

this did not amount to an abandonment to the public of the carbon anode.

12. SAME—SPECIFICATION—DISCLAIMER.

The Hall patent claimed a bath "composed of the fluorides of aluminum and a metal more electro-positive than aluminum." In his specification he described a bath composed of fluorides of aluminum and sodium, "these salts being preferably mingled together in the proportions of 84 parts of sodium fluoride and 169 parts of aluminum fluoride. A convenient method of forming the bath consists in adding to the mineral cryolite 338-421 of its weight of aluminum fluoride to secure in the bath the proper relative proportions of the fluorides. Such proportions may be varied within certain limits without materially affecting the operation or function of the bath, as, in fact, any proportions which may be found suitable may be employed." *Held*, that this could not be construed as a disclaimer of the use of cryolite alone (which is a double fluoride of aluminum and sodium) for the bath, and that the patent covers every double fluoride of aluminum and sodium which can be made to produce aluminum when used as a bath in the Hall process.

13. SAME—LIMITING CLAIMS.

The facts that Hall in his specifications describes an apparatus for fusing the bath by external heat, and that the claim speaks of dissolving alumina in the fused bath, "and then passing an electric current," do not limit him to the use of external heat as against the heat developed by the current itself, for the claims contain nothing as to the production of the heat, and the patent states that the apparatus described therein forms no part of the invention. Following *Tilghman v. Proctor*, 102 U. S. 707.

14. SAME—CONSTRUCTION OF CLAIM.

The claim in the Hall patent of a "carbonaceous anode" covers both anodes made partly of carbon and those composed wholly of that substance.

In Equity. Bill to restrain infringement of patent. Decree for complainant.

George H. Christy and W. Bakewell & Sons, for complainant.

Henry S. Sherman, Leggett & Leggett, and Frederick S. Betts, for defendant.

Before TAFT, Circuit Judge, and RICKS, District Judge.

TAFT, Circuit Judge. This is a suit in equity by the Pittsburgh Reduction Company against the Cowles Electric Smelting & Aluminum Company, to restrain the infringement of a patent process for reducing aluminum by electrolysis, (letters patent No. 400,766,) owned by the complainant under an assignment from the original patentee, Charles M. Hall. The patent was applied for July 9, 1886, and was granted April 2, 1889. The defenses to the suit are: First, that the patent is invalid for want of novelty; and, second, that the defendant does not infringe.

Electrolysis is a process for separating a chemical compound into its elements by passing through it an electric current. The current is effective for this purpose only when the compound is reduced to a liquid state, either by solution or fusion. The compound which is decomposed by the current is called the "electrolyte."

Aluminum is a metal which was first isolated by Wohler in 1827. There is great difficulty in obtaining the pure metal from its compounds because of the tenacity with which it unites with other

substances. The compounds of aluminum are very abundant in nature. The most common, perhaps, is the oxide of aluminum, called alumina, one molecule of which is composed of three atoms of oxygen and two atoms of aluminum. Alumina is insoluble in water, and practically infusible.

Fluorine unites with the metals to form fluorides. The fluoride of sodium and the fluoride of aluminum united form what is known as the "double fluoride of aluminum and sodium." There are several minerals found in nature which are double fluorides of aluminum and sodium, of which cryolite is much more common than the others, and is found in large quantities in Greenland. Its uses are so extensive that it has become a well-known article of commerce.

More than 50 metals are known to chemists. When one of these is united with nonmetallic substances, and the compound is reduced to a liquid state by solution or fusion, and subjected to an electric current, which decomposes it, the nonmetallic element of the compound will be drawn by the current to that point in the bath where the current enters it from the positive pole, called the "anode," and the metal will move in the direction of the point where the current leaves the bath for the negative pole, called the "cathode." Metals differ, however, in the ease with which the current can draw them to the cathode; and when one is more sluggish than another in yielding to this influence the one is said to be more electro-positive than the other. Scientists have arranged all known metals accordingly. The only metals more electro-positive than aluminum are magnesium, calcium, strontium, barium, lithium, sodium, potassium, rubidium, and caesium. All other metals yield more readily to the current. When several compounds in solution or fusion are electrolyzed, the current will attack and decompose that compound whose parts are least firmly united, or, as the phrase is, "which is least stable." As might be supposed from the foregoing, the more electro-positive a metal is, the more stable its compounds are likely to be. Alumina is so common in nature that every one, in a desire to get pure aluminum, would naturally turn to that as one of the simplest of its compounds; but the fact that the oxygen has proved to be so firmly united to aluminum as to resist the action of the highest heat has been very discouraging to chemists.

Hall, the original patentee of the patent in suit, was a resident of Oberlin, Ohio, and a graduate of the college at that place. He had a strong taste for chemistry, and after leaving college in 1884 gave his attention, among other things, to the aluminum problem, which had baffled so many before him. He conceived the idea of obtaining aluminum from alumina by electrolysis, and concluded that if he could find a bath made up of compounds more electrically stable than alumina, which would freely dissolve alumina, the application of the current to the mixture would precipitate the aluminum upon the cathode, and would free the oxygen at the anode. He discovered that the fluoride of aluminum, when united with the fluoride of any metal more electro-positive than aluminum, to form a double fluoride, would, when heated to fusion, dissolve alumina as freely as

sugar will dissolve in water, and that an electric current passed through the fused mixture would deposit pure aluminum at the poles. Hall took out one patent for the process, in which he used a double fluoride of sodium and aluminum, and in this patent he also claimed the general process broadly, as we have stated it above. This is the patent in suit. He also took out other patents, as permitted by the practice of the patent office, covering the process when the fluorides of other metals more electro-positive than aluminum are used. The two claims of the patent in suit which are here involved are as follows:

"(1) As an improvement in the art of manufacturing aluminum, the herein described process, which consists in dissolving alumina in a fused bath composed of the fluorides of aluminum, and a metal more electro-positive than aluminum, and then passing an electric current through the fused mass, substantially as set forth.

"(2) As an improvement in the art of manufacturing aluminum, the herein-described process, which consists in dissolving alumina in a fused bath composed of the fluorides of aluminum and sodium, and then passing an electric current, by means of a carbonaceous anode, through the fused mass, substantially as set forth."

The defendant is said to infringe both these claims. The validity of the first, so far as it covers defendant's process, and of the second, is attacked by the defendant.

We shall first consider the validity of the claims, and in that connection must refer to the history of the art. It is said on behalf of the defendant that as far back as 1859, De Ville, a famous French chemist, published to the world the process which Hall has included in his patent. De Ville gave a great deal of time to aluminum and its production from its compounds. He was the discoverer of the purely chemical process by which, without the aid of electricity, pure aluminum has been manufactured since his day down to the present time. He also gave some attention to the manufacture of aluminum by the process of electrolysis. In the publication by De Ville on aluminum, its properties, its manufacture, and its uses, in the year 1859, we find this statement:

"Aluminum by the Current. The same bath of the double chloride of aluminum and sodium can be used for coating with aluminum, especially copper, on which Captain Caron and myself have worked. In order to succeed well, one must employ a bath of the double chloride, which has been carefully purified from all metallic substances by the action of the current itself. When the aluminum which deposits at the negative pole appears pure, one attaches to this pole the piece of copper to be aluminized, and to the negative pole a bar of aluminum."

("Footnote. A compact mixture of carbon and alumina, which is transferred into chloride of aluminum gradually and in measure as the deposit of aluminum takes place, keeps the composition of the bath constant for an indefinite period of time.")

"The temperature must be kept somewhat below the melting point of aluminum. The deposit takes place with great facility. It is very adhering; but it is difficult to prevent the metal from getting impregnated with double chloride, which attacks it the moment one washes the piece, while, with some precaution, one succeeds. The washing of the piece must be done with much water, and for a long time. Cryolite, in the same way can be used in this operation, but it must be made more fusible by mixing it with a little double chloride of sodium and aluminum, and with potassium chloride."

The process here described is not for producing pure aluminum, but for plating aluminum on copper. It will be seen that the bath which is first and chiefly recommended by De Ville is not a fluoride of aluminum and sodium, but a double chloride of aluminum and sodium, i. e. a double compound of chlorine with each of these metals. Alumina will not dissolve in a double chloride of aluminum and sodium, heated to a fused state. The operation of the process first described by De Ville is this: The double chloride of aluminum and sodium is heated to a state of fusion. The piece of copper is made the cathode, and a bar of aluminum is made the anode. When the current is passed through the bath, the chloride of aluminum, being the less stable compound, is dissolved into its elements. The aluminum is deposited on the copper, and the chlorine gas is freed at the positive pole, where it attacks the anode of aluminum, and its atoms unite chemically with atoms of the aluminum, to reform again molecules of aluminum chloride, which, when formed, take their place in the bath. The bath, which was partially destroyed by the disruption of the chloride of aluminum, is thus restored, to be again electrolyzed. Instead of the anode of aluminum, the footnote suggests that the compact mixture of carbon and alumina may be substituted for the bar of aluminum as an anode, and that the escaping chlorine gas, being presented to the compact mixture of carbon and alumina, would unite with the aluminum of the alumina, while the oxygen of the alumina would unite with the carbon, and pass off as carbonic oxide gas. The chlorine gas and aluminum would make chloride of aluminum, and, being reintroduced into the bath, would keep it constant.

Finally, it will be observed that De Ville suggests that instead of the double chlorides of aluminum and sodium, cryolite may be used, but that it must be made more fusible by mixing it with a little double chloride of sodium and aluminum and with potassium chloride; and it is the proposition of De Ville to use cryolite in this way as the main part of the bath, and an anode of carbon and alumina in accordance with the footnote, which the defendant's counsel and experts contend is substantially the same process as that on which Hall claims a patent.

Cryolite, as we have seen, is a double fluoride of aluminum and sodium. The theory of the process of De Ville is that the electric current disrupts the fluoride of aluminum which is a less stable compound than the fluoride of sodium. Fluorine gas is liberated at the anode, and, being presented to the mixture of carbon and alumina, unites with the aluminum, and leaves the oxygen with the carbon to make carbonic oxide gas. The fluoride of aluminum thus constituted at the anode renews the bath, and is supposed to keep it constant; while the aluminum of the original fluoride of aluminum, which was in the bath, is deposited at the negative pole.

We are very clear in our opinion that this is not an anticipation of Hall's patent. The primary and most important step of Hall's patent is the dissolving of the alumina in the fused bath of the double fluoride of aluminum and sodium. This happens before any electrolysis occurs at all. When the electric current is ap-

plied, it disrupts the alumina, sending the aluminum to the cathode and the oxygen to the anode, where it unites with the carbon anode, and becomes carbonic oxide gas. The bath material in which the alumina was dissolved—that is, the double fluoride of aluminum and sodium—is not affected by the electric current, and the process is made continuous by the simple addition of alumina to the bath. In the De Ville process, however, alumina is not dissolved in the bath. The fused mass subjected to the current is composed of a double fluoride of aluminum and sodium with no alumina in it. No effect comes from the presence of the alumina in the anode until after the electric current is passed through, and the fluoride of aluminum has been disrupted, and fluorine gas has been produced at the anode; then the gas unites with the aluminum of the alumina, and restores the bath, in a manner, to its former state, to be again disrupted by the application of the current. In the one case there is a simple solution of the alumina in a bath and its disruption by the current, the bath remaining constant; while in the De Ville process the bath itself is disrupted, and restored again by the union of one of the disrupted elements with an element of the alumina in the compact anode. In the Hall process there is simply solution of the alumina and electrolysis; in the De Ville process there was electrolysis, followed by what is called an “electrochemical solution of the alumina.”

Defendant's counsel and experts, in their effort to make the two processes the same, rely upon the supposition that when the compact anode of carbon and alumina was inserted by De Ville into the bath of cryolite some of the alumina was necessarily dissolved in the cryolite, and so the current electrolyzed that alumina as in the Hall process. In the first place, the experiments made on behalf of complainant demonstrate that a compact mixture of carbon and alumina (which can only be made by the use of some binding material) may be kept in a bath of cryolite for many hours without dissolving the alumina at all. Some counter experiments by defendant are by no means so satisfactory, because the results may be attributed to the presence of other causes than the solution of the compact anode.

But suppose it to be a fact that in De Ville's process alumina was dissolved in the bath from the anode, and that thereupon it was electrolyzed as in the Hall process, it was a mere accident, of which De Ville made no note, and which, therefore, we may reasonably infer, he did not observe. Accidents of this character cannot be relied on as anticipations of a patented process (*Tilghman v. Proctor*, 102 U. S. 707, 711) when the operator does not recognize the means by which the accidental result is accomplished, and does not thereafter consciously and purposely adopt such means as a process for reaching the result. De Ville did not intend that the alumina should be dissolved in the bath. If he did, why did he unite it with carbon by means of pressure and a binding material? If he had intended to dissolve the alumina, he could not have done anything which would have so interfered with his purpose. Just as Prof. Langley says, such a course would have been as reasonable

as it would be for a man, wishing to dissolve a lump of sugar in his coffee, to varnish it or grease it. De Ville did not intend to dissolve the alumina in the bath—First, because, as we shall see hereafter, he had no knowledge that it would dissolve therein; and, second, because, until the fluoride of aluminum had been decomposed in the bath by the current, he did not need anything with which to restore that fluoride to the bath. He felt that it was necessary to have the alumina in a solid form, in close connection with the carbon, because, without the strong attraction that the carbon would have for the oxygen of the alumina, the fluorine gas could not get at the aluminum of the oxide.

De Ville was seeking to electrolyze the fluoride of aluminum, while Hall was seeking to electrolyze alumina. It was a condition precedent to Hall's success that his alumina should be in a liquid state. As we have seen, it was essential to De Ville's process that his alumina should be where it was, i. e. mixed in solid form with the carbon.

This brings us to a theory of the Hall process which has been advanced by one or more of the defendant's experts to show that the Hall and De Ville processes are alike. Hall says in effect, in the specifications for his patent, that the electrolyte in his process is the alumina held in solution, and that in the decomposition the aluminum of the alumina goes to the cathode and the oxygen of the alumina goes to the anode, the fused double fluoride constituting the bath remaining unaffected. The theory, or, we would better say, the alternative theory, of the defendant's experts (for they venture more than one) is that the fluoride of aluminum is the electrolyte, and that when it is decomposed the fluorine attacks the dissolved alumina, drives off the oxygen to the anode, and unites with the aluminum remaining, thus restoring or regenerating the bath. This theory is advanced for the purpose of showing that the Hall bath does not remain constant, as he claims, but has to be regenerated as in the De Ville process, the only difference being that in the former the alumina is held in the bath in solution, while in the latter it is held in a compact mixture of carbon and alumina. If this were the only difference between the two processes, we should hold that the Hall process was a patentable discovery, because the regeneration of the bath from the dissolved alumina, if such were the chemical action which took place, would be a successful process, because regeneration is so complete as not even to betray itself, while in the practical operation of the De Ville process the regeneration of the bath is very incomplete. The fluorine gas escapes into the air, and is so corrosive as to injure both workmen and apparatus, and the process is a failure for commercial purposes. The compact mixture of carbon and alumina is hard to make, and obstructs regeneration; and the substitution for it of dissolved alumina, even if their functions in the process are exactly the same, is the step from failure to success.

But there is no satisfactory evidence at all that the dissolved alumina is not the electrolyte, and the burden is on the defendant to show it. *Coffin v. Ogden*, 18 Wall. 120, 124. Prof. Chandler,

of the Columbia School of Mines, called as an expert witness for the complainant, demonstrates, so far as chemical actions and reactions are capable of demonstration, that it is the alumina which is decomposed by the current. He says that the alumina dissolves in the fused bath of cryolite, as sugar does in water, quietly, without any of the usual evidences of chemical action, such as the production of heat, or the reduction of fusibility or thickening of the liquid. This seems to show that the alumina in solution remains chemically unchanged. He refers to the fact, admitted on all hands, that when the current is applied, aluminum goes to the cathode and oxygen to the anode without any indication of any other product of decomposition. This result is fully satisfied by the explanation that the alumina alone is decomposed. He refers to another fact, also admitted, that, as soon as the alumina in the bath is exhausted, the resistance to the current and the voltage of the current to overcome it become doubled, and are not reduced until alumina is added to the bath. This would seem to show that the electrolyte has been changed by the exhaustion of the alumina, and therefore that, when present, alumina is the electrolyte. The professor further shows from the observations of the most reliable chemists that the heats of formation of the three compounds in the bath are such that it would require 4.8 volts to decompose sodium fluoride, 4 volts to decompose aluminum fluoride, and 2.8 volts to decompose alumina, which proves that the alumina would first yield to the action of the current, and in the presence of the other two compounds would be the electrolyte. More than this, Prof. Chandler points out a fatal contradiction in the theory that the fluoride of aluminum is the electrolyte in the Hall bath. That theory assumes on the one hand that the dissolved alumina will be decomposed by the fluoride of aluminum, and on the other that the alumina is a more stable compound than the fluoride when electrolysis ensues, so that the fluoride, and not the alumina, becomes the electrolyte. Finally, the theory is shown to be unfounded by the total absence at the anode of fluorine gas, which would certainly be there present in perceptible quantities if fluoride of aluminum is the electrolyte and fluorine is released by the current. No facts of any kind are advanced by the defendant's experts to meet this demonstration of Prof. Chandler, which is fully concurred in by Prof. Langley of the Case School of Applied Sciences, and Dr. Raymond. The arguments, such as they are, depend on analogies drawn from the electrolysis of entirely different compounds, as, for instance, water. With the burden on the defendant on this issue, we are very clear that it has not been sustained.

An alternative theory, advanced by some of defendant's experts, is that when alumina is dissolved in the bath, a compound of oxygen, fluorine, and aluminum, called "oxyfluoride of aluminum," is formed, which is the electrolyte. It is sufficient to say of this theory that no chemist, and certainly none of defendant's experts, ever isolated such a compound, and no one knows that it exists. The reason for its theoretical existence is that such a compound is formed with the chlorides. Analogies between the fluorides

and the chlorides constantly fail. In this very case we find that the former will dissolve alumina, and the latter will not. The oxyfluoride of aluminum theory is mere speculation, and not worthy of consideration in a case involving property rights.

The defendant company instituted a number of experiments to show that the De Ville process would work as well and in much the same way as the Hall process. The evidence concerning these experiments, although it all comes from the defendant's witnesses, leaves no doubt in our minds that they were not conducted in a fair spirit, but rather with an intense desire to force a demonstration of the identity of the De Ville and the Hall processes. Nothing else can explain the palpable disobedience to De Ville's express directions for carrying out his process. According to De Ville's directions, the bath must not be heated up to the melting point of aluminum. This is evident, because his main process contemplates an aluminum anode, and heat beyond its melting point would destroy it as an anode, and it is for this reason that he directs that the fusibility of cryolite be reduced by mixing it with chlorides. In the experiments of the defendant the bath was heated far beyond the melting point of aluminum. It was so hot that the carbon of the carbon-alumina anode, a large part of which was not sunk in the bath, but was exposed to the air, united with the oxygen of the air, and was burned out. This left on the exterior of the anode nothing but a ring of pure alumina, which, dropping into the bath, was of course dissolved as in the Hall process, and from it aluminum was deposited at the cathode. Then, too, stubs of the partly used carbon-alumina anodes were ground up and thrown into the bath of cryolite, and of course the particles of alumina, separated by the grinding process from the carbon, became dissolved in the bath, and the Hall process was again reproduced. De Ville did not contemplate the presence of alumina in the bath except in a compact mixture with carbon, and yet the experiments of defendant presented alumina to the bath wholly free from carbon. Even with these approaches to the Hall process, the cost of producing the aluminum which was produced exceeded that of the Hall process some sixfold. Nothing could more clearly demonstrate the difference between the De Ville and the Hall processes.

We have considered the Hall process as a whole, and thus compared it with the De Ville bath-regenerating process. A comparison of his process with De Ville's and the difference would not be complete, however, without some reference to Hall's claim that he was the first discoverer of the fact that alumina would freely dissolve in the fused double fluoride of aluminum and sodium. The fact is that such a bath will dissolve from 10 to 25 per cent. of its weight as completely as water will sugar. Defendant claims that this was well known in the art long before Hall's application. The first publication relied on to establish the claim is found in one of De Ville's works, as follows:

"Cryolite is a double fluoride of aluminum and sodium, which one may produce artificially or imitate by mixing hydrofluoric acid in excess in pure and

calcined alumina and carbonate of sodium in quantities such that the sodium and aluminum will be present in the proportions in which they exist in cryolite. After drying and fusing the mixture one has a limpid and homogeneous substance which possesses all the exterior characteristics of fused cryolite. I have not yet made an analysis of it, but the weight of the substance produced is such that one must suppose that the alumina and soda have lost all their oxygen by transformation into fluoride. This cryolite, like the natural cryolite, gives aluminum when reduced by soda. It also yields aluminum under the influence of an electric current, which a mixture of alumina and fluoride of sodium fused together will not do. When this experiment is made, one perceives that the alumina dissolves in the fluoride, but in small quantity, and remains in the condition of alumina, because an electric current, which passes through the well-fused substance, yields sodium and fluoride. These experiments, which succeed very well when one employs a mixture of fluoride of sodium and fluoride of potassium, prove further that alumina at red heat is decomposed neither by sodium nor by potassium."

There is no statement here at all that cryolite will dissolve alumina. The words, "when this experiment is made," etc., clearly refer to the experiment last spoken of; that is, to passing an electric current through a mixture of alumina and fluoride of sodium fused together. In such an experiment De Ville says that the alumina dissolves in the fluoride, i. e. the fluoride of sodium, in small quantity. There was no cryolite in this experiment.

All the other publications relied on relate to a feature of the purely chemical process which De Ville discovered for the reduction of pure aluminum by the use of sodium. In that process the aluminum appears in tiny granules or globules of the pure metal, which De Ville found much difficulty in running together to make a button. He attributed this difficulty to the presence of a thin film of alumina surrounding each globule, formed by a union of the aluminum with the oxygen of the moisture developed in the experiment. He found that this film could be removed by washing the globules with fluoride of sodium. De Ville says:

"The facility with which aluminum gathers together in the fluorides is due without doubt to the property which they possess of dissolving the alumina which the moisture adhering to the chloride of aluminum deposits on the surface of the globules on the instant of their formation, and which the sodium is unable to reduce."

De Ville does not here refer to the power which double fluorides have of dissolving alumina, but to the power which the fluorides singly have of doing so. For, as we shall see from a subsequent publication, he used in his experiments the fluoride of sodium. Speaking of the same process, Charles and Alexander Tissier, in a work on aluminum, say:

"This salt [i. e. fluor spar] is without action on aluminum, of which it constitutes one of the best fluxes, especially so because of the property which it has of dissolving the alumina with which the metal may be contaminated, and thus facilitating the reunion of the metallic particles."

In speaking of the chloride of sodium, the same authors say:

"This is the salt which we employ habitually in recasting aluminum. However, it does not possess, like the fluoride, the property of dissolving the alumina."

The fluoride here referred to is, of course, the fluoride of sodium. Again, the same authors say:

"Such was the state of aluminum manufacture, when, towards the close of 1855, De Ville, surprised by the facility with which the aluminum gathered together when it was reduced from its fluoride instead of reducing it from its chloride, conceived the idea of trying how the fluoride would act under these circumstances. He perceived that the success of the operation was due to the fact that the alumina interposed between the small globules (that is, the small globules of metallic aluminum) was dissolved by the fluoride of sodium which was formed, and thus imparted to the metallic particles a much greater facility of reunion."

Referring to the same operation, Pelouze and Fremy, in a work published in 1865, say:

"It is probable that the salty, pasty state of this slag (i. e. the film about the globules) is due to the alumina which the fluorides dissolve well, but thereby lose their fluidity. This slag is composed principally of common salt and fluoride of aluminum in the following proportions: Common salt, 60 parts; fluoride of aluminum, 40 parts. When this slag is washed, the salt is dissolved, and there is left fluoride of aluminum, and a little cryolite and alumina. This is the alumina which has been dissolved or retained by the fluoride bath."

Again, in a German work by Hoffman, published in 1875, there is this reference to De Ville's process of making aluminum by his purely chemical process:

"Instead of the pure chloride of aluminum, De Ville soon after employed the double fluoride of aluminum and sodium, which he reduced in a reverberatory furnace with sodium. However, the chloride of aluminum and its double salt eagerly attract moisture, and then yield, on heating, hydrochloric acid and alumina, (aluminum oxide.) This last coats over the separately reduced globules of aluminum with a thin skin of oxide, which makes it difficult to get the globules to unite in a mass. This oxide, as Rosseau and Morin found, is dissolved by fluorides. For this reason fluor spar, or, as Pelouze and Fremy recommended, cryolite, is added to the double salt."

Payen, another chemist, in a work published in 1878, refers to the same process, and says:

"Cryolite may always be used with advantage in the place of fluor spar. It acts both as a solvent for alumina, like fluor spar, and also increases the yield by furnishing more aluminum."

We have given all the references relied on by defendant. It is perfectly apparent to us that it was only known that cryolite would wash off the film of what was supposed to be alumina from the tiny globules of aluminum in the De Ville chemical process exactly as fluoride of sodium or fluoride of calcium would, and that cryolite was proposed merely as a substitute for those compounds in this process. But fluoride of calcium will dissolve only 1 per cent. of its own weight in alumina, and fluoride of sodium even less. This does not show that any chemist knew, until Hall discovered it, that cryolite would dissolve alumina as water does sugar. Indeed, it will be noticed that Pelouze and Fremy, who recommended cryolite as a substitute for fluor spar in washing off the alumina film, say that by such dissolving the cryolite will lose its fluidity. Considering the slight amount of alumina to be washed off, this would show conclusively that they did not know or realize that cryolite would freely dissolve alumina, and not lose its fluidity at all. It will not do to say that the difference is only one of degree. If cryolite only dissolved one per cent. of its weight in alumina, Hall's process would

never have been heard of. The difference between what Hall discovered and what was known before him in this regard is the difference between complete knowledge on a subject and so little as to be wholly useless and not to suggest further inquiry. It is impossible, if De Ville had any knowledge that alumina could be dissolved in cryolite, as Hall found, that he should not have made a note of it, for all the experts agree that he observed most carefully, and noted exactly all that he observed.

Another claim in this connection perhaps deserves some notice. In several patents which were taken out in England for the making of aluminum by what is the De Ville process without any variation, the anode, made of a compact mixture of carbon and alumina, is referred to as a "soluble" anode. This is said to show that the patentees knew that alumina would dissolve in the cryolite bath. The expression is used merely to indicate the action of the fluorine gas, released at the anode by the current, in uniting with the aluminum of the alumina in the anode, and regenerating the bath, which of course destroys the anode. It is an electro-chemical solution of the anode, and wholly different from a free solution of alumina in the bath without any aid from electricity. That the term "soluble" has no other meaning in this connection is evident, because an anode of pure aluminum is also called "soluble."

We have read with care every part of this voluminous record of over 1,500 pages, and, while we are not chemists, we have obtained a sufficient understanding of the principles applied in the Hall and De Ville processes to be entirely confident that they are wholly different, and that no skilled chemist and electrician could have developed the Hall process from the De Ville process without a real discovery.

The Bell patent of 1861, the Johnson provisional specifications of 1879, the Johnson specification of 1883, and the Graetzel patent of 1884, which are all recorded in the English patent office, and are produced here by the defendant and relied on as anticipations of Hall's patent, are mere reproductions of the De Ville bath-regenerating process, with various attempts to avoid the difficulties which the process presents in its practical operation. The Graetzel patent—the latest of them—was a failure. This is admitted by the patentee himself, who was a witness in the case. The Johnson specifications were never even proceeded with to the procuring of a patent, and the Bell patent has never been used at all to make aluminum commercially. It is said that one reason why these electrolytic processes, including De Ville's, were not brought into actual use, was that, until within a very few years, there were no dynamos capable of furnishing sufficient electric volume and force to make them practicable for commercial purposes. That the improvements in the machines for producing electricity have greatly facilitated the use of electrolysis as an agent in commercial processes is not to be denied, but the failure of the De Ville process for making aluminum by electrolysis finds a far better reason in the inherent difficulties of the process itself than in the mere expense of electricity. If the De Ville process is operative with the present modes of producing electricity, why does not the defendant adopt it? It is free to any one. The