To illustrate the principle of the Magdeburg hemispheres, make a ring of wood a little larger than a tumbler top, soak it in melted paraffin, attach to each side a packing ring of very soft rubber, fasten in one edge a piece of rubber tubing, which communicates with the interior of the ring; place on each side of the ring a tumbler with its mouth in contact with the packing ring; exhaust the air as in the case of the fountain bottle, and prevent its re-entrance by bending the tube short. The tumblers will press so firmly upon the ring that it will be difficult, if not impossible, to separate them from it.

It is not necessary to enumerate here the many interesting experiments that may be made with an air pump, as most of them are well known. If the construction of the pump has been made so simple as to enable the young readers of the SCIENTIFIC AMERICAN to construct one, the object of this article will have been attained.

THE LURAY CAVERN

BY H. C. HOVEY.

The marvels of this cave, lately opened in Page County, Va., have been made widely known through the columns of the New York *Herald*. Especial credit is due to Major A. J. Brand and J. J. Collins, C.E., for their graphic accounts, which have less of fancy and more of truth than commonly characterize the reports of enthusiastic explorers. We confess, however, that at first we were skeptical, and that our doubts have only been removed by an actual survey. And now, having gone through every avenue, hall, gulf, and gallery, and enjoying excellent opportunities for comparison with other caves elsewhere, we add our testimony that Luray Cavern may be safely counted among the chief wonders of the world.

The object now arrived at is to classify and explain phenomena, rather than to describe what is merely grotesque or beautiful, unless the ends of science may be thus promoted. Many of the things to be considered are so novel and ornate that any statements of their peculiarities, however coolly made, must seem florid and overdrawn to persons not familiar with cave scenery.

A cursory glance at the geology of the region will aid us in handling our subject. The official surveys are meager, and we had to rely chiefly upon such observations as could be made along the line of railroad from Harper's Ferry to New Market, where alternate beds of slate and limestone, displaced by volcanic upheavals, dip at an angle of 30° eastward into the Shenandoah valley. Crossing the lofty Massanutten range once by stage and the second time on foot, for the purpose of closer inspection, we saw impressive signs of the stupendous forces that have modified the original strata, lifting them vertically, and sometimes even inverting them. Amid all this rugged violence the general symmetry of periods is preserved; rising from Silurian limestones, through sub-carboniferous rocks, to thin deposits of coal said to lie on the highest peaks, and then descending through the same formations down the eastern slope.

This synclinal arrangement brings to view again in Page County the Lewisburg limestone (Formation II. of Rogers' Survey), which Fontaine locates between the Vespertine strata underneath and the Umbral series above. In this blue limestone, of the lower carboniferous period, many caves are found, the most noted of which, hitherto, has been the unique and attractive Weyer's Cave, about 1,600 yards long, and whose features were well described a few years ago, by Porte Crayon, in *Harper's Magazine*. It is in this same formation, indeed, as it appears with various modifications in different parts of the globe, that the most remarkable caverns in existence have been discovered; so that it is often spoken of by geological writers as the cavernous limestone. But in Virginia it has its peculiarities.

Volcanic action has been so powerful and recent, comparatively speaking, that masses of igneous rock are actually thrust through the sedimentary rocks, so that there is a dike of trap within a mile of Weyer's Cave. The veined condition of the limestone in Page County is due to such disturbances, by which it has been cleft into countless fissures, that were afterward filled by calc spar and silicates, with occasional streaks of the oxides of iron, manganese, and other metals and minerals, that play an important part in coloring the hard carbonates deposited on the walls of the underlying caverns. The loose rocks scattered on the surface are chiefly calcareous, often silicified, with occasional groups of quartz crystals and bowlders in the beds of streams.

The limestone in place is very compact and fine-grained, breaking with sharp edges. The color varies from light brown to deep blue, or even black, streaked, however, with fibers and veins of milk-white spar. Weathered surfaces are almost always stained with the oxide of iron. The analysis of five different specimens, from Luray and vicinity, showed an excess of carbonate of lime with from ten to forty per cent of the carbonate of magnesia, and even in one instance amounting to dolomite.

The valley of Luray is fertile, watered by the Hawksbill Creek, a tributary of the Shenandoah, and 150 miles from the sea coast. It is embosomed between the Massanutten range on the west and the Blue Ridge on the east. These ridges lie in vast folds and wrinkles, the fissures being often filled with metallic ores. Elevations found in the valley are, of course, such masses as had coherency enough to resist the wear of retreating waters by which gaps were opened in the mountain chains. Yet, as might be supposed, the lower hills are often pierced by the action of such mighty floods; and it is hardly necessary to refer any of the changes observed in these tunnels and hollows to the operation of volcanic forces. Water is as energetic as fire.

These geological conditions, thus hurriedly described, are favorable to rather deep and extensive excavations, marked by picturesque diversities and stalactitic ornamentation: but limited by the rapidly succeeding undulations of the surface and rifts dividing the strata.

There is no possibility of finding such immense domes, long avenues, and navigable rivers as characterize Mammoth Cave and others found in the vast, undisturbed, and homogeneous limestones of Kentucky and Indiana, varying in thickness from 50 to 500 feet, and oftentimes lying so nearly in their original position as to cause the surface above to assume the form of broad table lands, broken only by the sink-holes peculiar to all cave regions.

For more than fifty years an eminence a mile west of Luray has been known as Cave Hill. Climbing to its summit, which commands one of the finest views in the Old Dominion, we found a noble grove of pines and oaks, amid which is the pit-like entrance to Ruffner's Cave, full of drifted leaves and perilous of access. It has long been an object of local interest, but we explored it for only a short distance in order to ascertain its temperature, 60°, and its bearing, which is N. N. E.

Cave Hill is about 300 feet above the water level, toward which it slopes gradually, with many oval hollows called sink holes, each of which must have a subterranean outlet. Their axis invariably coincides with that of Ruffner's Cave, confirming the popular opinion that all the underlying cavities are in some way connected. One of these sink-holes on Mr. Brodus' land is fully 1,000 feet in diameter and 50 feet deep. Others at least two thirds as large are in adjacent fields.

At the foot of the long declivity, and at the distance of about a mile, is a pond near Blackford's furnace, fed by what is regarded as an unfathomable spring. A 50 pound weight attached to a cord 80 feet long failed to reach the bottom, and there is a legend of a wagon with four horses and the driver being swallowed down in this aqueous abyss without a vestige remaining. Doubtless it is really very deep, extending down to the level of Hawksbill Creek, and the volume of water it constantly pours forth is probably the drainage of all the cavities in the hill.

There is a small sink-hole about 70 feet lower than the summit and 320 paces N. E. from the mouth of the old cave. The crevice in the bottom of it was long since filled with stones and the space was overgrown with briers. Study of the topography led Messrs. Campbell and Stebbins to remove these obstructions, and dig through into what is now known to all the world as the Luray Cavern. That was done on the 13th of August, 1878. They only explored about 200 feet to a muddy pool, which they had there no means of crossing; and accordingly they returned to the surface, filled up the pit again, kept their secret, and bought 30 acres, including both the new orifice and Ruffner's Cave. Having thus gained possession by the double title of discovery and purchase, they proceeded with commendable enterprise to open their underground territory and make it accessible to the public.

Bridges have been thrown across pools and chasms that lie athwart the path; plank walks and tan bark have been laid down wherever needed on the main line; a large room at the further end has been floored; chandeliers are hung at several suitable points; railings guard the more dangerous places, and a building over the entrance is in process of erection for offices, dressing rooms, a cabinet, a dining hall, and other conveniences. Although but a portion of the cave is yet on exhibition, it has been visited by about 800 persons.

Mr. Stebbins was busied with these improvements, and we gladly accepted the services of Mr. A. J. Campbell as guide, whom we followed through every gallery and winding way, except three or four rooms now flooded by recent rains, and even into these we peered by the aid of fireworks, so as to get some idea of their dimensions and attractions.

Previous to our visit the cavern had never been illuminated by any better means than common lamps and candles in tin reflectors, or perhaps in a single instance by a few little tableaux-spirals. Anticipating this deficiency we had supplied ourselves beforehand with several pounds of the best quality of chemicals for making red and blue fires; and also with a large coil of magnesium ribbon, which we used very freely, as it burns with an intense white light, and emits no odor nor smoke, the sole product of combustion being wreaths of the pure oxide of the metal quickly falling to the ground.

The atmosphere within the cave is free from all hurtful gases, although Mr. Campbell has usually taken the precaution to lower a lighted candle into any pit he was to explore, in order to detect the presence of foul air. On the other hand we perceived no excess of oxygen, such as surcharges the atmosphere in caves where there is an abundance of saltpeter actively combining with lime and emitting free oxygen. The air is not exhilarating; it is merely wholesome and good to breathe everywhere, even in the deepest recesses. It sustains combustion well; but light seems to lack its usual power, owing to the fact that the atmosphere is optically as well as chemically pure. That is, there are no motes, or spores, or discernible atoms of any sort floating about, as in the sunbeams, each of which has its duty to perform in reflecting rays of light. In other words, cave chambers need a more powerful illumination to produce a given effect than would be required in a dark hall or church of the same size. This serves to explain the fact that the most honest observers nearly always have exaggerated estimates of cave distances. In one instance a room said to be 100 feet long, dwindled to 60 on measurement. Less extreme cases are common, and the cause of illusion having been pointed out, the necessity is evident of relying on the tape line rather than the eye; and where this is impracticable estimates should be cautiously made and from different positions.

The temperature observations made in all parts of the cave show an atmospheric range from 54° to 63°, averaging about 58°, which is 2° above that of Mammoth Cave, as fixed by repeated experiments made last summer. The temperature of the various bodies of water was about 54°. The mercury stood at 50° at the entrance. Hence there was a draught inward instead of outward, as would be the case in warm weather. The fact of fluctuations in the currents of air, in different parts of the cave, prove the existence of other openings than the one now known; and this ventilation aids us to understand the delightful purity of the cave atmosphere. It may be laid down as a rule in underground exploration, that wherever the draught changes, as indicated by wavering lights, an opening is near, either to the upper air or to some large arm of the cave.

A stairway of solid masonry leads down to the Vestibule, 30 feet below, where are stands and benches for the use of visitors. It is lighted by a chandelier hanging from the tip of a stalactite. It is a place of preparation. Putting on stout boots, overalls, and caps, and taking the tin reflector with its three candles provided for every visitor, we are ready to go on. The compass shows our path to lie due west. The eye, as soon as it has accommodated itself to the change of scene, is at once attracted by figures grotesque and majestic. Seldom does a cave have so fine an ante-chamber. On our right is the adit, now closed, through which the first explorers forced their passage. On the left is Specimen Avenue, from which the proprietors get most of the mementos tourists are allowed to take away. Next to it is Stebbins Avenue, which we leave, as we also do other side avenues, to be examined after we have followed out the main line.

Only ten paces in front of us is Washington's Pillar, broader at the base than at the top, a stalagmitic mass rising 25 feet from floor to roof, with a long diameter of 30 feet and a short one of 14. Its sides are fluted and jointed. The material is pure white carbonate of lime, fine grained, but not equal in quality to many to be found further within. A basin filled by trickling rills from the roof lies alongside the pillar. Against the opposite wall are rounded masses reminding one of the glyptodon and other monsters exhibited in museums.

Between a petrified cascade and a fossil garden we descend 18 steps to a lower floor, the roof retaining its altitude and supported by long slender shafts of alabaster. Brown buffaloes seem to hang from the roof, which on inspection were found to be spongoidal in appearance and blackened by the oxide of iron. They are really the network of silicious veins running through the limestone and remaining after the latter has been dissolved by acidulated water that would not affect silex. The floor was once lower than it now is, having been filled in by debris and washings from without. Fringed galleries mark the upper tier.

Next is the muddy lake already referred to as having put an end to the first exploring trip. On the second it was crossed in a small boat, and now it is bridged. It lies in a chasm from 12 to 30 feet wide and 75 in length. Midway there is a natural arch 4 feet wide and 8 high, through which the bridge is built.

The fish market is beyond this lake, getting its name from a row of folded stalactites, wet and shining, quite like a long string of black bass and catfish.

A hundred feet further on the way is obstructed, but with a small orifice through which a passage might be forced that would only lead to a point that is already accessible from another direction.

Our path now turns at right angles, up a flight of 25 steps, due north, to a floor on a level with the Vestibule. The roof is at this point nearly bare of ornaments. The floor is a bank of chalky substance, no doubt the product of disintegrated carbonates. The distance from floor to roof is only about 5 feet. But the width of these galleries is immense. We dispersed lights here and there in order to get some idea of their extent, and judged it to be 200 feet in one direction and 500 in another. The dimensions will more probably exceed than fall short of this estimate. Rambling to and fro we found many water-worn stalactites and columns half eaten through. This was plainly once a spacious hall, though now nearly obliterated by calcareous deposits and debris. It has been named the Elfin Ramble.

Trenches have been dug on the line of travel to enable persons to walk erect who prefer doing so to roving around as we delighted to do, spying out the secrets of the gnomes. Following one of these trenches we find ourselves on the edge of Pluto's Chasm, 500 feet long, 40 wide, and 70 deep, with a corresponding rift above, varying from 30 to 70 feet in height; making a total distance from top to bottom of from 100 to 140 feet.

Opposite where we stand is an alabaster formation surprisingly like a body of falling water suddenly congealed. There are many such objects in the cavern, and for want of some better term they are styled frozen or petrified cascades. On each side of this one are openings leading to a large room, to be reached perhaps at a future day by a bridge, but now by a circuitous route. The chasm is curved and its chord runs nearly S. W. to N. E. The compass was so affected by magnetic influences as not to be perfectly reliable; but

we are satisfied of the approximate accuracy of the bearings, and Mr. Campbell assures us of their general correctness.

Following the brink of Pluto's Chasm toward the northern end we find its character changed and its bare and gloomy walls hung by fine stalactitic drapery. By burning red fire and magnesium we gained some idea of its grandeur and beauty, both above and below.

Threading our way still further amid very old and decayed pillars, we climb to a balcony inclosed by clustering columns of more modern date, and overhanging a dark and forbidding pool far below. Within this lovely balcony, which, as a compliment to the SCIENTIFIC AMERICAN, the cave owners have named for your correspondent, there are rich marvels of nature's loom. Sixteen alabaster scarfs hang side by side, of exquisite color and texture. Three are snow white; thirteen are striated like rich bands of agate, showing every imaginable shade of brown, and all are translucent. The shape of each is that of one wing of a narrow lambrequin, one edge being straight and the other meeting it by an undulating curve. The stripes follow the curve in each detail. The scarf most admired resembles a white crêpe shawl, both in size and in its graceful, wavy folds, excelling the most artistic creation of the sculptor's chisel. Down the edge of each piece of drapery trickles a tiny rill, glistening like silver in the lamplight. This is the ever-plying shuttle that weaves the fairy fabric.

(To be Continued.)

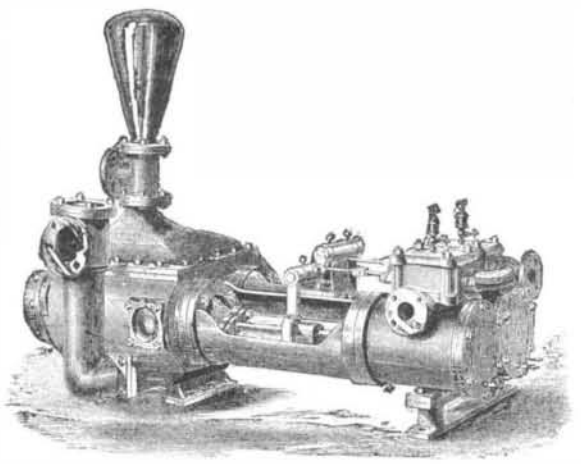
General Daniel Craig McCallum.

The necrology of 1878 contains few names of men who had served their day and country more worthily, in peace and in war, than Major-General D. C. McCallum, who died at his residence in Brooklyn, N. Y., December 27.

General McCallum was born in Scotland in January, 1815. Soon after his parents came to this country and settled in Rochester, N. Y., where young McCallum was bred to the trade of the carpenter. His attention was early directed to bridge building, at which he was notably successful. In 1851 he invented and patented the McCallum arch truss bridge, so widely introduced throughout the country. In 1855 he was appointed general superintendent of the New York and Erie Railway, but left the position two years later to superintend the construction of bridges of his design, chiefly on new roads in the West. At the same time he served as consulting engineer in the department of bridge construction for the Atlantic and Great Western Railway. When the war broke out he was called upon to serve his adopted country in connection with the transportation service, being assigned to the Department of the West, with the rank of colonel. In 1864 he was appointed general manager of all the military railroads of the United States, with the brevet rank of brigadier-general, in which capacity his splendid abilities in handling troops and supplies prepared the way for many important victories in the field. His final report on the military roads of the country, made in 1866, showed that he had had under his supervision 2,105 miles of railway, of which he had constructed 641 miles, with upward of 26 miles of bridges. On these roads there had been employed 419 locomotives and a large number of cars. The expenditure of the Government on this branch of the service exceeded $42,000,000. In June, 1865, General McCallum was mustered out of service with the brevet rank of major-general; and with the exception of a short service as inspector of the Union Pacific Railroad, has since lived for the most part in retirement. To the last General McCallum was proud of having carried the tin dinner pail of the mechanic, and of having made his way in life by hard and honest work.

DUPLEX STEAM PUMPING ENGINES.

The hydraulic works at South Brooklyn, N. Y., owned by Henry R. Worthington, the well known constructor of steam pumping machinery, are among the most extensive and complete of their class in this country. The buildings are nearly quadrangular in figure and cover an area of about 10,000 square feet, or about two city blocks. They consist, principally, of a large foundry, blacksmith, pattern, erecting and machine shops that are stocked with superior machine tools, many of which were designed and constructed for special purposes in the construction of steam pumps. At this establishment water works engines, condensing and non-condensing, of the largest size; air and circulating pumps for marine engines; stationary steam fire engines; boiler feed pumps; pumps for hydraulic pressure, and others especially adapted for oil pipe lines; water and oil meters; hydraulic cranes and hoisting machinery, etc., are constructed. Some of the larger steam pumping engines made at these works have already been described in this journal. The engraving now given represents one of the smaller description of pumps known as a duplex steam pump adapted to boiler feeding and other purposes where the service is of ordinary character. Pumps of this type have two double-acting plungers. The water valves are made of either rubber or metal. The diameter of steam cylinders ranges from 4½ to 20 inches, and that of the water plungers from 2¾ to 15 inches. The stroke varies from 4 to 15 inches. One of the most important features of the Worthington duplex steam pumping engines is the peculiar arrangement of the valve motion, which prevents all noise or concussive action. For this reason the pumps are highly suitable for hospitals, hotels, and public buildings. By reference to the engraving it will be seen that two steam pumps are placed side by side, and so combined as to act reciprocally upon the steam valves of each other. The one piston acts to give steam to the other, after which it finishes its own stroke, and waits for its valve to be acted upon before it can renew its motion. This pause allows all the water valves to seat quietly, and removes everything like harshness of motion. As one or the other of the steam valves must be always open, there can be no center or dead point. The pump is, therefore, always ready to start when steam is admitted, and is managed by the simple opening and shutting of a valve. The manufacturers state that special care has been taken to have all the parts easily accessible for inspection or repairs. All the moving parts are made to gauge, and therefore can be readily renewed.



DUPLEX STEAM PUMPING ENGINES.

The makers of this pump have adopted an excellent system of manufacture, and employ a large number of special tools, which, together with the increasing demand for their pumps, enables them to make their prices in accordance with the times.

The offices of Henry R. Worthington's Hydraulic Works are at 239 Broadway, New York, and 83 Water street, Boston, Mass.

THE CLIPPER INJECTOR.

Manufacturers of the different forms of injectors have each endeavored to accomplish some particular result—one, to feed the largest amount of water; another, to secure in

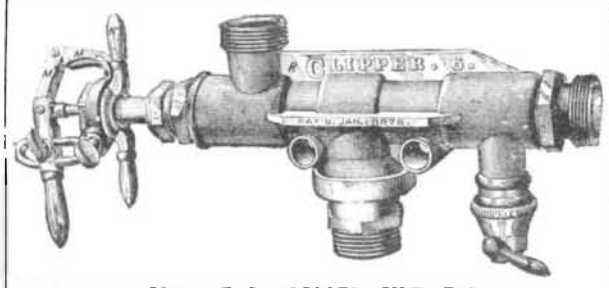


FIG. 1.—THE CLIPPER INJECTOR.

one instrument a large maximum and small minimum capacity; another gives prominence to lifting power; and still others to simplicity of construction and facility of adjustment.

The inventor of the injector shown in the accompanying engravings claims to have accomplished in one instrument all that is desirable in the perfect feeding of boilers, and states that it works at high or low pressure of steam; lifts the water, or receives it from tank or hydrant; can be regulated, without reference to steam or water valves, to feed from about one half to the full capacity; is not affected by jarring or jolting, as on a locomotive; cannot get clogged by anything entering with the water; cannot be sprung when the attachments are made; and it can be readily taken apart. The parts being made interchangeable are easily replaced, should it from any cause become necessary.

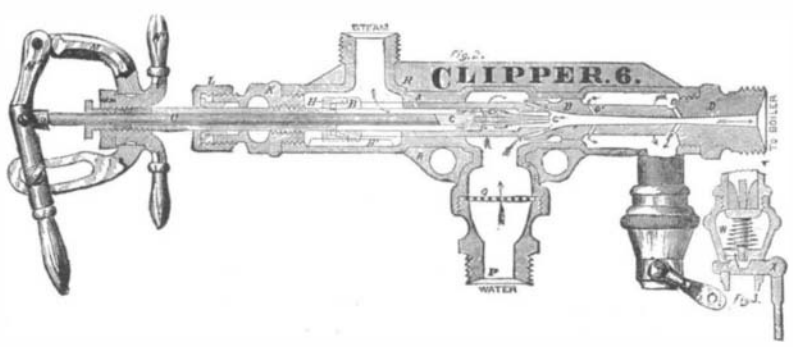


FIG. 2.—LONGITUDINAL SECTION OF INJECTOR.

The inventor says that every injector should be capable of drawing water whether it is overheated or not, without altering the adjustment. The Clipper being constructed in this way may be set so that it will feed either the maximum or minimum quantity. It is provided with a device which effectually prevents the entrance of foreign substances which might clog and impede the action of the instrument, and it is capable of working under either high or low pressure, is readily started and regulated, and is exceedingly simple and complete. The several parts are described as follows, reference being made to Fig. 2:

A is the shell, or body; B, the steam tube; C, jet, or lifting tube; D, main, or water tube; H, swivel, kept from turning by fin H'; K, bonnet, by unscrewing which, tubes, B and C, are removed; M and M', revolving lever and handle, to regulate water and steam; N', extra revolving handle, used to regulate water when room is insufficient to receive lever, M'; O, overflow holes; O', holes to assist in lifting and starting; Q, strainer, preventing anything from entering too large to go through injector; R, ribs to prevent springing or bending shell, A; W, overflow valve and spring. In Fig. 3 is shown a longitudinal section of overflow, turned one fourth round to show construction. X is the lever and revolving pin to set overflow valve when using injector to heat water in tank. A check valve is provided in connection with the swivel at the feeding end of the injector.

The injector is started by drawing the steam tube, B, back by revolving the lever and handle, M M', which turn the tube, B. The steam is fully turned on, and when it blows out at the overflow, the lever, M', is pushed forward and the water valve is opened. When the water appears at the overflow the lever, M', is pulled back and the tube, B, is moved forward slowly until no water appears at the overflow. The injector will then feed the maximum amount. It may as easily be set to feed the minimum. After adjusting in this manner it can be started without moving the lever, M'.

For further information address J. D. Lynde, patentee and manufacturer, 405 North 8th St., Philadelphia, Pa.

New Inventions.

Mr. Samuel Whitnum, of Greenpoint, N. Y., has patented a Novel Fire Shovel, having its handle and blade made in two separate pieces and connected together by a simple and strong fastening.

Mr. William Smith, of Carmi, Ill., has patented an improved Fly Trap which has an alarm mechanism in connection with a bait holder and wire gauze cone or other form of prison receptacle for flies. The alarm mechanism is operated intermittently, but at regular intervals it frightens the flies that have collected around the bait, when they ascend and pass into the prison chamber, from which they cannot escape.

Mr. Elias G. Sternberg, of Depauville, N. Y., has patented an improved Ventilator consisting of one or more perforated pipes, extending along and secured to the ceiling of a room, and provided with an outlet pipe, extending into and up through the chimney.

An improved Connector for Battery Carbons has been patented by Mr. Adam C. Kreis, of New York city. The object of this invention is to provide a connector for the carbons of batteries with the copper disks or strips that will prevent the rapid destruction of the metal attachments, which are subject to corrosion by the exciting fluid in the batteries.

Mr. Joseph H. König, of Mason City, W. Va., has patented a Process of Recovering Chloride of Sodium from its admixture with impurities in crude brine, which consists in precipitating the chloride of barium by sulphuric acid, filtering out the precipitate, then precipitating the calcium and iron together as a subcarbonate by the addition of sal soda, and afterward separating the clear liquor and crystallizing the pure salt out of solution from the bromide of magnesium.

Mr. Napoleon B. Heafer, of Bloomington, Ill., has patented an improved Kiln for burning tile, brick, pottery, or any other clay wares. It is so constructed that the heat passes directly through the wares in its upward course, and thus produces better results than it would if separated from them by a fire wall or bag, as is usual in a down draught kiln.

An improved Gas Light Extinguisher has been patented by Messrs. Philipp Brand and Edward J. King, of Jacksonville, Ill. The object of this invention is to improve the construction of the gas light extinguisher for which Letters Patent No. 206,926 were granted to the same inventors August 13, 1878, to make it simpler in construction and less expensive in manufacture, while being equally sensitive to variations in the gas pressure.

Mr. Ebenezer Miller, of Fredericton, N. B., Canada, has devised an improved Shifting Rail for carriage tops, which can readily be attached to and detached from the body of the carriage when the top is not needed. It consists of a rail provided with lugs having upper and lower lips, between which the flange or rim of the seat is clamped by thumb screws.

Mr. Henry E. Griffin, of Olympia, Washington Ter., has devised an improved Door Hinge that may be put on at a saving of screws without difficulty even by inexperienced hands, forming a cheap, neat, and strong support for the door.

Messrs. Thomas W. Platt and Arthur M. Orwig, of Windfall, Ind., has devised an improved Lifting Jack or Press Power, which is capable of exerting an immense power. It is simple and compact, and it may be used in a vertical, inclined, or horizontal position, as may be desired.