STUDY OF POWER CONSUMPTION AND CURRENT EFFICIENCY FOR THE PRODUCTION OF SODIUM HYPOCHLORITE IN AN ELECTROLYTIC CELL

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Abstract
The power consumption and current efficiency was studied for the production of sodium hypochlorite by the electrolysis of sodium chloride solution using graphite anode and stainless steel cathode. Due to the wide application of sodium hypochlorite, an electrochemical cell system was devised for its production. The cell is of simple geometric shape, ease of design and can be easily constructed. The cell box was closed so that hypochlorite can be easily formed in the cell from the evolved chlorine gas at the anode and OH^- at the cathode. The effect of current density, temperature, concentration of electrolyte and also addition of dichromate on the production of sodium hypochlorite were investigated. The operating current density was varied from $187.5 Am^{-2}$ to $750 Am^2$. The maximum current efficiency was obtained 91.06% at current density 625 Am^{-2} and the minimum power consumption was found to be 177.21 KWhr/ton for the maximum production of sodium hypochlorite.

Introduction

Sodium hypochlorite is a very important disinfectant and is used as a powerful oxidizing agent. It plays a very important role in the field of paper and pulp industries, jute, cotton and leather industries as bleaching agent. It is also used for sterilization of water in both drinking and swimming pools. It is a very useful oxidizing agent for converting Cr^{3+} to chromate and Pb salt to PbO_2. Sodium hypochlorite is not only a stronger oxidizing agent than chlorine but is much more reactive and can bleach more rapidly at room temperature. The production of sodium hypochlorite by this process has drawn our attention because of its wide application and can be produced from sodium chloride, which is easily available in Bangladesh. A good number of researchers have studied on the electrolysis of sodium chloride solution but not much attention have been paid to the hypochlorite production by this method. The commercial use of electrochemical methods for producing hypochlorite and chlorate from chloride probably were antedated by a few years. In these early cells, the production efficiency was low and the production was only economical where electrical energy was quite cheap, inasmuch as the simple addition of chromate to prevent cathodic reduction of hypochlorite had not yet been discovered. The mechanism of chlorate formation using thin film bipolar rod was studied by Ali[1].

The study of hypochlorite and chlorate production were also studied by Aziz et al[2] and Aziz[3]. Bashtan et al[4,5] investigated the mechanism of hypochlorite and chlorate formation in an electrolytic cell. Kuhn[6] investigated industrial electrochemical processes of the electrochemical production of medicinal sodium hypochlorite solution in a flow-through electrolyzing cell. He observed the best result in a cell with titanium electrodes that have a disperse platinum coating.

Roger[7] investigated sodium hypochlorite and it use as endodontic irrigant. Among the published investigations on electrochemical production of hypochlorite and chlorate, the comprehensive work is the paramount importance. The process of alkali chloride electrolysis is very sensitive to cell design that has been recognized from its early stages and various types of cells are available. In the present study graphite has been chosen as anode because at low temperature of operation it does not erode and stainless steel as cathode. The other frame of the cell body should be made of inert material such as Pyrex glass or Perspex.

The objective of this work **is to** develop an electrochemical method for the optimum production of hypochlorite and the performance of the cells was assessed in terms of current efficiency and power consumption.

Experimental

A number of experiments were performed in a novel cell for the production of sodium hypochlorite which is shown in Figure 1. The experimental procedure has been described by Aziz[3]. The electrolytic cells consisted of graphite anodes and stainless steel cathodes, which were rectangular in shape and placed vertically in the Perspex box. The number of the cells in the Perspex box were 8(eight). In each cell anode and cathodes were placed vertically at a distance of 10mm and one cell was kept apart from another by a distance of 15mm. The anode measuring 5cm x 4 x 0.635cm and cathode measuring 5cm×4cm×0.317cm were used. Two Perspex boxes at different sizes, measuring 33cm×23cm×19cm and 26cm×8cm×14cm were used.

The Perspex box was fitted with electrodes and filled with sodium chloride solution. Electrical connections were made to the power supply having an ammeter and a voltmeter in the circuit. Some experiments were also performed by using potassium dichromate (2.5g/l) to prevent the loss of hypochlorite produced due to chemical reaction in the electrolytic cell. The electrolytic products were collected through the outlet at an interval of 20 minutes for analyzed. The products were analyzed by iodometric methods[8]

A manually controlled power supply was used having an output of 0-15 A and 0-30V. An ammeter having the range 0-15A and a voltmeter ranging 0-30V were used. Stainless steel wire was used to hang the electrodes from the top. The anodes of all the cells were connected in series by a conducting wire to the positive pole and all the cathodes to the negative pole of the power supply via an ammeter and a voltmeter in the circuits. The box used for electrolysis consisted of two connections to the outside of which one was used as inlet of electrolyte to the cell and the other was outlet which was used to collect the samples for analysis as well as to drain the electrolyte.

Result and Discussion

In the present investigation it was aimed to study power consumption, current efficiency, concentration of electrolyte, temperature and with or without the addition of dichromate to the electrolytic solution for optimum production of sodium hypochlorite. Most of the experiments were carried out at the concentration of 4.0 molar sodium chloride solutions, although some experiments were carried out at other concentrations. This concentration has been

recognized as the concentration suitable for the optimum production of sodium hypochlorite industrially[1-3]. Precautions were taken so that any unreacted chlorine, produced during electrolysis could not escape. To prevent the consumption of hypochlorite to the chemical formation of chlorate, the electrolysis was carried out at low temperature and at high p^H (p^H>9).

Hypochlorite was produced at different operating current density. The operating current density was varied from 187.5 Am^{-2} to 750 Am^{-2}. The variation of concentration of sodium hypochlorite with time at current density 250 Am^{-2}, 500 Am^{-2} and 687.5 Am^{-2} are shown in figures 2 and 3 respectively. It is observed from figures 2 and 3 that the production of sodium hypochlorite increases with increase of time up to certain period and then it decreases. Figure 4 shows that the variation of concentration of sodium hypochlorite with time at temperature 22°C and 33°C. It is found from the figure 4 that low temperature favors the formation of sodium hypochlorite. The variation of current efficiency of sodium hypochlorite production with time is shown in figure 5. This indicates that the current efficiency of hypochlorite remains almost constant up to certain period and then it decreases with time. The decrease of current efficiency for hypochlorite production is due to the oxidation of hypochlorite to chlorate. The concentrations of hypochlorite have been plotted against time in figure 6 at current density of 625 Am^{-2}, at the condition of with or without the addition of dichromate. The amount of sodium hypochlorite production increases due to the addition of dichromate and current efficiency also increases. However, power consumption of sodium hypochlorite production is reduced due to the addition of dichromate. During electrolysis there is a chance of reduction of hypochlorite to chlorate, which was usually avoided by the addition of dichromate. Dichromate forms a thin film of chromium oxide on the cathode surface, which reduces the reduction of hypochlorite and hence increases amount of hypochlorite production. The variation of current efficiency with current density is shown in figure 7. It is observed from the figure 7 that the maximum current efficiency was found to be 91.06 % at current density of 625 Am^{-2}. Figure 8 shows the variation of power consumption with time. The power consumption almost remains constant for certain period and then increases with increase of time because the rate

of electrochemical oxidation of hypochlorite to chlorate increases. The minimum power consumption was found to be 177.21 KWhr/ton for the maximum production of sodium hypochlorite.

Conclusions

The maximum current efficiency obtained in this investigation was 91.06% at current density of 625 Am^{-2} at 22^0C using dichromate to the electrolyte and the minimum power consumption was found to be 177.21 KWhr/ton for hypochlorite production. The cell is of simple geometric shape, ease of design and can be easily constructed, so it can be setup industrially. Chlorine gas can also be collected easily by this procedure and from this chlorine gas we can prepare hydrochloric acid, ammonium chloride, bleaching powder etc.

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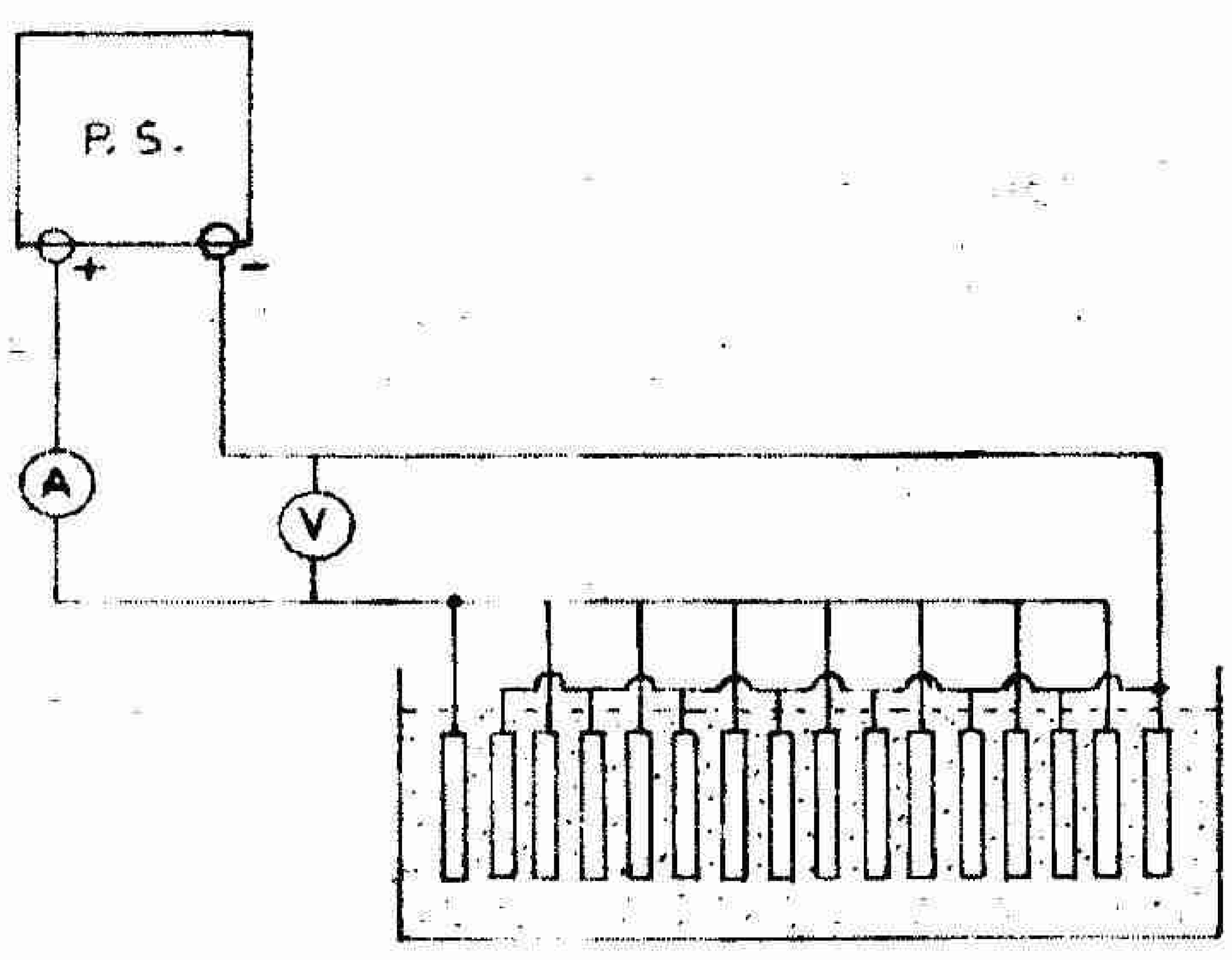

Fig. 1. Setup for Electrolytic Cells

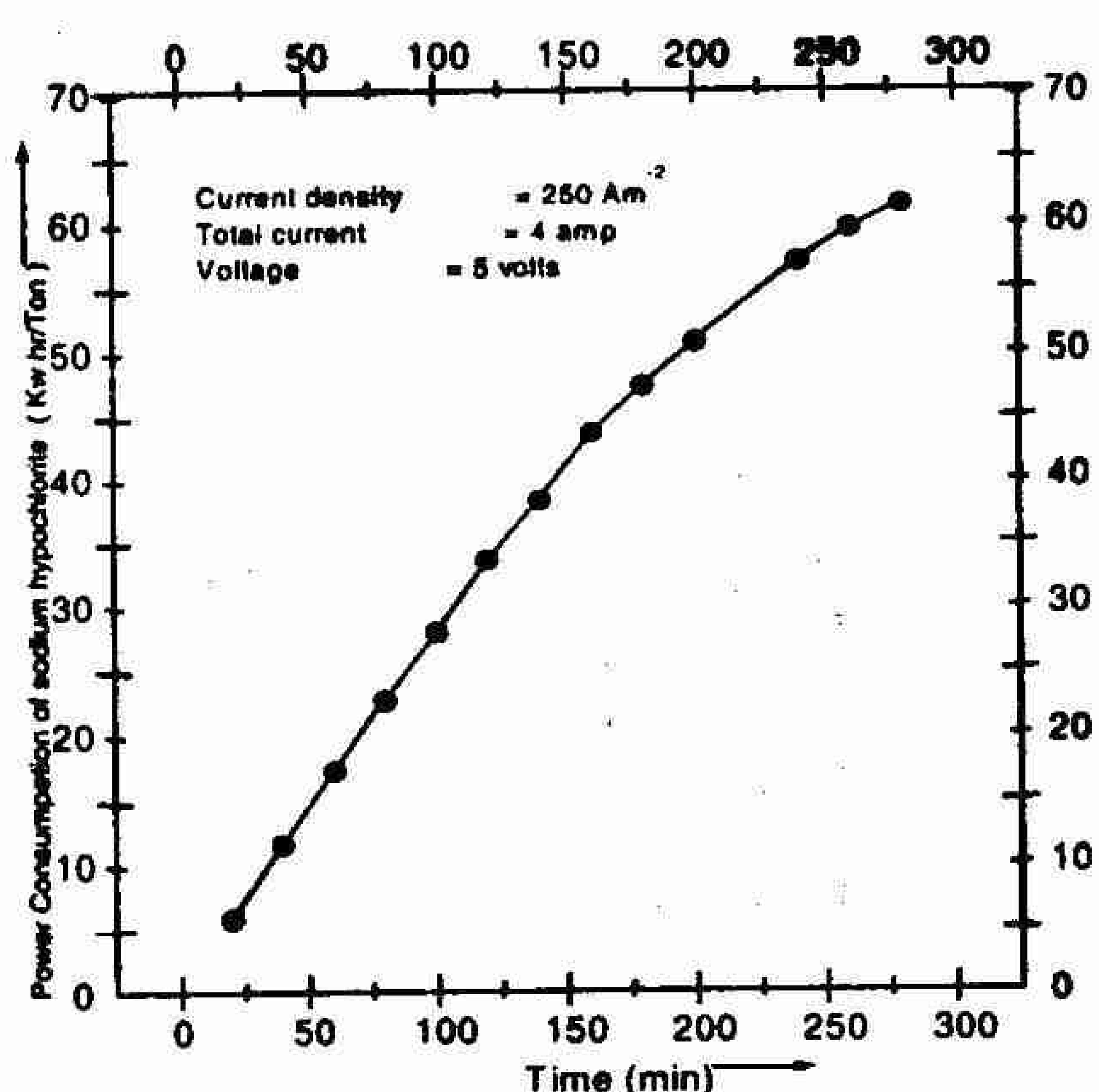

Fig. 2. Variation of Concentration of sodium hypochlorite with time

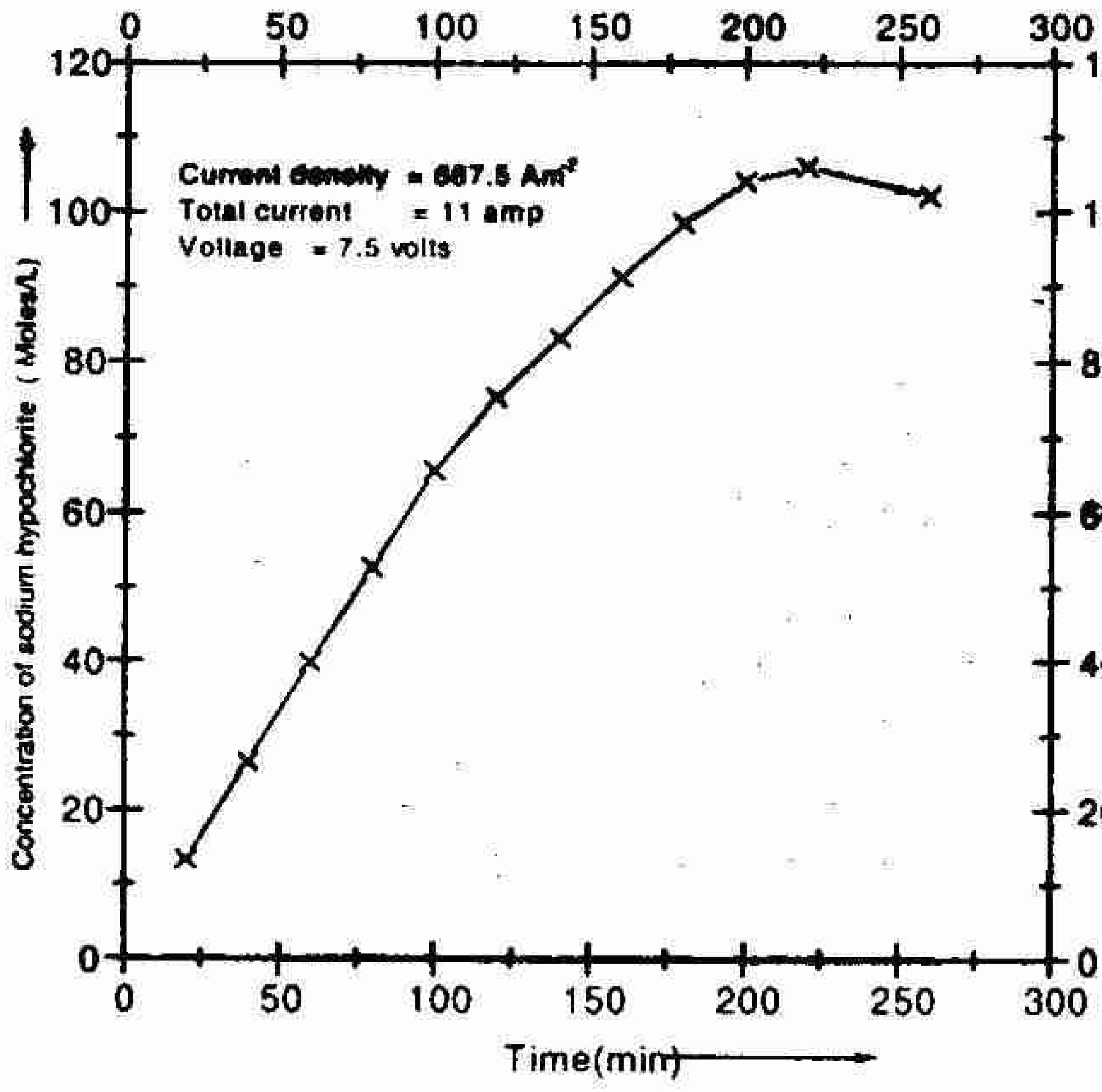

Fig. 3. Variation of Concentration of sodium hypochlorite with time

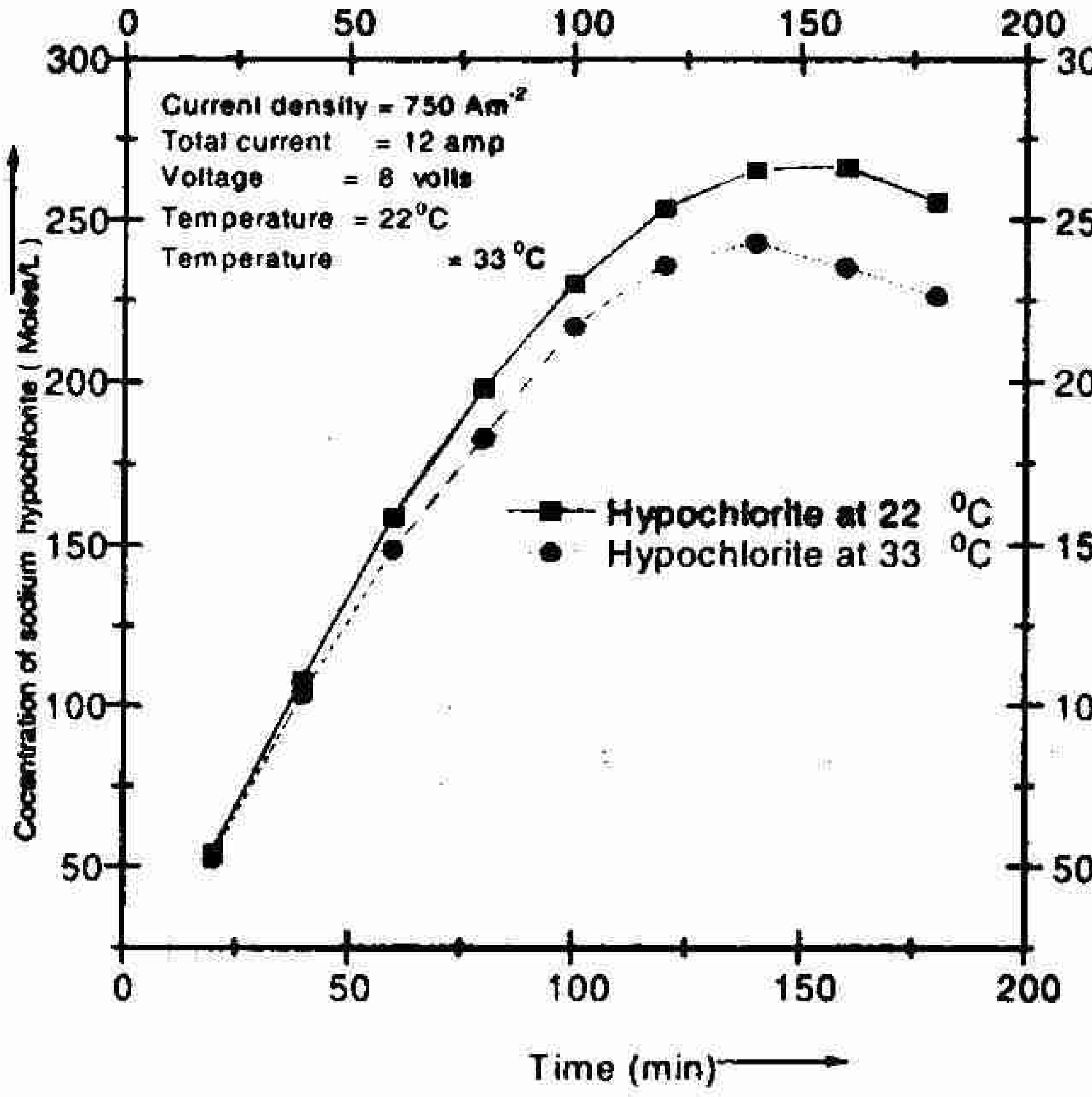

Fig 4. Variation of concentration of sodium hypochlorite with time at different temperatures

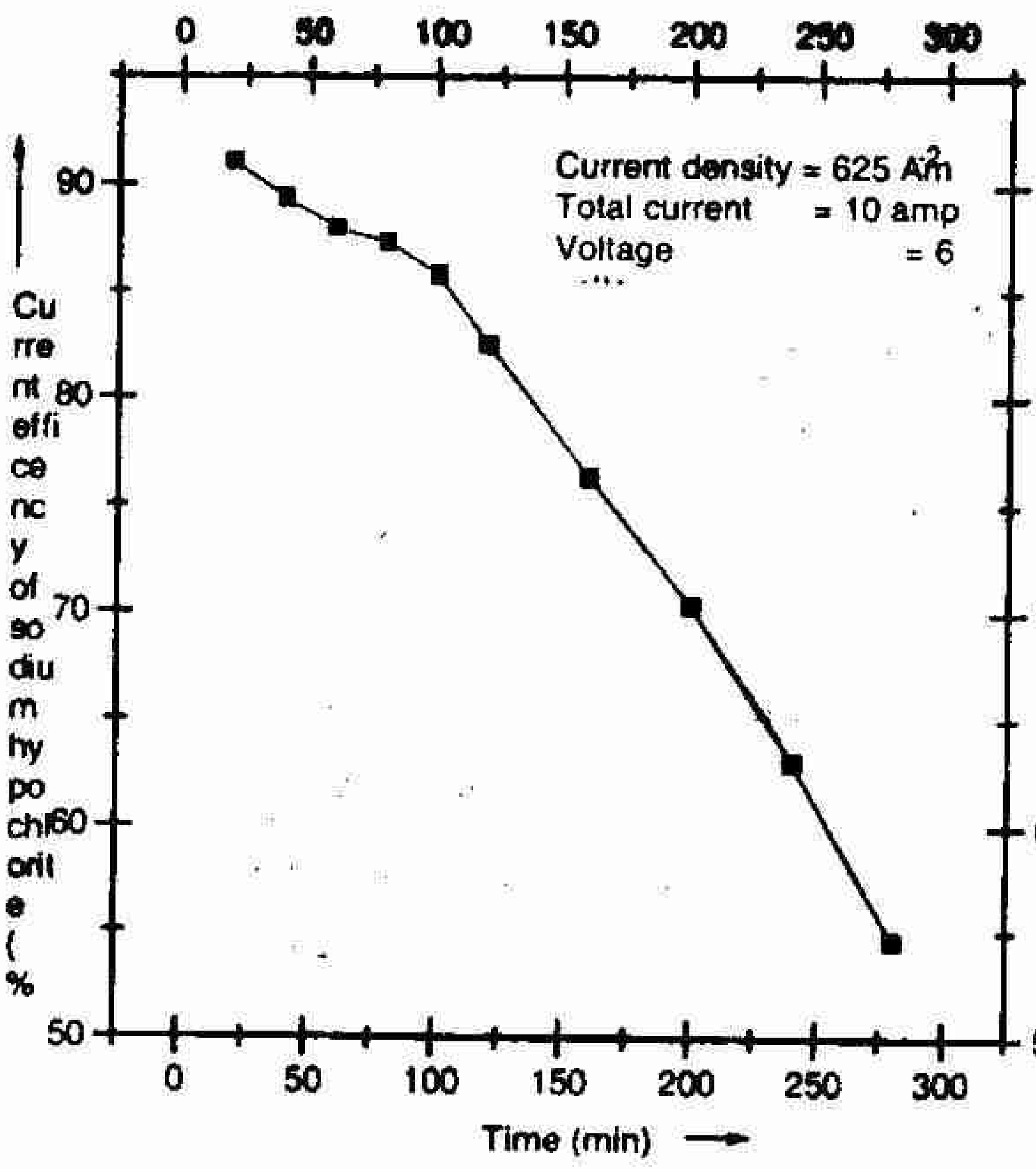

Fig. 5. Variation of current efficiency with time

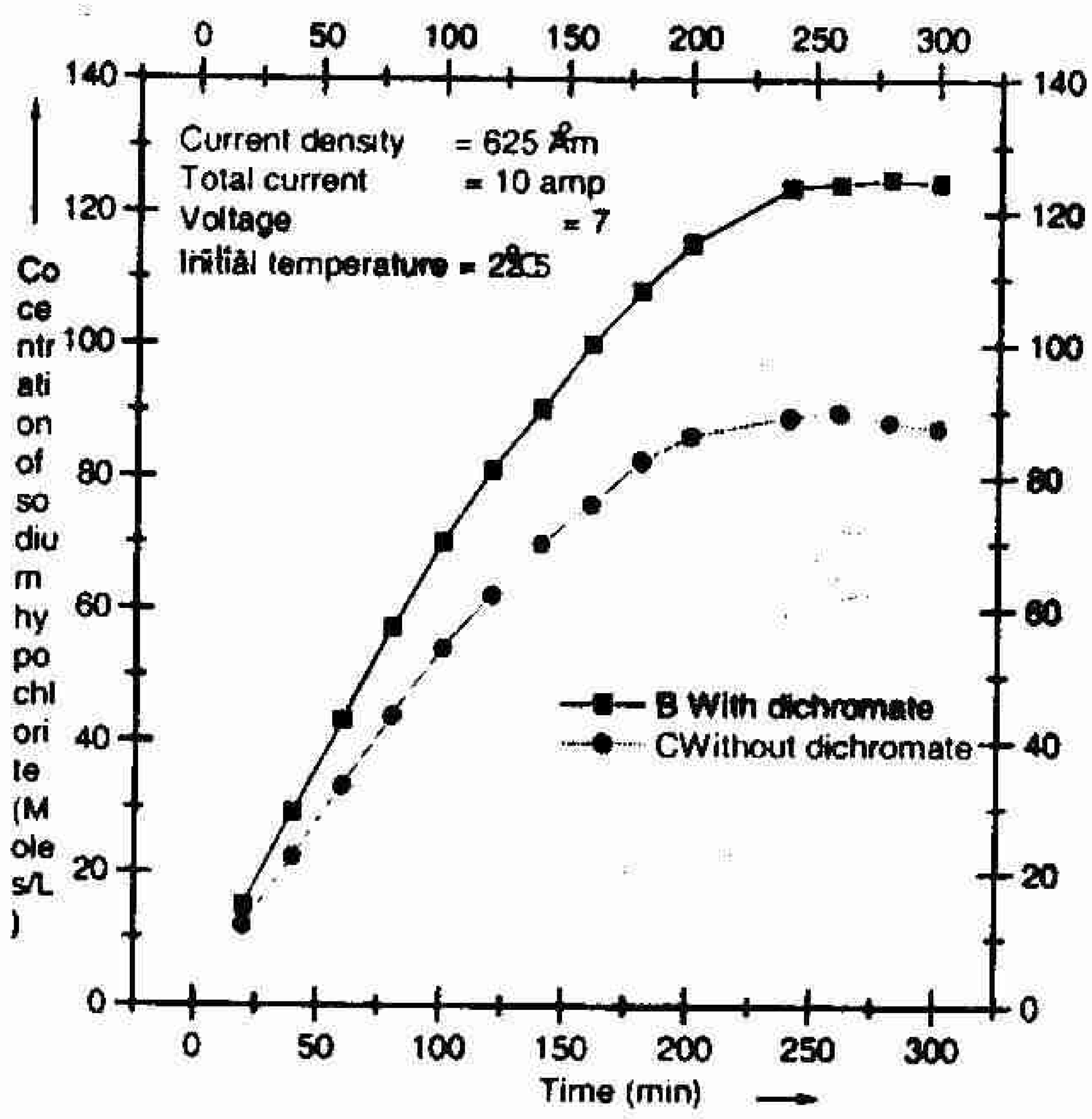

Fig. 6. Variation of concentration of sodium hypochlorite with time

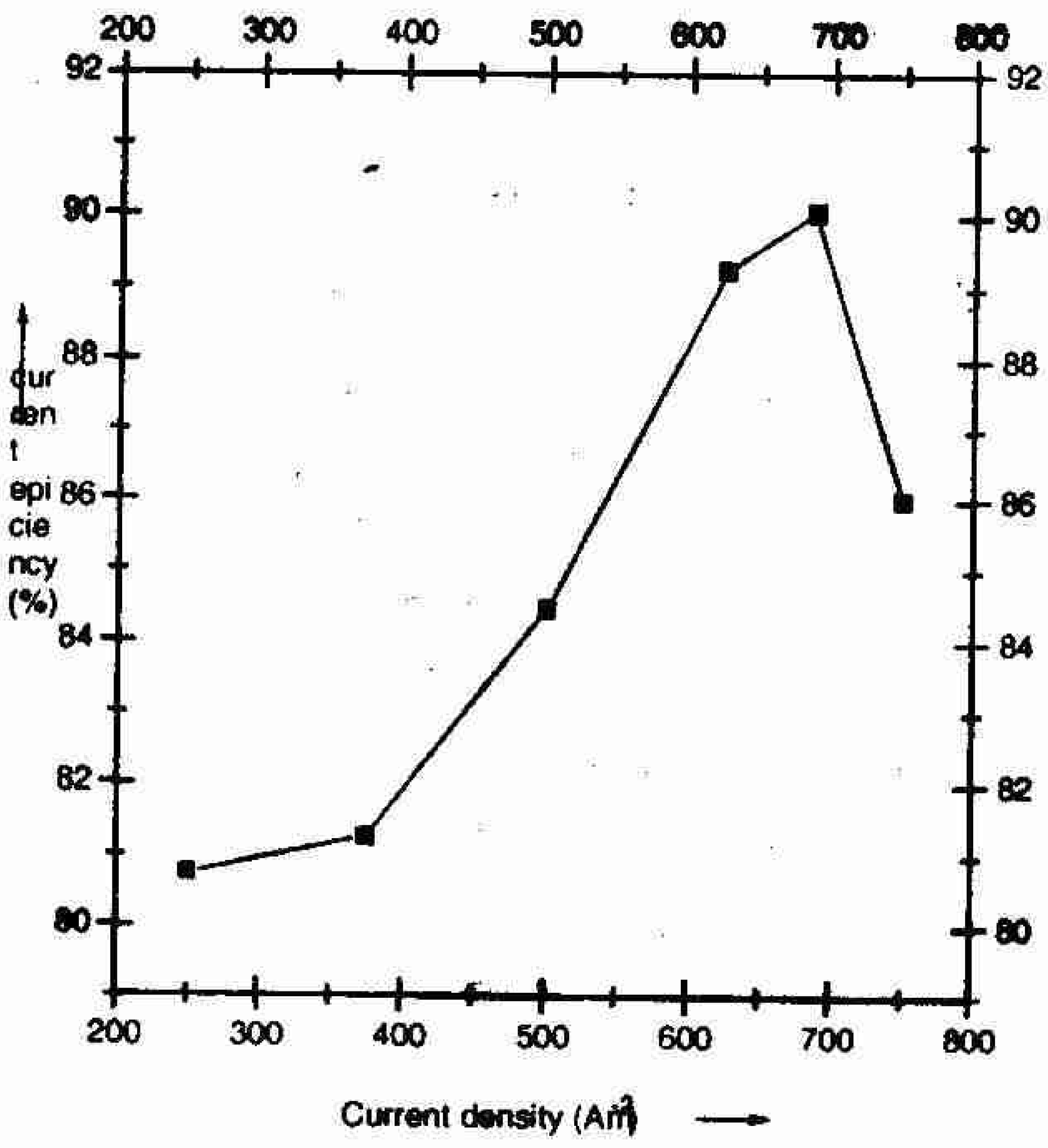

Fig.7. Variation of current efficiency with current density

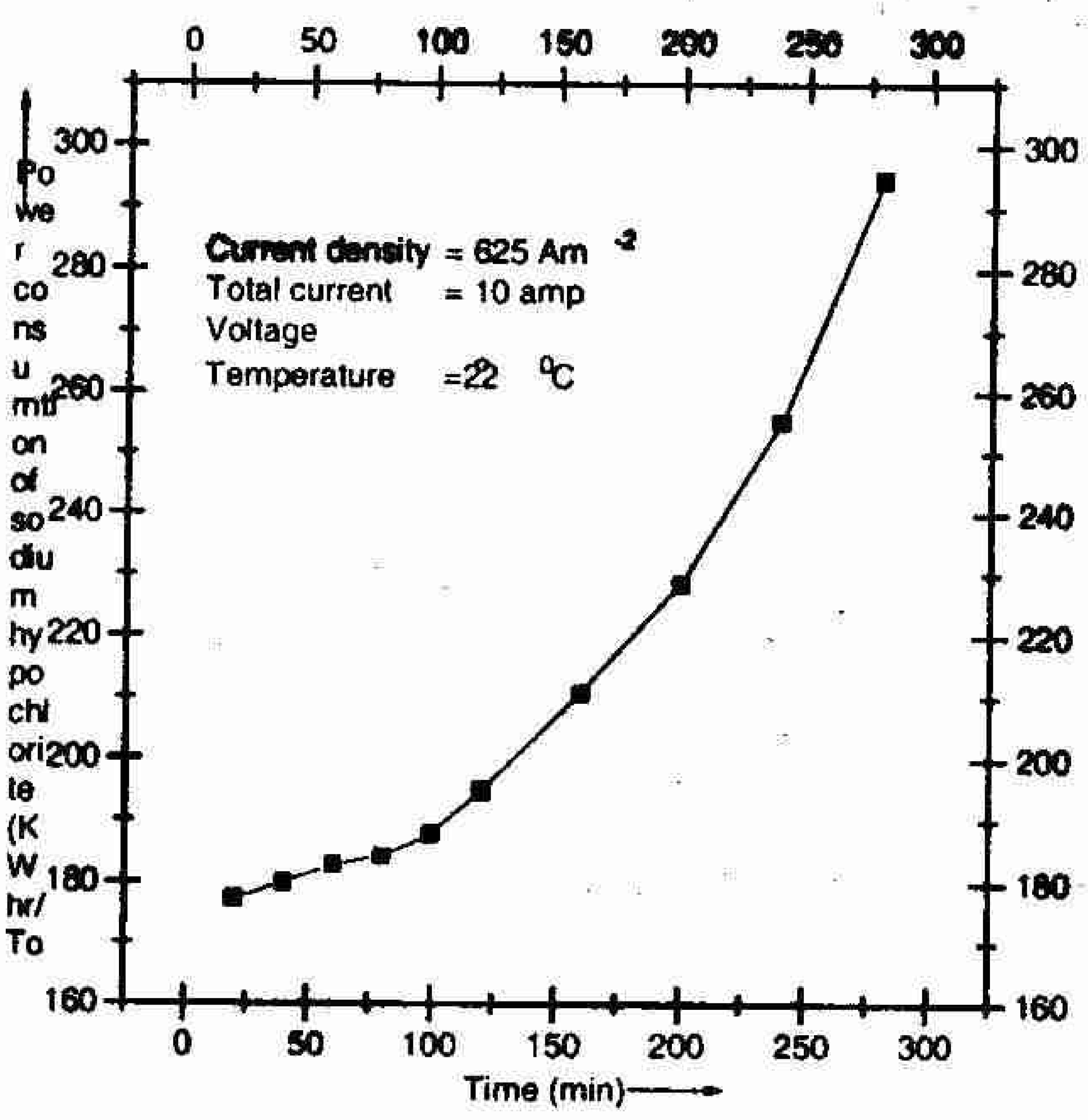

Fig.8. Variation of power consumtion with time