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Distr.
LIMITED

ID/WG.73/1
20 July 1970

ENGLISH
Original: SPANISH

United Nations Industrial Development Organization

Seminar on Tin Plate Production
Santiago, Chile, 9 - 13 November 1970

TIN PLATE PRODUCTION IN MEXICO [1/]

by

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1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO.

id.70-4056

DO 13

Page

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INTRODUCTION

At the request of the Metallurgical Industries Section of the United Nations Industrial Development Organization, Altos Hornos de México, S.A., a fully integrated Mexican iron and steel enterprise, commissioned me to prepare and present at the present Seminar on Tin Plate Production this paper giving a survey of tin plate production and describing experience in the selection, installation, start-up and operation of electrolytic tinning lines.

This experience is based exclusively on observations made since production was begun in our plant, which is responsible for meeting the tin plate requirements of Mexico, now estimated at 170,000 tonnes per annum, but expected to increase to 270,000 tonnes per annum over the coming five years.

We hope that the paper which we are presenting will be of help to some of those present and that others, after becoming acquainted with its contents, will be able to give us guidance to enable us to obtain better production results with our facilities.

I should like to express my gratitude to the sponsors of this Seminar for having given us the opportunity to benefit from this interesting exchange of experience and also to thank those whose help has made it possible for me to present this paper to you.

I. REASONS FOR THE USE OF TIN PLATE

The problem of obtaining food has always been of vital concern. Clans, tribes, and whole nations have migrated in search of food. At first, food was obtained my means of hunting; as civilization advanced, animals were domesticated and crops began to be grown. It was very soon appreciated that food must be preserved, and it was therefore salted, smoked, etc., but it lost its flavour and often spoiled.

In 1797, Napoleon offered a prize for anyone who could discover a method of preserving food. After much experimentation, the secret of cooking food, packing it in sealed glass jars and then boiling the jars was discovered. In 1810, the use of tin plate containers for food preservation was patented in England, and this marked the beginning of the tinned food era.

II. ORIGIN AND DEVELOPMENT

Because of its exceptional affinity for iron and steel and its great resistance to attack by oxygen, tin has become an indispensable anti-corrosion element.

The manufacture of tin plate was first developed in German States and the first experiments and progress took place from approximately 1240 to 1600, opening up what might be called the initial phase in the industrial development of tin plate production. Approximately 150 years passed before the first tin plate was produced in America by the immersion system, and it was not until 1937 that electrolytic tin plate was first produced on an industrial scale.

III. DEVELOPMENT OF ELECTROLYTES FOR TIN

The advent of the new continuous process for the production of electrolytic tin plate aroused great interest owing to the many technical and economic advantages of this process which made a spectacular increase in the use of electrolytic tin plate a certainty. One of the main technological advantages is the fact that the tin coating can be deposted in a controlled manner to any desired thickness and that it is easy to carry out differential plating of the strip, thus enabling the consumer to select, for example, a thicker coating for the inside of the can and a thinner one for the outside, where corrosion resistance requirements are less exacting.

Since tin salts are amphoteric, tin can act as either an acid or a base in the formation of its compounds, and hence can be electrodeposited with either an acid or an alkaline electrolyte.

The essential requirements for an electrolyte for the production of electrolytic tin plate are: low cost of the make-up solution, high productivity, high current efficiency, wide range of operating currents, low ohmic resistance and good chemical behaviour. The electrodeposted tin must be bright, cohesive and capable of being melted to form a glossy coating.

The three most important electrolytes now being used in the production of electrolytic tin plate are based on stannous sulphate, alkaline stannates and stannous halides. A fourth - tin fluoborate - is of limited application.

Investigation of acid electrolytes has been primarily directed towards the search for additives capable of producing cohesive deposits. After much investigation, it has been concluded that three types of additives must be combined: an aromatic sulphonate compound such as cresol-sulphonic acid to stabilize the solution by retarding oxidation, a protective colloid such as gelatine, and a hydroxy compound such as naphthol. In the actual production of electrolytic tin plate, phenol-sulphonic acid is generally used instead of cresol-sulphonic acid for economic reasons, and dihydroxydiphenyl sulphone is used instead of gelatine and naphthol, since the latter are not readily soluble in the bath.

IV. SELECTION OF PROCESS

All electrolytic tinning processes are designed to produce an acceptable product, but there are various factors which give each process some technological or economic advantage; similarly, each process has certain disadvantages in comparison to the others, that the decision to adopt a specific process must be based on certain economic and technological considerations and factors such as the capital to be invested, the expected production and market, etc.

In general, the processes can be divided, according to the type of electrolyte used, into acid and alkaline processes and, according to the type of installation, into vertical and horizontal processes.

Advantages in using an alkaline electrolyte

No additives are used, and control of the electrolyte is therefore simple.

The electrolyte does not corrode mild steel, and the construction materials for the installation are therefore cheap.

The electrolyte acts as a cleaning agent, and therefore the preliminary treatment section is simplified.

Advantages in using an acid electrolyte

The tin is deposited as a divalent stannous ion, in contrast to the tetravalent stannic ion deposited in the alkaline process, and hence the number of coulombs required to deposit a given weight of tin in an acid line is approximately half that required in an alkaline line.

Much higher current densities are possible, and the total electrode area required is therefore smaller.

The efficiency of the plating current is greater.

From the point of view of the plating operation, a vertical line provides better control over the tin coating at the edges of the strip than does a horizontal line.

Most of the high-speed lines, i.e., those running at 1,750 feet/minute or more, have been built as horizontal lines and it is probably true that the simplicity of the path followed by the strip reduces design difficulties as well as some problems of high-speed operation: something of great importance in the case of very thin strip.

To begin with, most of the vertical acid lines were constructed with the shears and sorter in the same line, and this was the most important factor limiting their operating speed. However, many of these lines have been altered by the installation of a coiler, thereby making it possible to increase operating speeds considerably, and the new vertical lines now embody innovations designed to secure maximum operating speeds.

It has been maintained that there is no appreciable difference in terms of capital investment per tonne of capacity between the three types of lines - alkaline, vertical acid or halogen. Since horizontal halogen lines are designed to operate at high speeds, they are generally installed to produce large tonnages, and the capital investment is relatively high. Until recently, the minimum installed capacity for economic operation of such lines was 250,000 tonnes per annum, compared to a minimum of 100,000 tonnes per annum for a vertical acid line. At the beginning of the 1960's, however, a halogen line with an annual production capacity of 40,000 tonnes and one or more new vertical acid lines of 30,000 tonnes capacity were installed with satisfactory commercial results.

As already mentioned, each process has technological and economic advantages and disadvantages in comparison to the others, but since all three processes give an acceptable product and it is really questionable whether one process can be selected for its technological advantages over the others, as none of them is sufficiently attractive to be considered universally preferable, I believe that the economic and market aspects should be analysed, for this will enable us to determine directly which process has the best attributes, bearing in mind the capital available for investment and the market which can be expected.

In 1946, for the first time in Mexico, tin plate production by the hot-dip system was initiated by Altos Hornos de México, S.A., which installed three machines with an annual production of approximately 12,000 tonnes. Later on, two additional machines were installed, increasing total annual production to 20,000 tonnes. In the mid 1950's, in view of the fact that the tin plate market was steadily expanding because of the growing industrialization of the country, the possibility of installing an electrolytic tinning line was considered, the idea being to produce more and cheaper tin plate for the manufacture of bottle caps, tin cans, etc., where the product to be packed did not require the use of hot-dip tin plate. At that time, tin plate for such uses was being imported.

Market statistics indicated that current and future electrolytic tin plate consumption was quite encouraging and that it would therefore be worthwhile to install a line with an initial annual production capacity of approximately 40,000 tonnes which could cover the country's requirements for about 10 years from the time when it began to operate.

The decision to install the line was taken in principle, and careful investigations were undertaken to select the process most suitable for our conditions.

Right from the beginning of the investigations the halogen process was ruled out, not for technological reasons, but because this type of line was designed to operate at a minimum of 1,000 feet/minute, i.e., to give an annual production of approximately 150,000 tonnes, which much exceeded our intentions. Moreover, the process was as yet not very well known.

Next, the alkaline process was also eliminated for several reasons. Firstly, it was still in the development stage and operating speeds were low; secondly, the electrolyte had disadvantages compared with acid electrolyte; and thirdly, it was impossible to halt the strip while passing through the plating tank, since the greenish yellow film covering the anodes would dissolve in that case, resulting in a substantial amount of wastage until correct plating conditions were restored. The restoration of acceptable quality after the film has disappeared is a problem when sodium stannate is used as an electrolyte, but it ceases to be one in the case of potassium stannate electrolyte which, in addition to permitting immediate restoration of plating quality, has other advantages such as being usable over wider concentration ranges, permitting considerable increases in current density, and producing a better result at higher temperatures. This has been demonstrated in several lines at present using this electrolyte.

The process which best met our economic and technological requirements was the vertical process using stannons sulphate in an acid electrolyte. This process gives lower operating costs, easier operation, better control of the tinning at the edges of the strip, fewer problems with the electrolyte, and high flexibility of operating speed, satisfactory operation being possible at speeds between 250 and 900 feet/minute, (equivalent to annual outputs of 40,000-150,000 tonnes), with operating costs decreasing as the maximum speed is approached.

It was thought that some operating difficulties could still arise in connexion with the need to move the strip through the line at the required speed and to maintain adequate control of the plating solution. In the former case, for example, if the strip was out of perfect shape it might snap or incline to the side, etc., causing the line to stop, while in the latter case additions would have to be made in order to maintain control of the plating solution. When these problems were analysed, however, it was found that the passage of the strip through the line did not result in serious difficulties or substantial wastage because the amount of strip in the plating tanks at any given time was very small and proper product quality could easily and quickly be restored when the line was again started up. As far as control of the plating solution was concerned, the additions which had to be made to the electrolyte did not present a major problem since their precise timing was soon learnt from experience.

Thus, the final decision was taken and the sulphate acid electrolyte process was selected for the establishment of a vertical line designed to operate initially at an annual capacity of 40,000 tonnes, with provision for subsequently increasing production in keeping with market growth.

V. INSTALLATION

The following factors must be taken into consideration in the installation of an electrolytic tinning line:

The equipment installed must be of a quality which ensures proper functioning of the line and be purchased from manufacturers with adequate experience in each speciality, since some items of equipment such as the rectifiers, melting tower, x-ray equipment, hole detector, oiler, classifier, etc., are of decisive importance for obtaining good operating results.

Free areas should be deliberately left at the most appropriate points in the line, to provide for future expansion which may become necessary in order to increase production.

Other essential factors are: location of the line to suit the flow of materials; a building large enough for the handling of materials; selection, checking and packing areas with the necessary ventilation and light; facilities for handling raw materials and scrap from the line; electric power, gas and water supplies of the required quality; steam, compressed air and drainage etc. lines; auxiliary equipment such as travelling cranes, lifts, ventilation systems, etc.; auxiliary services such as laboratories for physical and chemical testing, preventive maintenance facilities, shops for the manufacture of anodes, etc.

Underground areas adequate for the handling, preparation and recirculation of solutions, the installation of hydraulic systems, etc., must be provided. In similar, but preferably separate, underground areas electrical equipment such as transformers, motor-generator sets, rectifiers, switch panels, etc. should be installed so that they can be maintained at the necessary special conditions of temperature and cleanliness.

It must be very much borne in mind that the water supply for the lines must not only be adequate in quantity but must also be of the highest possible quality and purity, since some solutions and treatments make this indispensable. When the amount of water available is not sufficient to permit total renewal with fresh water, it is recommended that recirculation pumps should be installed, for example, for the strip cooling water in the melting tower, for the final rinsing of the strip, etc. Care must be taken, however, that the water does not become so contaminated as to reduce the quality of the finished product.

Having discussed the importance of the quality of the equipment to be installed, we cannot neglect pointing out the importance of the capability of the staff responsible for construction, which should at the very least have had experience in installing equipment similar to that of tinning lines.

VI. STARTING UP OF TIN PLATE LINES

To start up a line once it has been installed, all the necessary mechanical and electrical adjustments must be made to each piece of equipment forming part of the line, each item of equipment being tested at first separately and then all together in order to ensure reliable operation. The correct manufacture, cleanliness and levelling of all rollers, the correct manufacture and adjustment of the anodes, and the correct operation of the temperature gauges for maintaining each solution within the required temperature ranges must be verified. The main problem is then to run the strip through the line until the desired speed is reached For this to be achieved, the strip must be delivered in a properly flat condition and without any other defects which might further complicate the operation. If the line is to start operating successfully, the operating staff must also have received proper preliminary instruction.

If the items enumerated above have been borne in mind, the starting up of the line should not present any problem.

VII. OPERATION OF TIN PLATE LINES

The quality of electrolytic tin plate does not depend solely on the operation of the tinning line, but rather on a chain of processes which can be said to originate in the steel furnaces.

From the time when the steel is emptied out of the steel furnaces to cast the ingots, and throughout the subsequent processes preliminary to tinning, quite a large number of surface defects may arise, and if these are not eliminated or corrected they can cause serious problems which it is entirely impossible to correct in the tinning lines, even when these are operating under optimum conditions.

Usually, defects orginating in the steel furnaces and the rolling operations, such as laminations, spalls, surface laminations, rolled scale, scabs, etc. are detected in the pickling line, with the exception of lamination, which is generally eliminated in the blooming mill during the slab phase. The other defects are not easily detectable until the scale has been removed in the pickling process.

It is in the subsequent processes of pickling, cold reduction, cleaning, annealing and tempering that most of the defects affecting the quality of tin plate arise. In the pickling process, defects such as grooves, scratches, marks, etc., which may cause holes in subsequent processes are easily detected, and can be prevented by proper supervision. In the reduction process, defects such as marks, faulty shape, deviation from the proper gauge, etc. can also be detected with relative ease, making possible their elimination by proper supervision, but the elimination of the reducing oil in the following process presents a difficult problem for the supervisor, so that close contact must be maintained between the rolling mill supervisors and those of the cleaning line. The best guarantee for obtaining sufficiently clean strip from the cleaning line is constant operation of the line under optimum conditions and washing of the coils not more than 24 hours after their reduction, with, in addition, constant attention to maintaining the cleanliness of the strip through the use of sufficient paper towelling, adhesive tape, etc. In the annealing process, if a good reducing atmosphere such as HN or HNX is used and temperature control is good, there should be no major problems. It is the tempering mill which is basically responsible for ensuring that the strip is of sufficiently accurate dimensions to enable it to be run through the tinning lines at the required speed with a constant uniform gap between the strip and the tin anodes in the tinning tank. The gap must be constant because if the current density varies, so will the thickness of the tin coating. The strip must be sufficiently flat, not only for the requirements of the tinning lines but also because with every passing day, customers are also modernizing their own equipment to operate at higher speeds.

As already stated, good tin plate quality does not depend fundamentally on the operation of the tinning lines, but rather on the quality of the steel strip, and the leading tin plate enterprises have therefore not only taken steps to ensure better strip quality during the processes preliminary to tinning, but have installed preparation lines for the purpose of almost completely eliminating certain defects such as holes, deviation from gauge, faulty shape, etc., which it has not been possible to eliminate at an earlier stage. This further facilitates the plating operation. Furthermore, the preparation lines, which are equipped with side trimmers, can edge strip at speeds up to 6,000 feet/minute, thus eliminating the problem of limitation of speed in tinning lines where side trimming can be accomplished at a maximum of 600 feet/minute.

A medium-speed electrolytic tinning line generally consists of an entry section comprising uncoilers, double cross shears, a welding outfit, side trimmers between the storage pits and a flange device (in some medium-speed lines, side trimming takes place in a preparation line). These units serve to provide a continuous feed of strip to the central section, which comprises cleaning, tinning and finishing areas where the strip is first cleaned by means of alkaline and acid processes, generally of the electrochemical type, and is then plated with tin, rinsed and dried, and the deposited tin flow melted to obtain a glossy finish, if desired, by one of the conventional conduction or induction systems, or a combination of the two. Immediately following the cooling of the flow-melted tin by immersion in water, a protective film is applied by passing the strip through an oxidizing solution acting by chemical or electrochemical means and then applying an extremely fine coating of oil either by means of an emulsion or electrostatically. Finally, in the exit section, the strip is inspected if it is to be coiled, or, if it is to be in sheets, it is cut, inspected, the sheets counted and stacked.

An electrolytic tinning line comprises a series of interlinked operations, and the precision with which these are carried out will partially determine the quality of the tin plate obtained. Production control testing can usually be divided into two types, i.e., control of the process to maintain optimum operating conditions, and inspection of the product, including visual and instrumental examination and quality control tests.

The most important tests for process control are those made at frequent intervals on the solutions and electrolytes. The samples taken from the cleaning baths are analysed to determine their acidity or alkalinity and to ascertain whether certain undesirable contaminants are present. The electrolyte is tested to ascertain its content of acid, tin in the form of stannous and stannic ions, and impurities such as iron which must be kept below reasonable limits are determined. The electrolyte rinse is also analysed to determine its composition so that it can be maintained at the desired level. The solutions used in the chemical or electrochemical treatment are tested for pH and analysed for chromates, dichromates, phosphates, etc. so that the required contents of those can be maintained. The temperatures of the solutions for cleaning, plating, quenching, chemical treatment, rinsing, etc. are continuously recorded to facilitate control. Tests or analyses are also normally performed to determine the amount and distribution of the oil film.

To achieve satisfactory operation of the electrolyte, several additives must be used for the purpose of hindering oxidation of the stannous (bivalent) tin, achieving strong and compact deposits and improving adherence. These additives are used in such small proportions that it is not feasible to determine them analytically, however, and a test which is related as directly as possible to the plating process, such as tests using the Hull cell or the circulating electrolyte cell, are therefore employed. The circulating cell is most appropriate for this propose because it almost perfectly duplicates the operating conditions for plating, the solution being circulated between the anode and the cathode at speeds related to those of the tinning line. This type of cell can be used for routine tests, but is especially suitable for making detailed studies of electrolyte composition and for research work. At present, it is virtually never used for routine testing.

In addition to carrying out all the above-mentioned tests and analyses periodically in order to control the solutions for the various treatments, the electrolyte, etc., within the required ranges, the line operator must constantly check the finished product with the help of the inspectors, who determine its quality. The operator must also distinguish between defects originating in the steel strip and those originating in faulty tinning line operation, so as to be able to correct defects arising in the line itself immediately.

The operator must concentrate his attention primarily on the following factors which can affect tin plate quality. Good practice must be maintained regarding the preparation, adjustment and use of the tin anodes and other factors which may cause irregularities in the distance between the anodes and the strip. Otherwise, defects which take the form of dull stripes and run for considerable lengths in the finished strip may occur. Spots caused by incorrect temperature control of the water in the quench tank for the flow melted tin must be avoided. If the water is very hot or contaminated, irregular white spots may appear, and if it is very cold, the surface of the strip may acquire a dull finish. Care must also be taken, if the water is recirculated, to ensure that it remains clean so as to prevent salts and other contaminants from adhering to the tin plate. In fact, however, it is usually recommended that wherever possible the water should not be recirculated in this treatment. Another defect which is not exactly a spot, but where an area of the tin coating is dull rather than bright, is due to failure of the tin to flow-melt properly. If the unmelted area is relatively large, this is due to incorrect functioning of the melting tower, while partially melted areas may be caused by variations in the strip thickness or, more frequently, by the presence of moisture in the strip entering the melting tower (this can be corrected by adjusting the wringer rollers placed before the drying unit). Another interesting surface defect which is difficult to control because it is related to many variable factors, is that known as "wood grain", which appears most frequently in the lower layers of tin. The following line operation factors may be connected with this fault. Additive concentration has little influence; low tin concentration is a very important factor; current density in the pickling stage has a very significant effect; the speed of the strip has a moderate effect; high current density in the electrolyte plays little part; low electrolyte temperature has little effect; rinsing the strip in electrolyte solution reduces the tendency; and the speed of melting of the tin is important since slow melting encourages wood grain. Another very important matter which must be attended to is the problem of the small spots produced by arcing of the current between the strip and the feed rollers due to poor contact between the strip and the roller. This arcing sometimes results in holes in the strip. When these small spots are in the form of black blemishes surrounded by a whitish halo, they have most probably been caused by foreign bodies adhering to the feed rollers, with consequent arcing of the current; if there is no black blemish in the centre, the cause is generally small particles of tin adhering to the feed rollers. These particles adhering to the rollers are usually the result of incorrect plating conditions which result in weak adherence of the tin coating and its subsequent detachment. This can be avoided by keeping the feed rollers clean and maintaining adequate tension in the strip to provide good contact. While dealing with the problems which can be caused by the feed rollers, it should be added that it is not just the rollers which can be the source of difficulties: other parts can also cause them, the defects taking the form of marks, scratches, etc., which are primarily due to lack of cleanliness and, in some cases, to failure to synchronize speed with that of other rollers. Another factor which should receive adequate attention is the prevention of abrasion of the strip after application of the protective film by the chemical treatment, for such abrasion, which can be caused, in particular, by slipping of the exit tension rollers, damages the protective film and makes the protective treatment useless.

In describing these examples of defects, it is not intended to imply that these are the only ones which the operator shall be trained to look for: these defects are only mentioned as general examples and there are many other defects not mentioned here which may arise.

The tests to which the finished product is subjected to determine its quality can be divided into two classes, i.e, routine tests which make it possible to ascertain whether the line is operating under the required quality conditions, and special tests which are generally performed on tin plate intended for the packing of foodstuffs. The first class includes tests for hardness, tin coating, oil coating, discoloration, adherence of varnishes, solderability, moisture in the tin plate, etc., while the second class comprises tests for corrosion resistance, tin content in the ferro-alloy, free tin content, etc.

SUMMARY

The new continuous processes for producing electrolytic tin plate have awakened great interest owing to the number of technical and economic advantages which they offer, such as making it possible to deposit a tin coating of the desired thickness. These processes can be classified as acid and alkaline processes, the former presenting the greatest advantages.

It has been found that the capital investment per tonne of installed capacity does not differ appreciably between the three types of lines, i.e. alkaline, vertical acid or halogen, and all three produce an acceptable product.

In the mid 1950's, owing to the constant expansion of the market, the possibility of installing an electrolytic tinning line which could meet the requirements of the country for up to approximately 10 years ahead began to be considered.

In selecting the type of line, the halogen process was immediately ruled out because at that time it was only suitable for a large production capacity, while the alkaline process was also rejected for technological reasons and because it was still in the development stage.

The final decision was to adopt the vertical acid process and install a line with a planned initial production capacity of approximately 40,000 tonnes per annum.

Correct installation is of fundamental importance for proper line operation, and suitable attention must therefore be paid to the quality of the equipment to be installed; the location of the equipment to suit the flow of materials; the provision of areas within the line itself for future expansion; the planning of sufficient space in the building for the handling of materials, and the provision of adequate raw materials, services and auxiliary equipment, etc.

Before starting up the line, the correct installation and operation of all equipment must be checked. The main problem is that of running the strip through the line up to the desired speed, but this ceases to be a serious problem if the strip is sufficiently flat when fed in.

The operation of the line will be facilitated if the steel strip fed in is of good quality.

CONCLUSIONS

Most of the plants now producing tin plate started manufacturing by the old immersion system, and it was the constant expansion of the market which prompted the installation of electrolytic lines.

After the decision to install a line has been taken, an exhaustive study must be made in order to select the most suitable type, taking into consideration market requirements and the capital available for investment.

Proper functioning of the line will depend primarily on the quality of the equipment purchased, its proper installation, the arrangements made for flow of materials, auxiliary services, etc.

The quality of the product obtained will depend upon the condition of the strip and the operation of the line.

RECOMMENDATIONS

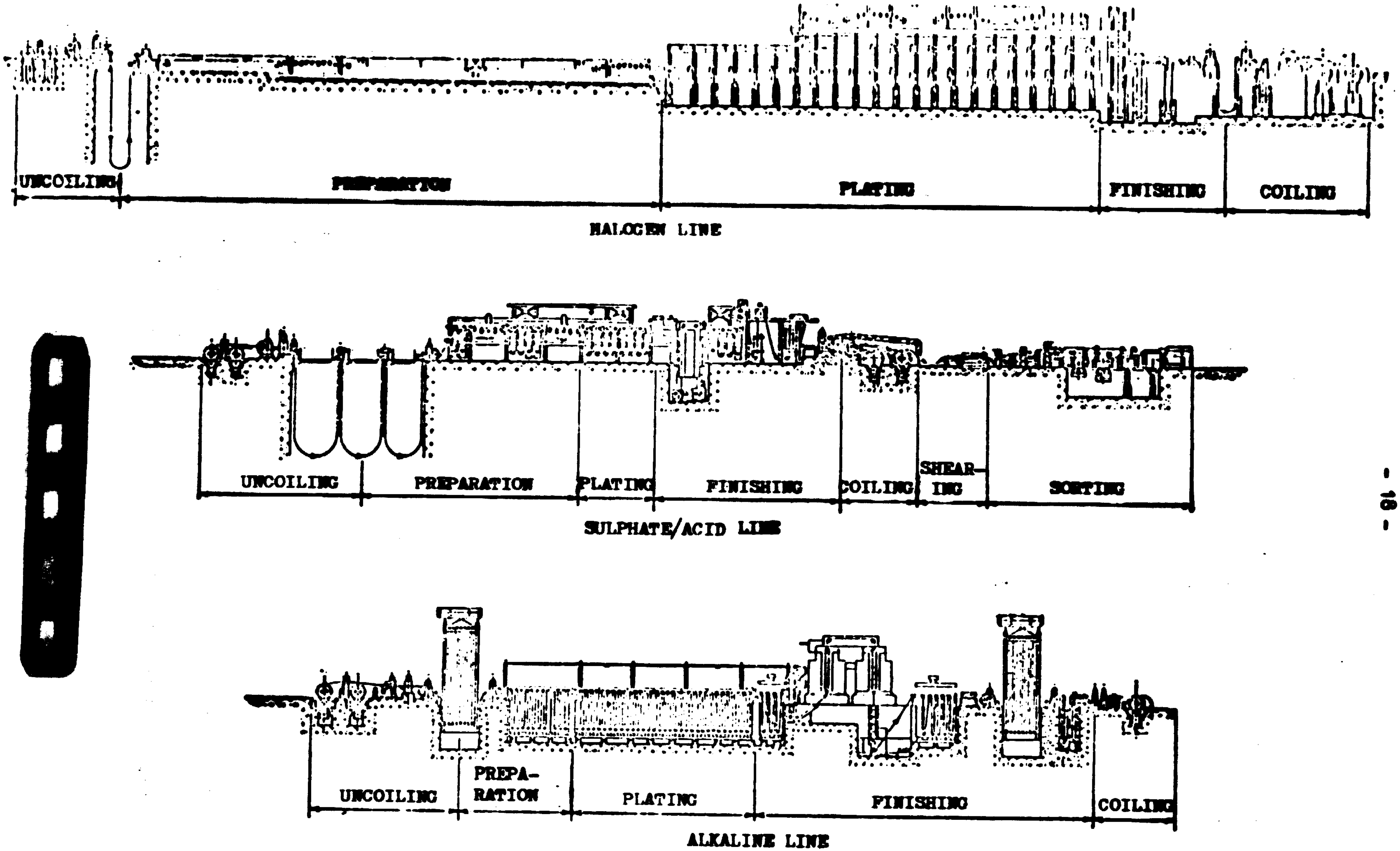
In order to take a decision regarding the installation of a line, full knowledge of the market and its future development is necessary.

At present, the general tendency is to install only lines of the acid type - horizontal halogen or vertical sulphate acid lines, with design speeds up to 2,200 and and 1,750 feet/minute, respectively. The ground lost by alkaline lines has been won by halogen lines. In world tin plate production, the vertical sulphate acid type of line continues to predominate, accounting for 65 per cent of total production, while the halogen type accounts for 30 per cent and the alkaline type for only 5 per cent.

The tin plate producers with vertical sulphate acid installations continue to show preference for these lines owing to the advantages to which they attach the most importance, such as the fact that these lines are cheaper to build and operate, easier to operate, provide better control of the tin deposit at the edges, etc. None the less, producers with halogen lines maintain that the operation of such lines presents no problems and that their operating costs are lower. There are two reasons for preferring the vertical sulphate acid process, however. Firstly, more experience has been gained in the use of this system all over the world for tin plate production, and secondly, the flexibility of the operating speed of lines running on this system makes it possible for installations to operate initially at low capacities. Nevertheless, it must be borne in mind that there are now halogen lines with a capacity of 350 feet/minute which provide nearly the same advantages.

For economic and market reasons, some new lines are designed to produce initially at low capacity, and in those cases it is advisable to make provision for future expansion of production capacity.

Since the quality of the finished product depends primarily on the state of the strip fed in, it is recommended that strict supervision should be maintained over the lines preceding the tinning line in order to avoid or minimize defects.



THE THREE MAIN TYPES OF ELECTROLYTIC TINNING LINES, DRAWN TO THE SAME SCALE

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