ON STEAM BOILER INSPECTION.

BY MR. E. B. MARTEN.

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Steam boilers are now so common, and so often seen working with apparent safety on steamboats or railways or in manufactories that familiarity is apt to breed contempt for the danger that surrounds them if they should be faulty or used without due care.

The wreck produced by the explosion of a steam boiler is often so extensive that the casual observer is easily persuaded that there must have been some sudden accession of power at the moment of explosion, and is readily made to believe in mysterious theories involving intricate suppositions as to the influence of electricity, the spheroidal condition of water in contact with hot plates, the decomposition of water and ignition of the gases, the sudden generation of steam from water heated to a high temperature, and a host of other phenomena which are themselves true and perfectly understood, but have little or nothing to do with boiler explosions.

A very simple calculation will enable any one to realize that there is plenty of force accumulated in an ordinary boiler to account for all the mischief, if it is liberated suddenly. A boiler of an average size contains when at work sufficient accumulated "force," in the shape of steam and heated water, to work a thirty-horse engine for about ten minutes without additional firing; and if this should be liberated *in one second* by the rupture of the boiler, the power to cause explosion is equal to the united effort of 18,000 horses. A boiler forms a reservoir of power, and, like a reservoir of water, is capable of producing much useful work if allowed to flow gradually through a proper mill or engine, but capable of vast destruction should the rupture of the sides allow the contents to escape suddenly.

It has been calculated that the explosive effect of each cubic foot of water in a boiler at sixty lbs. pressure is equal to the detonation of one pound of gunpowder; so that in the case before given there would be the same effect as from the explosion of about 500 lbs. of gunpowder.

The explosions of vessels containing high pressure steam, but not exposed to any fire which would render possible any overheating or decomposition of steam, etc., cause as much havoc as the bursting of ordinary boilers when the contents are suddenly liberated by rupture of the sides.

It has long been the object of engineers who have given especial attention to this subject to obtain accurate records of every case of boiler explosion, and I have done my utmost to assist in that object, and have obtained notice of more than 1,500 explosions, causing the death of over 5,000 persons, and the injury of some 4,000 others.

The records are discouraging in many respects, as they contain the names of some of the best and most careful engineering firms as owners of exploded boilers, and also give instances of explosion of nearly every form of boiler which has been in use for any length of time; for there are plenty of exploded locomotives, Cornish, Lancashire, and other boilers, once held to be almost incapable of explosion, as well as the more old-fashioned Balloon, Haystack, Butterley, or plain cylinder boilers.

In but few of the earlier explosions are trustworthy records obtainable; but for some ten or twelve years they have been far more complete and accurate, and their careful consideration has led to the conclusion that most of the explosions could have been prevented had the actual condition of the boilers been known.

Nearly all who have given special attention to the matter being agreed that most explosions could be prevented if the conditions of the boilers were known, the problem suggests itself—how are owners to keep themselves informed of the condition of their boilers; and the simple answer is, by periodical inspection.

Inspection may be done by any one, and its value will differ according to the care and intelligence of the inspector.

It may be well to describe what is usually meant by boiler inspection. To insure due attention a written report should be made, which must be perfectly intelligible to any one who has not seen the boiler, and to prevent confusion no two boilers should be mentioned on one paper, and the report should be made complete at once, so as not to need fair copying, and illustrated with sketches. In the first place, every particular of boiler and fittings and setting should be noted that can be seen from the outside of the boiler, with sketches and sufficient dimensions to make complete detailed drawings if required.

The boiler should then be entered, and internal sketch and dimensions taken sufficient to make a complete drawing. The plates should then be felt in every part with a light hammer, and the general condition noted.

The flues should be reserved for the last, because they are generally dirty, but this is often the most important part of the inspection. The fire grate and each flue should be entered and traversed, and every part of the boiler plates felt with a hammer, and also dimensions taken as before.

This is not all that is necessary to obtain complete information, for there still remain those parts of the boiler in contact with the brickwork, and the neglect of which often leads to disaster. It is easy to clear the brickwork sufficiently for examination, but a little arrangement when setting the boilers would make it far easier, and will be again alluded to.

It may be well to mention the chief impediments to carrying out this inspection. It is often impossible to make even the external examination, because boilers are so smothered up with brick and stonework. The clothing of boilers is often justly urged as leading to economy of fuel, but it should not be done in such a way as to preclude examination. The most rapid corrosion goes on if a leak should take place beneath the covering, especially if it consists partly of sand or ashes.

Internal examination is sometimes prevented by too small a man-hole, or one so awkwardly placed as to make it almost impossible to twist into the boiler; but the most usual difficulty is the want of room to move about, or to use a hammer. Sometimes also there is no means of cooling sufficiently to remain in the boiler many minutes.

Each form of boiler has its peculiar difficulties. The Cornish or one tube boiler is one of the most awkward, as there is so little space between the tube and shell at the sides and bottom, and a false step may cause the inspector to slip and become wedged. An instance of this occurred last year, where the plates of a boiler had to be cut out to extricate a man.

The Lancashire or two tube boiler obviates this difficulty, but involves another man-hole to get at the space beneath the tubes.

Most of the multitubular boilers, such as the locomotives, are too small to enter, and the impossibility of internal examination has led to many explosions.

Of course the difficulty of examination is much increased if the scale is not well cleaned off, as without this many a fault will be overlooked.

The easiest boilers to examine internally are the plain cylinders, or others without internal tubes, and this facility for examination is one of their chief recommendations.

The upright boilers, such as work from the waste gases from iron furnaces, are particularly easy to examine, as there is plenty of room to stand upright both inside and in the flues.

The flue examination is attended with some impediments, as in most boiler settings facility for entrance to the flues appears to have been the last consideration. In many cases entrance is simply impossible, as the brickwork is only a few inches from the boiler. In not a few cases the man-holes are little cast-iron frames and doors, and too small for even a lad to pass through. Even when the flues of the Cornish and Lancashire boilers are large enough to pass along, the narrow space and inclined or crawling position are awkward. The plain flash flues of the externally fired boilers are easiest to examine.

The value of the examination when all the above impediments are overcome must depend on the knowledge of the inspector as to the points to observe, and as to what mischief to be on the look out for. Of course it is presumed that the boiler when fixed was a good one; the object of inspection being to ascertain whether it has become weak or dangerous while working.

It is often found that boilers have been injudiciously altered in form. In one case the tube had been removed without due care in compensating for the loss of the support of the tube and the extra area exposed to pressure in the flat ends by suitable stays, and, of course, the end was blown out.

Great loss of strength is often caused by injudicious repair, even when there is no intended change in the form of the boiler. Plain cylinder boilers originally constructed in rings with joints crossed, are often found so much repaired with patch upon patch that the seams become nearly continuous from end to end. The strength of such boilers it is impossible to calculate, as the metal must be exposed to unequal strains from the new and more elastic plate not taking up its exact proportion.

The faults visible from the outside of the boiler are generally so apparent when the covering is removed that they can hardly escape detection. The chief danger is from corrosion from the neglect of leaking of joints.

The faults visible from the inside may more easily escape detection. In those boilers which depend upon stays for their strength, the stays need very careful examination to ascertain if there is any sign of weakness. It is not at all uncommon to finds stays of proper and good construction, but with the rivets attaching them to the boiler loose or nearly sheared off.

The effect of internal corrosion is generally easily detected, but there is a form of it called "furrowing" which may escape attention. It is found in Lancashire boilers, sometimes in the angle iron, and sometimes in the plate close to it, and as scale often fills the crevice or "furrow," it may escape notice. The same thing is found in locomotives just by the lap of seams. The furrows are supposed to be caused by the "fatigue" of the metal in certain lines of strain due to the bending backwards and forwards of the end of the boilers to accommodate itself to the varying lengths of the tubes and shell when expanded or contracted by alternate working and cooling. The same lines of strain are produced in the barrels of locomotives by their efforts to assume the truly circular shape. Not only is the metal in these lines rendered more open in texture and more liable to corrosion, but the scale is continually thrown off, exposing fresh surface. "Furrowing" should never be neglected, as it increases very rapidly when once set in.

The faults to be observed in the flues are numerous, but two or three only will be noticed. When boilers are patched the old metal is often strained and punished by the removal of the old rivets and the "drifting" to pull it up to the new plate. This not unfrequently sets up "seam rips" or cracks from hole to hole, which not only throws extra and ever increasing strain on to the rivets at each end of the "rips," but often produces a jerk which causes such enormously increased strain on each succeeding rivet that the whole seam rips round and allows the boiler to break up.

External corrosion is another most frequent fault visible from the flues. The leakage from a sprung seam will often run down the lap causing a "channel" or narrow line of corrosion. This is often found also in the seams of upright boilers on the upper side of the lap. As the channel is seldom more than one or two inches wide it is easily seen by marked contrast with the sound plate, but when corrosion is more general from dampness in the flues it is not so quickly noticed, as the edge of the upper lap also corrodes, leaving the same apparent thickness at the edge of the plates, whereas, in reality, the lower plate may be eaten more than half way through. The same thing may deceive where a new piece of plate has been inserted on to a thin plate. Very slight corrosion of the already thinned plate may be much more dangerous than would be supposed from anything seen on the outside.

The corrosion which goes on at a point of contact with brickwork is one of the most frequent causes of anxiety to those who have the inspection of boilers, as it is sometimes found when least suspected. It is caused by the damp being held against the plate, and is the more dangerous as it produces weakness in long continued lines in the directions of the greatest strain. The walls are often now constructed with removable bricks, or slight holes at each seam.

It is very frequently asserted that corrosion cannot be the cause of explosion, as the weakened place would blow out and relieve the boiler. This may be the case when it is only local, but when in continuous lines, and the giving way of one point throws the strain on the surrounding parts, it leads to a break up as described in the case of seam rips. In tubular boilers it is very necessary to measure both diameters of the tubes to detect the first signs of weakness from the departure from the true circle.

Some few words are necessary as to the testing of boilers by steam or hydraulic pressure. The former is so dangerous, and has led to so many accidents, that it should be avoided. Attempts to caulk leaking seams while under steam pressure have led to many fatal explosions. Many more fatal explosions would be caused by proving from steam pressure, were it not that makers often deceive themselves and their customers by supposing that a large boiler can be proved by connecting a small inch pipe to another boiler, the gage upon which shows the required pressure; whereas condensation goes on so rapidly that not half the pressure is ever reached in the tested boiler.

The hydraulic test is not attended with danger if all air is excluded from the boiler, but it is found in practice that it does not always detect dangerous furrows or corrosion. It is undoubtedly most useful when applied with judgment during the time of inspection, and should always be considered a necessary part of inspection, but it cannot be relied upon alone or as a substitute for inspection.

Many attempts have been made to construct boilers that should be free from all danger of explosion, by having all the parts exposed to pressure of very small diameter and avoiding the large quantity of steam and water accumulated in ordinary boilers. Such boilers are made of both cast and wrought iron, but the experience with them is short, and for ordinary work the absence of accumulations of power makes it difficult to maintain regularity. In all descriptions of such boilers, however, although absolute safety from explosion is unhesitatingly promised, facility for inspection of every part is mentioned as one of the advantages.

In conclusion, I would submit that periodical inspection is the surest means of securing the safety of steam boilers. Also, that this inspection is a very good and useful safeguard, if only done by the man in charge; but that it is a still greater safeguard if done by independent inspectors, who have the experience of seeing many boilers and are not influenced by the exigencies of the manufacturers, for whom the boiler may be used.

Such was the opinion of those who formed the Midland Boiler Inspection and Assurance Company, under whose auspices I have obtained a great deal of the information as to boiler explosions which I have been enabled to give to the public, and to whose courtesy I am indebted for permitting me to give whatever may be deemed useful in the present paper.

THE ARTISAN IN PRUSSIA.

Compulsory education being the rule in Fatherland, the German artisan has that much in his favor; yet his English brother would not care to change places; low wages and meager diet sadly counterbalancing a little extra culture. $3·00 a week is very good pay in Prussia, as determined from a long list of the rates of weekly wages in that country in 1867. In most cases twelve hours, and in many, thirteen, go to the working day. Women form more than a fifth of the factory operatives, and earn, comparatively, good wages; but public labor brings its too frequent consequences, and the female operatives bear a very indifferent character. As for seamstresses and milliners, those who work for commercial houses are, as usual, most miserably paid; so miserably, indeed, that to live at all they are compelled to eschew morality.

The wages quoted above are said to suffice thrifty men while single, and even leave a margin for saving; but to keep a family upon them, unless the mother as least can contribute something towards the income, is out of the question; and those who know most about the matter do not set the cost of a family at a very extravagant rate. According to official calculations, a man with a wife and three or four children can provide food enough for all at an annual expense of $60·00, if he lives in the province of Prussia; in Posen it would take more than double the amount; while in Pomerania it may be done for a little less. Certainly the Prussian dietary standard is not a very high one, bread, vegetables, butter, and milk being all that is considered necessary; meat, except, perhaps, on holidays and Sundays, coming in the category of luxuries. The daily fare of a workman in the Rhenish provinces is set down as consisting of one pound of rye bread, two pounds of potatoes, an ounce of meat, half an ounce of salt, and one sixth of an ounce of coffee.

Nor can the Prussian be said to be much better off as concerns his lodgment; high rents, confined spaces, little comfort, and less cleanliness being the rule throughout the kingdom. In the large towns, with very rare exceptions, artisans live in lodgings; several families herd together—sometimes as many as fifteen individuals crowding into one small, low, damp room—twenty-five cents a week a head being the Berlin tariff for sleeping accommodation and convenience for washing. Three years since the returns showed there were in the capital 15,574 dwellings with an average of six to seven occupants per room. In the country and in the small towns—unless lodgings are provided by the employer—working folks generally have a house of their own: a house, such as it is. In Memel it will be a mere mud cabin with nailed up windows; in Silesia, a one-storied thatched house, with diminutive windows, and rooms just high enough to allow the proprietors to stand upright in them. The miners of the circle of Ottweiler, in the Rhine province, are perhaps the best off in this respect, being looked after by the government itself. "The three royal coal mines of Heinitz have three large sleeping houses belonging to them to accommodate 800 men. The Rheden mine has two of these for the accommodation of 400 men. The miners pay thirty-six cents a month, for which they have a bed and towels, and the use of half a press. To enable miners to settle in the neighborhood, the Miners' Union has purchased 1,350 acres of land for founding a mining colony. It sells at cost price, or leases at a moderate rent, one sixth of an acre of land to any one who will build a house upon it, and one sixth of an acre upon the same terms for a garden. Money for building purposes is also advanced at four per cent interest, to be deducted from the wages, with a present of from 100 to 120 dollars as a premium for building." These houses at Ottweiler are, as might be expected, neat and cheerful; but, with the exception of them, the description "bad, small, and densely crowded" applies generally to the habitations of the Prussian workman, in whatever part of the land he may be domiciled.

A better condition of things might be looked for where such pains are taken to render the laborer worthy of his hire. Primary education is obligatory for all children from the age of six to that of fourteen, and afterwards the journeyman or apprentice may continue educating himself at the "Fortbildungsschulen," open Sundays, and occasionally upon week days, for a somewhat higher degree of instruction. When a Prussian lad has received the education prescribed by law, he chooses his trade, and binds himself to a master, who, for his labor, gives him board, lodging, and instruction. Apprenticeship seldom lasts more than three years, at the end of which time the young workman gets a certificate from his master, and sets out upon his travels—"wandering," as it is called, being reckoned necessary ere he can claim admittance into the ranks of journeymen. He usually makes a point of visiting the places specially famed for excellence in his branch of trade. If he be a stone-cutter, he must not miss Munich and Cologne; if a locksmith, Berlin and Vienna; if a tailor, Dresden must become his residence for a while; if no one wants his services at any town he enters, the Journeyman's Fund there supplies him with the means of taking him elsewhere. The more ambitious artisans are not satisfied with tramping through Germany, but betake themselves to foreign lands, where not a few of them are tempted to remain—and no wonder! Traveling about the world with open eyes cannot but do the travelers good, and the practice is therefore to be commanded; it is, however, doomed; the new Industrial Code of the North German Confederation has pronounced against it, by declaring wandering no longer compulsory, and that traveling handicraftsmen have no claim for assistance upon their associates in the trade. The Code only came into operation in October, 1869, so that what effect its provisions will have cannot yet be seen. By it a variety of restrictions upon the freedom of industry were swept away; all engagements between man and master are declared to be matters for mutual agreement, to be canceled by a fortnight's notice on either side; and the old prohibitions against workmen uniting, for the purpose of obtaining more favorable wages and conditions of work, more especially by means of strikes, are repealed. But, at the same time, "any one inducing, or seeking to induce, others, by physical force, threats, or outrages, or by placing them under an interdict, to take part in these coalitions," was made punishable by three months' imprisonment. Nevertheless, in Prussia, as elsewhere, labor and capital are continually wasting their resources in trying each other's strength and obstinacy.—*Chambers' Journal.*

THE APPLICATION OF PHOTOGRAPHY TO MILITARY PURPOSES.

Modern warfare may, in many respects be considered as so many applications of science. Not only is war *materiel* designed and manufactured now-a-days upon the most approved data, and according to theories worked out with mathematical accuracy, but a large section of our soldiers are educated in such a manner as fully to appreciate the value of their resources, and so to overcome difficulties which years ago would have been regarded as impossibilities. No instance demonstrates this more satisfactorily than the recent Abyssinian expedition, which, whatever may be said of it as a campaign, cannot but be regarded as one of the most wonderful feats of engineering accomplished in modern times. The nearer warfare approaches perfection, the more decisive, and therefore less cruel it necessarily becomes, as witness the brief duration of the wars of late years on the Continent; and for this reason the improvements in warfare effected by science cannot by any means be regarded as a misapplication of knowledge.

Our present remarks bear reference to the applications made of a very modest branch of science, if science, indeed, it can be called, our object being to demonstrate the many uses made by the War Department of photography. In the special application of this art-science to military matters, our Government is certainly in advance of others, if we except, perhaps, that of France. No less than three establishments have been organized in connection with the army in which photography is extensively practiced, the most important of them being the General Establishment at Woolwich; but, besides these, there are again many Royal Engineer stations, both at home and abroad, which are furnished with photographic requisites and employ the camera for divers purposes. At Chatham, the photographic establishment assumes the character of a school of instruction, at Southampton it forms an adjunct to the Ordnance Survey Office, while at Woolwich, of which department we desire more particularly to speak, the duties performed by aid of the camera are as various as they are numerous. For registering patterns, recording experimental results, imparting military instruction, and for other purposes too multifarious to enumerate, photography is extensively used, the faithful accuracy of sun pictures, as likewise the facility with which they are produced, causing the art to be eagerly employed in any way where it can be made available.

As an example of the value of photography in instruction, we would cite an interesting series of pictures taken to illustrate ordnance drill. This series comprises upwards of one hundred views, and demonstrates the practical working of the various kind of guns, mortars, rockets, etc., in the service. One picture, for instance, will illustrate the command, "Prepare for action;" a gun will be shown surrounded by a group of artillerymen in the positions they have been instructed to occupy on the issue of that order, each man having his respective number attached to his cap as a distinguishing mark. The next illustration in the series is probably that of "Load," and the next again "Fire," both of which will represent the change in position of the men, as one operation succeeds another, and the various duties performed in turn by each gunner or number, for it must be remembered that in gun drill every man is told off to a particular number and intrusted with a separate and distinct duty. Thus, on the promulgation of any new system of drill, or of any modification in the method of working, it is merely necessary for the military authorities to forward pictures of this kind to the different instructors, who cannot fail at once thoroughly to understand the new exercise; and even the rawest recruit who had assigned to him a certain number at a gun, would see at a glance the exact position he is to occupy by a reference to the photographs.

Another not less striking instance of the importance of photography in this connection may be given. At the outset of the Abyssinian campaign it will be remembered that several thousands of pack-saddles were required for transporting war *materiel* into the interior. These pack-saddles were made in and sent direct from England to Annesley Bay, so that the troops coming from Bombay knew nothing of their construction, nor of the method in which they were to be packed. This ignorance in the hurry of affairs would have been of serious consequence (for a military pack-saddle of the present pattern is a somewhat complicated contrivance) had not the authorities at home been fully alive to the subject and foreseen the threatening difficulty. A mule at Woolwich was harnessed and packed, after some experience had been acquired in the matter, in the most suitable and approved manner, and the animal then carefully depicted by the aid of the camera; the disposal of the harness and trappings, and the correct way in which the packages were to be carried, were thus clearly shown in a photograph, numerous copies of which were immediately sent out to Annesley Bay and distributed among the officers of the Quartermaster-General's department.

In recording experimental results photography again fulfills a duty which could not be discharged so rapidly and impartially by any other means. The stone iron-cased shields and armor targets built up of metal plates of different thicknesses, and then fired at by shot and shell of all descriptions, are carefully photographed after each decisive experiment, and a record of indisputable accuracy thus obtained. With a picture before us of a target, constructed to represent the side of an armor-plated vessel, which has been experimented on, we can at once form an accurate estimate of the impression made upon the iron wall by shot of different calibers, while rear and side views of the structure will show plainly the amount of damage which the backing or skin of the shield has suffered. As may be imagined these prints form important illustrations to the written reports made from time to time to the War Office authorities.

The photographing of newly adopted Government patterns, whether in the shape of guns, carriages, wagons, mantelets, tents, etc., is also an important section of the work undertaken at Woolwich, as likewise that of producing pictures relating to army equipment, such, for instance, as demonstrate the setting up of cooking apparatus, disposal of ambulances, refitting of ordnance in the field, etc. There is, moreover, the pursuit of photo-lithography to be mentioned, by means of which designs and sketches are copied and transferred to stone for printing off in the ordinary manner.

The subject of working photography in the field is a matter to which much attention has been given at the general establishment, for it will be readily conceived that the simplest and most effective methods of working, as likewise the different uses to which the camera may be put during warfare are questions of very serious study.

The photographic copies, many thousands of which are annually produced and distributed over all parts of Her Majesty's dominions, are not now printed upon silver paper in the ordinary way, but by the so-called carbon or autotype process, a method which produces prints of an absolutely permanent character. Ordinary silver prints are always liable to become faded and stained after the lapse of a few years, owing to the presence in the paper itself, or in the atmosphere with which it comes in contact, of sulphur compounds which attack the metallic silver composing the image. In the carbon pictures, however, no silver at all is present, the composition of the image being a mineral pigment in combination with an insoluble chromium.

Our description of the General Photographic Establishment at Woolwich has been very brief indeed, but enough has been said to show to what an important extent the art is employed in connection with the War Office; the department which we have described is a branch of the chemical establishment of the War Department, which was first organized in 1854, by Mr. Abel, and has gradually become intimately and indispensably connected with every branch of the military service.—*Nature.*

A Geological Excursion in the Moon.

[Translated for the Maine *Journal of Education* from *Cosmos*.]

Under this title Stanislas Meunier recently gave a lecture filled with interesting facts, and pleasantly illustrated by numerous photographic projections by the aid of the Drummond light.

The professor remarked at the opening that it is not wholly certain that there are not on the surface of the earth specimens of lunar rocks, since there is no absolute proof that the meteorites are not ejections from the volcanoes of the moon. He moreover added that one can very profitably study at a distance the geological structure of inaccessible localities.

The moon, which appears to be wholly deprived of all atmosphere and consequently of water, presents two very different kinds of rocks, those which constitute the mountains, and those which constitute the so-called *seas.* The former, from the form which they present, and the analogy of that form with that of terrestrial volcanoes, are evidently volcanic rocks. The others, according to Lecoq, are dry sands or melted rocks.

One may, in some instances, study very closely the structure of mountains, and draw, for example, the analogy of the form of the circles in the moon with that of the circles of granite and porphyry in the earth. Schrotter and Herschel both discovered in various mountains of the moon places where a very fine stratification may be seen.

This study of the mountains of our satellite has led to a comparison with the mountains of the earth, and in some instances very striking analogies have been found, especially at the Puys d'Auvergne, the volcanoes of Teneriffe, Palma, etc.

Finally, the observations of astronomers have furnished a basis upon which Chacornac proposes a theory concerning the geogony of the moon. It comprises three grand periods: 1. The formation of the circles. 2. The extension of the muddy diluvium which constitutes the seas. 3. The formation of the comparatively small craters.

After reviewing the various observations cited to prove the actual activity of the lunar volcanoes, the lecturer adopted the opinion of Beer, Moedler, and Arago that the moon is a *dead star.* He then went on to prove that this inference may also be drawn from that singular appearance upon the surface of the moon to which has been given the name of *grooves.* There are grooves with parallel sides nearly a mile in width, and from ten to one hundred and twenty-five miles in length. About ninety have been counted, and it is very probable that they are still in the process of formation. It was a very long time before any reliable explanation of the grooves was given. We are indebted to Professor Lecoq for it (*Traité de Géologie*). It has been further developed by Saeman, who made it the subject of a special article printed in the *Bulletin de la Société géologique de France.*

According to these geologists the grooves are due to the cracking which is evident on the surface of the moon as a result of the loss of heat. There is no reason to suppose that at a former period the moon had not upon its surface both an atmosphere and water. But the latter penetrating the crust, as it does upon our globe, has been gradually absorbed in proportion as the crust has increased in thickness. All the water had disappeared long before the cooling process had reached the center. The loss of heat continuing, the rocks in solidifying contracted in a way analogous to that which basalt manifests, and the grooves are the result. Into these grooves the atmosphere settled.

Everything indicates that the earth is actually passing through the various states through which the moon has already passed. It is estimated that already one fiftieth of its primitive ocean has been absorbed, and that what remains will have been drunk up when the thickness of the crust shall be one hundred miles. Our whole earth, from what is known of it, would easily absorb fifty oceans like ours, so that the water at present upon the earth, being once absorbed and which constitutes only $\frac{1}{24000}$ of its weight, would become absolutely insensible to the most precise chemical analysis.

Then the earth will crack open, as the moon has done, and its atmosphere will settle into the fissures beneath its surface. A long time before this all life will have ceased.

The prediction which the study of the moon allows us to make in regard to our globe will evidently be realized only in a far distant future, for after the experiments of Bischof nine millions of years will be needed for the earth to cool down 15°, a loss almost imperceptible, since the internal heat adds only one thirtieth of a degree to the temperature at the surface. We may go further and apply to the sun everything which has been said of the earth and the moon. Being larger, it will cool less quickly, but the time will nevertheless come, at least everything seems to indicate it, when it will have absorbed its waters and its atmosphere, and the fissures will be formed upon its surface. Our whole solar system will then be only an assemblage of dead worlds.