Waterproofing Concrete Structures

By C. G. DERRICK

THE rapid development in the use of cement plasters and concrete for construction purposes has brought forth many new problems for solution. Perhaps one of the most important has been that of constructing water-proof structures, that is, structures which are proof from percolating water as well as from dampness. Yet in another light, this problem of water-proof construction applies well to the use of building materials other than cement.

The reasons for water-proof construction are many, and differ with the locality. In general it is very desirable to make reservoir dams of material impervious to water. Along the sea coast the problem becomes very acute. Cellars to our modern business blocks are sunk far below high-tide mark, and in certain cases under the writer's observation sub-basements were subjected at high-tide to the pressure of eighteen feet of water. But such basements are of great value for storage and must be water-proof. Again, in certain places water and sewage mains must run in parallel and it is of the greatest importance that no contamination of the water supply should be possible. But perhaps the greatest argument for water-proof construction is durability and permanency. The reinforcing, which makes the extended use of cement concrete possible, must remain intact. But many observations have shown that this is not the case where the concrete is pervious to water and exposed to the action of chemicals in solution in the water. From this viewpoint, water-proofing is very necessary to prevent the disintegration of reinforcing as well as the cement itself.

To construct water-proof structures for one or more of the above reasons has long been the task of the engineer. A question much discussed is whether or not it is possible to construct buildings from cement concrete alone which shall be water-proof. Beyond a doubt this is possible, for a carefully applied cement plaster lining of foundation wall has in many cases rendered these walls impervious to water. But such work requires special materials and workmanship. The sand and stone must be carefully graded and applied with the greatest care. A member of a prominent New England firm, summing up the whole matter, stated that it is not a question as to whether or not cement concrete may be made water-proof by the careful gradation of materials in the hand of expert men, but that with the ordinary type of unskilled labor employed water-proof construction is impossible. This statement was made in spite of the fact that this company held the record for the construction of water-proof structures in that neighborhood. Further, he stated that anything which could be added to the concrete to insure its being water-proof without greatly increasing its cost was to be desired, and had an almost unlimited application.

It is a well-known fact that alum and soap mixtures have been used for water-proofing since the middle of the last century. Very probably at first they were used as external washes, but more recently they have been applied to concrete itself, by means of the water used in the mix. Various proportions of alum and soap have been recommended, but in every case there is a distinct lack of cleanness about such procedure, caused apparently by a lack of the knowledge as to how water-proofing effect is brought about. The water-proofing effect is due to the precipitation of the insoluble aluminium salts of the organic acids occurring in soap. These salts partially fill the pores of the concrete and give the finished concrete a repellent action toward water. Hence it is evident that the alum and soap should be used in the exact proportion demanded by the chemical equation. But to determine this proportion the analysis of the soap must be known as well as the composition of the alum. Moreover, the best practice today recommends that the amount of alum and soap precipitated into the concrete should be equal but not greatly exceed two per cent. of the neat cement used in the ordinary mix for concrete. But the use of alum is needlessly expensive. Alum has the formula K2 SO4, Al2 (SO4)3, 24H 2 O in which the desired material, aluminium sulphate, Al2 (SO4)3 makes up only thirty-six per cent. of the whole. It would be far better to use alum sulphate, which as a commercial product has the formula Al2 (SO4)3 18H 2 O, in which there is fifty-one per cent. of the desired Al2 (SO4)3. Even with this modification the method is much more expensive than many others which give just as good results.

Until very recently the use of the tar and felt seal method for water-proofing buildings has had universal application. It can be applied to structures built of any ordinary building material and if successfully applied gives very satisfactory results. This seal is applied to the outer surfaces of the foundation walls and floor. Second it may be applied to the inner surfaces of the same.

One method of applying this seal to the outer surface of walls and floor consists, in brief, in first building a small retaining wall of some cheap material which will support the seal until the foundations are put in place, as well as to protect it from the outside wear. This retaining wall is mopped with tar, to which is applied tar paper, which is then carefully mopped with hot tar to seal all joints. Several successive layers of paper and tar are applied according to the specifications. Great care is taken, or should be, to insure each layer's being water-proof before the next is applied. When the seal is completed the foundation walls are built snug against it. The seal makes a complete water-proof shell within which the foundation walls and floor rest.

In the second method the shell is constructed within the finished structure. To protect it and hold it in place a retaining wall is built within the foundation walls, and this retaining wall varies in thickness according to the external water pressure.

Practice differs as to which method shall be employed, but many firms desire to apply the seal to the inner surface of the foundations as given in the second method, the reasons for which will appear presently. With the first method careful overseeing is necessary to prevent the seal from being punctured while the foundation walls are being built, for often one firm applies the seal and another puts in the foundations. If the seal is punctured, it is very difficult to fix the responsibility, and this is one reason why the seal method is undesirable. The strongest argument against the use of the seal is the difficulty of patching it after the structure is completed and the seal becomes punctured. A break in the seal is made evident by a damp spot on the wall, or, often, percolating water. At this point the walls are torn away to expose the seal; but as often happens the puncture is not at this point—so the wall must be removed until the leak is found. It is very evident that this process is much simpler in the second case where the shell is within the foundation's walls and supported by a thin retaining wall. In either case the cost of repairing the seal is very great and the uncertainty of quickly locating the leak makes the method undesirable. In one case, where the writer was called in to assist after three weeks of steady searching the leak was found. In another case—that of the Shawmut Bank Building in Boston—where the seal was applied to the outer surface of the foundations—the writer found the only way to make the completed structure water-proof was to apply a patent water-proof cement coating to the inner surface of the brick walls of the entire cellar. The objections to the use of the second method of applying the seal are that much valuable storage space is taken up by the retaining walls and that the reinforcing in the foundation walls is exposed to the actions of the ground water.

The result of the general dissatisfaction with the seal method has resulted in the discovery of many new methods of water-proofing, and today there exist several firms making chemicals which, when applied to the cement, will insure its imperviousness to water. The present methods are very different but fall into two general groups, namely, those that are applied as external washes or paints, and those that are incorporated in the cement during the mixing.

Under the first division, the use of alum and soap washes, cement grout, finely suspended slaked lime or magnesium carbonate, asphalt paints and interior coatings of tar or asphalt are the most important. In the cases where the external pressure due to the water is small these methods will give more or less water-proof structures, but in every case they are exposed to wear and soon become punctured. Here again the reinforceing is exposed to the action of the ground waters which seep through the concrete.

The modern water-proofing that is giving the most satisfactory results is that in which water-proofing material is made a constituent part of the concrete. Such material must be insoluble in water and possess permanency toward heat, atmospheric conditions, and the substances carried in solution in the ground water—weak organic acids, alkalies, etc. Moreover, they must have a harmless action upon the concrete itself, that is, they must not decrease its temporary or permanent strength. With these qualifications in mind the problem becomes much restricted for the chemist, and the result has been several very successful methods of rendering the concrete, within itself, impervious to water.

This type of water-proofing is accomplished by three different general methods. By the first the foreign material may be added to the concrete by means of the water used in the mix, either as a true solution or a a suspension. In such cases where the water-proofing material is added as a true solution, the chemicals must react with each other or with chemicals in the cement to produce the desired insoluble water-proofing compounds. Few processes of this type are now employed and they are trade secrets. One firm, which well illustrates the recent development in this type of water-proofing, first used a true solution, next employed a treated cement, and at present uses a prepared cement ready for application as a plaster, which consists of cement, sand and water-proofing compounds. Many reasons may be advanced for this development, namely, secrecy, insurance of equal distribution of water-proofing compounds, and profits upon the cement, sand and chemicals.

Under the second division of this first general method, the alum and soap mixtures are representative examples. But the use of lime and soap mixtures is by far the cheaper and of exactly the same waterproofing value. The product formed by these mixtures is a calcium soap, which is insoluble in water and very stable under ordinary conditions. But if used in a boiler room it must be protected by a considerable thickness of concrete where it underlies the fire box. Ordinary, insulated steam pipes do not affect these soaps. Very recently experiments have shown that colloidal clay may be used as a water-proofer with excellent results. Yet many tempting dangers follow in its course, since it offers a great incentive to fraudulent cement making. Moreover it is not always accessible and unskilled labor is hardly to be trusted with its use.

In the second general method the foreign material is added to the neat cement by means of organic solvents. The water-proofing materials are in general paraffine, stearic acid, and waxes. A solution of these in benzine is applied to the neat cement and the organic solvent evaporated while the cement is agitated to insure equal distribution of the water-proofer. It is very evident that this method is costly because of the materials and special apparatus needed and it can never hope to compete with the calcium soap method.

Lastly, in the third general method, the water-proofing material is added by mechanical mixing of the foreign material and the neat cement, of the foreign material and the neat cement and sand, or of the foreign material, neat cement, sand and stone. By whatever process employed, its success as a water-proofer depends upon its thorough and equal distribution throughout the concrete so as to render each part of the finished structure equally impervious to water. The literature upon this subject very early noted the use of mixtures of slaked lime and waxes, which were ground with the neat cement, the idea being, that in the presence of water, insoluble calcium salts of organic acids would be precipitated within the concrete. Such a method introduces needless materials of excessive cost. In the place of lime and waxes should be added calcium soaps which are a commercial product and very cheap. Many trade products such as the Medusa water-proofing compounds are undoubtedly nothing but the lime salts of certain organic acids or their equivalents. For a detailed description of these compounds and their use, the prospectus put out by the Medusa Water-proofing Company will suffice.

The writer has experimented with each of the fore-going classes of compounds used to make cement impervious to water. The substances used being paraffine, beeswax, carnauba wax, spermaceti, linseed oil and salts of organic acids which were applied to some of the above-mentioned methods. A qualitative test adopted to show the presence of water-proofing characteristics consisted in making small cup-like pieces of cement plaster treated by each of the above chemicals. These molds were filled with water, after having thoroughly set, and if the chemicals gave the cement plaster water-proofing characteristics of any value no percolation or dampness should appear on the bottom of the molds no matter how long the water remained in them. In general a 1 : 1 or 1 : 2 mix with a good sharp sand was used in making the molds. Molds containing the following percentages of water-proofing compounds were used: 1-100, 1-10, 1-2, 1, 2, and 5. In every case marked water-proofing qualities were noted even with the percentage of material as low as 1-100 per cent., but more satisfactory results were obtained only when the water-proofing material ranged from 1-2 to 2 per cent. of the neat cement employed. In every case 5 per cent. of foreign material destroyed the strength of the plaster, while 2 per cent or under apparently made no difference in the tensile strength tests. The presence of the water-proofing material had a marked effect on the rate of the preliminary hardening which was always checked. Of all the chemicals used, the lime soaps appeared the most desirable, and with these quantitative tests were made. The first test was to patch a leaking brick wall which had been previously coated with a plaster of a water-proof cement. After checking the flow of water, the leaks were coated with the treated cement containing 1 per cent. of lime soap using a 1 : 1 mix. After successfully completing this test, the original concrete on a piece of new construction was treated with the same chemicals. The result was a water-proof structure quite impervious to the external water pressure of eight feet. Furthur, this test showed that concrete may be more easily water-proofed than cement plaster and that it requires no greater percentage of water-proofing materials.

The question now naturally arises as to how such water-proofing is brought about. To this question no correct answer can be given at present. However, it is evident that the small percentage of foreign material added to the concrete does not fill the voids in the same, completely nor to any appreciable extent. Yet one characteristic of water-proofed concrete is very evident. The capilarity, which causes the water quickly to creep over and through ordinary concrete, is destroyed in the case of the water-proofed product. In this direction, the cause of water-proofing may find its ultimate explanation.

Typical Sponge Market Where Sponges Are Sold to the Highest Bidder

The Greek Diver Is Fast Exterminating the Sponge

HOW SPONGES ARE GATHERED AND ARTIFICIALLY GROWN

WHERE do all the sponges come from? We see them every day, and while everyone knows that they are products of the sea, few know how they are gathered and how limited are the fishing districts where they are caught. The sponge industry of the United States dates back half a century or more, when the people of Key West, with that little island as a base, began fishing in adjacent waters. Gradually, as the sponges became scarce, operations were extended up the Gulf coast.

The two places where sponge fishing can now best be studied are Tarpon Springs, on the west coast of Florida, and Batabano, on the south coast of Cuba. Though these points are what might be called within a stone's throw of each other, the modes of gathering the sponges are so entirely different that they might be half a world apart. In Florida the industry is pursued with all the ceremony and science that money and modern ingenuity can employ, while on the coast of Cuba the business is conducted with all the primitiveness and leisure associated with sponge fishing since classic times. The Cuban goes out in what is called a chalupa, a craft that might be described as a cross between a flat-bottom river boat and a canoe. He takes with him his professional instruments, which consist of three poles ten, thirty, and fifty feet in length (the ends of each being fitted with a three pronged harpoon) and a "deep-sea" spyglass.

This optical instrument—an important one too—is nothing more or less than a water-tight cylinder with a plain piece of window glass fastened in one end. Sometimes a simple water bucket with the bottom knocked out answers the purpose. In seeking sponges in rough water, this device is placed upright in the waves, and the head of the fisherman thrust into it as deep as possible beneath the surface. Looking through the glass in the bottom, the hooker sees the bed of the sea to a depth of fifty feet. This is explained by reason of the fact that the flat surface of water pressed under the glass is absolutely devoid of those ripples and irregularities which are caused to appear on the surface by the wind and tide. As soon as a sponge is spied through the crude marine telescope, the sponger grasps his hook and brings it into play. By reason of his trained eye and skillful hand, it is rarely that he misses, even while the boat is being propelled. This old method of gathering sponges is tedious and trying, and requires a patience beyond belief. To maintain one's self in a shallow skiff without upsetting it, and at the same time to spy the game through the bottom of an inverted bucket, and further, to catch it on the end of a fifty-foot pole while the boat is in motion, is a complication of feats of which not many are capable.

Up to a few years ago this antiquated method of catching sponges was followed along the Florida coast. In fact, it is still employed to some extent by the natives in that section. These folk go out from the harbors in small schooners, which are built with large decks for carrying the catch. The crew of such a craft consists generally of half a dozen men and a cook. Every morning at daybreak they launch their dingies from the schooner. Each of these small craft is manned by two, known in the fisher-folk lore as "hooker" and "sculler." The former remains on his knees with his head thrust down into his spyglass most of the livelong day, while the "sculler" slowly propels the boat, unless their efforts have been unusually successful, when they return to the schooner and "lay up" before sundown. The main craft sometimes stays offshore for eight weeks catching its load of sponges.

In Florida, however, most of the sponge fishing is done today by professional Greek divers. These experienced foreigners, driven out of the Mediterranean by the governments bordering on that sea, have immigrated to Florida for the purpose of applying their vocation in American waters. With years of training in the deep waters of the Mediterranean Sea, they have become experts in the art of sponge gathering. In a diving suit called "shafander," they can easily secure sponges—and choice ones too—that cannot be reached by American hookers. The diving suits worn are of the most modern and perfect make, heavily weighted with lead. Even leaden soled shoes are worn. The divers carry with them to the bottom a large mesh sack, into which the sponges are placed with both hands just as if they were oranges. The boats follow along on the surface, pumping fresh air to the divers and hauling up and lowering the sponge bags whenever full or empty. The diving suits worn by these sponge gatherers are so perfect, and the water so clear at the depth to which the divers descend, that there is little risk of life except from sharks. The water where the sponge abounds is infested with man-eaters, and many are the thrilling escapes of the men who walk the bottom of the sea. These sponge fishers carry no weapons, because a weapon that would cause death under water would have to draw blood. One shark killed, the first trace of blood would attract a dozen more. The diving suits are too heavy for rapid movement. When one of the man-eating sharks appears on the scene, the diver's only course is to remain absolutely still, for a shark will not disturb anything it thinks dead. As one of the oldest sponge fishers of the Greek race states, it requires an extraordinary amount of nerve for a man alone at the bottom of the sea to keep still all the while a fifteen-foot hungry shark is circling him and lashing him with its tail.

As the small boats carry their loads to the main ship the sponges are placed on the deck, where they are left until all the slimy matter they contain has drained off. While the sponges are dying, they give off a strong odor of ammonia, which after a few days changes to the more pleasant smell of seaweed. The schooner then returns to its base of operation, and places its catch in pens made of stakes driven in the shallow water near the shore, so that the flowing tide washes the sponges as it comes and goes. This washing takes about one week, after which the sponges, one by one, are thoroughly squeezed out and beaten with sticks until all the living matter has disappeared. After this process they are strung in bunches upon pieces of rope about six feet in length, and piled upon the shipping wharves, to be sold at auction to persons known as the packers' agents, who ship them to their packing houses. Here they receive their last treatment, bleaching, which is accomplished by a solution of lime and sea water. If the solution is made too strong with lime, it makes the sponge harsh and easy to tear. But notwithstanding this fact, it is the custom of many of the packing houses to use large quantities of lime. The sponges are then made to weigh more, and they are sold by weight.

The finest sponges in the world are the Turkish. They have brought as much as $50 a pound, but they are scarce. Next in quality is the sheepwool variety, so called because of its close resemblance to the wool of that name. Notwithstanding the fact that this variety is much cheaper, it is often preferred to the Turkish sponge as a toilet article. Next in order of value come the velvet, yellow, grass and glove sponges. The velvets are very scarce on the Florida coast and vary in price according to quality, while the grass and glove sponges sell as low as a few cents a pound. It takes a good measure of well-dried sponges to make a pound.

Experiments have recently been conducted for the purpose of testing the feasibility of transporting sponges alive in aquaria. These experiments are reported to have been a success, and it is now possible to transplant the valuable varieties of Turkish sponges in the sponging grounds of American waters.

Not only were the experiments of transplanting sponges successful, but an eminent biologist, Dr. H. F. Moore, has conducted a series of experiments, which have resulted in the production of a rootless sponge. The root of a sponge is its most vulnerable part, and at this point it first begins to tear. A rootless sponge, therefore, will far outlast the common variety. Dr. Moore's method of producing the rootless sponge is to cut the animals into pieces two cubic inches in volume. This is done by means of a very sharp knife while the sponge is alive, and has at least one face covered by the original skin. A slit an inch deep is made lengthwise in each cutting, which is then placed astride a wire. This slit is then closed by a piece of aluminium wire, so that there can be no rust or corrosion of any sort. Within a week the cutting heals around the suspension wire. Long wires strung with these cuttings are then driven into the shallow sea bottom, about fifty feet apart, the cutting being suspended free from the bottom. In eighteen months these seed, as it were, attain twenty-five times their original weight. When this method of artificial sponge growing is carefully carried out, ninety-five per cent. of the cuttings will not only survive, but will grow into a perfect ball or ellipsoid with no vulnerable point, their roots being on the inside. Such a sponge of the sheep-wool variety will last for years. All of the species of sponges can be reproduced in this extraordinary way.

These valuable fishing grounds have been so over-fished in and out of season, that the Congress of the United States found it necessary to pass stringent laws to protect the industry from annihilation by the Greek divers. The new law prohibits these divers from working after the first of May until the first of October in water that is less than fifty feet deep, and the revenue cutter service will have vessels to patrol the Florida waters to see that the law is strictly enforced. This law was made not only for the protection of the sponge industry itself, but likewise for the protection of American sponge fishers, who rely on the sponge market for a livelihood, and who still gather their prizes with a harpoon.

So many Greeks have immigrated to the Florida sponge waters from the Old World to follow their calling in the New, that one may see in the Greek quarters at Tarpon Greek houses, Greek costumes, and hear only the Greek language spoken. Even the boats from which the divers work are brought from Greece.

BRITISH BACKWARDNESS IN FLYING

WHY do the English, who pride themselves on their sporting blood, seem to take so little interest in the latest and most exciting thing in this line—the sport of flying? The nation is taken sharply to task by Engineering for its inexplicable backwardness in aviation. There is no apparent reason for it. No unfavorable and hampering legislation, such as handicaps the electric industries in Britain, no lack of a good start—for the English were "among the first to take seriously to aeronautics"—has held our transatlantic cousins back. They have, nevertheless, sat calmly down and witnessed American, French, and German successes galore, while their own blood has apparently remained stagnant. Some of the abortive English attempts to do something aeronautic are satirized as follows:

"After being satisfied with seeing, and hearing of, remarkable results achieved abroad, this country gradually realized, some time ago, its true position. The Government attempted to grapple with the situation, and Mr. Haldane delivered a lengthy speech in the House of Commons. Robbed of all rhetorical ornamentation, however, this amounted to little more than the announcement: 'We have an engine and a car; all we want is a gas-bag,' reminding us of the would-be motorist who, knowing full well that a car was beyond his means, consoled himself with the purchase of a motor cap. Mr. Haldane's confidence is reposed in dirigibles, as the above remark implies. . . . . Yet, even since the occasion above referred to, when Mr. Haldane made many depreciatory remarks concerning aeroplanes, the progress made with them has been enormous. Mr. Farman has, for instance, covered a distance of 144 miles, and Mr. O. Wright, in Berlin, has flown at an 'unofficial' height of 500 meters. The Comte de Lambert, in his flight over Paris and round the Eiffel Tower, has accomplished one of the boldest feats witnessed for many a long day. M. Paulhan is reported to have reached the altitude of 1,800 feet recently at Bouy, though this height has not yet been accepted as official. He has officially attained a height of over 1,200 feet, however, at Bouy, and M. Latham a height of over 1,300 feet. All these achievements bespeak extremely rapid progress, the like of which cannot be shown in the case of the lighter-than-air machines, whose progress is so slow as to amount to little more than stagnation. In view of recent progress, who can say what the future may have in store? The modern bicycle, motor-car, high-speed steamer, etc., are all so different from their inventors' prototypes that it would be rash to attempt much in the way of a forecast. One things seems clear, however, and that is that we should actively encourage development, and, by all means, help forward that branch of the science which appears of the greatest promise."

"Many people among us seem to think that any kind of machine will fly, and dabblers of all sorts consider they have solved the problem once for all. Our few earnest workers worry along independently, often working over ground already covered and proved barren by someone else, until financial stress directs their attention to other matters. It is difficult to say why so few of the efforts made here should fructify, unless it be that they are mostly made along erroneous lines. The proportions of weight, surface, and power of the successful machines of today are all well known, and any engineer should be able, with these limits, to produce a machine that would rise. The fact is that the movement is not altogether in the right hands. It has got into the hands of sportsmen and dilettante enthusiasts, and, with a few exceptions, is not taken up by engineers."

The trouble is, curiously enough, that this king of sports is suffering in England at the hands of sportsmen, especially the members of the Aero Club, whose performances the writer regards as "sophomoric." Sport, he reminds us, although it has in the past been of service in new developments, and was, for instance, of material value in the development of motor-cars, needs to be kept in its proper place. In motoring the racing-car has largely given place to the touring vehicle—a more rational machine. Similarly in aviation, the machine now built merely to win races will probably, in time, when the movement has become leavened with the ideas of engineers, give place to more serviceable types. The exclusion of the engineer from the development of aviation has prevented this kind of development in England, while it has rapidly taken place in America and France. Thus its progress, even as a sport, has been retarded, for a purely mechanical sport cannot be trusted to sportsmen who are not at the same time mechanics. The writer concludes:

"In the early part of the year we passed through an aeronautical-invasion scare. Men, dreaming, thought they saw 'Fierce, fiery warriors fight upon the clouds, in ranks and squadrons and right form of war'; and it may be that the Aero Club's behavior echoes of this scare. Such puny protection as it can afford us is, however, not needed yet, and such is our backward state that it is at present to our advantage that we should see all there is to be seen of this kind of thing, in order the better to make our progress when we do get under way. Rather than occupying itself in placing a ban upon meetings and disqualifying men who can fly, the Aero Club would be better employing its time in endeavoring to discourage such attempts at flight in public as bring ridicule on us as a nation.

"The present regrettable situation, precipitated by a sophomoric club, needs to be quickly righted if our credit is to be retained. Neither sport nor the real value, which, after all, is the great thing of aviation, will be encouraged by vetoing meetings and disqualifying several of the still few proficient manipulators of aeroplanes. On the other hand, combined effort, in which science is encouraged to advance with sport, may, in the not distant future, lead to most interesting results. At the same time we need not even despair of the club, for does not Robert Louis Stevenson assure us that 'it is better to be a fool than to be dead,' especially if the folly perpetrated be an indiscretion of youth—youth which elsewhere he describes as jogging on the foot-path way, pursuing butterflies. The Aero Club has at least proved itself alive by its action, and as it is as yet quite an infant among clubs we may still have good hopes of its future."

BIBLICAL ELECTRICITY

A CURIOUS study entitled "Electrotechnics in the Bible" is contributed by E. Stadelmann, an electric engineer of Munich. The writer asserts that the ancient Jews had some knowledge of electricity, and he tries to prove this by an ingenious analysis of Scriptural narrative. In the first place, says Stadelmann, Moses evidently understood the uses of the lightning conductor. As we read in an abstract of his article in the Revue Scientifique:

"Did he not make a brazen serpent to defend his people against the fiery serpents (lightnings) sent upon them by the Almighty, so that the fiery serpents were seized by the brazen one? The temple at Jerusalem was protected against lightning by interconnected metal points communicating with the ground through reservoirs of water."

Still more curious is the explanation given by Mr. Stadelmann of the construction of the Ark of the Covenant and of the terrible punishments visited upon the unfortunates who dared to approach too near it:

"If we study the details of its construction we find that it was composed of an insulating receptacle (of acacia wood) and of two metallic coatings (gilding), one exterior, one interior; it therefore formed a Leyden jar of great dimensions. This condenser, charged with atmospheric electricity by the metal conductors of the temple roof, had, as may be calculated from its dimensions, a capacity amply sufficient to produce a fatal discharge. Only the initiate could touch it, and this immunity enjoyed by the officiating priest is explained by the nature of his costume, which was in part of gold tissue, thus protecting him from electric discharges."

Mr. Stadelmann cites in support of his hypothesis many Scriptural texts, on the construction of the Ark, on the nature of the priests's costume, and on the punishment dealt out to profane persons. Moreover:

"The altar, also, must have been a powerful Leyden jar, although information regarding its installation is not available; but the passages in the Mosaic books forbidding approach to it on penalty of death to persons not wearing the prescribed costume, authorize us to consider it such.

"It would perhaps appear improbable that such powerful effects could be obtained with metallic rods on elevated points, but we must bear in mind the atmospheric peculiarities of Palestine; and even the experiments made in Europe on the collection of electricity by means of kites, have shown that huge sparks nine or ten feet long may thus be obtained.

"Moses probably got his notions of electricity from the Egyptians, and perhaps, Mr. Stadelmann concludes, Egyptologists may discover facts indicative of the state of electrical knowledge in the Pharaonic times."