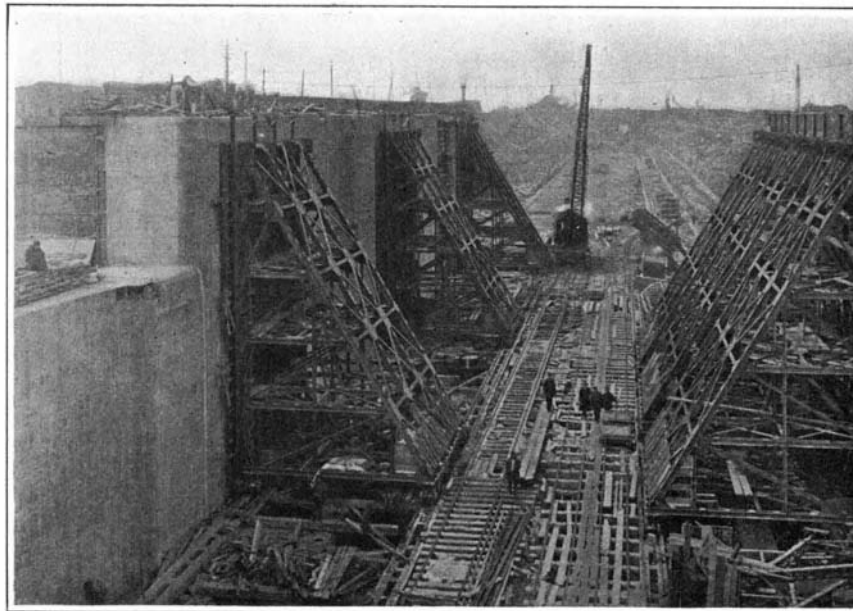


Third lock masonry. Erecting forms for emptying culverts.



Third lock construction. General view, looking west from mixer plant.

## The "Soo" Canal

### The World's Busiest Locks

By Harry Chapin Plummer

GRAIN of the Golden Northwest, iron ore and copper of the Superior region and coal of the Pennsylvania and Ohio fields! For the movement to and fro of this mighty traffic, which, from 1905 to 1912, totaled almost half a billion tons, a second great American canal is in course of construction at Sault Ste. Marie, at the outlet of Lake Superior. The new waterway will be opened early this year. Steamships, sailing vessels and barges will pass through the longest locks in the world.

Already a canal on the American side of "the Soo," with a lock 800 feet long, 100 feet wide and 21 feet deep on its entrance sill, and another on the Canadian side, with a lock 900 feet long, 50 feet wide and 22 feet deep are in constant service during the open season of navigation. But such has been the growth of shipping in both directions through the famous "Soo" that a third and greater passage is imperatively demanded. Hence the new canal. Nor is this all. For work is well under way in the building of the second of two locks of the dimensions of 1,350 feet in length, 80 feet in width and 24½ feet in depth, the first of which is rapidly nearing completion. These will require the ultimate deepening and possible lengthening of the larger of the locks already in operation in the American canal and undoubtedly will call for the corresponding deepening of the channels and, finally, of the chief harbors of the Great Lakes.

Like all great engineering works conducted in the midst of heavy and constant traffic, the construction of the two locks is being attended with manifold difficulties that are really apart from the actual and gigantic task which has confronted the Government in providing safer and more expeditious facilities for the passage of Lake shipping through what is regarded as the busiest

canal in all the world. The excavation for the fourth lock, now in progress, instances the exceeding care with which the War Department engineers are obliged to proceed in preparing the foundation for the latest lock and with which, also, they were obliged to proceed in the excavation for the third lock, the masonry of which is well advanced.

A drama in statistics is the record of traffic which has passed through the portage of the Sault Ste. Marie since Congress, in the '50's, reluctantly granted an inconsequential area of public lands to aid the Commonwealth of Michigan in building the first American canal. From 1855, the year of completion of the canal, until 1864, a total of 1,203,358 tons was recorded, and in the ensuing decade, from 1865 until 1874, 4,829,247 tons, showed a quickening of public use of the waterway. From 1875 until 1884, 14,868,639 tons was the total, while from 1885 until 1894, 80,343,218 tons passed through "the Soo." The decade from 1895 until 1904 registered a traffic of 253,002,697 tons, and in the seven years following, from 1905 to 1912, this was almost doubled, with a total of 441,837,790 tons.

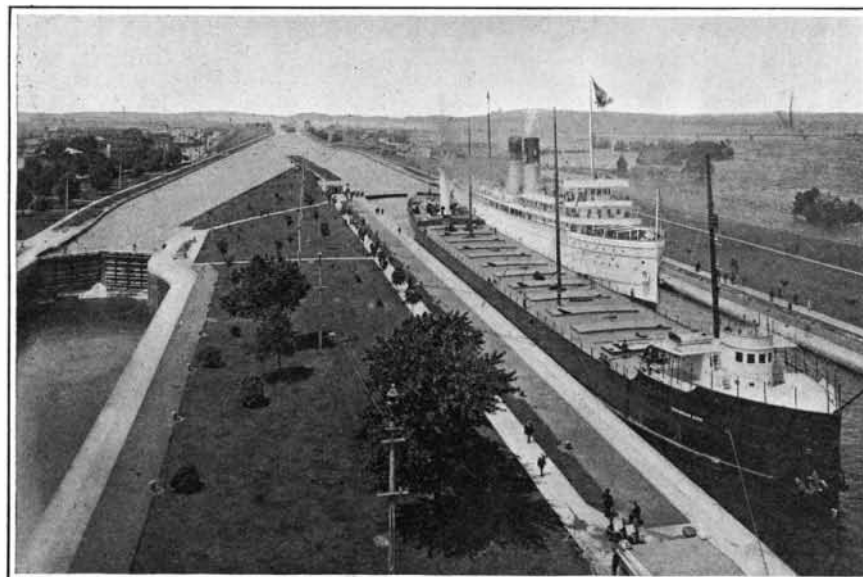
This glance at the development of traffic suffices to show that under normal conditions and with no disturbing factors, "the Soo" presents a scene of undue shipping congestion. It is the last place wherein one would look for excavation and building operations upon a colossal scale. Not only must these in no way interfere with the mighty volume of traffic passing to and fro two score rods to the southward, but the greatest caution must be exercised lest a heavy blasting charge injure the mechanism of the existing locks and bring to a sudden stop the shipping in and out of the greatest of the Great Lakes, with a resulting paralysis of commerce

that would be fearful to contemplate. Another reason for infinite care in blasting is the fact that the scene of the excavating is near to a public park which is the playground for the 13,000 inhabitants of the City of Sault Ste. Marie, Mich., and the rendezvous for the crowds of tourists and excursionists from near and far that flock to "the Soo" every year, during the open season. Yet another reason for limited charges of dynamite is the fear of shattering the rock face of the excavation, which is to be left undisturbed.

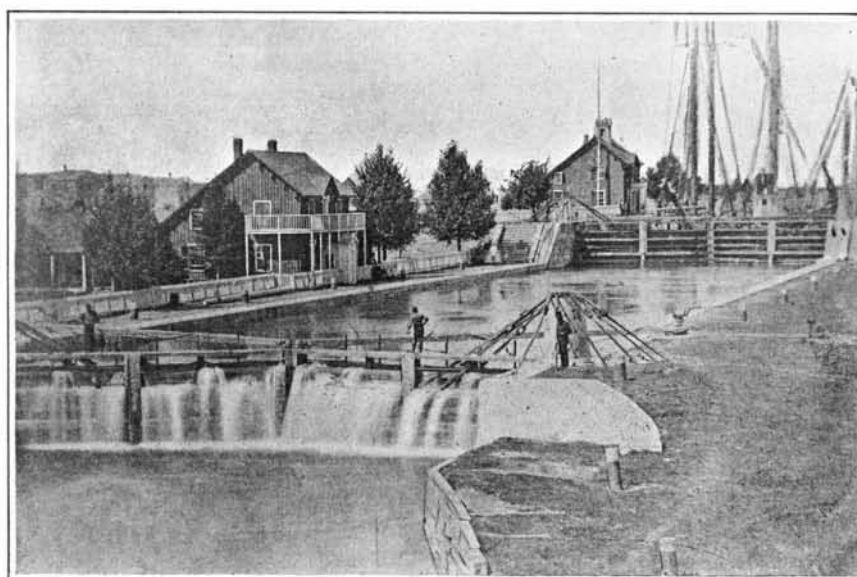
The process that is being resorted to in the excavation for the fourth lock is identical with that followed in the case of the third lock. Advantage has to be taken of a time when not only traffic through the canal is lightest, but when there are the fewest persons in the nearby Canal Park.

Rock channelers strip the rock of earth and vegetable growth, effecting two vertical cuts of 12 and 8 feet, respectively, on either side of the excavation. It is necessary to complete the channeling before any blasting may be done, and so thorough are the precautions taken against accident that the blast holes are stopped at least one foot above the established grade planes within the lock limits and wherever concrete is to be used for future work, and the last yard or so of rock is excavated by hand.

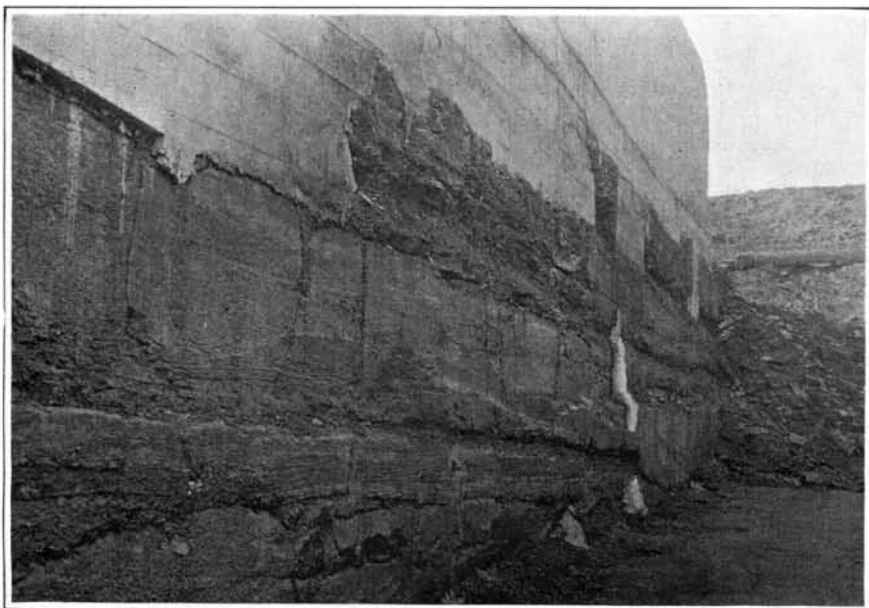
In parallel rows, 35 feet long across the short way of the pit, holes are placed about 4-foot centers in the harder ledges of rock and loaded with 14½ sticks of dynamite and fired electrically by current taken from the electric light wires at 120 or 240 volts. A double system of wiring connects to each of the two caps and the running of several branches from the main feeder lines insures the firing of all charges. Rand and Ingersoll-



The present American canal at St. Marys Falls, through which much of the Superior traffic moves—on the left the Weitzel lock and on the right the Poe lock. It is estimated that traffic totaling in value \$8,622,141,001 has passed through the American and Canadian canals since the first was built.



For a quarter of a century, from 1855 to 1881, State-built-and-maintained wooden locks provided the only entrance for deepwater craft to the greatest of the Great Lakes, but during that interval a commerce of approximately 15,000,000 tons was recorded as passing through "the Soo."



Such have been the demands of traffic made upon the existing American and Canadian canals at the outlet of Lake Superior that a second American canal is now in course of construction, to be opened to shipping this year. It will have the two largest locks in the world, measuring 1,350 feet in length, 80 feet in width and 24½ feet at extreme low water.



Great as is the Poe lock of the American canal at Sault Ste. Marie, with its dimensions of 800 feet in length, 100 feet in width and 21 feet in depth at extreme low water, it has come to be superseded by a yet greater lock, or locks. The first of these two is approaching completion; excavation has been started for the other.

Rand air drills are used in two groups, to each of which air is furnished through 3-inch pipes under about 100 pounds pressure. A ten-machine Ingersoll-Rand steam outfit and a sixteen-machine Sullivan electrically-driven compressor each supply a group of drills.

Such is the determination with which work upon both locks is being prosecuted by the Government, under the immediate supervision of L. C. Sabin, Assistant Engineer, U. S. A., that three shifts of men are employed. These enter upon their task at 7 A. M., 3 P. M. and 11 P. M. Illumination for night operations is provided by strings of incandescent lamps hung over the drills and improvised clusters of lights centered about the two shovels.

The severe Northern winter has no terrors for the engineers and their crews, for the masonry work is enclosed by sections, as progress is made, and salamanders used for heating the sand, lime and cement afford warmth for the working forces. As the construction of the fourth lock will be advanced to the masonry stage by next

winter, the same system will be followed for operations upon that lock.

Of the concrete gravity type, the walls of both locks rest on a Potsdam sandstone foundation. They are of 50 feet maximum height, with a width at the top of 10 feet and irregular back facing and a bottom width of 26 feet, making an average volume of 1,060 cubic yards per linear foot. Six 9 x 10-foot culverts, 7,000 feet long and separated by 4-foot reinforced concrete partition walls, lie under 2-foot foundation slabs, reinforced transversely with 1-inch rods spaced 5 feet apart, and over the culverts are 7/8-inch bars spaced on 6-inch centers. The culverts are anchored down by two rows of 1½-inch apex bolts, 20 feet long and 4 feet apart. These are let into the rock about 7 feet and extend upward into the partition walls. Supplementary anchors are pro-

vided by 1-inch boulder bars, 5 feet apart, on the center line, the tops of the apex bolts being tied together by two 7/8-inch longitudinal bars.

A cable haulage system consisting of two 35-horsepower Stevens haulage machines, each operating ¾-inch steel cables at a speed of 260 feet per minute, effects the transportation of concrete from the mixers and sheds, located downstream from the lower end of the third lock on the St. Marys River, opposite the end of the Poe Lock entrance. There, also, is the crushing plant, which furnishes broken stone and screenings, the stone being obtained from the Bruce limestone quarries on the river, 40 miles away.

The plan of construction of the lock walls is to build

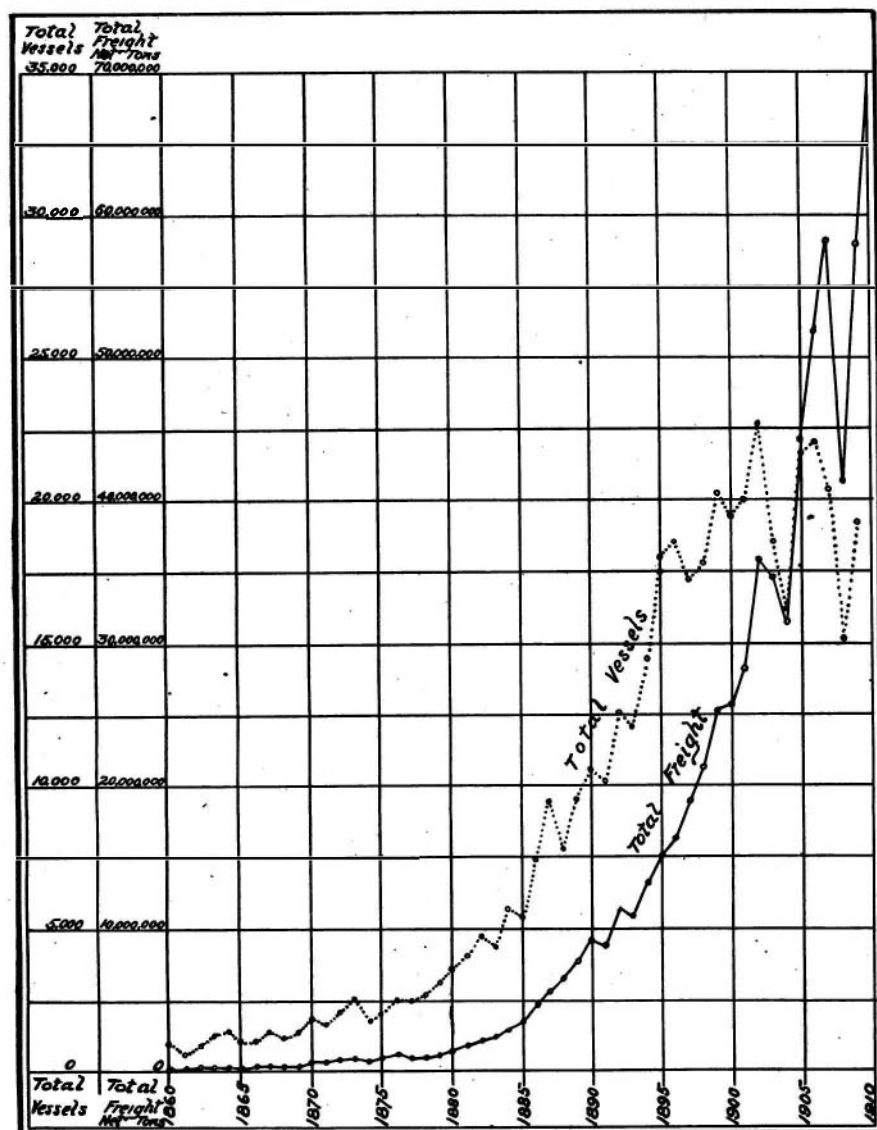
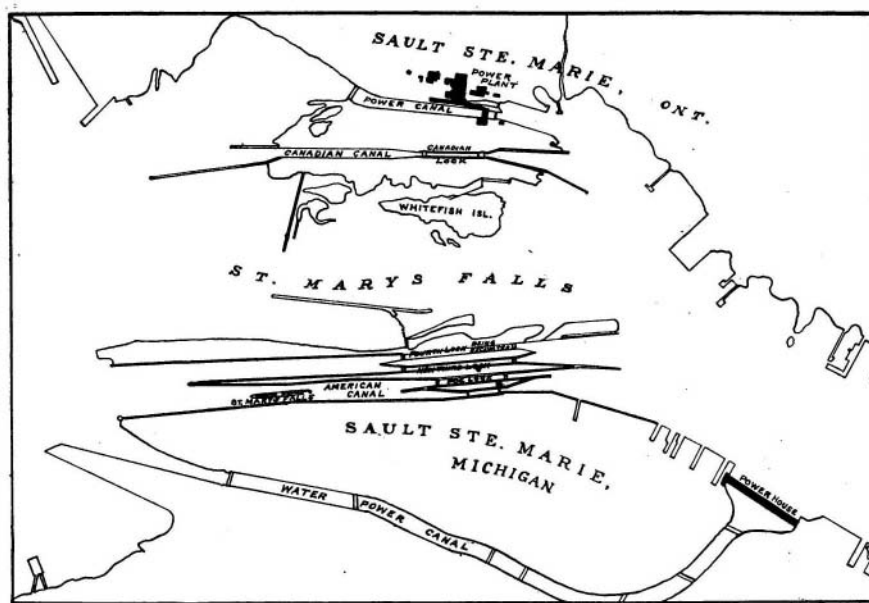


Diagram of the increase in totals of vessels and of cargo tonnages passing through the Sault Ste. Marie canals during the half-century from 1860 to 1910, showing how, by the advances realized in modern Great Lakes ship construction, the number of cargo tonnages leaped ahead of the number of vessels in the last decade.



Map of the falls of the St. Marys River, at the outlet to Lake Superior.

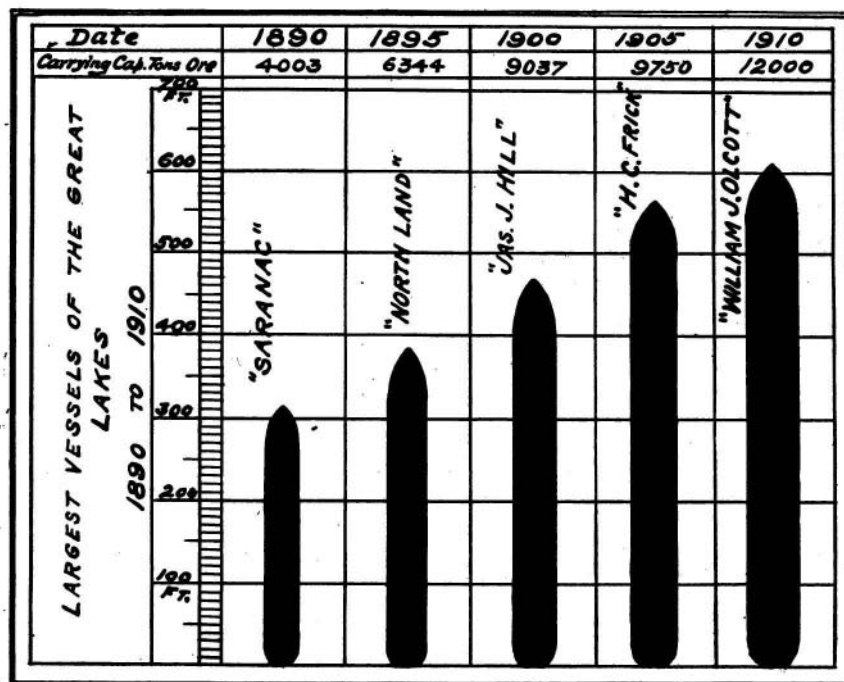


Diagram of the growth of Great Lakes vessels in the twenty years from 1890 to 1910.



away from the mixers, beginning with the steel forms, until one half of each wall is completed. The second crane, with its forms, is then brought back to the center and worked toward the mixer plant while the first continues to the end in the same direction as it started.

For the inner face of the lock walls sheet steel forms in 39-foot lengths are held in place by a mounted structural steel frame made up of 4 angle trusses designed to withstand pressures set up by the successive deposition of 40 cubic yards of concrete per linear foot. Concrete is assumed to exert a hydrostatic pressure for a height of 10 feet and to weigh 100 pounds per cubic foot. For maximum stresses a wind pressure of 20 pounds per square foot in either direction is added to the concrete pressure. Forms for the bulkheads at the ends of the section and the back face are of wood, braced in the customary manner.

The construction of a fourth, as well as a third lock, is the alternative of a plan which was under consideration by the War Department officials before the present work was entered upon, to build only the third lock and to deepen the present Poe lock, the larger of the two already in operation. Assistant Engineer Sabin, than whom none is more familiar with engineering and transportation conditions at "the Soo," argued convincingly against this proposal. He declared that on the Panama Canal the six locks have been built in duplicate merely to provide for accidents and repairs, "where the probable tonnage in sight at present does not exceed one tenth of the present tonnage of the Sault Ste. Marie canals." He observed:

"In determining the relative advisability of building a fourth lock or deepening the Poe lock the difference in the cost of maintenance, as well as the difference in the cost of construction, must be considered. If the Poe lock were deepened no additional force would be required to operate it, but to operate a fourth lock would call for 25 or 30 additional men. If the fourth

lock were held as an emergency lock, however, it need not be operated when the emergency did not exist. Another point to be considered is the service that will be given while construction is in progress. If the construction of a fourth lock were begun either before or after the completion of the third lock, an accident to the third lock could not be more serious than a return to the conditions now existing. If, on the other hand, the deepening of the Poe lock were started on the completion of the third lock, the latter would not be able, without serious delays, to handle all the traffic during the year that it would be necessary to close the Poe lock, and a serious accident to the third lock during that year would stop practically all commerce so far as the American canal is concerned. If account is taken of the Canadian lock, however, the importance of this contingency is somewhat modified, but still serious."

To the fact that the existence of the great deposits of high-grade iron ore in the Lake Superior country is supplemented by the cheap transportation of that product, is due the supremacy of the United States among the iron and steel-making countries of the world. The staggering total of 490,539,866 tons has been accomplished by the iron-ore shipments, east-bound, through "the Soo" since the initial traffic of 1,447 net tons in 1855. So the very existence of the steel industry of the United States, concentrated at Pittsburgh, Pa. and Gary, Ind., and at other centers, which annually consumes 30,000,000 tons of iron ore moving eastward and southward through the Great Lakes—and through "the Soo"—is vitally related to the great transportation project. Dependent upon it, also, are the electrical industries, with their tremendous takings of copper, and, likewise, the consuming public of two Hemispheres, who derive their cereals from the common channel of—the Great Lakes. Thus the economic vitality of the American nation, of Canada and of old Europe, are immediately concerned in the improvements at "the Soo."

It is this movement of a vast commerce that would be hazarded by the work of deepening the Poe lock upon the completion of the third lock. Against this Col. W. H. Bixby, the Chief of Engineers, U. S. A., warned in his recommendation of the present improvement, as follows:

"I doubt the advisability of taking any chances of the Poe lock being out of commission for a single season until after the completion of a second deep lock, as in case the Poe lock were out of commission any accident to the first deep lock now under construction would then make the coal and iron ore and grain navigation entirely dependent upon the single existing medium-depth Canadian lock, which is unable by itself to carry the existing traffic."

In the year 1855, 1,441 tons of coal entered Lake Superior, through "the Soo," from the eastern mines, and last year 14,931,594 tons entered.

In the 15 years from 1855 to 1870, little or no wheat moved eastward through the canal, and in the latter year only 49,700 bushels were recorded, but in the year following the wheat traffic amounted to 1,376,705 bushels, and last year it totaled the enormous number of 174,086,456 bushels.

Through the 57 years, from 1855 to 1912, a miscellaneous traffic moved through the canal as follows: 1,797,994 passengers, 29,871,692 tons of general merchandise, 3,067,435 tons of copper, 6,926,423 tons of manufactured and pig iron and 10,930,749 barrels of salt.

It was 12 years or more before Fort Sumpter was fired upon that the bill to grant the public lands for the commencement of the work of construction of "the Soo" canal was before the Senate, and no less distinguished a Solon than Henry Clay arrayed himself among the opponents of the measure. As illogical as non-grammatical was his denouncement of the measure. Said he:

"It is a scheme to squander the public resources upon a chimera beyond the remotest bounds of settlement, if not in the moon!"

## Pressure Rises in Electrical Circuits and Apparatus\*

FAILURES of insulation and apparatus consequent on unexpected and more or less unexplained rises of pressure were for many years a concomitant of commercial electrical practice. Nowadays, however, trouble of this kind is relatively infrequent, and in general it may be said that the causes of such pressure rises are well understood. None the less, a proper consideration of the matter demands a fair amount of mathematics, and it may be doubted if the average electrical engineer is as much at home with the subject as he would like to be. If we interpret his position correctly, he must find much to interest him in the able review of the whole matter contained in Mr. Duddell's address with which the present session of the Institution of Electrical Engineers was opened. The address was not in general concerned with new material. Its purpose was to give in a small compass a connected account of work and investigations the official records of which are spread over the technical publications of half a dozen countries.

Although we have suggested that trouble due to pressure rises is of less frequent occurrence at the present time than in the past, it must not be supposed that the subject is not still of great practical importance. So far as it from being unimportant that Mr. Duddell's address is likely to become a sort of standard reference in the future for engineers who may have to deal in practice with the subject of which it treats. In giving a brief account of the ground covered by Mr. Duddell, we regret that we cannot do more than mention the striking series of experiments with which he so skillfully illustrated his subject. We can but remind our readers that as an experimentalist Mr. Duddell has few equals, and state that his display on the occasion here reported was worthy of his reputation.

The causes of pressure rise in cables and apparatus were divided by Mr. Duddell into three main classes—viz., resonance, switching, and arcs and sparks. In respect to the first of these, it is well known that a circuit which contains self-induction and capacity has a free period of its own, and that electric oscillations may be produced in it provided the resistance does not exceed a certain limit. If now an alternator, the period of which is the same as the period of the circuit, is connected to the circuit, very violent oscillations may be set up, with the production of large pressure rises. This effect is known as resonance. The case of resonance which most generally occurs in practice is when a long unloaded cable is connected to an alternator. The necessary capacity for the circuit is furnished by the cable, and the necessary self-induction by the alternator itself. Resonance in such a case as this, owing to the coinciding of the fundamental period of the alternator

with the free period of the circuit, does not in general occur in practice. Mr. Duddell quoted only one such case. Resonance of the third, fifth or seventh harmonic of the alternator is, however, not uncommon, although much less frequent with modern than early alternators, owing to the better wave-form of the later machines. Some examples of resonance were quoted by Mr. Duddell. With an old type 400 kw. 2,000-volt alternator, working through a 3 to 1 transformer, resonance with the third harmonic gave a maximum voltage reading of 10,140, or 1.60 times the R.M.S. value, while resonance of the thirteenth harmonic on a 500 kw. 6,600-volt machine of modern type gave a maximum voltage of 14,000, or 2.33 times the R.M.S. value.

Apart from cases of resonance at the normal period of an alternator, the state may arise owing to alteration in speed of the machine, with a consequent alteration in the periodicity. This may cause serious pressure rises if an alternator is run up when excited and connected to a cable system. The same sort of thing may occur if a cable feeding a running motor, or converter, in a substation is switched off at the generating station. The motor or converter will, of course, begin to slow down, and there is risk of resonance occurring at some point. Mr. Duddell suggested that the risk was serious and that the self-induction of the machine might be high enough to cause resonance of the fundamental. He quoted a case in which the switching off of a feeder supplying two motor generators in a substation caused resonance of the thirteenth harmonic and a voltage peak of 16,200, the bus-bar pressure being 6,420 volts. Resonance in the type of cases we have been dealing with only occurs when the cable system is on open circuit, but the same sort of thing can occur on a high-tension system containing a number of step-down transformers, if the secondaries are open circuited. Another possible case would be a step-down transformer supplied through a fairly long cable from a generating station and switched out at the generating station, but left connected on the low-tension side. If this side were alive from the low-tension system in some way, the transformer might transform up with the appearance of resonance on the high-tension side.

Switching, the second case considered by Mr. Duddell, may cause pressure rises quite independently from any arcing or sparking at switch contacts. The best known case is probably the breaking of an induction circuit, such as the field of a generator. In such cases the voltages reached may be very high if the current is suppressed quickly enough, because the whole of the energy stored in the self-induction is set free, and must either be dissipated or stored in some available condenser. A second case of pressure rise owing to switch-

ing occurs when an uncharged condenser is suddenly switched on to a generator. In the general case the potential difference between the terminals of the condenser will rise not only to that of the generator, but will overshoot the mark, and may, if there are no losses, reach twice the value. Two examples of this type of pressure rise were quoted by Mr. Duddell. The first concerned 3 miles of cable on open circuit switched on to a 1,000 kw. 5,600-volt generator. The peak rose to 14,500 volts, or 2.6 times the R.M.S. value. The second case was of 2 miles of cable switched on to a 5,000-volt generator of old type. The potential difference rose to 11,000 volts, or 2.2 times the R.M.S. value.

Normally no rise takes place when a condenser is switched off, but if vibration or sparking takes place at the contacts, pressure rises may occur, since after the circuit has been first broken, it will be made again owing to the sparking. This may cause a pressure rise equal to twice the applied voltage, as before mentioned. This effect may be repeated with a series of sparks, and in the worst case it is possible to get a pressure rise of 4.2 times the R.M.S. voltage. Mr. Duddell stated that, in practice, when cables were switched in and out on open circuit, if no sparking took place the peak rarely exceeded the R.M.S. voltage. With sparking the rises might be serious, but with switches in good condition he thought a peak of three times the R.M.S. voltage might safely be considered as the limit. The next case of pressure rise due to switching is concerned with the switching in and out of circuits containing both induction and capacity. Pressure rises may occur in such cases if the resistance is low enough. When the capacity and self-induction are not distributed, the voltage rise may be determined by comparatively simple calculation, but the general case of a circuit with distributed induction and capacity demands advanced mathematics for its solution. From the point of view of pressure rises Mr. Duddell stated that for practical purposes power supply cables could be looked upon as approximating to the limiting cases either of very long or very short cables. This much simplifies their consideration.

If an infinitely long cable be suddenly connected to an alternating-current generator at the moment when the potential difference is zero, as the potential difference increases a current will flow into the condenser, formed by the cable and the earth. The charge will travel along the cable with a certain velocity, and, owing to the resistance and capacity of the cable, the quantity of electricity will gradually become less as it travels along. It will form a wave of gradually decreasing amplitude. As the wave travels along, the phase of the current wave, applied to the end of the cable, continually alters, owing to the revolving of the alternator. Consequently,

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