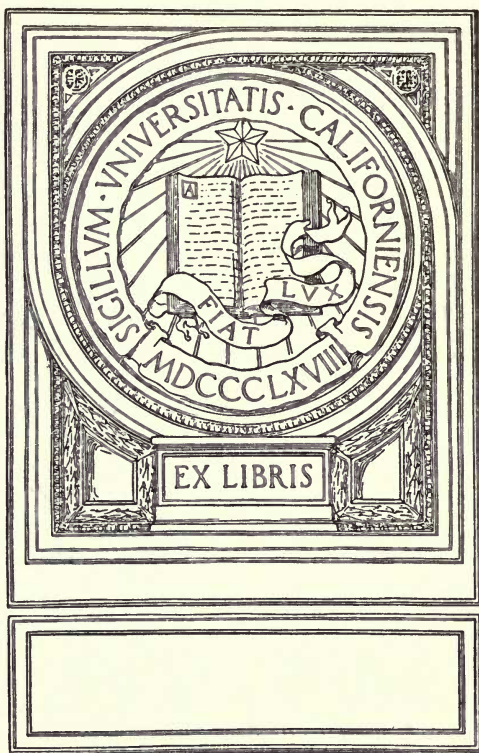


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EFFLORESCENCE OF BRICK

BY

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EFFLORESCENCE OF BRICK.

BY

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During the reign of Napoleon III of France, while a large part of Paris was being rebuilt, the walls of the new buildings became coated with unsightly splotches of a white crystalline substance known as efflorescence, or whitewash. The cause and cure of the phenomena so baffled the scientists of that time that the emperor offered a reward of 100,000 dollars to any one who would discover a means of preventing its occurrence. Many of the prominent scientists of Europe at once investigated the problem, but beyond determining the composition of the efflorescence little was accomplished. (Brick, vol. VI, p. 195.) In our own country the first published notice of efflorescence appeared about the year 1882, at which time there was an unusual amount of it on buildings both here and abroad. It appeared not only on buildings under construction, but also on those never known to be troubled before.

Among the several scientific societies which took up this problem was the Academy of Natural Sciences of Philadelphia. They reached the conclusion that the cause of the trouble was principally magnesium carbonate. Many of the recent writers mention that the efflorescence was supposed to be nitre or saltpeter, evidently because it resembled the deposit which appears on stable walls which have manure and other refuse piled against them. Seger seems to have been the earliest of the ceramists to have studied this problem and he demonstrated that the efflorescence is not saltpeter but rather, that it is generally sulfate of the alkalis or alkaline earths. Seger was followed by several other German investigators among whom Hans Guenther seems to stand foremost. Guenther laid particular emphasis on the role that pyrite plays as well as on the reactions that take place between the salts in the

brick and mortar. In our own country, Dr. Otto Gerlach clearly stated the possible reaction of the lime in the brick with the sulphur in the kiln gases that causes the formation of soluble sulphates.

In spite of this work that has been done, the entire cause and prevention has not been found. Efflorescence is as abundant as ever and can be found on new and old buildings alike. What has been done, however, has been a great step in advance, and by far the greater part of the unsightly stains on our buildings can be done away with if brick manufacturers and builders take the precautions already determined. Each investigator has laid particular emphasis on the particular cause he has been investigating, leaving the impression that it was the cause of all efflorescence. The fact is, there are a number of causes for the trouble, and a number of precautions to take. It is the purpose of this paper to gather together as far as possible all of the causes and means of prevention known to the writer in the hope that it may aid those who are endeavoring to overcome these unsightly stains on our brick.

Effect of Efflorescence.

It has been stated that the crystallization of salts on the surface of brick would have the same distintegrating effect as the formation of the ice crystals and cause the brick to weather so much more rapidly.¹

On the other hand, it has been suggested that efflorescence is of benefit to the brick when it is burned because it concentrates the fluxing material, calcium, etc., near the surface of the brick. It was observed that the whitewashed bricks were the better vitrified. This is, however, an open question.

While efflorescence may or may not harm the brick in a mechanical way, it certainly does harm its appearance, and means an actual monetary loss when the appearance of the brick is part of its intrinsic value as in a face brick.

¹ (Seeger, p. 372. Coll. Writ.)

Kinds of Efflorescence.

For convenience in discussing the sources and causes of efflorescence it is best to divide it into two classes, first, that which appears on the brick in the kiln or kiln white, and, second, that which appears afterwards or wall white. The kiln white is burned into and is a part of the brick, while the wall white is powdery and can be rubbed off. Kiln white is often subdivided into dryer white, or that which originates in the dryer, and kiln white, or that which originates in the kiln. While this distinction is often convenient in assigning the cause of a whitewash on the brick, yet it is often impossible to distinguish between the two without experimenting. In general, however, dryer white is almost always brought to the surface of the brick through the evaporation of the water and so appears in small pimply crystals, while the kiln white is most often caused by the reaction of the kiln gases and the lime in the brick and appears as fluffy clusters. This is not a sure means of distinguishing the kiln and dryer whites, as kiln white may also come from evaporating water, and the dryer white may also be formed, in case of a waste heat dryer, by the reaction between the sulphur in gases and the lime in the clay. For the purposes of this paper I shall not distinguish between kiln and dryer white, as they are identical in origin and composition.

Composition of kiln white. Analyses of kiln white show it to be almost entirely calcium sulphate with small amounts of magnesium and alkaline sulphates and occasionally alum.

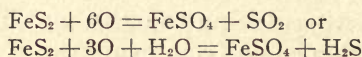
In order to form some idea of the relative power of the various salts to cause efflorescence a series of trials was made containing 0.5 gram each of sulphates of calcium, magnesium, and aluminum, the carbonates of calcium and sodium, and the chloride of sodium. These salts were added to 100 grms. of clay that had been previously washed thoroughly, the mass formed into brickettes, and burned under oxidizing conditions. The sulphates caused by far

the greater amount of efflorescence, the alum coating the trial entirely, the others covering the sides. The carbonates gave a thin coating of efflorescence, the sodium much the heavier of the two, and the sodium chloride simply discolored the trial, making it a little darker. From this it was seen that the sulphates were the most dangerous, but that any soluble salt is liable to cause trouble.

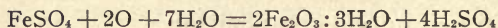
Source of kiln white. The sources of the kiln white salts may be said to be in the clay, in the water used in manufacture, or in the kiln gases, or perhaps in many cases all three of the sources named.

Efflorescence from the Clay.

Practically all brick clays contain or have contained sulphur in the form of iron pyrites. When the clay is exposed to the action of the air and its weathering influence, which action extends to the permanent water line, iron sulphide or pyrite oxidizes to iron sulphate.¹

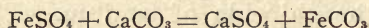


The iron sulphate alters with the further addition of water and oxygen to limonite, setting free the sulphur as sulphuric acid.



This sulphuric acid then enters into solution and reacts with the calcium, magnesium, aluminum, and other bases originally in the form of carbonates, silicates and chlorides, and forms sulphates as gypsum, alum, etc.

Again, the iron sulphate may react directly with the calcium carbonate, which is nearly always present, and form iron carbonate and gypsum.



As the iron in an unoxidized clay is usually in the

¹ (Van Hise, *Metamorphism*, p. 214.)

form of either the sulphide or carbonate, and since gypsum is also a common constituent, the reaction between the sulphate of iron and carbonate of lime is probably more common than that of mere oxidation and hydration. Both reactions are, however, initially oxidation. From the foregoing it will be readily seen that the amount of whitewashing sulphates formed in a clay depends directly upon the extent to which the clay has been exposed to oxidizing influences. The oxidizing zone in the earth's surface extends down to the permanent water level. In this zone the process of oxidation is at its maximum and consequently the changes from the insoluble sulphides to soluble sulphates takes place here most rapidly. The sulphates, once formed, are soluble and will be removed by solution by the water percolating through the clay. As the clays are, as a rule, very compact and impervious, the water circulates through them very slowly. Consequently until the clay has been opened up by the action of frost and the roots of vegetation and made more pervious, the sulphates are not removed to any appreciable extent.

When soluble sulphates are present in the clay they appear on the surface of the green brick as it is drying. They may be concealed, in fact generally are, by the similarity of their color and that of the brick, but as the brick is burned the sulphates stand out as white specks on a darker background and the whitewash is brought out apparently in the kiln. Since the evaporation of the water contained in the green brick can only take place at the surface the water of the interior must come to the surface through the action of capillarity. The soluble salts are brought out in solution by the water and the water evaporating leaves the salts concentrated on the surface. Perhaps I can make this clearer by an actual case. A clay whitewashed and by experiment it was found that the trouble lay in the soluble salts of the clay. Analyses of the clay showed 0.75% sulphur trioxide, of which 8.92%, or 0.065%, in terms of the clay, was soluble. Analysis of the face of the dried brick gave 1.30% of sulphur trioxide, of

which 40.77%, or 0.56% in terms of the clay, was soluble. The gain in sulphur by the face of the brick will be readily seen to be entirely of the soluble form. In other words the soluble salts had been collected on the face of the brick by the process of drying. It is also interesting to note the very small amount of sulphur trioxide, only 0.65%, about 1.95 gram, or 0.07 of an ounce per brick that it takes to cause decided efflorescence.

As before stated, nearly all the shales and fire clays contain iron pyrites. That part of it which escapes the action of the weather enters into the brick in its original form. Although it does not cause either kiln or dryer white, it is a very large source of the wall white and it is simplest to consider it at this point. Pyrite is peculiar in the fact that it will part with one molecule of its sulphur quite readily at the comparatively low heat of 400° C., but holds tenaciously to the other until at least 900° C. In fact, there seems to be good reason to believe that it is not driven off at all except under good oxidizing conditions.¹

The first molecule of sulphur, however, is set free at a time when there is an abundance of water and oxygen in the kiln gases, and as it passes the lime and magnesium carbonates in the clay it combines with them to form sulphates. These, once formed, are not decomposable under ordinary conditions and remain unnoticed in the brick until they are laid in the wall. Then, due to the leaching action of the rains and the water passing through the wall from the water pipes, gutters, and foundation, they appear as efflorescence.

Efflorescence from kiln gases. The sulphates in the clay are not the only cause of whitewash, however. Calcium carbonate is nearly always present in the clay, often in large quantities, and occasionally magnesium. As these are comparatively insoluble, they are not carried to the face of the brick to any extent during dryness and consequently do not form a large part of the kiln white. If,

¹(Orton. Role played by iron in the burning of clay wares. Transaction Cer. Soc., Vol. 5, p. 398.)



however, they lie at the surface, especially if in the form of pebbles, they are almost certain to form kiln white by reaction with the sulphur dioxide of the kiln gases, while that which lies in the interior, reacting with the kiln gases, forms the sulphates which come out later as wall white.

Guenther was the first to prove this in a positive manner. He burned feldspar, kaolin, and marl at a red heat in a furnace with sulphurous fumes present and found that while the feldspar was unaffected, the kaolin and marl were attacked with the formation of calcium, sodium, and other sulphates. Further, with mixtures of clay and chalk the efflorescence increased with the increase of the lime.

Gerlach, in somewhat similar experiments, found that

1. In a clay containing pyrite and calcite burned in a flame free from sulphur the amount of sulphates was increased 5 times.

2. When both clay and fuel contained sulphur the increase in sulphates was 20 fold.

3. When the clay contained calcite and the fuel sulphur the increase in sulphates was 40 fold.

4. When clay and fuel were both free from pyrite, there was but slight increase.

5. When the clay contained a large amount of pyrite but no calcite, and the fuel was free from sulphur, there was but slight increase.

6. When both fuel and clay contained pyrite but no calcite, there was but a slight increase.

From these experiments it can be readily seen what an important role the calcite in the clay and the sulphur in the fuel play in the formation of the efflorescence.

The coal burned in kilns, especially bituminous coal, contains sulphur in the form of iron pyrites or marcasite, as well as free sulphur. This is generally easily seen in the coal as bright specks or seams and is commonly known as sulphur. When the coal is burned, the iron sulphide is oxidized and sulphur dioxide, a gas, results. This passes through the kiln with the other gases. Seger¹ tried

¹ (p. 216, Collected Works.)

the experiment of condensing the water vapor in the gases of a burning kiln and an analysis showed considerable amount of sulphuric acid and some hydrochloric acid. As most chlorides are quite volatile it is probable that the hydrochloric acid does not play any large part in the formation of whitewash, but passes out into the open air. The sulphuric acid, on the other hand, reacts with the carbonates and other calcium salts to form sulphates which are stable under all kiln conditions except a reducing fire. Thus it is possible that a clay that did not originally contain any sulphates could show whitewash, and in fact the work of Guenther and Gerlach has shown that this is a very fruitful cause.

It is an often observed fact that the bricks in the colder parts of the kiln show whitewash when the rest of the ware is free from it. This can be explained by the fact that the bricks in the warmer parts of the kiln begin to give up their water before the other brick have become heated. These colder brick then would condense this water vapor containing sulphuric acid from the kiln gases and absorb it. The absorbed acid acts on the lime, etc., forming sulphates which are left on the surface of the brick.

Again it is a fact that a brick set wet will whitewash. This can be explained by the absorption of the sulphurous gas by the water in the brick and as the acid will penetrate all parts of the brick through diffusion sulphates will form and be carried to the surface of the brick as it dries out. There are probably other salts, chlorides, nitrates, etc., which occur in minute quantities that contribute their share to the trouble, but they are very rarely present in large enough quantities to cut any figure.

Efflorescence from the water. The water used is generally drawn from wells or streams and always contains salts dissolved in it. These are principally calcium and magnesium carbonates, sodium sulphate and other chlorides, phosphates, and nitrates. As a rule these do not amount to more than from .02% to .05% and since there is

only approximately 800 grams of water used in each brick, this would introduce only 0.4 gram of salt, an amount entirely too small to cause trouble. If the salts rise much above 0.05%, the water may be an important factor in causing efflorescence, since the principal salts, calcium and magnesium carbonates, combine with the sulphurous fumes of the kiln gases as has been explained before.

Means of prevention. The principal causes of the kiln and dryer white lie, then, in the sulphates and carbonates of the clay, and in the sulphurous gases in the kiln. The remedies, therefore, must be applied with this in view.

The following means of prevention are suggested:

1. Use the clay before the soluble salts form, i. e., unweathered.
2. Remove the soluble salts entirely from the clay, i. e., weather it thoroughly, thus causing the washing out of the salt.
3. Transform the soluble salts to a harmless form by precipitation.
4. Prevent the concentration of the salts on the surface of the brick by rapid firing.
5. Remove the whitewash in the kiln by means of a reducing flame.
6. Coat the brick with some combustible substance that will remove the whitewash as it burns off.

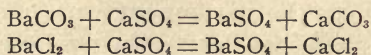
1. Since the sulphates in the clay nearly always result from the weathering of its pyrite, it is often possible to avoid the whitewash simply by using the clay fresh from the bank, rejecting that which has been exposed to the weather any length of time. This is only possible with clays that lie below the permanent water level. This use of the fresh clay, however, leaves the pyrite in the clay, and as has been shown, it will sooner or later come out as efflorescence on the walls. While the manufacturer is thus enabled to produce a clean brick, he is simply passing the trouble on to the user of his wares.

2. Since the whitewashing salts are all soluble or can be rendered so by weathering, it is possible to remove them

entirely by exposing the clay to the action of the air, rain and frost as long as is necessary. As the action is slow and will not penetrate the clay unaided, the clay should be spread in thin layers and worked over occasionally. As the object is to remove the salts entirely, the ground upon which the clay is spread should slope enough to thoroughly drain the water away from the clay after it has done its work. This process not only removes the whitewashing salts, but also increases the plasticity of the clay. The process takes several months and is too expensive on that account for most brick plants.

It is possible to remove those soluble salts already formed in the clay by washing it. In using this process it must be borne in mind that the object is to remove the impurities and soluble salts and consequently a good supply of water must be at hand. In one case, at least, the water was being used over and over again until gypsum crystals of good size could be found quite plentifully in the storage tank of the washer. As in the process of weathering, the washing not only removes the salts but gives a more homogenous and better product. Its only disadvantage is the increased cost which need not be large if a good supply of water is to be had.

3. The method in most common use to transform the soluble into insoluble sulphates is to mix small amounts of barium carbonate or chloride with the clay. When either of these salts are introduced into a clay containing soluble sulphates the barium combines with the sulphur and forms barium sulphate, one of the most insoluble compounds known.



As the barium sulphate is very insoluble and is not decomposed during the burning the sulphur is firmly locked in the interior of the brick as long as the brick endures.

Barium carbonate is also a very insoluble compound

and must be ground finely and very thoroughly mixed with the clay to accomplish the end that is sought. A German writer¹ recommends that it be ground in a tube mill together with fine sand, which has the effect of soon reducing it to the very fine powder that is wanted. The correct amount, which necessitates a chemical analysis for its determination, is then added to the clay as it enters the pug mill. The carbonate is perfectly safe to use, as neither an excess of the barium nor the calcium carbonate formed will cause efflorescence. Its success depends on the thoroughness with which it is ground and mixed with the clay.

The chloride, on the other hand, is soluble and consequently does not need much care in grinding and mixing. As it is soluble, it is rather dangerous to use, for any excess is carried to the surface of the brick and forms there a whitewash with the sulphur in the kiln gases. Its by-product, calcium chloride, is also soluble and is liable to form whitewash in the same way. The Germans frequently use both the carbonate and chloride, adding enough of the chloride to overcome most of the whitewash and depending on the carbonate to take care of whatever whitewashing salts remain.

4. It is often possible when a clay shows a tendency to whitewash, to hold the whitewash inside of the brick by drying as quickly as possible. The mechanics of this is simple, and depends on the property of capillary tubes.

A simple experiment suggested by Dr. Lincoln of this University will make this clear to any one who will try it. If a strip of filter paper be hung with one end in a solution of potassium permanganate, as the solution ascends the paper it will soon be noticed that the water is traveling faster than the permanganate. The clear strip of the water will grow broader until the top of the paper is reached. This is due to the fact that the wet paper has a stronger attraction for the salt than the water, and consequently the salt cannot travel until enough of it is attached to the fibres of the paper to allow the water to

¹(Brick, Vol. 9, p. 32.)

draw the salt higher. Just why this should be is not known, but it is the phenomenon chemists have named adsorption. So when the brick is dried quickly the water is evaporated before the salt reaches the surface in sufficient quantities to cause trouble. When the clay will not permit of rapid drying this method cannot be used.

5. The sulphates once formed cannot be decomposed or removed in an oxidizing flame at any temperature ordinarily reached in the kiln. In a reducing flame the sulphates are reduced at temperatures of 1000° C. to sulphides. The bases enter into combination with the silicates of the brick, while the sulphur is driven off with the gases. By use of this principle it is possible to drive off the whitewash by finishing the burn under reducing conditions. This has the disadvantage of darkening the color of the brick and also causing the slagging of the iron into a ferrous silicate, thus starting fusion prematurely.

6. A method in vogue in Germany is to coat the brick on the face, as they leave the machine, with coal tar or wheat flour. As this burns away it has a strong reducing action and removes the whitewash as just explained. From all reports I have seen of the method, it seems to give good results. I do not know of its having been tried in this country, however.

Summary.

To sum up, kiln and dryer white can be avoided by using only fresh clay, by weathering and washing it, by the use of barium, by quick drying, by alternately reducing and oxidizing when finishing the burn; or by coating the face of the brick with coal tar or wheat flour.

Wall White.

The composition of wall white is somewhat more varied than kiln white and several additional factors enter into its production. As examples of the different modes of occurrence and composition of the efflorescence I will mention a few samples that were collected from some of the buildings of the University of Illinois.



Building.	Brick.	Mortar.	Position, form, color, etc.	Composition.
1. Engineering	Yellow pressed	Lime	Efflorescence noticeable on all of the brick, not on the mortar. Especially thick on a column that had water pipes behind it, also bad patches where radiators were near wall. Also on sand stone in first story near entrance which projects from the building	MgSO ₄ , with traces of Ca and Cl.
2. Agricultura'	Yellow pressed	Lime	On brick wainscoting in hall. Sink just back of the wall. Efflorescence white in a patch just below the level of the sink	MgSO ₄ , and trace of calcium.
3. Agricultural	Bedford lime stone	Lime	White efflorescence on first story on the north wall of creamery	CaSO ₄ , and NaCO ₃ .
4. Wood shop	Red pressed	Lime	White efflorescence especially bad on the north wall near cornice	MgSO ₄ , and NaCl.
5. Library	Brown sand stone	Lime colored red	White efflorescence on front of the building near cornice. Generally on or near the mortar	Not determined. Probably a sulphate.
6. Pier back of Engineering Building	Red, common	Neat cement	White efflorescence on both the brick and mortar, near the top	CaSO ₄ , trace of CO ₂ .
7. Pier back of Engineering Building.	Red, common	Lime	White efflorescence on brick and mortar near the top	MgSO ₄ , trace CO ₂ and Cl.

Building.	Brick.	Mortar.	Position, form, color, etc.	Composition.
8. Pumping Station	Yellow pressed	Lime	White efflorescence on and near mortar, about two feet from the ground	CaSO ₄ , trace of CO ₂ .
9. Hydraulic Laboratory	Yellow pressed	Lime	White efflorescence on the stone trimmings of basement	MgSO ₄ , CaSO ₄ .
10. Hydraulic Laboratory	Pressed	Lime	White efflorescence on the north wall, with large testing tank behind it	HNaCO ₃ , Na ₂ SO ₄ .
11. Hydraulic Laboratory	Pressed	Lime	Same situation as above. Greenish efflorescence	MgSO ₄ , trace Ca.
12. Electrical Laboratory	Yellow pressed	Lime	Drab efflorescence on wall to basement entrance	CaSO ₄ , trace of Mg.

From the above it will be readily seen that the sulphates of magnesium and calcium are the most constant constituents of the efflorescence, although sodium and potassium may be present. The carbonates are also a fairly constant part of the whitewash and occasionally chlorides may be present. In No. 10 the principal salt of efflorescence was found to be sodium bicarbonate. This particular efflorescence was peculiar in that it deliquesced and became syrupy after it was corked up in the specimen tube. Sodium and potassium are probably more frequently present than these results would indicate, as with the means at hand it was not possible to detect small amounts of these substances with certainty. In fact, analyses made here a few years ago by Steinmeyer, thesis 1902, Chemical Department, showed them to be present in all the specimens of efflorescence examined at that time.

All of the efflorescences are not white, but are discolored more or less by the soot that finds lodgment in them. Some are green, as was No. 11, but the amount of the efflorescence that could be collected was too small to determine the coloring matter. Seger states that some green efflorescences he examined were colored with salts of vanadium. Other writers have ascribed the color to iron and chromium. Unfortunately not enough of the green was found for examination and nothing further can be added at this time. It is certain if vanadium is the cause it does not exist in the clay in a soluble form before being burned, as both Seger and Gerlach were unable to find it after lixiviating large amounts of clay. The green efflorescence seems to occur only on the lighter brick and has not been observed on the red brick so far. Much of the greenish scum appearing on the walls especially in damp places is due to a minute plant and is not an efflorescence at all.

Means of determination. It was thought that it might be possible to determine the main constituents of any efflorescence by observing the forms of the crystallized salts as they appeared on the wall and with this end in

view a number of briquettes were made of a surface clay that had been thoroughly washed to remove any soluble salts that might be present. After being burned, these were then placed in 0.5% solutions of the sulphates of calcium, magnesium, iron, sodium, and potassium, the carbonates of sodium and potassium, and sodium bicarbonate. The briquettes were left with their tops exposed to the air and after the efflorescence had appeared they were taken out of the solution and dried. As before, the sulphates took the lead, especially the sodium, iron and magnesium sulphates, although the sodium carbonates were not far behind. One surprising result was that the potassium and sodium salts did not effloresce. Consequently, the small amount of the salt that came through remained in two or three small white knobs. The main result was, however, negative, for as soon as the salts crystallized on the surface they effloresced, and all crystalline form was lost.

Again it was thought that it might be possible to dissolve a little of the efflorescence in distilled water and allow it to crystallize by the evaporation of the water. Then, since each salt should crystallize by itself, the composition of the efflorescence could be determined by examination of the crystals. With the pure solutions of the salts this plan worked very well, but on mixing them, as would be the case in the efflorescences, it was found that the salts as a rule no longer retained their characteristic forms and the plan had to be abandoned. The reason for this seemed to be the fact that the several crystals formed were so superimposed as to hide their shape.

Occurrence of wall white. Referring again to the efflorescences described, with reference to the places where they are most apt to occur, it will be seen that they only appear as a rule where there is excessive moisture such as near the cornices, near the ground where the water in the soil passes up through the foundation and evaporates and where the wall carries or has water pipes or radiators near it. In other words, the efflorescence is not trouble-

some except where there is plenty of water to bring it out. The rain undoubtedly has something to do with the appearance of the efflorescence on the walls, for it is a well known fact that a dry brick will absorb water very quickly. So with every rain storm there is a certain amount of water that penetrates the brick and brings out the soluble salts and deposits them on the surface when it evaporates again. As the salts, calcium sulphate excepted, are very soluble, the rain washes off what was deposited from the last rain and so the efflorescence is not large in amount at any one time, and besides, as it is evenly distributed over the wall, it is not unsightly.

At the cornices where the water of the roof is concentrated, especially if the gutters leak, the water is able to enter the wall and to travel a distance through it before it evaporates from the surface. During its passage it dissolves the soluble salts of the brick and mortar, and carries them to the outside of the wall. As the part of the wall where the salts are deposited is generally rather limited in extent the result is an ugly blotch that disfigures the building. In the same way water pipes or radiators supply the necessary water to carry the salts to the surface either through direct leakage or by condensing the moisture of the air upon them and thus keeping the wall damp. The foundation is generally in intimate contact with the soil and the water in the soil, travelling through the capillary pores of the soil and the wall, evaporates on the wall just above the ground. This again causes the salts to be gathered on the surface of the brick and again the disfiguring whitewash appears.

In every case of efflorescence I have been able to examine the blotches were caused by an excess of water produced in one of these three ways. Often on buildings not supposed to whitewash the faint even coat produced by the leaching action of the rain could be seen, showing that if care were taken to prevent the other causes, the whitewash from this cause would not be troublesome.

Pressed brick are especially subject to this disfigurement, since their smooth surface shows every spot. It has often been observed that sand-molded brick did not show efflorescence, while pressed brick made of the same clay would. This can be explained only by the difference in the structure of the faces of the two bricks. The rough surface conceals the little pimples raised by the salts and besides retains more dust and dirt with which to color the efflorescence, while on the smooth surface of the pressed brick the salts stick out obtrusively and retain their natural whiteness, since the dust and soot that colors them must come from the air.

Again the law of adsorption explained in regard to the drying of the brick holds good here. The pressed brick have a dense surface and fine pores, necessitating slow evaporation, while the sand-molded brick are more porous and water can evaporate from them more rapidly. In consequence the greater amount of efflorescence is brought to the surface of the pressed brick.

The sources of the wall efflorescence lie in the brick, the mortar, or in materials brought in contact with them as water, soot, or refuse.

As has been stated in explaining kiln white, practically the only soluble salts left in the brick are the sulphates of calcium and magnesium. These may have been originally in the clay or may have been formed in the brick during the process of manufacture through the reaction of the pyrite in the clay and coal with the carbonates in the clay. The manner in which these salts affect efflorescences differs.

Of the two, magnesium is much the more soluble and, as we have seen, effloresces much more freely. On the other hand the calcium sulphate once formed on the surface of the wall is much more difficult to remove. Again, while the magnesium generally effloresces unaltered, the calcium is more apt to react with the carbonates of magnesium, sodium, and potassium brought into the brick by the water from the mortar, forming calcium carbonate which is quite

insoluble and remains in the interior of the brick, while the sulphates of magnesium and sodium formed by this reaction, effloresce. This was well illustrated in the first case mentioned, where it was possible to pick bits of calcium sulphate from the face of the brick with a knife, while the efflorescence consisted almost entirely of magnesium sulphate.

The lime in the mortar furnishes the sulphates, carbonates, and chlorides of calcium, magnesium, sodium, and potassium. The sulphates are formed during the burning of the lime by the reaction of sulphurous gases formed by the burning coal with calcium, etc., of the limestone. This reaction is the same as was worked out by Guenther and Gerlach in the brick as a cause of kiln white, but as far as I know has not been mentioned as a possible cause of the wall whites. Such samples of lime and mortar as were at hand were found to contain considerable soluble sulphates and it seems possible that this is one of the most fruitful causes of the wall white. Surely it offers an explanation for many cases of efflorescence that were due to the mortar, but which was difficult to prove because the sulphate came from a medium which was principally composed of carbonates.

The sand and the water used in the mixing of the mortar may, under exceptional circumstances, be responsible for efflorescence, but as the sand used has generally been washed over and over again by the streams and circulating earth water, it is not reasonable to suppose that any amount of soluble material remains. Only in some situations where water circulating through the bed of sand is charged with material in solution can there be any deposited in it. Again the amount of salts in the water used in the mortar is so small, as a rule, it is hardly possible to believe it could cause any amount of efflorescence.

Other things added, such as coloring matter, salt, are very often responsible for the trouble. The oxide of iron generally used to color the mortar red is made by heating iron sulphate and generally all of the sulphate is not

decomposed. This reacts with the lime to form soluble sulphates and these in turn effloresce. This particular case was well illustrated by example No. 5, where the stone is a very porous silicious sandstone laid in red mortar, the efflorescence indicating its origin by appearing on or near the mortar.

Again, sodium chloride, or common salt, is added to the mortar in winter time to keep it from freezing before it sets. This salt comes out on the surface of the brick as soon as it has the water to carry it and appears as efflorescence. This was illustrated by example No. 4. An analysis of this efflorescence showed it to consist of more than 80 per cent. of salt.

Besides by the brick and the mortar, efflorescence is often caused by substances in contact with the brick. The efflorescence of brick stacked in stock piles is often caused by the cinders upon which they are stacked. The cinders contain sulphates from the coal from which they were formed and the water of the ground seeps up through them and through the brick evaporating from the faces of the brick and leaving the salts behind. Manure thrown against the wall will cause efflorescence through the nitrates and other soluble salts it contains. This is abundantly illustrated on stable walls and was first noticed there, the nitre found giving its name to all efflorescences. The soil contains nitrates especially where there is abundant vegetation and this occasionally enters the wall to appear higher up.

Benfy¹ explains the appearance of an efflorescence on the walls of buildings in Chicago by the leaching out of the sulphates of the soot, adhering to the walls by the rain which then entered the brick and evaporating, left the efflorescence behind, the soot having been washed off in the meantime.

If the water seeping through the wall has much material in solution, it is possible it would cause efflorescence on evaporation.

¹(Brick 1895, p. 358.)

As will be seen from the above, the causes of wall efflorescence are numerous, and one, at least, is omnipresent, the sulphates in the lime. If this is the case, why is it that every brick building does not show efflorescence? The answer is clear. No building can have efflorescence unless there is a supply of water to bring it out. The rains can do no more than bring out a faint even coat that is washed off by the succeeding rain. This is not a disagreeable thing and the efflorescence only becomes a nuisance when it is collected in blotches. What, then, is the remedy?

Make the walls as impervious as possible. Use well burned brick, lay a drain around the foundation and coat the foundation with a good waterproof paint before the ditch is filled in; likewise water-proof the walls and flues that convey water, or steam pipes. Take care that the cornice and roof is watertight. Attention to these simple things during the erection of a building will mean a clean wall and a much improved appearance.

After the building is finished, if the efflorescence comes out, there are only a few things that can be done. The walls may be painted which conceals the brick as well as the efflorescence and is liable to peel off in the damp spots. The walls may be treated with paraffine or linseed oil, which will darken the brick but not conceal them entirely. Then, as before, all source of water supply to this wall must be stopped if possible. In that way alone is there any hope of success for the present.

I wish to acknowledge here the helpful suggestions I have received from the various members of the faculty of the University of Illinois, and especially from Mr. Purdy, who has aided me throughout the preparation of this paper with kindly criticism and suggestions.

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