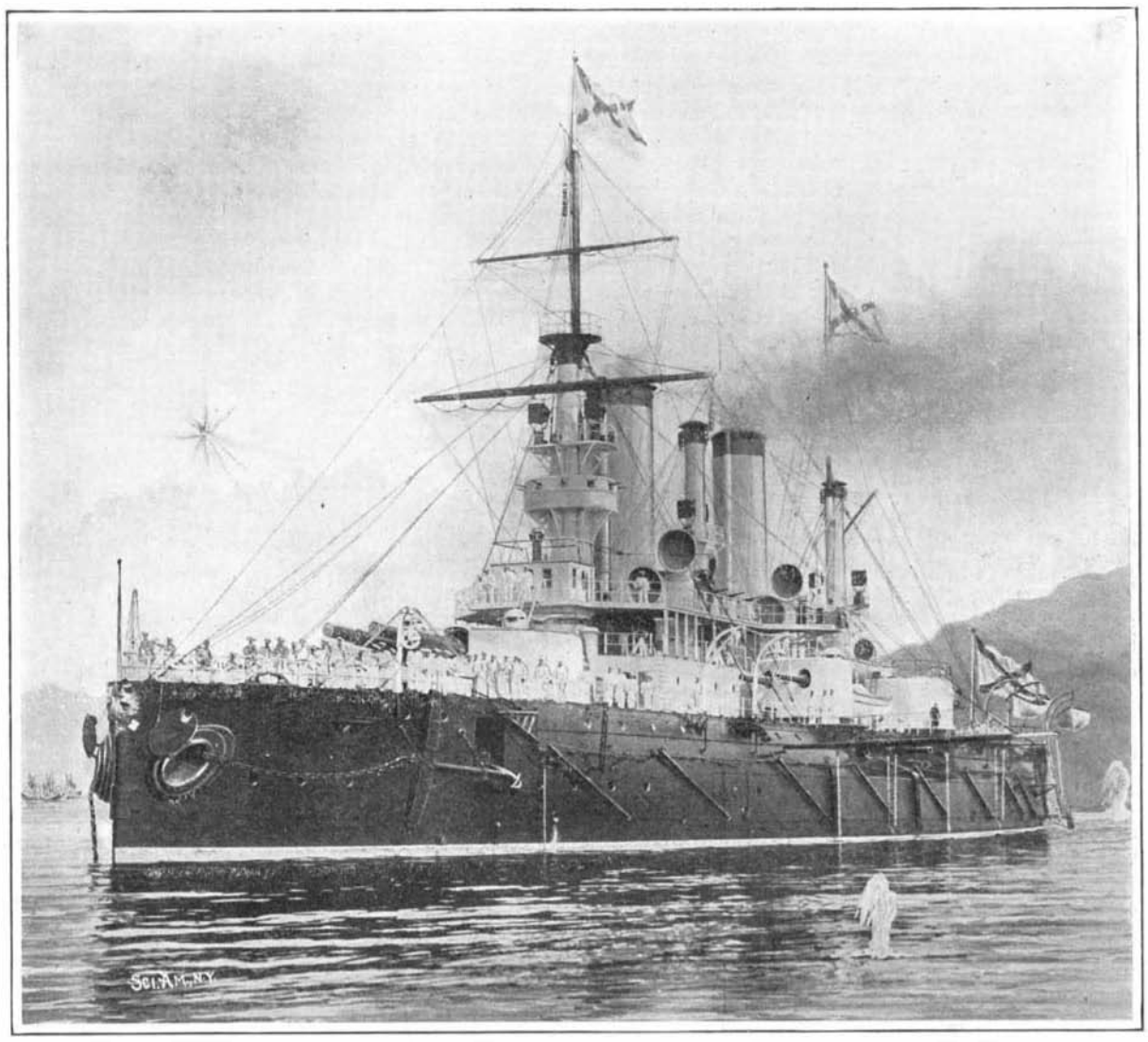
portions of one to one, sand and cement, was plastered on the old work, forming a seal and making the structure almost entirely a homogeneous one. The 6 by 7½ lateral tunnels were constructed with 13-inch bottoms and 10-inch walls of concrete. The trunk system tunnels were built with 21-inch bottoms and 18-inch walls. The cement used for the making of the concrete was American Portland (Atlas and Chicago A. A.), and the company subjected each and every barrel to a fourteen-day test under rigid specifications. On the straight work mixtures of five parts broken stone and screenings, or five parts mixed gravel and sand, to one part of cement were used, while at the intersections a mixture of four parts stone or gravel to one of cement was adopted.

A large equipment of small tramcars, some 900 in number, built to run on a 14-inch gage, double-track system, was provided to dispose of the excavated material. The cars were hoisted by power-driven elevators up the shafts to the head-houses and the material dumped into wagons. Much of this was deposited on the lake front, a special 10-ton, stiff-leg derrick being provided for unloading the wagons. In this way much valuable land was added to Grant Park. At one shaft near the river an endless chain drew the cars up an incline onto stagings or platforms extending over dump scows moored to the dock below, and the cars were then emptied into these. The platforms could be raised and lowered as required, so as not to interfere with the river traffic.

The steepest grade in the tunnels is 1.75 per cent, and the grades at the railway terminals do not exceed 12 per cent. The latter steep grades form the approaches to the tunnels, which are built with the rails some 30 feet below the street level. The four-way intersections have curves of 20-foot radius, and the sharpest curves on the main lines are of 16-foot radius.

The track is 2-foot gage, laid with 56-pound T-rails fastened by bolted clamps to cast-iron chairs imbedded in the concrete floor of the tunnel. Part of the system is overhead trolley, while the rest is of the Morgan third-rail traction system. This latter consists of a perforated metal plate (½ inch thick and 4 inches wide) forming a rack which is bolted between two lines of timber stringers. These serve to protect and support the rail. A special construction for the tunnel work was devised in the use of chairs of bent steel channels to support the rack. The locomotives are of the class used in mine haulage work, but are peculiar in the method of taking current. The rack rail serves both for traction and as a third-rail conductor, the current being led to motors, geared to the axles, with suitable controlling devices. The track rails are used for the return current. The wheel base of the locomotives is 24½ inches. With one 75-horse-power motor the weight is about 3 tons; with two 80-horse-power motors, about 5 tons. The trolley locomotives are of the ordinary type used in mine systems.



This ship was twice struck by mines, and once by a torpedo, without being sunk. She was the last of the Port Arthur fleet to be destroyed. When 203-Meter Hill was captured she went outside the harbor, where the lofty Liaoshan Mountain screened her from observation. She let down her torpedo nets and was three times attacked by the whole torpedo squadron before she was hit. She did not sink; but next day, Capt. Von Essen opened her valves and sank her in deep water.

The Battleship "Sevastopol" in Port Arthur Harbor.

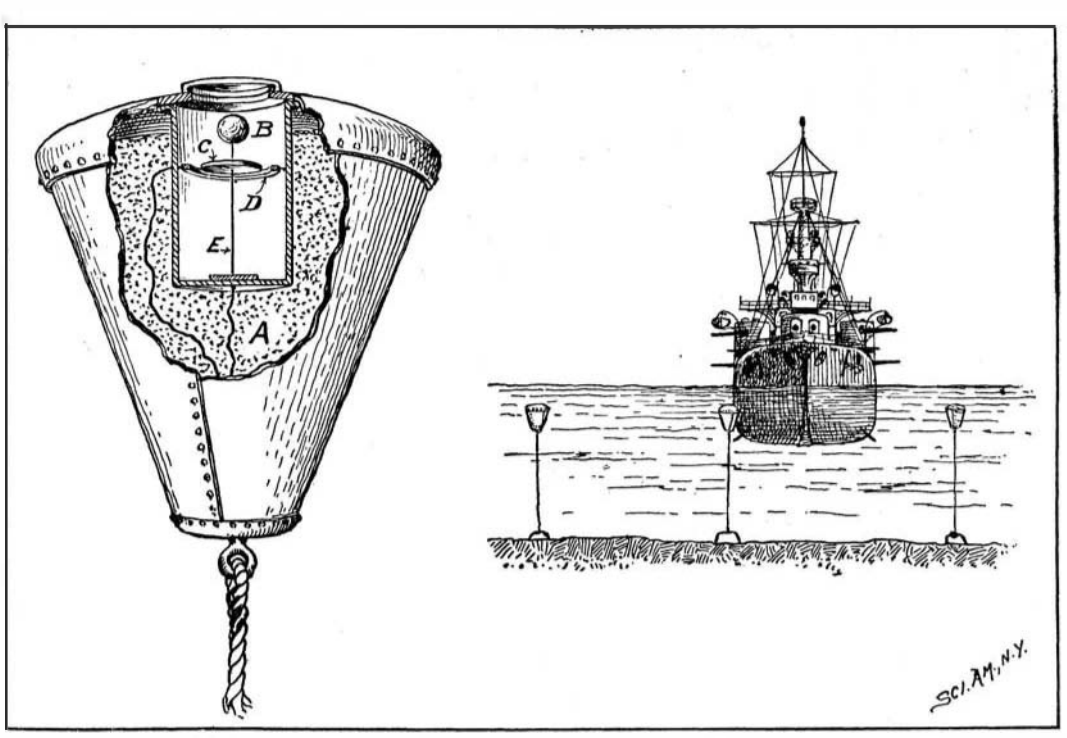
Eighty-five and six-tenths per cent of the freight cars of the United States now have air brakes.

STORY OF THE OPERATIONS OF THE RUSSIAN FLEET AT PT. ARTHUR AS TOLD BY ONE OF THE COMMANDERS.

To all interested observers of the great naval conflict between Russia and Japan, it has been a matter of regret that so little has been made known as to the actual work done, during the long siege of Port Arthur, by the ships of the Russian navy. The information contained in official dispatches has been sufficient to give the general public only a vague idea of what was taking place behind the impenetrable curtain, which a strict censorship flung before the stage whereon this, the greatest and most heroic naval drama of modern times, was being enacted.

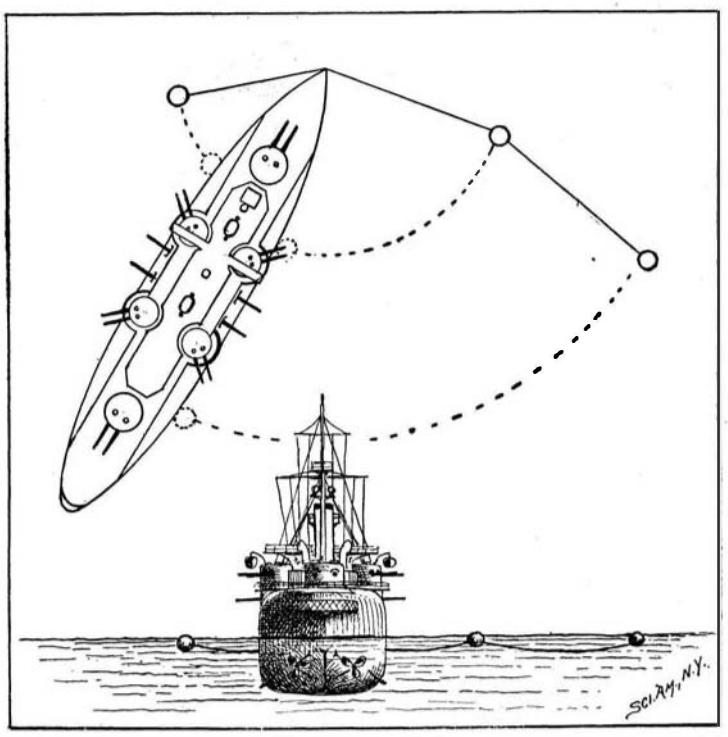
The sudden loss of three of the best ships of the Russian fleet, in the unlooked-for torpedo attack on the night of February 8, placed the Russians at such a numerical disadvantage, that there was little hope of achieving any decisive victory over the Japanese until reinforcements should arrive from Europe. All the subsequent engagements were fought against odds which rendered the result, barring accident, a foregone conclusion. To be convinced of this, it is only necessary to bear in mind that the torpedo attack of February 8 and the battle outside Port Arthur on the morning of February 9, resulted in the torpedoing of the two best battleships and one of the finest cruisers of the fleet, and the disablement of one of the battleships and three of the cruisers by shot holes below the waterline. From that time to the final sinking of the "Sevastopol" in the last days of December, practically all our information regarding the Russian fleet has come from Japanese official reports; and while these have been in the main reliable, they have consisted chiefly of statements of the damage inflicted by the Japanese either by gun, torpedo, or mine, and have given us very little information as to the damage and loss which they themselves have received from the Russians.

During the long months of the siege, it was a matter of frequent speculation as to what was being done by the Port Arthur fleet in repairing the serious injuries



This is the type of stationary, or anchored, mine used by the Japanese, whose torpedo boats ran in to the mouth of the harbor at night, and dropped them in position across the channel. They consisted of an iron shell filled with high explosive, *A*. The firing mechanism consisted of a ball, *B*; flexible rod, *E*; contact disk, *C*; and contact ring, *D*. When mine was struck by ship, *C* was thrown against *D*; circuit was closed and *A* was detonated.

Anchored Mines, Laid by the Japanese, and Removed by "Sweeping."



The Japanese strewed in the outer channel, leading to Port Arthur, a number of floating mines, connected by cables, in sets of two or three. The "Petropavlovsk" struck one of these, and as she moved forward the mines swung in, wrecking her hull at three separate points.

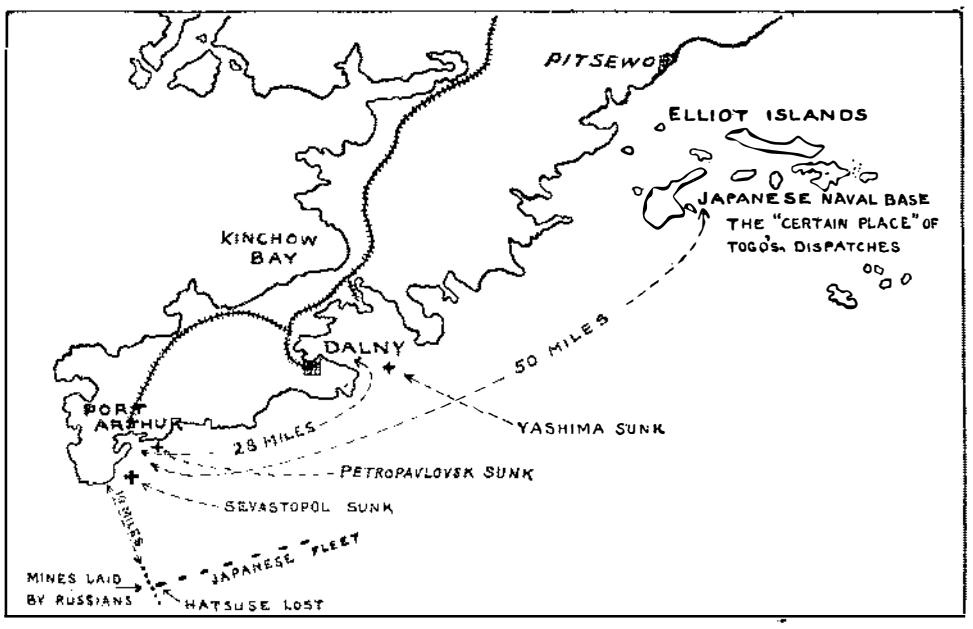
How Makaroff's Flagship, "Petropavlovsk," Was Sunk.

THE OPERATIONS OF THE RUSSIAN FLEET AT FORT ARTHUR.

received in the first attack, and there was much curiosity as to how it was possible for these torpedoed ships to be put in such serviceable condition that they could make frequent sorties, and finally engage in one of the fiercest and most stubborn naval battles of history. It was known that Port Arthur possessed but one drydock; and yet here were four battleships and a large cruiser, that in the space of a few months recovered from torpedo injuries which, theoretically, should have put them out of action for the rest of the war. Moreover, they were able to engage in evolutions, keep proper station, and inflict serious damage upon the enemy in a long-drawn-out and fiercely-contested battle.

The answer to these questions is given in the present article, in which the SCIENTIFIC AMERICAN is enabled to present to the world, for the first time, the story of the brave struggle made by the crippled Russian fleet, in its uphill fight against the combined forces of Admiral Togo afloat and Gen. Nogi ashore.

For our facts we are indebted to the courtesy of Capt. N. O. von Essen, who was in command of the battleship "Sevastopol," and to Commander N. A. Saxe, who kindly furnished the information from which the accompanying diagrams were drawn. These gentlemen are now on their way to St. Petersburg from Port Arthur, and the editor is indebted to them for a lengthy interview, in which, concurrently with the narration of the heroic work done by all grades of the service in the Russian fleet, they paid a high tribute to the skill, courage, and courtesy of the Japanese officers and men.

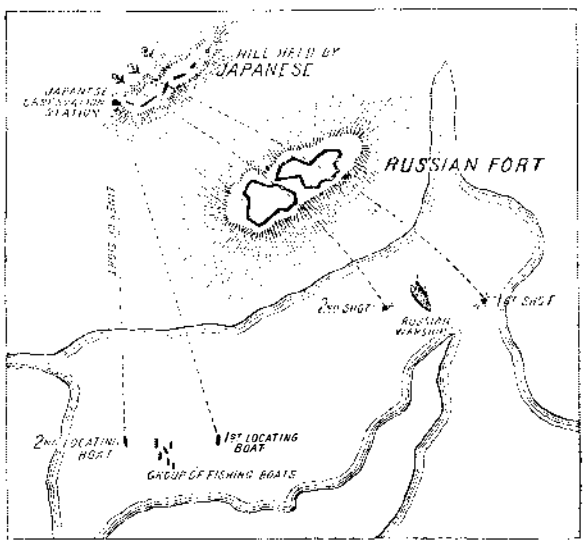


The naval base (the "certain place" so often mentioned by Admiral Togo) was a sheltered bay in the Elliot Islands. Here the ships were coaled, watered, and their stores of ammunition, etc., replenished. Dalny was the base for the besieging army of General Nogi.

Map Showing Port Arthur and the Japanese Naval Base, Fifty Miles Distant.

Immediately after the disaster of the night of February 8, the cruiser "Pallada" was floated into drydock, and the battleships "Czarevitch" and "Retvizan" were taken into the inner harbor, and repairs executed by means of caissons of timber built around the gaping holes which had been blown into their hulls by torpedoes. The repairs to the "Pallada" were completed early in April, and about the 20th of June the "Czarevitch" and "Retvizan" were also in condition to take the sea. On the 13th of April, during the sortie in which the "Petropavlovsk" was sunk with Admiral Makaroff on board, the battleship "Pobieda," in returning to the harbor, struck a contact mine, and was heavily damaged. Similar repairs were executed, and this ship was able to take her station in the line in the great sortie of August 10.

On June 23, Capt. von Essen's ship, the "Sevastopol," was sent outside the harbor to drive off several Japanese cruisers that were shelling the line of fortifications to the east of Port Arthur. This she accomplished; but, in returning, she struck a Japanese mine, which blew in about 400 square feet on the starboard side, abaft the foremast, at a depth of about 7 feet below the waterline. The rent was from 7 to 10 feet in depth and 35 feet to 40 feet in length. The frames, ten in all, were bent inward, or torn entirely apart, and the plating blown bodily into the ship. She was taken into the inner harbor, and a repair caisson was used to inclose the injured portion of the hull, in the manner shown in the accompanying engraving. The caisson was built of 9 x 9 timbers, tongued and grooved and dovetailed. The floor, which was from 17 to 22 feet in width, rested against the bilge keel, and the outer wall, which was at a distance of about 10 feet from the hull, had a total depth of from 32 to 35 feet, the length of the caisson being about 75 feet. Knee bracing of heavy timbers was worked in between the floor and the wall, and the construction was further stiffened by heavy diagonal bolts, which passed through from floor to outside wall, as shown in our sketch. The joint where the edge of the caisson abutted on the hull of the ship was formed of hemp packing covered with canvas. The whole of the outside of the caisson was covered with canvas, and outside of this a heavy coating of hot tar was laid on. The caisson was then floated into position, and drawn up snugly against the side of the ship by means of cables, some of which passed entirely underneath the ship and were drawn tight on the port side, while others were attached to the top edge of the caisson and were led across to the steam winches on deck. After the caisson had been drawn to a snug fit, the water was pumped out, and the hydraulic pressure served to hold the caisson tightly against the hull. The damaged plating was then removed by cutting off the rivet heads, and the broken portions of the framing were cut away. While this work was proceeding, new frames and plates were being prepared in the dockyard shops. The frames were built into the ship, the plating riveted on, and the vessel finally restored to first-class condition. The whole of the work was accomplished in six weeks' time; which, considering that the shops in which the new framing was prepared and the ship herself were under fire, must be regarded as a most remarkable and highly creditable performance.

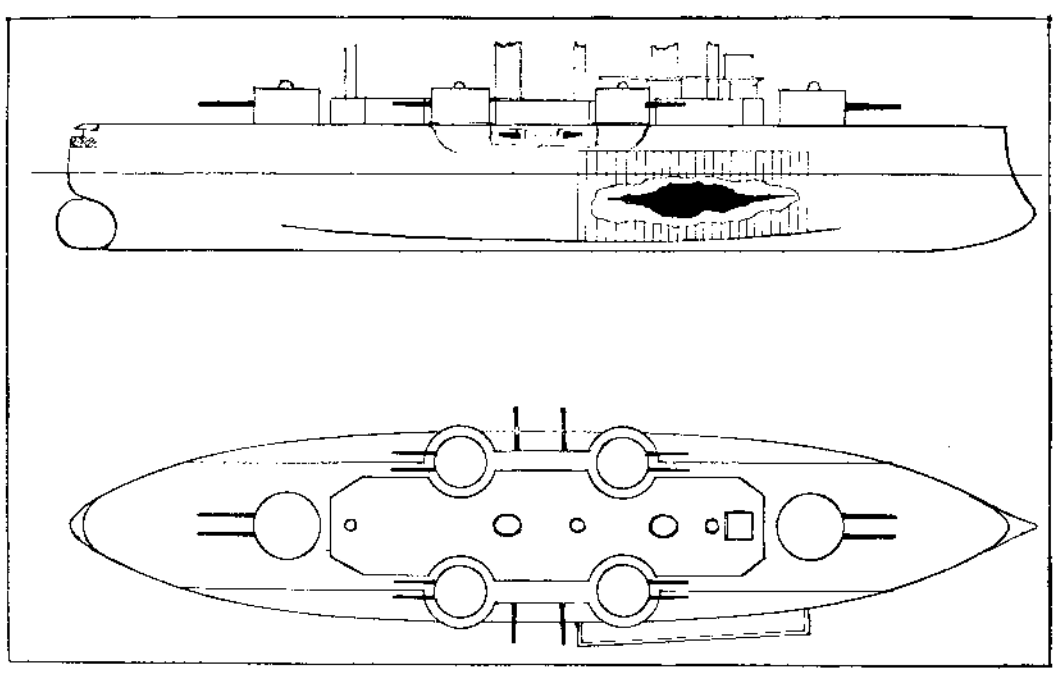


Before the capture of 203-Meter Hill, the Japanese could not see the Russian fleet, which lay behind lofty hills. Chinese spies went fishing at a spot where they could see the fall of Japanese shells and signal the result to a distant Japanese observation station. If a shot fell to the right of the ship, one boat would move to the right; if to the left, another boat would move to the left.

Why the Russians Forbade all Fishing at Port Arthur.

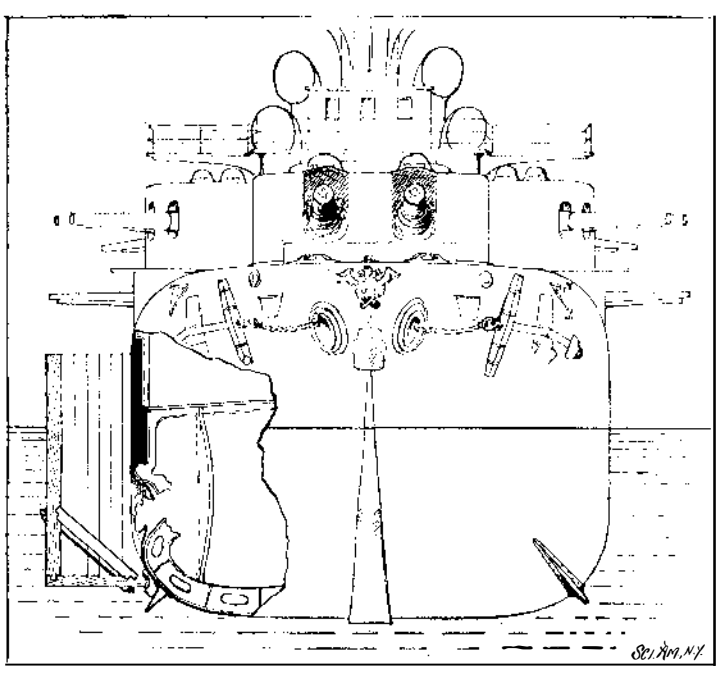
On September 20, during operations outside the harbor, the "Sevastopol" again struck a mine, and by a curious coincidence she was damaged in the exact spot where she received the first injury. This time, however, the mine was very much larger, and is estimated to have contained fully 400 pounds of high explosive. The shock was terrific, and the area of injury covered fully 700 square feet. A repair caisson was applied to the ship, which had been kept on an even keel by opening the valves on the port side, and admitting sufficient water to balance the inflow on the starboard side. The repairing of this damage was, of course, a longer job. Moreover, it was done at a time when the 11-inch mortar batteries, which ultimately sank the fleet, were getting the range and making frequent hits. One 11-inch shell struck the bridge just above the caisson, and, bursting, a shower of heavy fragments tore through the outer wall of the caisson, letting in the water and necessitating extensive repairs. Nevertheless, the "Sevastopol" was again put in seaworthy condition in about two and a half months' time.

As showing the heroic efforts, made under these most distressing circumstances, to turn defeat into victory, it may be mentioned that during the eleven months of the siege, five big repair jobs of the magnitude above described were completed, and over one dozen perforations in the hull below the belt, due to heavy projectiles, were repaired, either in drydock or by the caisson method. This work was done under a constant rain of projectiles, and in the case of the drydock repairs, the shells that missed the ships would burst on impact against the stone walls of the dock, and the fragments scatter among the workmen. Evidently, the Russians have lost none of their proverbial fortitude.



Outboard profile and deck-plan of the "Sevastopol," showing the cofferdam, and (in black) the area of hull affected by the mine explosion.

How Repairs Were Made Without Entering Drydock.



Sectional view showing the water-tight caisson 10 feet wide, 35 feet deep, 75 feet long, by which the injured side of the "Sevastopol" and other battleships was laid clear of water, while the wrecked structure was removed, and new frames and plating were built in place.

Five Vessels Wrecked by Mines Were Repaired by the Caisson Method.

THE OPERATIONS OF THE RUSSIAN FLEET AT PORT ARTHUR.

Before the capture of 203-Meter Hill, the hits that were made upon the ships were due to indirect or high-angle fire, in which the gunners could not see the ships. The aiming was largely guesswork, for the Japanese did not command any height from which they could see the vessels. Nevertheless, the fire for a while was so intelligently directed as to make it evident to the Russians that some system of signaling existed. It was ultimately found that some Chinese fishermen were in the habit of frequenting a certain spot in the harbor, from which they could watch the Russian ships, and be themselves clearly discerned by field glasses from a distant hill that was occupied by the Japanese. Careful observation of these simple-minded Celestials, as they were engaged in their laudable effort to pick up some greatly-needed food from the sea, revealed the fact that when a shot fell beyond a particular ship, one of these boats immediately moved out beyond the group in a corresponding direction, say to the right; that if the next shot fell to the left, John Chinaman would immediately conclude that he could find better fishing if he moved somewhat over to the left of the fleet of boats. These movements were duly noted from the Japanese observation station, and the fire directed accordingly. Needless to say, there was no more fishing permitted in that particular section of the harbor. Not long afterward, however, the fire began again to grow remarkably accurate, and it was noticed that a certain Chinaman (so called) occasionally waded into the shallows with a couple of buckets, apparently in search of crabs, and that one bucket was white and the other black. If the Japanese shot fell beyond the mark, the black bucket would be carried off a corresponding distance beyond the white bucket; or if the shot fell short, or to the left or right, strange to relate, the black bucket would move in sympathy; and if a hit were made, the industrious crab catcher would place his buckets together. Commander Saxe, who related this particular circumstance to the writer, said that he was satisfied now that they had treated the native population altogether too leniently; for in spite of undoubted evidence that signaling was carried on extensively both by day and by night, not a single native was executed as a spy during the course of the siege.

The severest loss of the whole campaign was the tragic death of Admiral Makaroff when the "Petropavlovsk" was blown up by striking three floating mines. These mines, as shown in our sketch, were connected by cables, and floated at the surface of the water. They had been dropped by the Japanese on the night preceding the sortie, and directly across the course usually taken by the Russian fleet. When the bow of the "Petropavlovsk" struck the connecting cable, she carried it along with her and, of course, swung in the mines against her side, one probably to port and two to starboard. The terrific shock in all probability detonated the high explosives on board; for the ship disappeared bodily from sight within two minutes after the explosions. Most of the damage by mines was wrought by anchored mines of the type shown in accompanying engraving. The cone-shaped steel shell, containing from 200 to 400 pounds of high explosive, is anchored to a heavy weight resting on the bottom, by means of a cable of such a length as to maintain the mines at a depth of from 8 to 10 feet below the surface. Within the shell is a cylinder which contains the firing mechanism. This consists of a steel ball, carried at the top of a flexible vertical steel rod, which passes through and supports a metal disk. Arranged concentrically around the disk, but not touching it, is a metal ring. When a ship strikes the mine, the inertia of the weight or ball carries the disk against the ring, closes an electrical circuit, and detonates the charge of gun-cotton.

The damage wrought by mine, torpedo, and gun was not by any means confined to the Russian fleet. Commander Saxe confirms the story of the sinking of the battleship "Yashima" by a mine at Dalny, and the loss of the "Hatsuse," also by a mine, near Port Arthur. These ships are lost beyond recovery. Several Japanese cruisers have been sunk by mines, by the torpedo, or by collisions, to say nothing of a considerable number of torpedo boats and torpedo destroyers that were sunk by gunfire. The story of the loss of the "Hatsuse," as told by Commander Saxe, is particularly interesting. It had been observed that the blockading fleet was in the habit of steaming slowly to and fro, in line ahead, on a course generally parallel with the coast line and at a distance of ten miles from the harbor. Accordingly, the torpedo transport "Amur" was sent out at night ten miles from shore, with orders to commence dropping torpedoes from her stern at intervals of from 50 to 100 feet, on a line one mile in length and at right angles to the course ordinarily followed by the Japanese fleet. This was done, and the next day the battleship "Hatsuse," in passing over the line, struck one or more torpedoes, with the result that her magazines were exploded. The vast cloud of smoke was distinctly visible from the Russian forts; and she sank in not over one minute after the explosion took place. This left the Japanese fleet with but four battleships as against six that were able to steam out of Port Arthur in the famous sortie of August 10.

Limitations of space prevent us going at full detail into the description of this famous sea fight—the greatest in modern times. The Japanese battleships, warned by their torpedo boats of the sortie, came up rapidly and opened fire with their big guns at a range of from seven to nine miles; and owing to the fact that they carried telescopic sights, and the Russian ships did not, the Japanese made fairly good shooting, even at this great distance. As the ships drew to closer range the Russian gunners found the enemy, and placed their shells with telling effect, great destruction being wrought on both fleets. On the Japanese side the flagship "Mikasa" suffered the most heavily, and was at times completely enveloped in the smoke of the bursting Russian shells. Matters were going fairly evenly between the two fleets, until a 12-inch shell entered through the sighting slot between the wall and roof of the conning tower of the flagship "Czarevitch," which was at the head of the line; burst inside; killed the admiral; and jammed the steering gear over to port, causing the "Czarevitch" to commence steaming in a circle. The "Retvizan," next in line to the "Czarevitch," began to follow her to port; but discovering the plight of the "Czarevitch," and in the endeavor to protect her, she swung sharply to starboard and steamed directly for the Japanese line, followed by the "Pobieda." The Japanese, true to their policy of avoiding close ranges, turned also to starboard and drew away. Capt. von Essen noticed that, as the range decreased, the Japanese shells flew high; and it was at this time that the bridges, masts, and smokestacks were riddled. The mishap to the "Czarevitch" and the change of course of the "Retvizan" threw the Russian line into disorder, and ultimately the admiral who had taken over the command, signaled the fleet to return to Port Arthur. Capt. von Essen is of the opinion that the Japanese must have suffered very severely; for they drew off at a time when, had they been in good fighting condition, an opportunity was afforded for dealing a crushing blow to the scattered Russian fleet. Toward the close of the action the "Mikasa" had only one 12-inch gun in action, and orders were finally signaled by Admiral Togo to his fleet to draw off toward Dalny, taking particular caution against torpedo-boat attack. As night closed in, it was seen that the "Mikasa" was gradually falling astern. Subsequently to the capitulation of Port Arthur, it was learned from the Japanese that three of their torpedo boats, which were searching in the darkness for the crippled "Czarevitch," encountered the "Mikasa" and attacked her, thinking she was the quarry they were after. One torpedo struck her before the mistake was discovered. Confirmation of this disaster was seen in the fact that, after the first attack on 203-Meter Hill, sailors' caps bearing the name "Mikasa" were found among the Japanese killed. It is believed, however, that she has been repaired, and probably she is in service at the present time.

In that fight the "Sevastopol" lost over 100 men killed and wounded. Subsequently, all hope of effecting a movement to the port of Vladivostock was deemed hopeless, at least until the arrival of the Baltic fleet. The lighter guns were accordingly sent ashore to the fortifications, and the intervening time between the sortie and the surrender of the fortress was occupied in repairs, in work at the forts, and occasional demonstrations outside the harbor. Ultimately, word was sent to the fleet from Gen. Stoessel that the Japanese had captured 203-Meter Hill, and that the ships would be subjected to direct observation. The "Sevastopol" was the last ship to be destroyed. To escape observation from the captured hill, she steamed outside the harbor and took up a position under Liaoshan Mountain. Her torpedo nets were let down, and, although only 100 men were left on board, and the rapid-fire guns had been sent ashore for use in the forts, Capt. von Essen prepared for the inevitable night torpedo attack. Three of these were made before a torpedo got home. The torpedo boats steamed past under a fierce fire from the ship and the forts at a distance of about 1,200 yards, discharging a great number of torpedoes, which exploded on contact with the net, and at the same time using their machine guns, 12-pounders and 6-pounders. Four of the torpedo boats were crippled or sunk. Finally, in a blinding snowstorm and a very rough sea, a small torpedo boat managed to rush in within a few hundred yards and discharge a torpedo that struck the "Sevastopol" near the stern. The torpedo flotilla now considered that their work was done, and withdrew; but the next day Capt. von Essen, steering with his two engines, carried the ship out into 90 fathoms of water and opened the sea valves. As he was rowed away, he saw the ship turn bottom up and sink in waters from which she can never be recovered.

In conclusion, we asked both of these officers what was their opinion, after eleven months of the very fiercest and most destructive kind of fighting, as to the relative value of battleships and cruisers. They both affirmed their belief that the battleship had demonstrated itself to be the supreme engine of modern naval warfare; and that the nation which can put the largest number of battleships into the fighting line, and that can handle them, when there, with skill, courage, and fortitude, must ever maintain the command of the seas.

Science Notes.

Two French aeronauts, Faure and Lathom, have made a balloon voyage from the Crystal Palace, South London, to St. Denis, a suburb of Paris, a distance of 250 miles, in 6½ hours.

The Ibis contains a short but interesting account of the discovery of the hitherto unknown eggs of the knot (*Tringa canutus*). A nest of this species, containing four eggs, was found on June 17, 1898, in the island of Hrisey, to the north of Iceland. The bird was breeding with several pairs of *Tringa maritima*—the purple sandpiper—and was kept under close observation for some time before the eggs were taken. It was not killed, as the collector hoped to have the good fortune to obtain a second clutch. The eggs are described as "quite like very large eggs of the dunlin (*Tringa alpina*), of the closely-spotted type, and cannot be confounded with any others of the same size."

In dry weather the fibers used in the textile industries are liable to become electrified during combing and other similar operations, with the result that their treatment becomes very difficult. It is now well known that the discharge of a-rays from a radio-active substance "ionizes" the air in its neighborhood (that is, renders this air a conductor of electricity), so that an electrified body placed near a radio-active substance is quickly discharged. Technics suggests that this property might perhaps be utilized in the textile industries to prevent the electrification of the fibers. The cost of radium is so great that this substance could scarcely be used; but thorium (which is much cheaper) has similar properties, although its ionizing capacity is smaller; even disused gas mantles will quickly discharge an electroscope in their neighborhood.

John B. Eyster, of York, Pa., senior at Wesleyan and captain of this year's football team, was the subject of an interesting experiment in the calorimeter in charge of Prof. Benedict of the science department. The regular mid-year examination began February 13. Eyster had an examination in advanced French, and instead of taking it with the rest of the class, Prof. Kuhns of the French department consented to let him take it alone in the calorimeter. The purpose of the experiment was to determine the amount of mental energy expended in the course of a college examination. This was Eyster's first experience as a subject of scientific investigation, and that no element of nervousness might interfere with the grade of his examination or with the operation of the experiment, he had an hour to accustom himself to the "box." He was to enter about 8 o'clock and the experiment will last from 9 until 12. The results have not been published as yet.

X-rays have proved valuable in the examination of patients suffering from diseases of the chest. "It is scarcely going too far" (to quote from Dr. Holland) "to say that the only certain means of diagnosing thoracic aneurism is a careful X-ray examination, and that the skilled radiographer can nearly always answer 'yes' or 'no' if the question for or against is put to him. Next to aneurism, the great value of X-rays is seen in cases of pulmonary consumption. In the first place, a careful examination of an affected chest at intervals, during the course of an illness, may not only be of great interest, but also of great use, as an additional means of indicating the course of the disease; and in the second place, in the very early cases—the merely suspicious cases, indeed—an X-ray examination is essential. It has been proved beyond all doubt that marked radiographic changes from normal, suggestive of tubercular disease, have now been found when only the merest suspicion of phthisis has existed; when no so-called physical signs have been detected; when no tubercle bacilli have been found in the sputum, if there was any of the latter to be obtained; when the only symptoms giving rise to anxiety have been some ill-health, loss of weight, and perhaps cough and dyspeptic troubles. It is a serious matter to urge, say, a business man, with much depending upon him, to throw up everything and go through several months of open-air treatment on a vague suspicion alone; it is still more serious to put off doing this until unequivocal signs have developed, and it may be too late. Radiography, in these cases, is now invaluable; and it is not going too far to assert that in such a case, given a radiographic examination by one competent to form an opinion—a most important matter—if suggestive radiographic changes are found, the patient can be unhesitatingly advised of his danger and the necessity of immediate action; given no radiographic changes, it is quite justifiable to wait and watch.