then suddenly lowered in the succeeding layers. Zones of that type, the formation of which has been fully studied and their cause explained by the author, produce brittleness and peeling.

10. Further, gaseous or volatile hydrocarbons, when used alone as agents, also give rise to too rapid case-hardening, the causes being identical with those referred to in the case of cyanogen and its compounds.

In the light of the facts recited in the foregoing, the great advantage of the use of agents, the activity of which is due, if not exclusively, at least principally, to the specific carburizing action of carbon monoxide, is clear. In order to obtain the best results with such an agent, the author has demonstrated in his publications previously quoted that it is necessary to satisfy the following fundamental conditions:—

1. The chemical composition of the agents should be absolutely definite, and should be accurately known.

2. The compounds should be as simple as possible.

3. The reactions which take place during the case-hardening process between the various constituents of the agent and those of the steel should be simple, and should proceed rapidly—under the conditions most easily obtaining in practice—to a well-defined state of equilibrium corresponding to definite concentrations of carbon in the carburized zones.

The author in his previous work has demonstrated from the theoretical point of view that the agent which best satisfies these conditions would be pure carbon monoxide, except that by its use the concentrations of carbon in the carburized zones, which correspond to the conditions of equilibrium, are in general too low, when working within the ranges of temperature and pressures ordinarily maintained in practice, and when the metal subjected to case-hardening is an ordinary mild carbon steel or a steel containing a low percentage of nickel or chromium.

On the other hand, that inconvenience can be avoided, and the three conditions indicated above can be sufficiently well realized by the use of case-hardening agents, in which along with the carbon monoxide small quantities of hydrocarbons of known composition, or solid carbon in a properly divided state, are allowed to act either throughout the whole period or during a portion only of it.

Further, of these two classes of agents, those of the second-class, based on the simultaneous use of free carbon and of carbon monoxide, are the most suitable for the majority of ordinary technical applications, since by their use the operation can be performed with the maximum degree of simplicity and the certainty of obtaining predetermined results.

Below are enumerated the principal technical advantages which the author has shown to be obtainable by the employment of case-hardening agents, which satisfy the three essential conditions previously mentioned, and, in particular, of the "mixed" agent based on the simple simultaneous action of carbon and carbon monoxide. The following are the principal advantages:—

1. The great speed of penetration of the carburized zone. That fact, if indeed it does not constitute the chief value of any given case-hardening process, as many manufacturers still believe, is certainly most advantageous on economical and technical grounds too numerous to mention.

2. Great uniformity in the distribution of carbon in the carburized zones, which is the cause of the fact, as already stated, that the peeling of case-hardened and tempered pieces are reduced to a minimum.

3. The possibility of regulating, either by diluting the carbon monoxide with nitrogen, or by limiting the contact of the solid carbon with the surface of the steel, or by suitably varying the temperature during the case-hardening process, the concentration of the carbon in the carburized zone so as to maintain it within the most suitable limits for conferring the maximum hardness combined with minimum brittleness. The extent of carburization must, of course, vary according to the composition of the steel subjected to cementation.

4. The possibility of establishing with certainty from the start the necessary conditions for obtaining a predetermined result which may be chosen within sufficiently wide limits, and may be obtained with great accuracy.

5. Continuous use of the same carburizing materials (solid carbon and carbon monoxide), which do not become attenuated, but may be used up to their last residue. This also permits of carburizing to any depth without the necessity of renewing the agent during the operation.

6. Absolute security against the introduction into the steel of any foreign substance apart from the carbon. This is an advantage of the highest importance in most cases, and cannot be realized in the case of most of the case-hardening powders habitually used, consisting of organic nitrogenous substances, such as alkaline cyanides, or ferrocyanides.

7. The ease with which the surface of the case-hardened pieces is preserved without alteration, thus obviating the necessity of any subsequent dressing of the case-hardened pieces.

8. The deformation and change of volume which the steel pieces may undergo during case-hardening are reduced to a minimum. In any case it is possible to determine from the start the extent of such volume changes as may occur.

For a full account of the experiments and their results the author would refer readers to his previous reports on his research work on this subject.

Besides the advantages enumerated above, which refer particularly to the quality of the product, the use of the mixed agent having a carbon monoxide base offers other practical benefits, consisting in the ability to modify very advantageously the method of operation. In one of the reports referred to, it is shown by the author how the method may be used even without discarding the ordinary horizontal muffle generally used for case-hardening. The same advantages, to a greater extent, may be more easily secured by using the mixed agent in a furnace the form of which differs radically from that of the ordinary case-hardening furnace, and by following a special method of operation.

FURTHER RESULTS OF ELECTRO SMELTING IN SWEDEN.

The following important results in connection with the electric smelting of iron ores at Trollhättan, Sweden, were recently forwarded to the Canadian Engineer by the Canadian Boving Company, who represent the above referred to Swedish interests:—

As might have been expected, the first six months' working suggested various alterations in the construction of the furnace. It was, therefore, shut down at the beginning of June last, for the carrying out of these alterations. The plant was again started during the first week of September, and has been in uninterrupted work ever since. During the