being required to keep the temperature constant at 1,400 deg. C. The temperature of the fluid metal at tapping is from 1,600 deg. to 1,700 deg. C. The cost of a furnace of this type of 600-h.p. is, according to Mr. Kjellin, about $4,000.

Since the measurements of the absorption of electric energy constituted the most important factor in ascertaining the cost of producing steel by this method, and since there was no guarantee of the accuracy of the electric measuring instruments employed at the works, standard instruments were rented from David Bergman, consulting engineer in Stockholm, and placed in the circuit. Mr. Brown reports for an absorption of electric energy per ton of product of 0.116 and 0.145 electric horse-power years respectively. Mr. Harbord reports the estimated cost of steel by the Kjellin process to be $34 per ton of 2,000 lbs.

The capacity of the furnace is comparatively small, but for a larger plant Mr. Kjellin states that three furnaces of the pattern now used might be joined into a compound furnace, and supplied with a three-phase alternating current. This would treble the capacity and reduce the wages, since the number of workmen now employed in operating the one furnace could attend to all three.

Samples of the steel produced and of the materials employed were taken and shipped to England, to be tested as to quality and composition.

The following figures on which the cost of power per electric horse-power year, delivered at the furnace, is based, were furnished by Mr. Kjellin.

| | |
|---|---|
| Cost of hydraulic canal | $22,000 |
| Cost of power house | 10,000 |
| | $32,000 |

The quantity of water which can be delivered by the canal at low water is 22 cubic meters per second. The head is 3½ meters. Allowing an efficiency of 75 per cent. for the turbines, the available horse-power is 770.

225 horse-power are delivered to the furnace. Losses in generator, exciter and line, 40-h.p., a total of 265.

| | |
|---|---|
| Part of the cost of power-house and canal to be charged to power for electric furnace is | $11,000 |
| Cost of turbine | 1,900 |
| Installing turbine | 500 |
| Generator and exciter | 5,850 |
| Transmission line | 1,000 |
| Switchboard and instruments | 600 |
| | $20,850 |
| 10 per cent on first cost for interest, depreciation, repairs, taxes, insurance, etc. | $2,085 |
| The part of operating expenses which is chargeable to electric furnace | 500 |
| | $2,585 |

Cost of 225-h.p. delivered to electric furnace is $2,585, or $11.50 per electric horse-power year.

Mr. Harbord, in his report on this furnace, says: "In my opinion, the furnace would require considerable modifications before it could be conveniently used for the manufacture of mild steel to compete with the Siemens furnace, as the difficulty of removing the whole of the slag, while retaining a small portion of the metal in the furnace, would, I fear, be considerable, and I anticipate that repairs could not be so readily effected if the walls were badly cut by the slag, as in the case of an ordinary Siemens furnace. Mr. Kjellin has, however, shown so much ingenuity in surmounting the difficulties in connection with the manufacture of high carbon steel, that, given the opportunity to experiment with a furnace on a reasonable scale, it is quite possible that he may be able to overcome these difficulties, and make the manufacture of mild steel a commercial success. The process, as at present worked, is admirably adapted for the highest class of steel from pure materials and the only objection to it, is that it is limited to these pure materials and can only be used where they are obtainable. I do not think in its present stage of development it is adapted to treat ordinary pig iron and miscellaneous scrap of more or less irregular composition, as the complete elimination of any impurities present could not always be relied upon. Under the special conditions existing at Gysinge and in some other places, it is capable of doing most excellent work and is a most efficient and economical metallurgical appliance. There seems no reason why the size of the furnace should not be very considerably increased, whatever difficulties there may be being electrical, rather than metallurgical, and with furnaces of 5 to 10 tons' capacity the labor costs would be very greatly reduced. Five men and one boy could do all the necessary work if they had a little assistance in charging, on a five-ton or even a ten-ton furnace without being in any way overworked, and this would at once reduce the cost of labor by nearly five to ten times, according to the size adopted, so that with a fair-sized furnace the cost of labor in Canada, notwithstanding the much higher rates paid, might be actually less than at Gysinge."

In another issue we hope to give some account of the other furnaces.

### GENERAL CONCLUSIONS.

The following are the conclusions arrived at by Mr. Harbord, as a result of his investigation into the metallurgy of the electric production of steel, and the electric reduction of iron ore:

1. Steel equal in all respects to the best Sheffield crucible steel can be produced, either by the Kjellin, Héroult, or Keller processes, at a cost considerably less than the cost of producing a high-class crucible steel.

2. At present, structural steel to compete with Siemens or Bessemer steel cannot be economically produced in the electric furnaces, and such furnaces can be used commercially for the production of only very high-class steel for special purposes.

3. Speaking generally, the reactions in the electric smelting furnaces as regards the reduction and combination of iron with silicon, sulphur, phosphorus and manganese, are similar to those taking place in the blast furnace. By altering the burden and regulating the temperature, by varying the electric current, any grade of iron, grey or white, can be obtained, and the change from one grade to another is effected more rapidly than in the blast furnace.

4. Grey pig iron, suitable in all respects for acid steel manufacture, either by Bessemer or Siemens processes, can be produced in the electric furnace.

5. Grey pig iron, suitable for foundry purposes, can be readily produced.

6. Pig iron, low in silicon and sulphur, suitable either for the Basic Bessemer, or the Basic Siemens process, can be produced, provided that the ore mixture contains oxide of manganese, and that a basic slag is maintained by suitable additions of lime.

7. It has not been experimentally demonstrated, but from general considerations there is every reason to believe, that pig iron, low in silicon and sulphur, can be produced, even in the absence of manganese oxide in the iron mixture, provided a fluid and basic slag be maintained.

8. Pig iron can be produced on a commercial scale at a price to compete with the blast furnace only when electric energy is very cheap and fuel very dear. On the basis taken in this report, with electric energy at $10 per E.H.P. year, and coke at $7 per ton, the cost of production is approximately the same as the cost of producing pig iron in a modern blast furnace.

9. Under ordinary conditions, where blast furnaces are an established industry, electric smelting cannot compete; but in special cases, where ample water-power is available, and blast furnace coke is not readily obtainable, electric smelting may be commercially successful.

It is impossible to define the exact conditions under which electric smelting can be successfully carried on. Each case must be considered independently, after a most careful investigation into local conditions, and it is only when these are fully known that a definite opinion as to the commercial possibilities of any project can be given.

Nothing requires to be added to Mr. Harbord's conclusions regarding the electric production of steel; in reference to the production of pig, however, it must be pointed out that the results obtained at Livet were results of experiments in furnaces not specially designed for the production of pig iron ore. With the improved furnace, permitting, on account of the higher column of charge, a more effective use of the heat of the resulting gases, and of the reducing power of the CO