with a capacity of 28,000 tons of ore. The trestle approach to the dock

is 3100 feet in length making its entire length about 3/4 of a mile. All the lumber used was sawed in a mill built for the purpose at the head of the dock.

The piles were driven by a two track pile driver. On these piles the superstructure consisting of 12" x 12" timber with a lattice work of 4" x 12" timber was erected the parts being bolted together.. On this superstructure were laid four tracks of standard gage any of which migh be used without interfering with traffic on any of the others. An elaborate fire extinguishing system was installed.

The spouts and hoists of the 120 pockets of the dock are of the Denton pattern, built by Pettibone & Milliken Company of Chicago. Each spout may be operated by one man and is counterbalanced, and each has its own hoisting winch. The spouts drop from the vertical to the horizontal by gravity but from the horizontal down the winch is used. In lifting the spout it is raised to the horizontal by the counterweight and from the horizontal to the vertical by the winch.

The dock will accomodate vessels of 20 foot draft;5,800,000 of timber and 207,000 lineal feet of piling was used in its construction.

The problem of unloading a lake vessel is a more intricate one than that of loading it for in the unloading process the ore or coal must be picked up and removed from an awkward holding space and oftentimes through a comparatively small opening. The difference in the cost of the two operations is considerable being approximately 4 cents a ton for the loading and trimming if there is any to be done, while the cost of unloading is 22 cents a ton.

The first type of unloading machine was known as the bridge tramway system of hoisting and conveying machinery. This permits the transferance of the ore either directly to the cars or to stock or storage piles at the rear of the docks.The apparatus just referred to consists primarily of an elevated bridge or tram - way which spans the dumping ground and also the railroad tracks upon which are the cars which it is desired to load. A trolley travels

on this bridge and to it in turn is attatched the bucket holding about 1 1/4 tons of ore. These buckets were lowered through the hatches of the vessels and loaded by gangs of men. The bucket was the hoisted and conveyed along the bridge simultaneously and such is the rapidity of its operation that it is possible for a bucket to make a trip from a vessel to the extreme end of the dock and return in less than a minute. These machines are usually built in plants of three or four machines but each bridge rests on an independant pier. By the use of this machinery it was possible to unload 5,000 or 6,000 tons of ore from a single vessel in the space of ten or twelve hours.

Another type of unloader is now being placed in extensive use. It is known as the automatic unloader and consists of a heavy steel structure supporting a walking beam which can be run out over the hatches of the vessel. To this walking beam is attatched a revolving mast and to the bottom of this mast is in turn appended an ordinary clam shell bucket which is capable of scooping up ten tons of ore at a time. It is possible

by the use of this machine to unload ore at the enormous rate of 300 tons per hour and the time of unloading the average vessel is reduced by fully one half.

Electricity is being extensively introduced as the prime motive power for operating Great Lake dock machinery and lake men generally believe that it is a move of great importance to the future of ore handling. The great advantage in electrical dock machinery is in the compactness of the units and the fact that every corner of every machine may be as light as day thus enabling all night runs to be made.

By far the best example of ore unloader both as regards to economy and capacity is the one known as the Hulett automatic and manufactured by the Wellman Seaver& Morgan Company. These machines are erected on the face of the wharf and each one has two paralel girders at right angles to the face of the wharf, spanning four or five lines of rails and carried on wheels so they can move along the dock. On this moving frame

a carriage travels to and fro and to this carriage at its extreme end is pivoted a long rocking beam similar to that in the machine already described. By mechanical means the rocking beam is made to oscillate, carrying the bucket which is suspended to the outer end of a vertical leg hung from the walking beam. The man operating the bucket rides in a chamber in the lower end of the leg.The bucket is carried down into the hold and upon being closed fills and is raised from the ship.The travel of the carriage on the girders carries the bucket out to the ship and brings it back with its load. To reduce the travel of the carriage as much as possible hoppers for receiving the contents of the bucket are mounted between the main girders. These hoppers discharge into railway cars or into a steel car which travels on rails paralel with the carriage and running out on a frame in the rear of the machine to discharge theore into the train or into the storage yard.

The suspended leg carrying the bucket is mounted on rotating trunions on the end

of the walking beam so that it can be rotated to let the bucket reach out in all directions. The buckets are usually of ten tons capacity and have a telescopic motion so that they have a spread of 18 feet,by which they can be made to reach any portion of the hold or from the center of one hatch to the center of the next one. The carriage moves the bucket to any desired position across the hold and the beam lowers it to any desired depth. Consequently the operator is able to reach almost the entire cargo . As high as 97% of the cargo has often been removed without the aid of a single shoveler. Many boats are being built to fit these machines, a rather reversed order of proceedings. A group of four of these machines has a record of unloading 7257 gross tons of ore in 4 1/2 hours an average of a little over 403 tons per hour by each machine. The highest record of any one machine was 687 tons in one hour.

Hulett ore machines are operated either by steam or by electricity. In the

former case the steam engine is used to travel the machine along the wharf and to operate the larry running on the cantilever discharge frame. Hydraulic pumps apply power for lowering and hoisting the rocking beam, moving the carriage, and operating the bucket. In electric machines all the operations are effected by motors and the powers of these are as follows. Rocking beam 150, moving the carriage in and out 50, operating the bucket 80, and moving the machine along the wharf 260. These figures are for a machine built for the Lackawanna Steel Works. The movements of the rocking beam and carriage are affected simultaneously, the carriage being run out as the beam descends with the empty bucket and running back as the beam ascends. The load of ten tons is delivered at the rate of one load per minute.

The future development of the loading and unloadiny machinery will undoubtedly be along the line of increasing the number of buckets in operation at any one time. The amount of material carried in a ten ton bucket is considerable and there is no

desire to have it dumped in greater quantities than this. The speed seems to have reached a practical limit as the parts of the machine are all heavy and starting and stopping consume both time and power. Electricity may be looked to to operate most of the machines built in the future.

The following interesting figures have been compiled from reports in the possession of the Division Engineer of the Ashland Division of the Chicago & Northwestern Railroad. The office of this engineer is at Kaukauna Wisconsin and is to be moved to Antigo Wisconsin this year. The Chicago & Northwestern Railroad has two docks at Ashland Wisconsin and five at Escanaba Michigan. Their capacities are 36036, 24156, 24104, 20928, 30284, 32750, 43152 tons. The Duluth & Iron Range Railroad has five docks at Two Harbors, Minnesota with the following capacities,18000, 23900, 16000, 30000, 33000, tons. The Duluth Missabe & Northern Railroad has two docks

at Duluth with capacities of 57600 and 34560 tons. The Duluth South Shore & Atlantic Railway has three docks at Marquette Michigan with capacities of 27000, 12780, 28000 tons. The Duluth Superior & Western Railway has one dock at Allouez Bay, Superior Wisconsin with a capacity of 40500 tons. The Lake Superior & Ishpeming Railway has a dock at Marquette Michigan with a capacity of 36000 tons, the Minneapolis St. Paul & Sault St. Marie Railway one at Gladstone Michigan with a capacity of 15000 tons and the Wisconsin Central lines one at Ashland with a capacity of 33500 tons. This list includes every modern dock of any size.

## PART V.

## CURVES.

This thesis would be incomplete without a graphical representation by means of curves of the most of the important developments and changes and more particularly the growth of the lake traffic, the increase in the size of the vessels, their value, the increase in the use of iron and steel as their structural material and the decrease in the freight rates. There follows a series of curves in which these main features are accurately recorded. Some of these curves are drawn on data running back as far as 1857 and are most of them drawn to the present year. In a few cases the data was not obtainable in which case they were drawn to the year 1907.

The writer is indebted to Mr. E. T. Chamhetan , Commissioner of the United States Bureau of Navigation of the Department of Commerce and Labor for valuable statistics and figures, particularly those covering the total tonnage built on the Great

Lakes.

CURVE NO. 1.

Curve No.1 shows the gross tonnage constructed on the Great Lakes from 1880 to 1908, 1880 being the earliest date at which authentic figures are procurable and the 1908 figure being an estimate made by the United States Department of Commerce and Labor. The curves show to what a remarkable extent vessels built of iron and steel have replaced those of wood construction. Practically the entire wooden tonnage consists of barges which although used as freight carriers do not run under their own power.

The figures used in this curve were taken from a report of Mr. George G. Tunnel of Chicago made to the United States Bureau of Statistics and first published in 1898.

The growth of the iron and steel tonnage was more or less spasmodic until the year 1888 after which it was a healthy and continuous one. The decrease in the tonnage of the wooden vessel has been continuous from about 1891 when the wooden

tonnage reached its maximum.

CURVE NO. 2.

Curve No. 1 shows the increase in the gross tonnage and in order to show that the growth of this has been due to the increase in the size of the vessels and not entirely to their increase in number Curve No. 2 has been drawn. The figures for this chart were obtainable as far back as 1868 and run to 1907. The figures for the years 1868 to 1889 inclusive are taken from the traffic statistics of the Detroit river, these having been recorded accurately and strangely being almost identical with the average figures for all the lakes. Figures from 1889 to the present date were supplied by the United States Bureau of Statistics.

The curve shows the very rapid growth in the average size of the lake vessel especially those using steam as a motive power. The sailing vessel also shows a growth in size it having about one third the average tonnage of the steam vessel in 1907. Curve No. 1 shows that in the year 1886 the gross tonnage of the iron and steel vessels rose

rapidly. Curve No. 2 shows that during the same year the average tonnage of the steam vessel more than doubled, indicating that with the advent of iron and steel as a material for vessel construction, boats of double the length and ten times the carrying capacity were practicable.

CURVE NO.3.

While the size and tonnage of the lake fleet may be increasing rapidly we are more vitally interested in the reduction of the freight rates, we being the ultimate users of the coal iron and grain so carried. To show that the trend of the freight rate is downward there has been drawn Curve No. 3 for the rate on wheat, Curve No. 8 for iron ore and Curve No. 5 for the combined scheduled rates.

The lake freight rate is a variable one. They are higher when there is heavy traffic and lower when the traffic is light. They vary with the various products, depending on the ease with which they may be loaded and unloaded. Other elements enter into the

making of the rate such as liability to fire, danger to the vessel, liability to destruction by water and danger to the crew. The greater part of the lake traffic is eastward so eastbound rates are higher than the westbound. Many vessels are unable to find a cargo for their west bound trip, particularly in the seasons of light traffic, and they are obliged to carry no cargo at all or to take such goods as they are able to secure at a rate lower than the actual cost the returns from the low rate being better than running the vessel back light. Most of the vessels are now built so as to need either a load or a water ballast in order to balance the boat and to give the propellers a sufficient depth of water to work in with reasonable efficiency.

The curve shows the rate on wheat from Chicago to Buffalo from 1857 to the present year. It shows the gradual decrease on the rate on this commodity. The curve also shows that with the introduction of iron and steel vessels and the accompanying increase in

their size in 1886 the rate on wheat fell 40% in one year or from 4.1 cents a bushel to 2.6 cents. Since 1886 the rate has exceeded 2.6 cents but once and that was in 1899 when it was 2.71 cents. Upon consulting the figures for the receipts and shipments of wheat it is found that in 1899 they were unusually heavy for the port of Chicago. From figures compiled by the Chicago Board of Trade the receipts reached 320,000,000 bushels and the shipments 287,000,000 during the year. This bears out the fact that rate rate varies with the amount of traffic.

CURVE NO. 4

Curve No. 4 is drawn from figures furnished by the United States Bureau of Navigation and figures contained in Document No. 227 of the House of Representatives. It shows the regular growth of the lake fleet. The curve is drawn from the added figures of the sail, steam, canal and barge, tonnage both wood and metal.

Going back again to the year 1888 when iron and steel was introduced we find

that in twenty years the total tonnage has tripled while for the twenty years previous it scarcely doubled. It will be noted that at no time has the total lake tonnage decreased during the thirty years but a healthy and continuous growth has been experienced.

CURVE NO.5

Just as the condition of the steel market become the indicator of the country's prosperity so have the statistics of the traffic through the Sault St. Mario ship canal become an accurate criterion of the general condition of the lake traffic. For this curve, a curve showing the average cost of carrying per ton mile, the average of all the freight rates on grain, coal, iron ore, copper ore, lumber, flour, feed, limestone etc. as recorded by the canal officials was taken.

The curve shows a reduction in twenty years from a cost of 1.5 mils per ton mile to one of 0.84 mils per ton mile, a saving of nearly 50%. These figures are not obtainable previous to 1888 but inasmuch as it was during that year that steel was intro-

duced into vessel construction extensively they serve our purpose.

CURVE NO. 6

The Sault St. Marie statistics also furnish a first class indication of the increasing value of the American craft. The vessels passing through this canal in 1906 represented an investment of $90,000,000. In 1888 the value was $20,000,000 or the increase has been at the rate of 450% in twenty years, an interesting and somewhat startling figure. The increase may partly be accounted for by the tendency upon the part of vessel owners to put in their ships only the best of materials, engines of the highest efficiency and therefore the greatest initial cost, and minor conveniences safety appliances, and machinery. The cost of the engines alone has increased 260% during the last twenty years.

CURVE NO. 7

Second only to iron ore coal is the greatest freight item on the Great Lakes.

In Curve No. 7 the rates on hard and soft coal from Ohio ports to Chicago and Duluth from 1892 to 1907 are represented. The data for this curve was taken from the Marine Review and the 1906 Statisiical Report on Lake Commerce published by the Sault St. Marie Canal authorities. The curve needs no discussion as it only confirms the statement already made that the average freight rates on the great lakes are decreasing for all products.

CURVE NO. 8.

Curve No. 8 shows the decrease in average freight rates per gross ton from Escanaba Michigan to Ohio ports. The figures for the curve were taken from No. 6 series of 1907-1908 of the reports of the Commerce and Finance of the United States and published by the Department of Commerce and Labor in December 1908.

The curve shows a reduction in the contract price from $1.40 per gross ton in 1887 to $.60 in 1907.

CURVE NO. 9.

This curve and the one following it were drawn from figures compiled by Mr. O. P. Austin chief of the Bureau of Statistics of the Department of Commerce and Labor to show the progress of the United States in area, population and material industries.

Curve No. 9 is perhaps the most interesting one in this thesis for it dates back as far as 1820 when there was practically no building on the Great Lakes. In this year the total tonnage built was 3500 and in 1907 it was 2,439,741 tons. In 1820 the total tonnage built was less than that of a single vessel of the present day. These figures are given below in detail.

| Year | Tons American Vessels Built |
|---|---|
| 1820 | 3,500 |
| 1830 | 11,106 |
| 1840 | 54,199 |
| 1850 | 198,266 |
| 1860 | 467,774 |
| 1870 | 684,704 |
| 1880 | 605,102 |
| 1890 | 1,063,063 |
| 1900 | 1,565,587 |
| 1907 | 2,439,741 |

CURVE NO. 10.

This curve showing the total tonnage of the vessels passing through the Sault St. Marie Canal for the years 1860 to the present one. It shows a continuous increase in the total tonnage. Because of their value in connection with the figures given on the preceeding page the figures for this curve are given.

| Year | Total tonnage passing through the canal. |
|---|---|
| 1860 | 403,657 |
| 1870 | 690,826 |
| 1880 | 1,734,890 |
| 1890 | 8,454,435 |
| 1900 | 22,315,834 |
| 1906 | 41,098,324 |

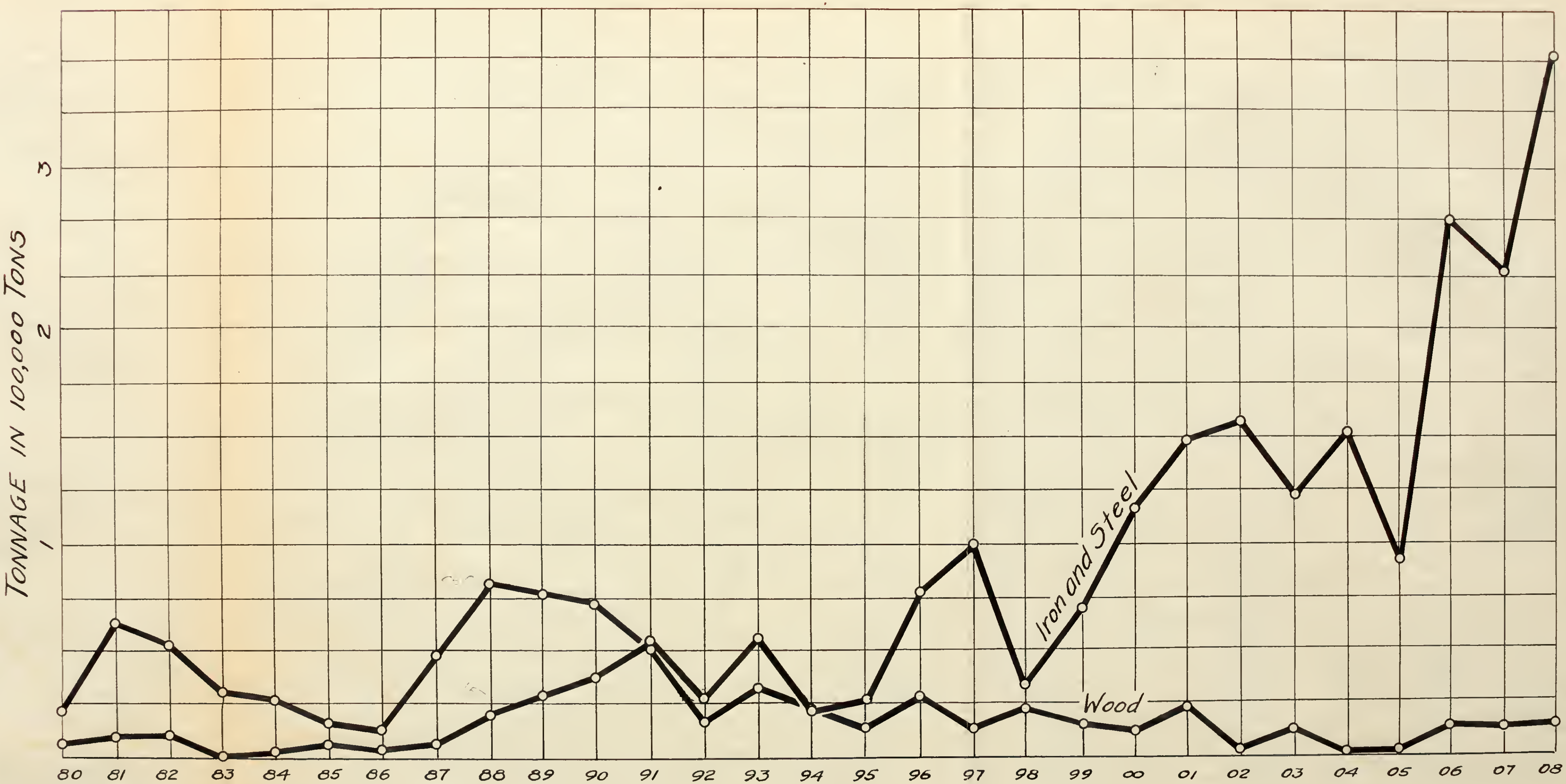
ACKNOWLEDGEMENT.

The writer acknowledges courtesies extended by The United States Bureau of Statistics, The United States Department of Commerce and Labor, The United States Bureau of Navigation, The Chicago Chamber of Commerce, The Detroit Chamber of Commerce, The Managers of the Sault St. Marie Canal, The Duluth Board of Trade, The Buffalo Merchants Exchange, The Cleveland Chamber of Commerce and the Officers of the Chicago Customs House. Without the aid from these sources much which is contained in this thesis could not have been secured.

1.

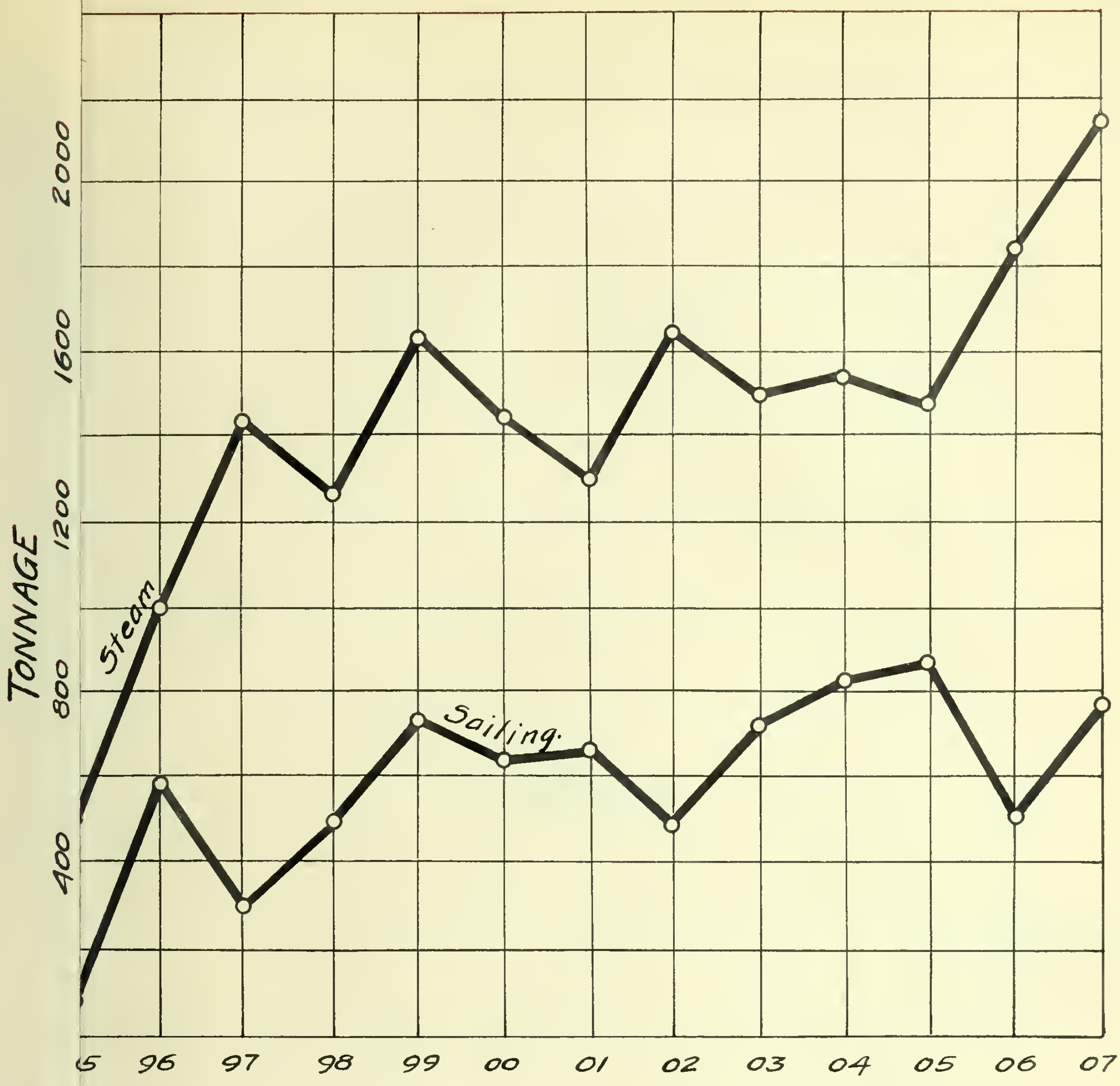

THE GREAT LAKES

Ingold.




CURVE SHOWING GROSS TONNAGE CONSTRUCTED ON THE GREAT LAKES 1880 TO 1908.

Ingold.


TONNAGE
2000
1600
1200
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Steam
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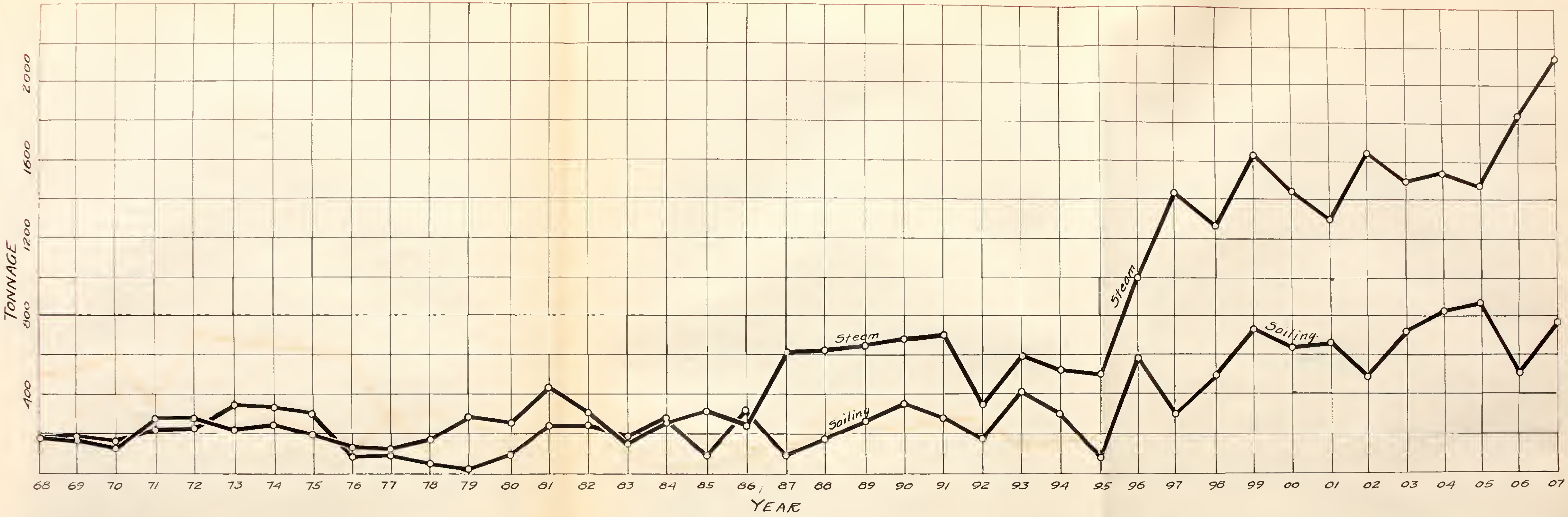
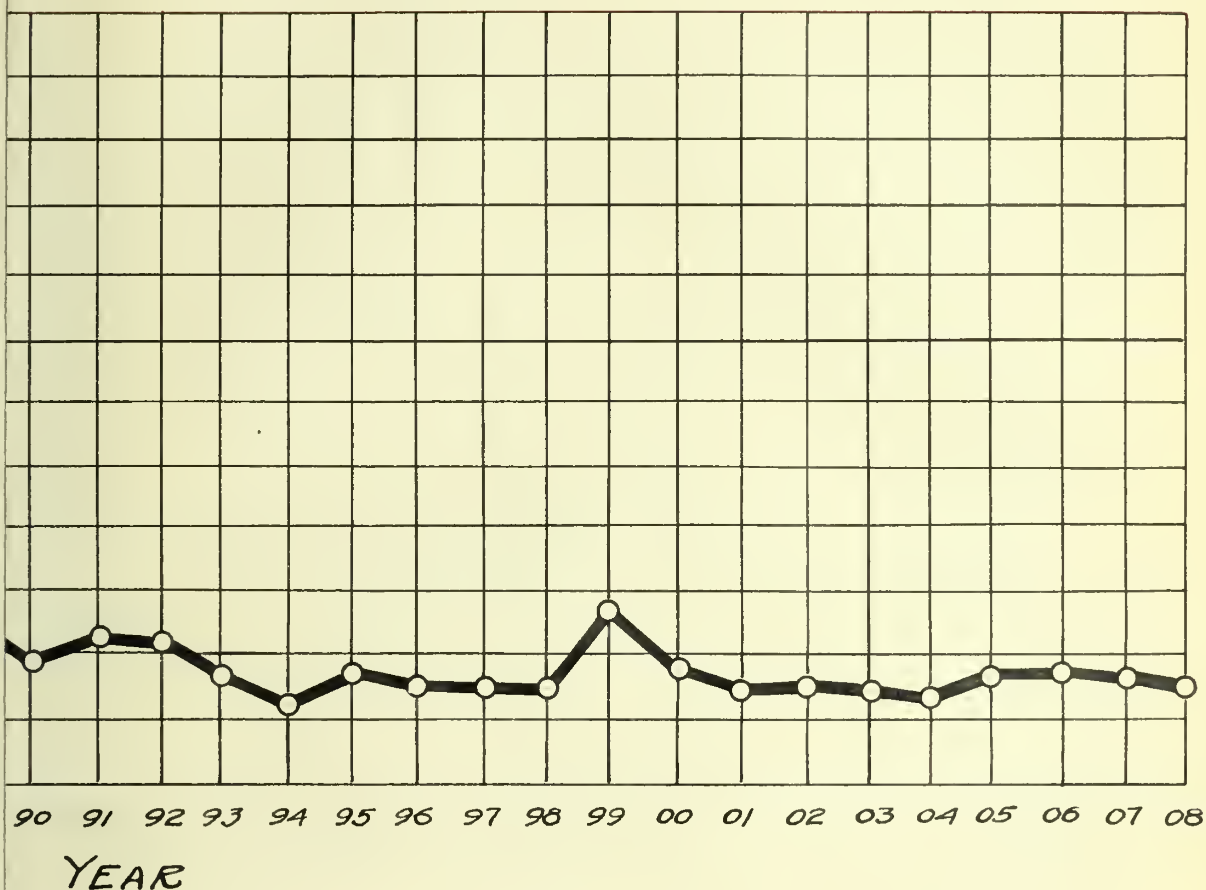



CURVE SHOWING AVERAGE GROSS TONNAGE OF VESSELS BUILT ON THE GREAT LAKES.
1868 TO 1907

Ingold.

3.

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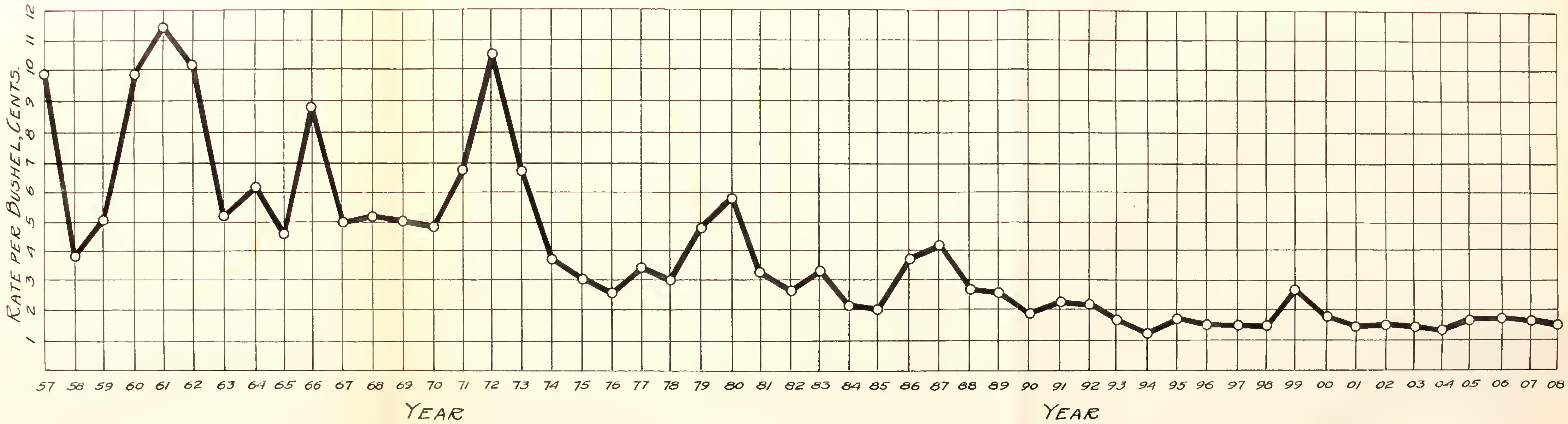


CURVE SHOWING FREIGHT RATE ON WHEAT
FROM CHICAGO TO BUFFALO. 1857 TO 1908.

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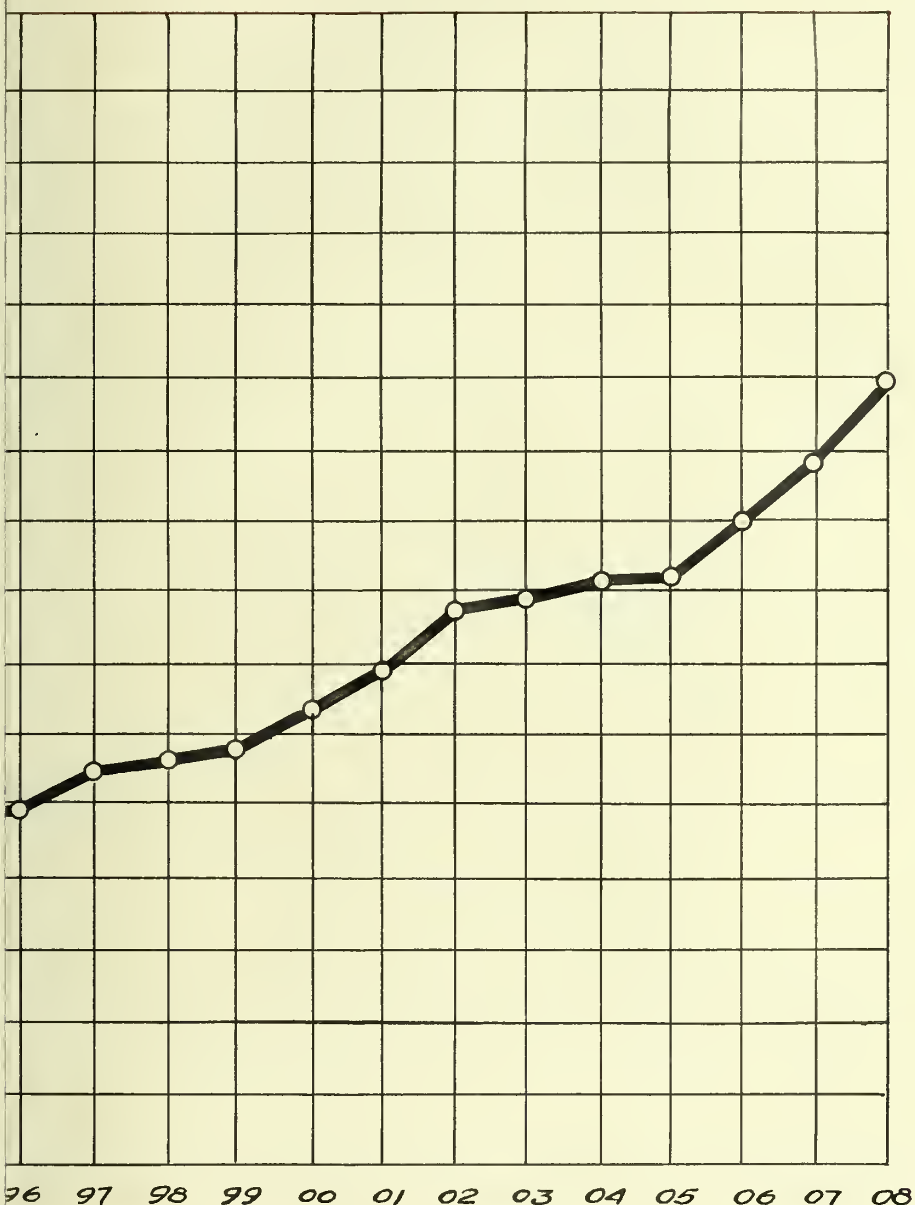
4.




1868 TO 1908.

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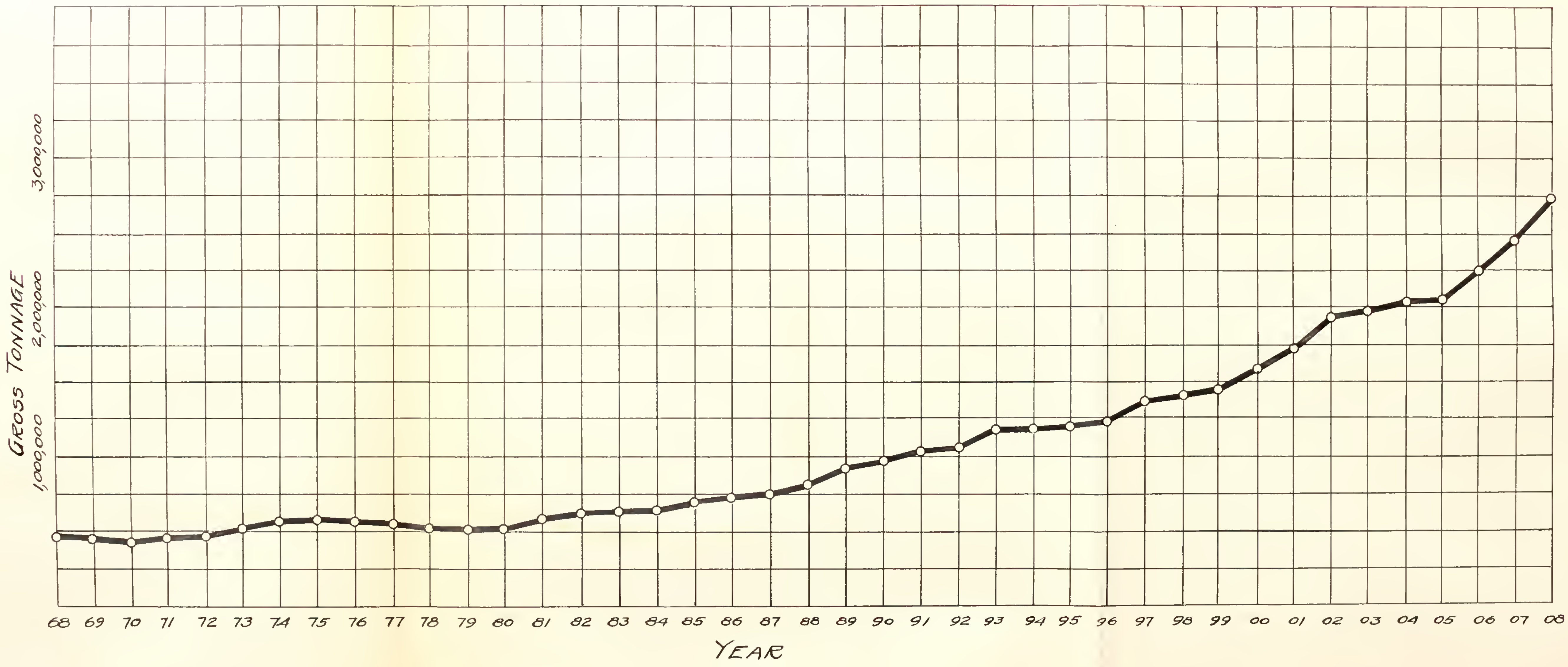


CURVE SHOWING THE TOTAL TONNAGE ON THE GREAT LAKES 1868 TO 1908.

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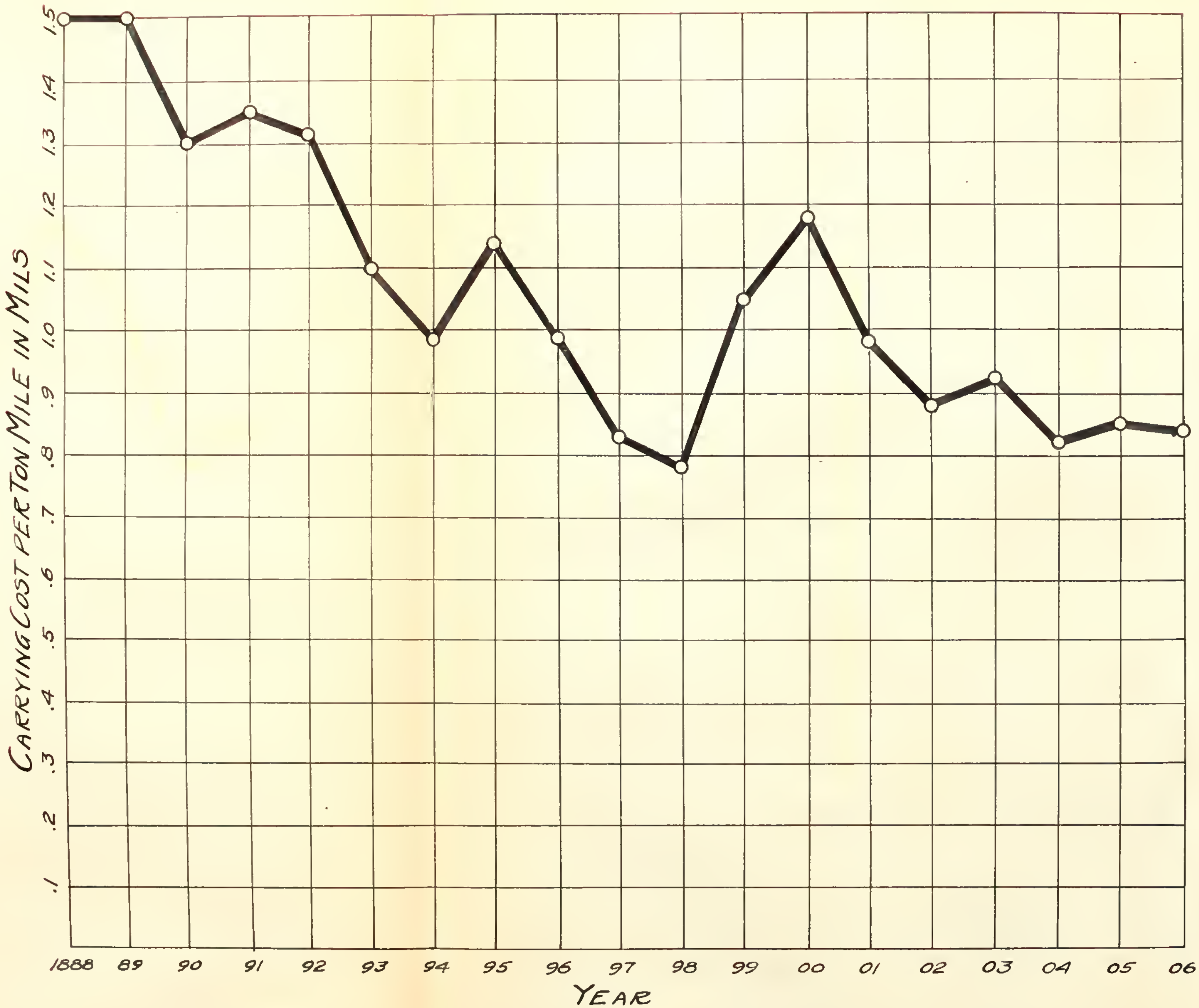
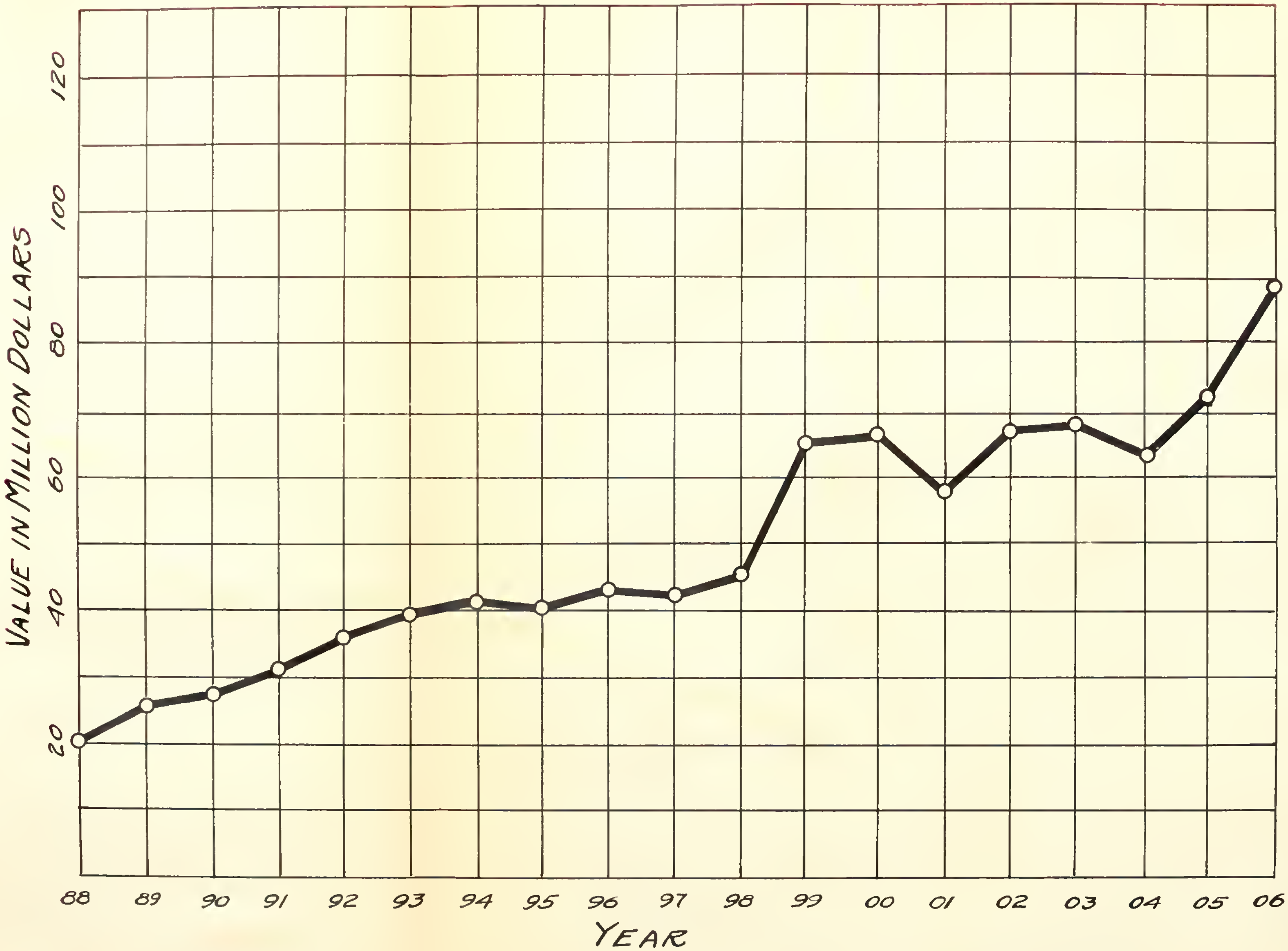
gold.




Curve Showing Cost of Carrying per Ton-Mile, Compiled from the Traffic Statistics of the Sault St. Marie.
1888 to 1906

Ingold.



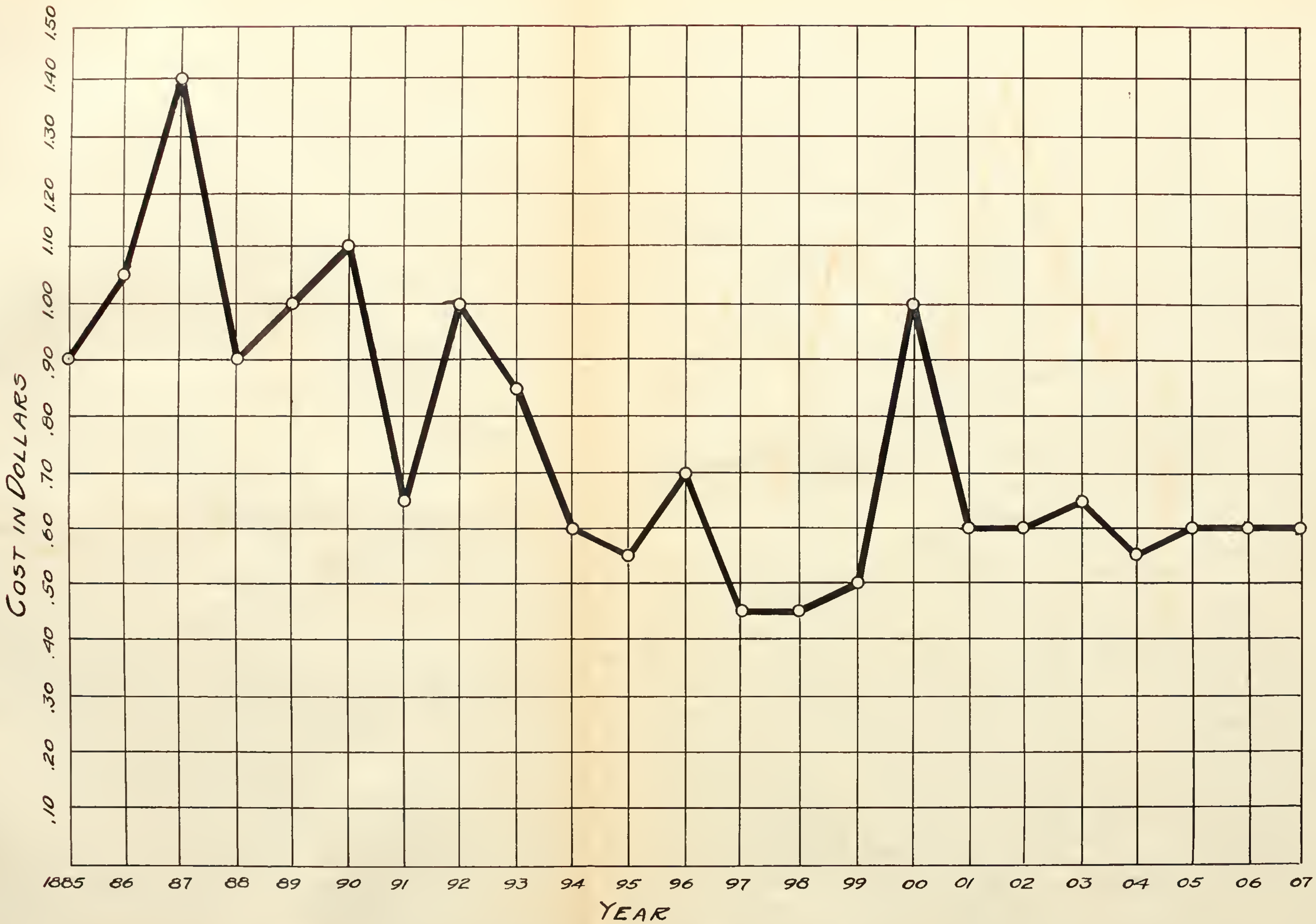

VALUE OF AMERICAN CRAFT PASSING THROUGH THE SAULT ST. MARIE

1888 TO 1906.

Ingold.

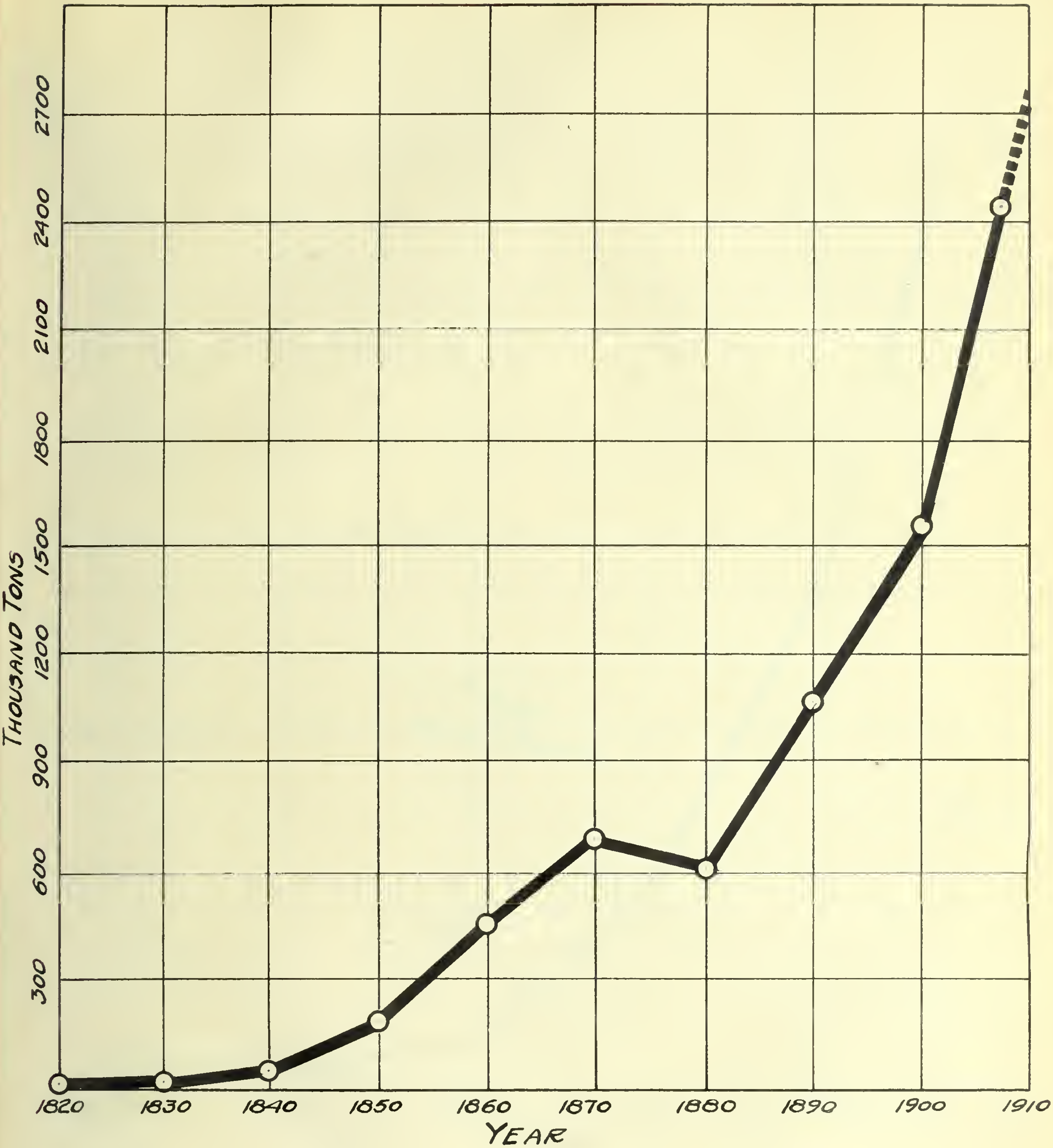

CURVE SHOWING AVERAGE RATES ON HARD AND SOFT COAL FROM OHIO PORTS TO CHICAGO AND DULUTH. 1892 TO 1907.

Ingold.



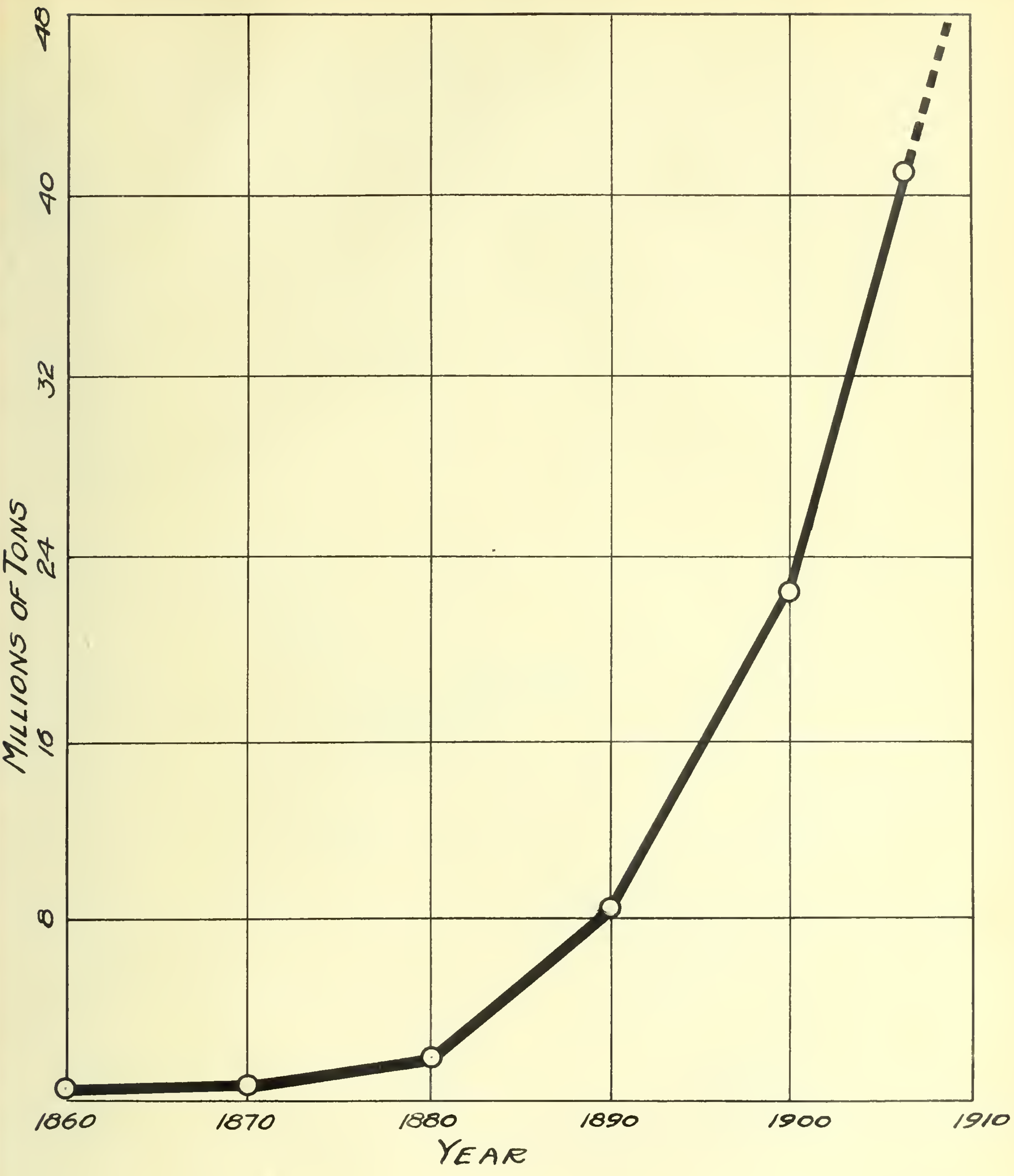

CURVE SHOWING AVERAGE LAKE FREIGHT RATES ON IRON ORE,
PER GROSS TON, FROM ESCANABA, MICHIGAN TO OHIO PORTS.
1885 TO 1907.

Ingold.




CURVE SHOWING TOTAL TONNAGE
OF
VESSELS BUILT ON THE GREAT LAKES
1820 TO 1907

Ingold




Curve Showing Total Tonnage
of
Vessels Passing Through the
Sault St. Marie
1860 To 1907

Ingold.