APPLIED SCIENTIFIC RESEARCH CORPORATION OF THAILAND

MISCELLANEOUS INVESTIGATION NO. 14
APPRAISAL OF LOCAL HOT-DIPPED TINPLATE

REPORT NO. 1
EVALUATION OF THAI HOT-DIPPED TINPLATE

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F O R E W O R D

The current annual demand for tinplate in this country is about 32,000 tonnes, of which about 25,000 tonnes are imported (see Appendix), primarily for the food packaging industry, and the rest of the demand is met by materials produced locally. The capacity of the only local producer is about 24,000 tonnes, but only a quarter of the capacity is being utilized since orders for tinplates from the food industry continue to be placed overseas. The main reason for this is attributed to the lack of confidence in the quality of the local product on the part of the food processing industry.

As part of the ASRCT programme to promote the use of local products and to provide technological support to local industry, ASRCT has been giving advice to the Thai Tinplate Company, Ltd., the sole local producer of tinplate, following a request made by the company for assistance in overcoming problems encountered in its operations. The investigation aims to evaluate the quality of the local tinplates and to recommend appropriate measures that might be necessary to maintain the quality of the products at a high level to meet the requirements for food containers. The present report deals with an evaluation of the quality of the tinplate produced undertaken in the course of this work.

EVALUATION OF THAI HOT-DIPPED TINPLATE

By Kasem Balajiva* and Suwat Riebroichareon*

SUMMARY

As part of an investigation to provide technological support to the local tinplate industry and to promote use of local products, samples of the Thai hot-dipped tinplates manufactured over a period of 4 months were evaluated. The criteria of the tests employed are based on recommendations of the International Tin Research Council, which have been universally accepted in industry. These criteria include general surface quality, chemical composition and mechanical properties of the steel base and tin coating weight. The tests have shown that the Thai tinplates are of satisfactory quality for application as containers for most items of food and other contents. In addition to the standard tests, a comparison of the corrosion resistance of the Thai tinplate and the imported material has been made and the Thai tinplates have been found to compare favourably with the electrolytic tinplates imported by some of the local food packaging companies.

INTRODUCTION

Tinplate is composed of low-carbon steel sheet or strip coated with commercially pure tin. The combination of these two materials gives the tinplate two outstanding properties: malleability for forming into containers and suitability for containers which will efficiently preserve and protect their contents. By virtue of these qualities, tinplate is widely used as containers for various kinds of food and other merchandise.

Tinplate is manufactured by either hot-dipping or electrolytic coating processes. The latter method is more economic when the produc-

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tion capacity is well over 100,000 tonnes per year. About 95 per cent of the world production of tinplate for food containers today is manufactured by the electrolytic process.

The hot-dip method is used when the demand for tinplate is smaller; the process consumes more tin, producing a heavier tin coating than the electrolytic method. In the case of Thailand where the demand is relatively small and the country is one of the main world producers of tin, the hot-dip method is considered appropriate. The hot-dipped tinplate has been accepted as a material for food containers by all standards institutions long before the introduction of electrolytic tinplates.

The properties of tinplates intended for food containers, where conditions are more stringent than for other applications, are usually specified between the consumer and the manufacturer. These properties include general surface quality, chemical composition and mechanical properties of the steel, and the tin coating thickness. Although various test procedures have been recommended by the various standards institutions, only the ductile quality of the tinplate appears to have been specified under different grades by the British Standards Institution. The basic requirements of tinplate quality generally adopted are those recommended by the International Tin Research Council and the evaluation presented in this report is based largely on these recommendations.

MATERIALS AND METHODS

The tinplates examined were of hot-dipped type. Fourteen samples of the plates made over the period from August to November 1968 were obtained and the details of the samples are given in Table 1. The samples were taken from the mill products after rejects have been extracted by the works quality control inspection.

Sampling schemes for tinplate sheets are usually based on a consignment or lot of 20,000 sheets and the sampling frequency depends on the tests required. Since it was not possible to follow such sampling schemes in the present investigation, the sample plates collected were taken at random from the works production line at different periods.

TABLE 1

LOCAL HOT-DIPPED TINPLATE RECEIVED FOR INVESTIGATION

Date received	Number of sheets	Lab mark	Temper grade	Substance (lb/basis box+)	Tin coating weight grade (lb/basis box+)	Dimensions of tinplate (wide x long x thick)	Intended application
6 Aug.1968	4	M14/1 M14/2 M14/3 M14/4	3	75	1.25	$28\frac{13}{16}$" x 33" x 0.215 mm or 733 x 839 x 0.215 mm	For local milk canning, as can bodies.
	4	M14/5 M14/6 M14/7 M14/8	4	80	1.25	$30\frac{7}{8}$" x 32" x 0.228 mm or 784 x 813 x 0.228 mm	For local milk canning, as can lids.
29 Oct.1968	1	M14/9	3	85	1.25	$20\frac{1}{2}$" x $28\frac{1}{8}$" x 0.254 mm or 512 x 715 x 0.254 mm	Selected quality for local pine-apple containers.
	1	M14/10					For local cigarette canning.
	2	M14/11 M14/12		108		$19\frac{5}{8}$" x $36\frac{1}{8}$" x 0.312 mm or 500 x 918 x 0.312 mm	For export to the Metal Box Co., Singapore, for pine-apple containers.
20 Nov.1968	2	M14/13 M14/14	3	80	1.25	$28\frac{3}{16}$" x $33\frac{15}{16}$" x 0.228 mm or 717 x 863 x 0.228 mm	For export to the Metal Box Co., Kuala Lumpur for milk canning.

+ Basis box: The unit of area defined as 112 sheets each 20 x 14 in or as a "nominal" area of 31,360 in^2 of sheets or coiled strip of tinplate of any size or gauge.

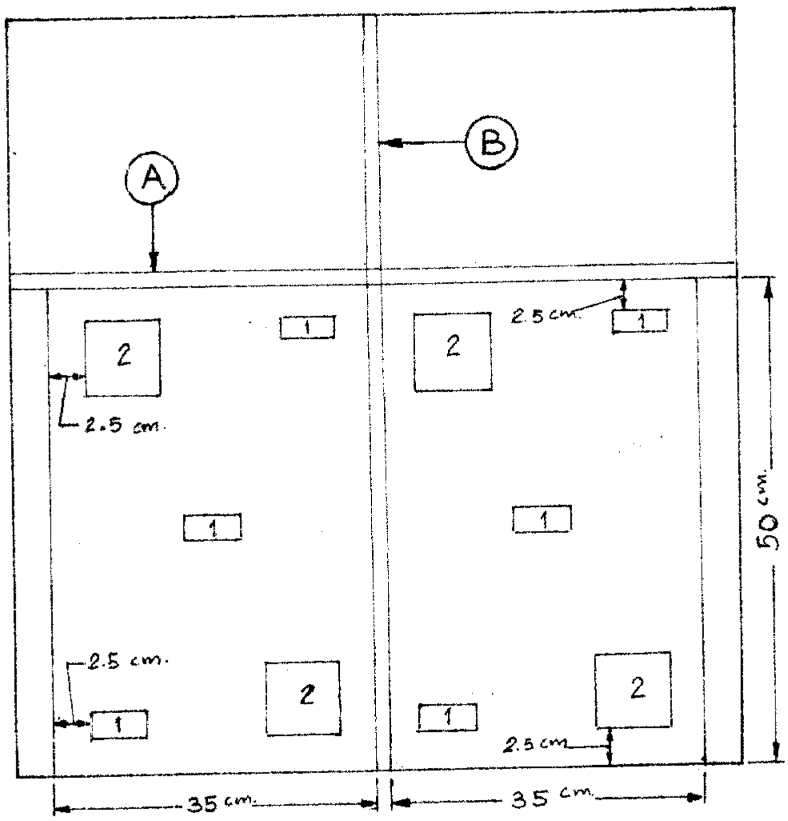
Each plate was then sectioned into standard areas from which test specimens were taken at locations shown in Figure 1. These specimen locations follow the recommendation of the Tin Research Institute (Hoare 1964).

Evaluation of the surface quality was based on careful visual examination together with micro-examination of several sections of the plates, which also indicates the direction of rolling of the steel, a property usually required to be known for can forming and fabrication purposes.

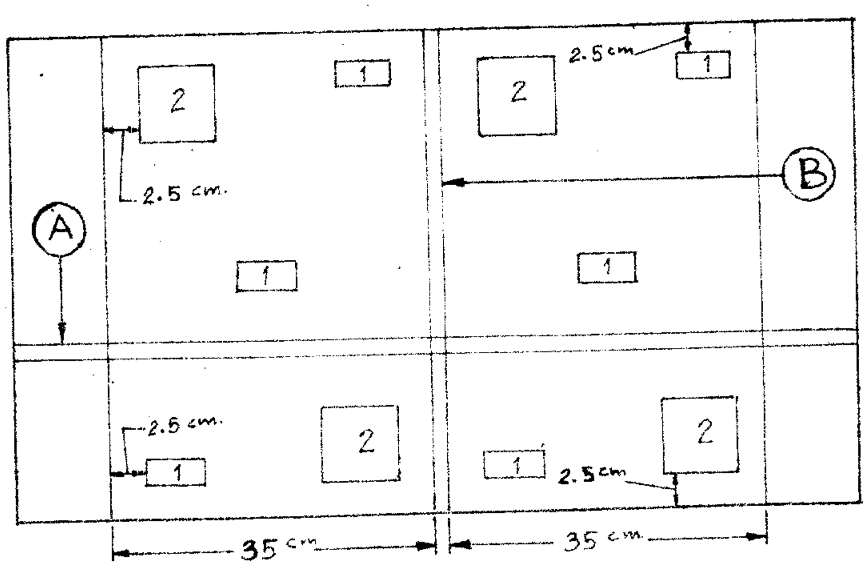
The mechanical properties of the steel base were assessed by the cupping test and indentation hardness test. Cupping tests are widely used to determine the ductility and formability of the tinplate. The principle underlying such tests is that a cup is formed in the sheet specimen by means of a punch and die and the depth of the cup at the commencement of fracture is taken as the measure of ductility. The Erichsen method recommended in British Standard BS 3855:1965 and in International Organization for Standardization Recommendation ISO/R149-1960 was adopted, using a punch and die assembly as shown in Figure 2. The load was applied by the use of a Denison universal testing machine with a strain rate of about 7-10 mm/min. The depth of the cup at fracture as indicated by the drop in force was measured with a dial gauge at the conclusion of each test.

The hardness was measured for 7 samples representing the steel of each weight grade (usually referred to as substance). The test was aimed to determine not only the temper quality but also the variation in the property both across the width and along the length of each plate. The test used in this study was the Vickers Diamond Hardness test using a $2\frac{1}{2}$ kg load applied at points approximately 5 cm apart giving 10-16 measurements across the width of the plate and 14-18 measurements along the length.

The tin coating weight was assessed for 6 samples. Each plate was cut to provide 6 test specimens, each 51.62 cm^2 ($8\ in^2$) in area, from various locations to cover the possible variation of the tin coating inherent to the hot-dip process (Hoare _et al._ 1965). The tin coating weight was assessed by the volumetric method recommended in British Standard BS 2920:1957 where reproducibility of $\pm$0.1 oz ($\pm$2.83 g) per



a) Lab marks M14/1-M14/8, M14/13-M14/14



b) Lab marks M14/9-M14/12

A & B are hardness survey strips.

[1] Tin coating weight specimens.

[2] Cupping test specimens.

Figure 1.—Location of test specimens in sample plate.

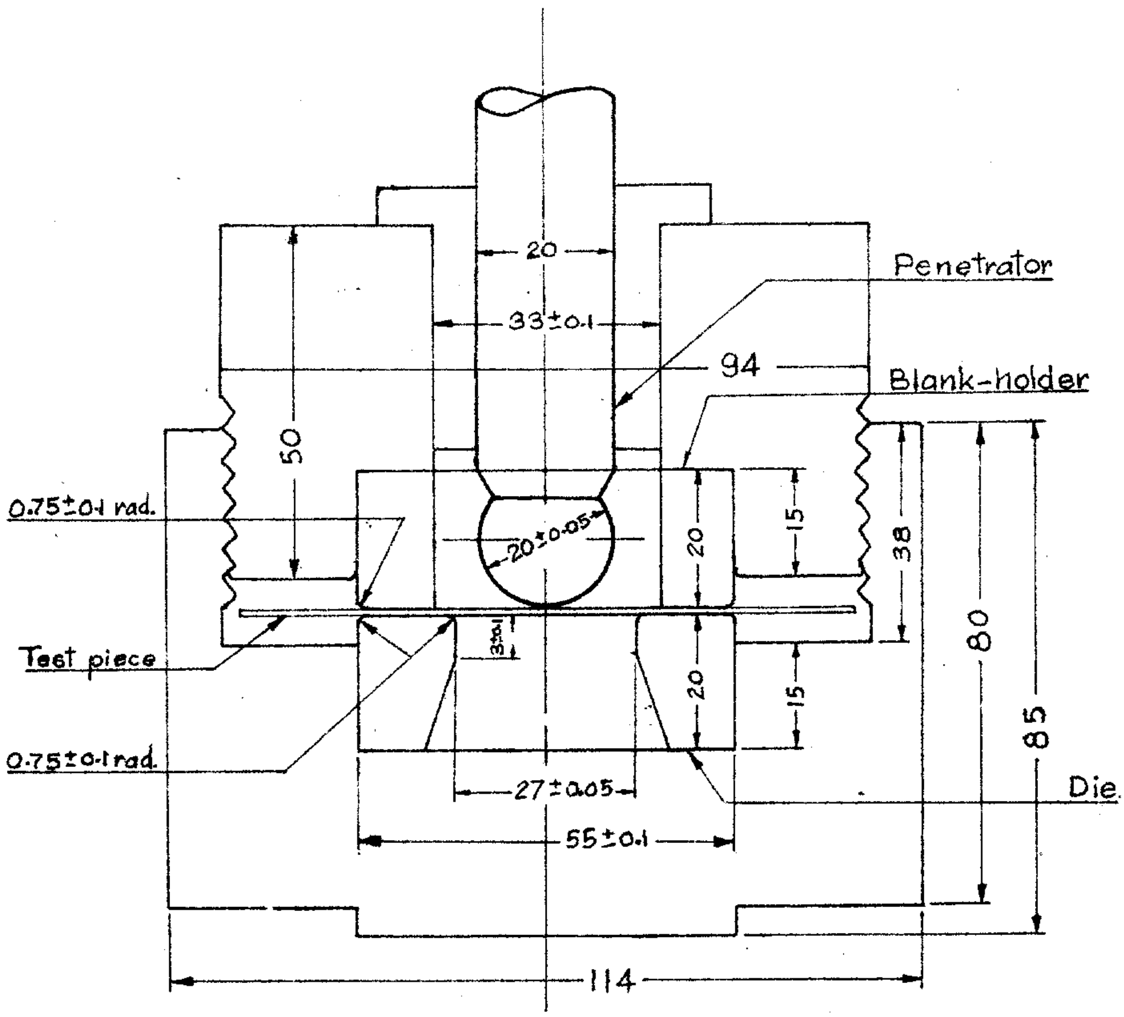


Figure 2.—Punch and Die assembly for the Erichsen test.
(All dimensions are in millimetres.)

basis box can be expected.

In addition to the generally accepted tests indicated above, limited tests were also applied to some of the tinplates to determine the corrosion resistance of the tin coating. There is no British or other standard specification requiring the use of corrosion test of tinplate for qualification purposes although some food-can manufacturers may occasionally set it in their specification, mainly to reveal abnormal coating defects. As applied to tinplates, it is a comparison test based on the appearance produced against some agreed standard reference material. The results of the corrosion test may, however, be evaluated by counting the corroded pores, a method defined in British Standard BS 3745:1964.

The rust resistance test described by Britton and Michael (1955), which is the sulphur dioxide test, was adopted in this study. As-received specimens of about 100 x 75 mm were suspended for 24 hours in a small test chamber according to the Tin Research Institute design (Hoare et al. 1965). The reference materials were electrolytic tinplates imported by some local can manufacturers. The use of as-received samples is considered realistic from the practical point of view since it takes into account not only the protection afforded by the tin coating but also any degree of protection given by the oil or oxide film on the coated plates. The solutions used were 160 ml of 1 per cent sodium thiosulphate solution and 40 ml of 0.1 N sulphuric acid.

RESULTS AND DISCUSSION

General surface quality

The surfaces of all the tinplates were clean and smooth with bright finish. There was no sign of mechanical damage and no indication of rust spots which would indicate significant porosity in the tin coating. The samples M14/1-M14/10 had a few hair-line scratches on the surface presumably introduced in the handling subsequent to the tinning process. Hair-line marks were not visible on the samples M14/11-M14/14. Such superficial marking is not considered to be detrimental to the services of the plates.

Some faint ripple appearance of the tin coating, typical of the hot-dipped tinplate, were noted on all the sheets, the ripples running parallel to the length of the plates for samples M14/1-M14/10, but parallel to the width of the plates for the other samples. Micro-examination of several sections of the tinplates indicates that the ripple effect is confined entirely in the tin layer and that there is a satisfactory iron-tin layer between the tin coating and the base steel.

Rolling direction of the steel

The direction of rolling of the steel was revealed by the micro-examination to be parallel to the width of the plate in all cases.

Chemical composition

The chemical composition was determined for the representative steel intended for each application. The steel for local cigarette canning, lab mark M14/10, was not analysed since it is of the same batch of steel as lab mark M14/9. The analyses shown in Table 2 indicate that the samples M14/9 and M14/11 are of fully killed steel whilst all the other samples may be steels of capping grade in view of the very low silicon content. The analyses, together with the results of the hardness study to be discussed later, suggest that none of the steel is of rimming type. All the steel compositions conform to the accepted limits recommended by the Tin Research Institute (Hoare 1964).

Tin coating weight

The results of the tin coating weight determination are given in Table 3. In all cases, the average tin coating weights determined were higher than the rated value given by the company although in some cases the range of variation in the coating thickness could be improved upon by closer control of the operating conditions.

The tin coating weight of 1.25 lb/basis box rating (equivalent to a coating thickness of 1.92×10^{-3} mm on each face) appears to be adequate for most food items. Suggestions made by the Tin Research Institute for hot-dip tin coating weight for a variety of products are shown in Table 4. It will be seen that for most applications 1.25 lb/basis box are adequate, whereas for relatively strong acid contents such

TABLE 2

CHEMICAL COMPOSITION OF THE STEEL BASE

Samples lab mark	Composition (weight per cent)				
	C	Si	Mn	S	P
M14/3	0.12	Traces	0.36	0.03	Traces
M14/5	0.08	Traces	0.37	0.04	Traces
M14/9	0.11	0.19	0.44	0.03	Traces
M14/11	0.07	0.20	0.37	0.02	Traces
M14/13	0.10	Traces	0.32	0.02	Traces
Recommended limits	0.04-0.12	Traces-0.08	0.20-0.60	0.15-0.05	0.015-0.06

TABLE 3

TIN COATING WEIGHT OF THE SAMPLES

Samples lab mark	Determined tin coating weight (lb/basis box)		Coating grade stated by the Company (lb/basis box)
	Range	Average	
M14/3	1.22-1.48	1.35	1.25
M14/4	1.22-1.60	1.39	
M14/5	1.20-1.64	1.43	
M14/9	1.39-1.54	1.45	
M14/11	1.10-1.41	1.26	
M14/13	1.27-1.47	1.35	

TABLE 4

SUGGESTED TIN COATING WEIGHT AND FOOD CONTENTS

Product	Coating weight (lb/basis box)
Milk	1.00
Pale acid fruits (citrus, pine-apple, apple, pears, peaches)	1.25
Apple juice	1.50, lacquered
Meat in general	1.00
Meat and vegetables in vinegar or acid sauce	1.50
Fish in general	1.00, lacquered for some products
Leaf vegetable	1.25
Peas, tomatoes	1.00

as pickled products, a higher tin coating weight of 1.50 lb/basis box would be desirable.

Mechanical properties

Hardness. The results of the hardness tests shown in Table 5 indicate satisfactory average hardness values corresponding to the temper grades stated by the Company. The range of variation in hardness values also satisfy the limits recommended by some authorities (Hedges 1960). Temper 3E grade, ordinary quality, is normally used for standard can bodies and ends whereas temper 3B grade, ordinary quality, and temper 4 grade are used for larger can bodies and ends.

The variation in hardness from edge to centre of each plate is relatively small, at most 10 Vickers diamond hardness values. Such small variation indicates that none of the steel is of rimming quality and uniform formability may be expected of the material.

Ductility. The results of the Erichsen test (Table 6) show that each steel has the desirable characteristics indicative of good formability. By the British Standard rating, all the steels of the temper 3 grade conform to the deep-stamping quality; a few samples, lab marks M14/9, M14/3, and M14/14, would in fact conform to the deep-drawing quality. The steels of the stronger temper 4 grade, lab marks M14/5-M14/8, could only satisfy the ordinary quality, but this is to be expected in view of the amount of cold rolling which must have been given to the steels to obtain the degree of temper required.

Corrosion resistance

As already stated, the purpose of this test was merely to compare the property of the local products with that of a reference material. In this case samples of the electrolytic tinplate imported by some companies for food packaging have been arbitrarily chosen for reference. The results of the rust resistance tests are illustrated in Figure 3. It will be seen that the property of the local hot-dipped tinplate compares favourably with that of the imported electrolytic tinplates, as indicated by the extent of brown corroded spots resulting from the tests. These results suggest that with the availability of the local hot-dipped tinplates of the qualities shown, little advantage would be gained by

TABLE 5

HARDNESS OF THE STEEL BASE

Samples lab mark	Direction*	Vickers diamond hardness HD/2½ kg		
		Range	Average	Recommended
M14/3	W	108-117	114	Temper 3 B Ordinary quality 108-125
	L	111-117	115	
M14/4	W	105-114	108	Temper 3 E Ordinary quality 104-121
	L	106-113	108	
M14/5	W	112-119	116	Temper 4 108-124
	L	108-117	113	
M14/6	W	111-121	115	
	L	109-117	115	
M14/9	W	113-118	116	Temper 3 B Ordinary quality 108-125
	L	107-116	114	
M14/11	W	108-114	110	
	L	105-112	109	Temper 3 E Ordinary quality 104-121
M14/13	W	103-110	107	
	L	103-110	107	

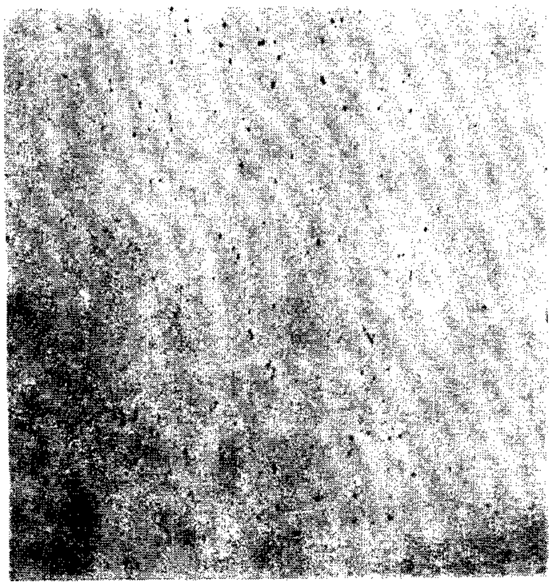
* W = width, L = length

TABLE 6

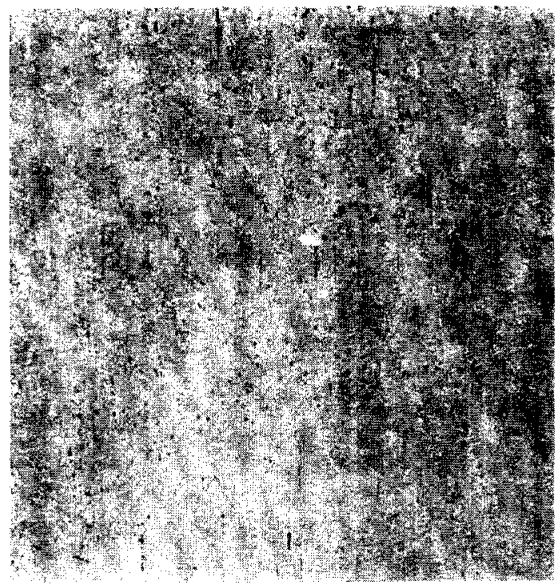
RESULTS OF THE ERICHSEN TESTS

Samples lab mark	Substance (lb/basis box)	Thickness (mm)	Depth of cup (mm)		Minimum depth of cup (mm) BS 2920:1957		
			Min.	Range	Ordinary quality	Deep-stamping quality	Deep-drawing quality
M14/1	75	0.215	6.42	6.42-6.81	5.8	6.3	6.9
M14/2			6.67	6.67-7.02			
M14/3			6.40	6.40-6.63			
M14/4			6.24	6.24-6.91			
M14/5	80	0.228	6.12	6.12-6.90	5.9	6.4	7.0
M14/6			6.30	6.30-6.50			
M14/7			6.0	6.0 -6.80			
M14/8			6.12	6.12-6.45			
M14/9	85	0.254	7.16	7.16-7.56	6.0	6.5	7.1
M14/10			6.46	6.46-7.35			
M14/11	108	0.312	7.20	7.20-7.93	6.3	6.9	7.5
M14/12			7.23	7.23-7.78			
M14/13	80	0.228	7.27	7.27-7.72	5.9	6.4	7.0
M14/14			7.15	7.15-7.71			

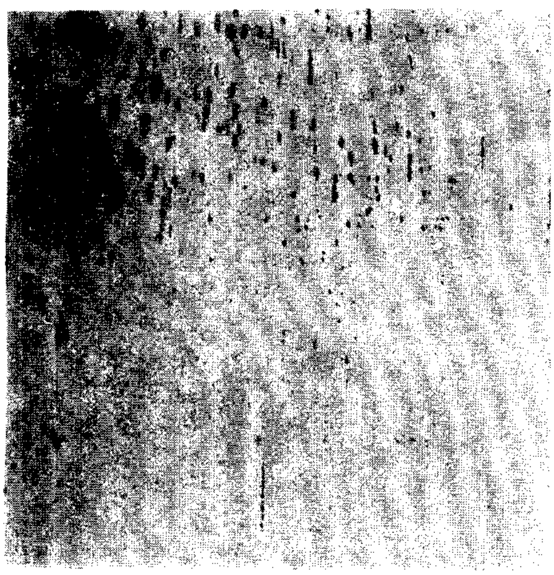
Note: Room temperature during tests = 24°C.



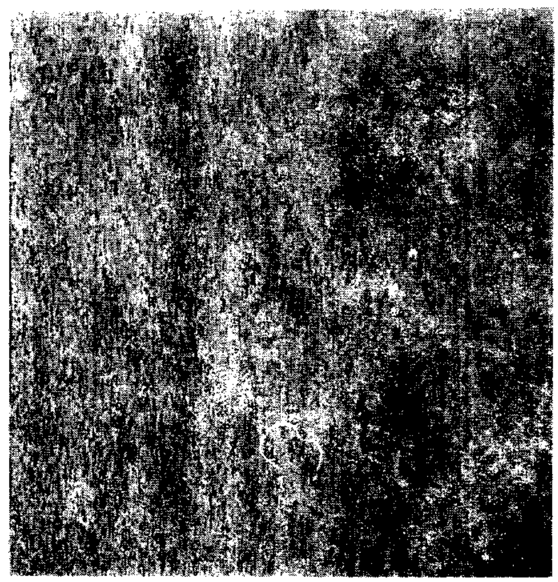
Hot-dipped tinplate
Lab. mark M 14/10



Hot-dipped tinplate
Lab. mark M 14/12.



Hot-dipped tinplate
Lab mark M 14/14



Electrolytic tinplate
Lab. mark M 14/E

Figure 3. Comparison of corrosion resistance of some tinplates.

using imported electrolytic tinplates.

General remarks

The results of the evaluation tests have shown that the samples of the hot-dipped tinplates manufactured locally possess properties which can be considered adequate for packaging most items of food and other products. The criteria of the tests are based on the recommended procedure which has been universally accepted in industry and experience has shown that the results of such tests correlate well with the actual behaviour of the material under service conditions. For food packaging in particular, however, where requirements and conditions should be stringent, the tests should not be regarded as completely conclusive for such end applications. It will be appreciated that the life and effectiveness of cans are influenced by so many factors involved under fabricating and service conditions which it would not be feasible to simulate under laboratory conditions. In the absence of a better known short time test procedure, therefore, it is suggested that a long time shelf life test of packed can could beneficially be employed by the food packaging industry to confirm suitability of the materials for specific contents.

The present study has been confined to evaluation of the tinplates which have been passed by the quality control based on visual inspection on the production line. It has been reported by the Company, however, that the reject rate has been variable from time to time. To maintain the yield of good products at a maximum, a study of the causes of defects has been planned and will form the subject of a separate investigation.

CONCLUSIONS

The following conclusions may be drawn from the investigation:

(1) Samples of hot-dipped tinplates manufactured locally have been evaluated using the generally accepted criteria recommended by the International Tin Research Council. The criteria of the tests include general surface quality, chemical composition and mechanical properties of the steel base, and the tin coating weight.

(2) The quality of the samples has been found satisfactory for most packaging applications including the majority of food contents.

(3) In addition to the standard tests, limited tests on the corrosion resistance of the tinplates have also been made. The results indicate that the local hot-dipped tinplates compare favourably in this respect with the imported electrolytic tinplates.

(4) The samples examined have been obtained from the mill output after rejects have been extracted. The variable reject rates suggest that further examination of the processing conditions is desirable to define the causes of the rejects and to develop appropriate measures for maintaining the yield of good products at a maximum.

ACKNOWLEDGEMENTS

The authors wish to express their indebtedness to the Tin Research Institute, London, for valuable advice and suggestions relating to tinplate quality evaluation. Appreciation is owed to the Managing Director of the Thai Tinplate Company, Ltd. for the full cooperation provided for this study. Acknowledgement is also made to the Analytical Unit of TRI for much effort in selecting appropriate techniques for the tin coating weight determination.

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APPENDIX

IMPORTS OF TINPLATES FOR THAILAND

Year	Quantity (kg)	C.I.F. value (baht)
1960	15,498,311	66,016,578
1961	14,299,450	50,620,146
1962	14,620,852	47,111,319
1963	13,146,012	36,470,282
1964	13,007,240	37,004,891
1965	14,303,660	41,640,243
1966	21,928,089	63,523,062
1967	25,009,108	75,133,998

Source: Department of Customs.