of really intelligent study and unselfish legislation had been tried.

A beginning of the new state of things was being made. Municipal and socialistic enterprises were in the air. They were running the gantlet of criticism and suspicion, as all things had to do before they were purged of their dross. He maintained that never before was the outlook so hopeful; never were all classes so permeated by the spirit—not the phrases, but the essential spirit—of brotherhood and co-operation; never was there such universal recognition of the beauty of the spirit of real and vital Christianity, far above the differences and dogmas of the sects. With the extension of local self-government legislative progress might be more rapid. The best men would throw themselves into public service with more heart and energy than now, when, in an overloaded and centralized Assembly, progress was so slow and the machinery so old and cumbersome that the output was quite incomparable with the time and labor involved in getting it through.

STRANGE MAZES AND CHASMS IN MAMMOTH CAVE.

By DR. HORACE C. HOVEY.

THE Mammoth Cave is not one immense cavern, but a congeries of many caverns, whose walls or floors have worn through into each other. For the sake of convenience, certain familiar routes are fixed; but equally grand and beautiful halls and galleries are rarely seen, and the very existence of some of them would be forgotten were they not indicated on the cavern maps. As an instance of this, the discovery of two magnificent domes was recently reported to the writer, and names were given them; but on consulting my notes I found that I had visited them in 1878, and that they were on Blackall's map of 1870 as Olivia's Domes. Mr. Norman A. Parrish, an expert climber, made the discovery in 1904 that the standard map of Mammoth Cave errs in its location of Marion Avenue, which he reached by a short cut from Washington Hall; but this same correction was made by Blackall. He also explored what he regards as a new avenue, branching from Mary's Vineyard to the right, and to which he gives the name of the Grand Canyon. After going half a mile he came to a crossing of passages and a cleft six feet wide and forty feet deep. The guide, John Nelson, did not think it had ever been crossed. Safely leaping over it, they found no signs of previous exploration. (This chasm has since been explored by Nelson and Einbiglers.) They found a curious complex of upper and lower galleries, extremely beautiful, which they illuminated by Bengal lights, the effect being such as to seem to warrant the name above mentioned. They went a long distance, but did not reach the end of the canyon. They also explored several small avenues branching from Marion Avenue, one of which leads to a series of deep pits. I regard Mr. Parrish's work, done last year, as valuable, and do not doubt that he made a number of original discoveries.

The guides ascribe daring exploits to Robert Louis Stevenson, who never set foot on Kentucky soil. They also say that Stephenson's Avenue is named for him, although it has had that name for fully forty years. Inquiry was rewarded by finding that an English traveler, named F. J. Stephenson, visited Mammoth Cave in 1863, and wrote an account of what he saw in some letters to his mother in London. Through the kindness of Mr. Edward Valpy these interesting letters are now in my hands, with permission from the author to publish such parts as might have public interest. Of course, much of the narrative traverses ground already familiar to cave-hunters.

Stephenson's visit was in war times. Mr. Owsley,

gish stream, on whose margin lies an old flatboat filled with sand. It was the rude craft in which Stephenson made one of the wildest voyages ever known. It was lowered by what is termed the "window" of the dome, after which he and his guide went down the well-like chasm known as Garvin's Pit. At the place of embarkation the arch was only eight inches above the water, and he had to lie flat on his back and push the boat along by his hands. As he advanced the tun-

JOHN M. NELSON, MAMMOTH CAVE GUIDE.

nel widened, the roof lifted, the stream was deeper, and he could use his paddle.

The guides had fastened a rope to the boat as a tether; but the solitary voyager cast this off, and passed beyond the reach of their voices. Presently he landed on a broad island, overhung by a dome with fine formations. After exploring this island, he took to his boat again, and passed many side branches, marking his course by signs on the walls, as a necessary precaution. After a while he came to a gloomy labyrinth of arches like inundated catacombs.

While debating as to which current might be the main stream, the solemn silence was broken by a strange noise, like the cough or bark of some underground monster. Stephenson fired his revolver with a crash and resultant echoes, enough to frighten any ordinary enemy into fits. But the ominous barking only grew louder than before. Resolutely he sought and found the cause, which was a small orifice just above water level, into which the motion of the boat forced successive wavelets with the result described. In trying to catch some eyeless fish one of his lamps was put out, his matches were wet, and his boat was nearly capsized, which might have been fatal. Accordingly he made his way out, after first carving his name on the wall as a token of his farthest advance. On this trip he was gone for three hours from the time of embarkation.

The next day, on his second voyage, he took Nick on board, with as many lamps as they could carry, and a lot of matches in a bottle. The two men were too heavy for so small a boat, and Nick was landed on the broad island, with a couple of lamps, while

half to get back to the island where Nick had been left, and the whole trip took four hours. The two trips consumed seven hours in all on waters no other man has ever explored, and whose source and outlet no man knows.

Stephenson claims to be the first white man that explored the Roaring River, which he reached by a passage opening at the Cascade beyond Echo River. He waded about for some time, catching eyeless fish. Then he and Nick set sail in a strange, cranky little boat, and paddled along for a mile. It is not stated if they explored what is now known as Aquarius Avenue; but they probably did so, as the long avenue into which this opens bears the explorer's name, Stephenson's Avenue, and contains Neptune's Cups and other objects of interest.

Croghan's Hall is usually spoken of as the end of the cave. On its right is a horrible pit called "The Maelstrom." Its opening yawns for 20 feet amid wet and slippery rocks. The depth was long said to be 175 feet; but as measured by the writer is only 90 feet.

In 1859 William C. Prentice, of Louisville, rigged a set of pulleys, and by means of a stout rope and basket descended this pit. The story was published at the time in the Kentucky papers, and was done into spirited verse by George Lansing Taylor. The story was highly embellished, but the main fact was verified to me by witnesses.

During Mr. Proctor's management, as he himself told me, a man named Babbitt was successfully lowered to the bottom of the Maelstrom by the guides Matt and William. He is said to have found a side opening, through which he essayed to go, but found the water too deep to be forded. William told me that the guides did not lose sight of Babbitt's light at any time. The date of this descent I do not know.

Mr. F. J. Stephenson claims to have made the descent four years after it was made by Prentice, and in the presence of thirty persons; namely, Nicholas Brandsford, Frank de Mowbrand, two other guides, five of Owsley's slaves, a visitor from Boston, and a number of officers and soldiers. The slaves cut and carried a stout pole and a new rope, which they lashed firmly to stalagmites, so that the middle of the pole overhung the pit, and the rope fell clear of the sides. Two loops were made for the legs, and a hitch was taken around the waist, leaving the hands free. With two lamps in one hand and a stout stick in the other, Stephenson started down, while De Mowbrand and the stout negroes held and paid out the rope. To the explorer's surprise, he found that the floor of the hall where the party stood was a thin crust. The torsion was distressing till he landed on a ledge forty feet below, when the vertigo ceased. He was within speaking distance of the guides. After a short respite he ventured down the second or inner pit, whose walls were polished and perpendicular. He ordered the rope to be paid out slowly, and contrived to keep near the wall, thus escaping the whirling that had annoyed him. Soon he reached the bottom, drenched by the waterfall from above. The pit here was 30 feet in diameter, and the bottom covered with blocks and debris. The stones that were knocked off from above endangered him. Accordingly he crawled into a crevice, and took refuge in it, while waiting for Nick and De Mowbrand to descend. On the floor of this side avenue were curious black stones and fragments of alabaster, with which they filled a small basket. At the end of an avenue Stephenson wrote his name and address and the date, August, 1863. So far as known, no one has ventured down this abyss from that date till May of the present year. The managers have denied all requests for permission to descend, till a recent exception was made in favor of Mr. Benjamin F. Einbigler, of New York city.

On May 13, 1905, he and John Nelson, guide, went down a pit 60 feet deep, near Serena's Arbor, hoping to find a crevice by which to pass easily into the larger pit. But the crevice was too small for them to go through. Accordingly, on May 15, they approached the Maelstrom directly, accompanied by Ed. Hawkins and Levi Woodson, on whom they relied to hold the rope while they went down.

The accompanying diagram will show the contour and surroundings of the pit, and their method of approach. The thin shell of stalagmite, which had for forty years been regarded as an element of danger, was found to be supported underneath by an earth pocket, so that the wall did not very greatly recede during the first part of their descent. They were not much troubled by torsion. Each man was in a kind of rope basket that left him free to use both hands. The present shape of the chasm does not exactly tally with former accounts. Grave doubts are expressed as to Babbitt's having ever gone down the pit at all. Prentice went down, but his story was made so romantic as to be of little use. There is no doubt that Stephenson explored the depths as described, yet certain features mentioned by him do not now exist. No black stones were found at the bottom, but only smooth water-polished limestone blocks, with fragments of so-called "onyx," and debris thrown down from above. Instead of a deep stream they found only a shallow one. The avenue in which both Prentice and Stephenson were said to have wandered so far, shrinks to a mere niche with a wide opening. Of course, the names written in the sand vanished long ago. The fact should be remembered that all these deep pits are wrought by steady and continued erosion, which, in the writer's opinion, may have caused many changes in the period of forty years, even to the extent of occluding an avenue that formerly existed. The general details of earlier visits are so circumstantial, and so well established by testimony, as not to be hastily cast aside by

1. Mouth of pit. Arrow indicates direction from which water came for the waterfall. 2. Bottom of pit. The location of the monument shows the outlet of the water disappearing through the ledge. + is where the waterfall strikes the bottom. It is estimated mouth of the pit is twenty feet in diameter and the bottom about fifteen feet.

MAMMOTH CAVE—THE MAELSTROM PIT.

the landlord, though a unionist, was a slaveholder. Guerrillas confiscated his valuables, but his slaves were not taken, being hidden in caverns on the other side of Green River. Nick Brandsford, Stephenson's guide, was an ex-slave, who had bought his freedom by the sale of eyeless fish. A French guide, Frank de Mowbrand, also served him.

Visitors to Gorin's Dome find at the bottom a slug-

Stephenson went on by himself. After passing the record of his first day's trip, he proceeded without special incident till he found the passage obstructed by fallen rocks. He then landed and went for a long distance on foot, when he again reached open and deep water. By this time he was so exhausted that he resisted the impulse to try to drag his boat over the rocks and launch her again. It took an hour and a

reason of alterations which may have been wrought by time.

The only visible drainage of the Maelstrom is through a small crevice at the bottom, into which both Stephenson and Einbigler went, in order to escape from falling rocks dislodged from above. It seems as if so large a chasm must have had at some former time a correspondingly large outlet, even though now occluded. The recent explorers found a scantling that had been thrown into the pit, and they set it upright, with massive stones piled around it. A square flat stone was fixed at the top, on which they inscribed "B. F. Einbigler, John Nelson, guide, May 15, 1905." This done, they returned to the mouth of the Maelstrom, their heroic task accomplished.

The early charts indicate two openings from the vicinity of Mary's Vineyard, one of which is Boone Avenue, and the other an avenue to the Mystic River. The latter has been sought diligently by many explorers, including myself, and sought in vain. Accordingly, we came to the conclusion that the Mystic River was a myth. But Mr. Einbigler reached it in May of this year. He went through Boone Avenue, passing around several "fall-ins," and deep pits, and then turning back through a parallel passageway till he came to the river sought. At the time of his visit the stream was about six feet wide and a foot deep, but the banks were strongly marked by signs of its having recently been much wider and deeper. Going still farther, he entered what is regarded as a newly-discovered dome of immense proportions, fully equal to anything previously found in the Mammoth Cave. In honor of his sister, who was with him at the time, he gave this magnificent room the name of the "Eena Dome." It is to be hoped that the management of the cave may soon make some of these new attractions of their wonderful cavern accessible to the general public, instead of limiting visitors so strictly to the beaten paths of the more familiar routes.

DAIMLER'S COMPOUND MOTOR.

At its factory in Germany the Daimler Company is bringing out a compound motor of original design fitted with combined intake and exhaust valves, on which patents have recently been issued. It is a well-recognized requirement of the successful compound gas engine that the passage between the cylinders for the gas already expanded in the high pressure cylinder must be as short as possible, so that a minimum of heat will be lost before its entrance to the low pressure cylinder. But its efficient accomplishment is attended by the difficulty of burnt valves, which rapidly ensue unless some means of cooling be provided.

This has been overcome in the Daimler engine without the employment of any intermediate valves, by causing the exhaust valve of the high pressure cylinder to act as the inlet of the low pressure as well. This will be noted in the accompanying longitudinal cross section.

The cooling of the body of the valve is by means of the fresh gas, and being housed in the center of the cylinder head, is surrounded by a cooling medium best adapted to maintain the loss of heat suffered by the exhaust at a minimum. A water circulation is also maintained, not alone in the cylinder jackets, but also about the seats of the valves and the cylinder heads. Differing from the usual practice, this is not cold, but warm, water, which in evaporating serves to absorb the excess heat. It is said to be readily possible by this method, not only to maintain an exactly uniform temperature, but further to prevent the latter from dropping below a determined minimum.

In order to prevent the return of the exploded gases from the low pressure cylinder and to exclude them from mixing with the incoming fresh charge, a specially designed check is provided about the valve itself. It is in the form of an annular movable chamber surrounding the valve and depending entirely for its operation upon the reaction of the once exploded gas.

The cross section shown represents an engine of the usual design employed in gas engine compounding. It consists of the two high pressure cylinders, disposed symmetrically on each side of the low pressure cylinder, B.

The exhaust valve, *a*, is composed of a hollow tubular body, having as its seat the upper face of the inlet valve, *b*. By this means the exhaust valve is also caused to act as a heater of the fresh charge of fuel, and during the passage of the latter it is cooled. When the cylinder, A, exhausts, the valve, *a*, leaves its seat and permits the once expanded charge to pass into B through the passage, *c*, which, on account of the placing of the valves in the cylinder heads, is extremely short. This passage is composed partly of the cylinder, B, and partly of the high pressure cylinder, which provides both a seat and a guide for the valve, *a*.

The burnt gases are thus not permitted to part with more than a negligible quantity of their heat before again expanding in the larger cylinder, and by means of the method of cooling the cylinder head shown by the sketch, all the parts are maintained at a constant normal temperature.

It will be seen that the valve, *a*, governs the admission of these gases as well as preventing their return by moving up and down, this travel being guided by *d*, which is an extension of *a* in the shape of a hollow piston. When the latter rises it engages the circular piece just above it, so that the exhausted gases are compelled to pass into the passage, *c*. The suction stroke of the high pressure piston then draws it downward again and permits of the entrance of the fresh charge. This exhaust valve is thus delicately balanced and quickly

responds alternately to the action of the incoming and exhausted gases.—The Motor World.

RECENT DEVELOPMENTS IN THE APPLICATION OF LIQUID FUEL TO MARINE BOILERS.

By the English Correspondent of SCIENTIFIC AMERICAN.

INTEREST among British engineers concerned in the utilization of liquid fuel for marine boilers has been recently directed to some highly successful tests that have been carried out in England with various types of burners. The results of these trials, in view of those that were obtained a short while back by our own Admiralty board, provide interesting and comparative reading. After a series of exhaustive tests on many injector burners sent to the United States Admiralty

DAIMLER'S COMPOUND MOTOR.

for competition, two injectors were selected by the board from the group as giving the best results. Another series of tests were then made with these two injector burners. The oils used in the trials were California crude and semi-refined Texas. The heating power of the Texas crude oil varies between 19,500 and 20,690 B. T. U. Taking both figures, the lower and the higher, viz., 19,500 and 20,690, these give a theoretical (say 100 per cent) evaporation of 20.16 and 21.40 pounds of steam respectively per pound of oil calculated from and at 212 deg. F. Such figures in practice are not obtained, as so much is consumed in radiation, conduction, flue-heating, etc., which altogether amount to a considerable percentage. The results of the series of tests carried out by the board on these two injector burners average 12.29 pounds of steam respectively per pound of oil with the one, and 12.08 pounds with the other, circulating from and at 212 deg. F., which may be taken to be about 60 per cent duty. Doubtless these figures are high, probably as high as an injector burner will go, but they are low in comparison with the systems in use in Great Britain. Prof. Watkinson, of

84 per cent—a point beyond which it is barely possible to go when the usual furnace allowances are taken into consideration. Thus it will be seen that with the oil used in the United States tests, giving as mentioned above 19,500 as lowest and 20,690 B. T. U. as highest, the Lucal system at 75 per cent only gives an evaporation of 15.12 and 16.05 pounds of steam per pound of oil from and at 212 deg. F., while 84 per cent gives 16.93 and 18 pounds respectively. It may also be added that while 4½ per cent of the total amount of steam formed was consumed to atomize the oil by the injectors as found by the United States board, Prof. Watkinson found that the Lucal device only took 1½ per cent.

The result of these investigations has directed attention to the Lucal apparatus, which is the outcome of seven years' patient study and experiments. The inventors of the system have especially devoted their energies toward obtaining the full duty from the oil, and to use the heat safely and as satisfactorily as coal under a boiler. With this apparatus the oil globule is broken into vapor and floating particles by highly superheated steam, before it leaves the burner head. By this arrangement complete aerification is assured. It is impossible to aerify liquid globules for burning purposes, but once the oil is brought into the condition of gas, perfect aerification can then be effected. It is similar to what occurs in a blowpipe flame, and a blowpipe flame is produced by the Lucal system. In this burner the oil (which may be supplied by gravitation) is fed into a cup, whence it flows in a fine stream to meet the steam near the mouth of the apparatus. The oil is thus kept as cool as possible until the last moment, so as not to break it up in any way. When it meets the steam, the great heat at that point vaporizes the oil, or all that will vaporize, while the unvaporizable remainder is broken into fine molecules, to burn as incandescent particles. Simultaneously, the air which has been drawn in by the action of the steam, and which is highly heated on its passage, mixes with the vapor and the unvaporable portions of the oil, the whole enters a passage in the cap of the burner, where the mixing becomes complete, and it is then ejected in this highly-prepared condition, to instantly burst into flame when lighted, without smoke, and in the best condition to do full and safe duty in the boiler.

It may be mentioned that an injector of the ordinary type is unsatisfactory for employment with superheated steam of the requisite temperature, since it becomes overheated. The heat then disintegrates the oil, deposits carbon, and the ports become charred up, rendering the apparatus useless in a few minutes.

The fundamental principle of the Lucal system is the preparation of the oil outside the furnace, so that it can work effectively inside the furnace. Further, the oil must be brought partially or wholly into a state of vapor, and be thoroughly commingled with air before it reaches the furnace, by means of highly superheated steam. The latter is formed on its passage to the ejecting nozzle.

One very prominent feature of this system is that the flame itself may be regulated from a slow, smoky flame to that of a fierce blowpipe. This is attributable to the fact that all the entrances of the oil, air, and steam respectively may be controlled to a point. For

A SYSTEM FOR BURNING LIQUID FUEL UNDER MARINE BOILERS.

Glasgow, recently carried out a series of tests with the system of the Lucal Light and Heating Company, of that city, and obtained results far in advance of those achieved by the board appointed by our own Admiralty. Prof. Watkinson's results showed that combustion was practically perfect, and that an effective evaporation of 75 per cent was obtained by the Lucal apparatus, and with a little careful working it ran up to

steam-raising purposes the device is fixed to give a flame similar to that of coal in perfect combustion. Extensive lining of the furnaces with brickwork, as is necessary in other systems, in order to protect the boiler plates is thereby dispensed with, and full and free play is secured for the radiant and for the contact heat of the flame.

The steam is drawn from the boiler for injection,