tive wave to the end of the following negative wave would signify a dash. The interruption must last just half a cycle or a whole cycle, a positive and a negative wave together constituting a cycle. The intervals between dots and dashes must also, of course, be either half cycles or multiples of a half cycle.

The transmitter in the experiments consisted of a narrow wheel with a flat metallic periphery, which was rotated at a high rate of speed, which was such that it was an exact multiple of the length of one cycle. The current was transmitted to the wheel by two metallic brushes, which were arranged side by side in contact with the periphery of the wheel. It is evident that the current would ordinarily flow from one brush through the wheel to the other brush; but if a strip of insulating material were pasted on the wheel in the line of one brush, every time it came round and passed under that brush the current would be broken. A strip of paper was perforated with holes of various length corresponding to the Continental Code, which was used in the experiments, and it was carried over the wheel in much the same way as a belt is by a pulley. Just as long as the brushes were separated by the paper the current was intercepted, and whenever the brush reached a hole and touched the wheel the current was restored. The breaks and contacts were arranged so as to occur exactly at the zero point of the alternations, as explained above, so that no sparking occurred.

The receiver was the polarizing photo-chronograph which Messrs. Squier and Crehore designed for use in timing the flights of projectiles. This ingenious instrument was fully described in a paper contributed to the SCIENTIFIC AMERICAN SUPPLEMENT by these gentlemen and published in the issue of January 2, to which our readers are referred for the full details and illustrations. The current in this instrument passes through a coil of wire which surrounds an instrument called an "analyzer." A ray of polarized light from an arc lamp passes through a series of lenses, and when no current is flowing the analyzer is in such a position as to shut out the ray. When the current passes through the coil the plane of polarization is rotated in such a way as to permit the light to pass again, and the very rapid flashes of light are recorded upon a photographic plate.

The paper of Messrs. Squier and Crehore closes with a suggestion as to the changes that will be effected by introducing a telegraph postal system. It is estimated, for instance, that it would require only two lines working on their system, if they were in continuous operation, to handle the entire postal business between New York and Chicago, which amounts to about 40,000 letters daily. By the present system it takes three days to receive a business reply between the cities named, but by the aid of machine telegraphy working at the rate of 3,000 words a minute, a letter could be sent and a reply received on the same day.

Our readers will recognize in this proposal some of the features of the Delany system, and the inventors of the "synchronograph" have given very generous credit to this ingenious system in the course of the paper under discussion.

## OUR SALTPETER CAVES IN TIME OF WAR.

BY HORACE C. HOVEY.

Saltpeter, literally rock salt, chemically potassium nitrate, also known as niter, is remarkable for storing oxygen in a solid form. One volume of it has three thousand times as much oxygen as a like volume of atmospheric air. At a certain degree of heat this immense quantity of oxygen combines violently with carbon, thus forming carbonic acid gas, and also setting free a quantity of nitrogen. Gunpowder contains about 75 parts of niter to 15 of charcoal and 10 of sulphur. If ignited in vacuo, the powder quietly resolves itself into gas. But in the chamber of a gun, behind a ball, it explodes with energy and hurls the missile with deadly effect. For this reason saltpeter is essential to any nation engaged in warfare.

Edward Rawson was the first to attempt the manufacture of gunpowder in the New England colonies. In 1639 the General Court of Massachusetts granted him five hundred acres at Pequod, "so he go on with the business of powder, if the saltpeter come." By act of June 14, 1642, all towns and families were ordered to promote the manufacture of saltpeter. But nothing was accomplished, and in 1648 the General Court voted to indemnify Rawson for his losses in the experiments made. I am indebted to Mr. R. N. Toppan for this authentic information, not found in local histories. Rawson was deputy from Newbury, and secretary of the colony.

At the opening of the revolutionary war the military stores of New England were mainly kept at Quarry Hill, near Medford, Mass, where they had two hundred and fifty barrels of powder, which was seized by the British on September 1, 1774. The act set the country aflame, and stirred the indignation of Burke, Pitt and Fox. After the news from Lexington and Concord, in 1775, the colonies were scoured for powder, and less than sixty-eight barrels were found. New York had but one hundred pounds. Lord Dunmore had seized the entire supply in Virginia, and when Patrick Henry demanded its restoration at the head of troops, he only got its money value and not the powder. When Washington took command of the troops raised by the colonies he "made the alarming discovery that there was not more powder than sufficient to furnish each man with nine cartridges. By great address this dangerous deficiency was concealed from the enemy." (Holmes' Annals, vol. ii, p. 240.)

It is remarkable that no American history, so far as I know, tells us whence the robbed and impoverished colonies got their powder wherewith to wage the war of the revolution. A similar gap exists concerning the war of 1812, when an embargo cut us off from foreign supplies. We are told about almost everything else, but not where we found our saltpeter. That question is now answered.

Among those who resisted the tyranny of Lord Dunmore in stealing the ammunition of Virginia were two young men named Thomas Jefferson and James Madison. They were not only patriots and statesmen, but were also cave hunters. Among the caves found by Jefferson was one that he named for his friend, "Madison's Cave," located in the Grottoes Ridge, in which also occur Weyer's Cave and the Cave of Fountains. Major Jed Hotchkiss, the veteran map maker and geologist, is my authority for saying that Madison's Cave was mined for saltpeter during the three great wars, of the revolution, of 1812, and of the rebellion—probably the only cave on the continent of which that can be said. But Jefferson found many other and richer saltpeter caves, which he describes in his "Notes on Virginia," page 44. He says that one of the largest was on Rich Creek, a branch of the Kanawha, from which more than eleven thousand pounds of niter were obtained. Others were on the Cumberland River, and at least fifty were in the Greenbrier Valley, in one of which Jefferson found the typical megalonyx made famous by Cuvier. His account is all the more valuable because written while the war of the revolution was going on, and thus showing us whence the patriots obtained their means to carry it forward. To a limited extent gunpowder was seized from the enemy, and a few pounds of saltpeter were made from excavations under old stables, and by artificial processes, but the bulk of it undoubtedly came from the caves of Virginia.

Kentucky was originally set off from Augusta County, Virginia, as Kentucky County, in 1776, and was made a State in 1792. Among its early settlers were strolling chemists who knew of the caves in the Greenbrier Valley and elsewhere, and hunted for similar ones in the newly organized State. They were richly rewarded. Under ledges, in "rock houses" and "rock castles," they found solid masses of niter weighing from 100 to 1,600 pounds. Previous to 1800 there had been found 28 saltpeter caves in Kentucky, from which more than 100,000 pounds of saltpeter had been obtained. These facts led Dr. Samuel Brown, of Lexington, Ky., to make a journey of 1,000 miles on horseback, in 1806, in order to lay them before the American Philosophical Society at Philadelphia. He closed his able paper, probably the first of its kind, with these words: "A concern for the glory and defense of our country should prompt such of our chemists as have talents and leisure to investigate this interesting subject. I suspect that we have much to learn with regard to this salt, so valuable in time of peace, so indispensable in time of war." The time of war was nearer at hand than he may have thought, for it burst upon us in 1812, and we were cut off from foreign supplies. Dr. Brown had estimated that what he termed the Great Cave contained 1,000,000 pounds of saltpeter; Scott's Cave, 200,000; Davis' Cave, 50,000; three others not named, 30,000. Since then the Mammoth Cave has been discovered, and the Wyandot Cave and others in Indiana, and the niter fever almost rivaled the subsequent gold fever of 1849. We have the authority of Flint's Geography for the statement that, during the war of 1812-15, the annual yield of manufactured saltpeter from Kentucky alone was 400,000 pounds, besides what was made in Indiana, Tennessee and elsewhere. Part of this was used at home; but most of it was carried by ox carts, or on pack mules, across the Alleghanies to the seaboard to be used in making gunpowder.

The term "saltpeter caves" is a misnomer only justified by the general usage. That which is found in these caves, and which is colloquially called "peter dirt," is soil impregnated with the nitrate of lime, whereas true saltpeter is the nitrate of potash.

Prof. W. B. Rogers holds that the "peter dirt" is derived directly from the overhanging rocks, which agrees with Dr. Samuel Brown's observation that the water trickling from rocky crevices has the same properties as the liquor got by lixiviating the cave clay. Dr. Brown says: "The nitric acid is formed within the caves and is condensed upon the rocks, the lime of which it dissolves."

The fact seems to have been generally overlooked that the strata of sandstone overlying the cavernous limestone is rich in niter. It was from this source that the first supplies of Kentucky saltpeter came. The process was to blast the sandrock and break it into small fragments for the boilers, thus getting niter directly without the aid of lye. The reason it was given up was that the best sandrock was extremely hard, because of the presence of iron, and it was practically easier and cheaper to treat the nitrous earth found in the caverns.

In order to give some idea of what was once a vital industry of our country, though now wholly abandoned, I shall briefly describe the work done at the Mammoth Cave, which may be taken as typical of the rest. This includes what was done at the Salts Cave and Dixon's Cave, belonging to the same estate. Dixon's Cave was, at some prehistoric time, a part of the Mammoth Cave. As measured by me it is 1,500 feet long, from 60 to 80 feet wide, and about 100 feet high. The floor of this enormous hall is ridged by eighteen transverse rocky piles some 40 feet high and as many thick, cut by passageways for convenience. And every block and fragment of those massive ridges was laid there by the old saltpeter miners. By this means they got at the peter dirt to be carried outside for further treatment.

The main works, however, were at the entrance to the Mammoth Cave. Cart roads were made through the more accessible avenues, and from the more distant places, even from rooms three miles under ground, the negro miners brought the dirt in sacks. Hardly a yard of the cave as then known was left undisturbed. Audubon Avenue was particularly rich in nitrous earth. So was Bat Avenue, near the end of which is the Crevice Pit, the ugliest black hole mortal ever looked into, and at whose bottom the men thought there must be a nitrous mine. The story has been often told of the miner's lamp dropped into that black chasm, and the sprightly negro let down as an animated plummet, who brought back, not the missing lamp, but a marvelous story whose truth was confirmed thirty years later by the discovery of the so-called Egyptian Temple. The Gothic Avenue was also diligently worked. The shovel and pick were plied from room to room of the main cave, and out through the windings of the Blue Spring Avenue. Abundant aboriginal relics were found.

The nitrous earth thus collected was put in hoppers with each a capacity of fifty bushels, and which are still to be seen in the rotunda and vicinity, a few hundred feet within the cave, where may also be seen the pumps and double set of wooden pipes, one set to bring water from the cascade at the mouth of the cave and the other to convey to the surface the liquor obtained by solution from the hoppers. The floors of the latter were peculiarly grooved to allow the saturated water to run into the basins, whence it was pumped out to the great iron boilers. When the lixiviated earth had been exhausted, it was cast aside and a new charge put into the hoppers. These piles of indurated earth extend for a long distance like miniature mountain chains. The liquor, after sufficient boiling, was poured into another set of hoppers containing wood ashes, whence, by filtration, a clear solution of the nitrate of potash was obtained. This was again boiled down to the right condition for crystallization in troughs, whence, after twenty-four hours, the crystals were taken and packed for transportation.

The proportion of ashes to be used to the nitrified liquor was a source of much perplexity. Too much would "kill" the saltpeter, and too little would leave it "in the grease;" and in either case the salts would have to be run through the hopper again. Ashes from oak are three times as rich in potash as those from pine; and only half as rich as those from elm or maple. Best of all were the ashes made by burning the dry wood in hollow trees, two bushels of which, according to Dr. Brown, were equal in strength to eighteen of oak ashes. It is stated that "the contract for the supply of the fixed alkali alone for Mammoth Cave, for the year 1814, was $20,000." That, if correct, gives us an idea of the extent to which saltpeter was manufactured here in the days when Gratz and Wilkins carried on the business exclusively for the Philadelphia market.

Many curious facts might be added as to the antiseptic and sanitary value of the atmosphere in Mammoth Cave, which is both chemically and optically pure, except as tainted by torches. None of the deep pits contain foul air. Indeed, the interior air is purer than that which is exterior, showing that its purity is not due to ventilation, but probably to the disengaging of free oxygen in the formation of the nitrate of lime, a theory advanced by Professor Silliman.

In time of peace it is cheaper to import saltpeter from Chile, India and elsewhere than to make it at home. But when the Southern Confederacy was cut off by the blockade of all its ports, it resorted to the caves of Virginia, Tennessee and Alabama, particularly to the great Nicojack Cave, near Chattanooga, for the means of making gunpowder, the process being substantially like what has already been described.

It is strange that these interesting materials of American history seem to have completely escaped the attention of our best historians. It is certainly of historic moment that, when the fate of the nation trembled in the balances, the mineral contents of our numerous caverns enabled a waning force to gather new strength, and to prolong war far beyond what would otherwise have been possible. We doubt if victory could have been won in the war of the revolution, or in the war of 1812, without the aid of the saltpeter caves of Virginia and Kentucky.