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HONG KONG PRODUCTIVITY CENTRE - TECHNICAL

ASSISTANCE IN HEAT TREATMENT

DP/HOK/76/006

HONG KONG

(R) Technical report: Development of a heat-treatment unit within HKPC*

Prepared for the Government of Hong Kong
by the United Nations Industrial Development Organization,
executing agency for the United Nations Development Programme

Based on the work of Brian J. Meadows, heat treatment expert

United Nations Industrial Development Organization
Vienna

*This report has been reproduced without formal editing.

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Explanatory notes

The Monetary unit in Hong Kong is the dollar ($HK). During the period covered by the report the value of the Hong Kong dollar in relation to the United States dollar was $US 1 = $HK 5.10.

The following abbreviations are used in this report:

HK	Hong Kong
HKPC	Hong Kong Productivity Centre
WHTC	Wolfson Heat Treatment Centre (located at University of Aston, Birmingham, United Kingdom of Great Britain and Northern Ireland)

ABSTRACT

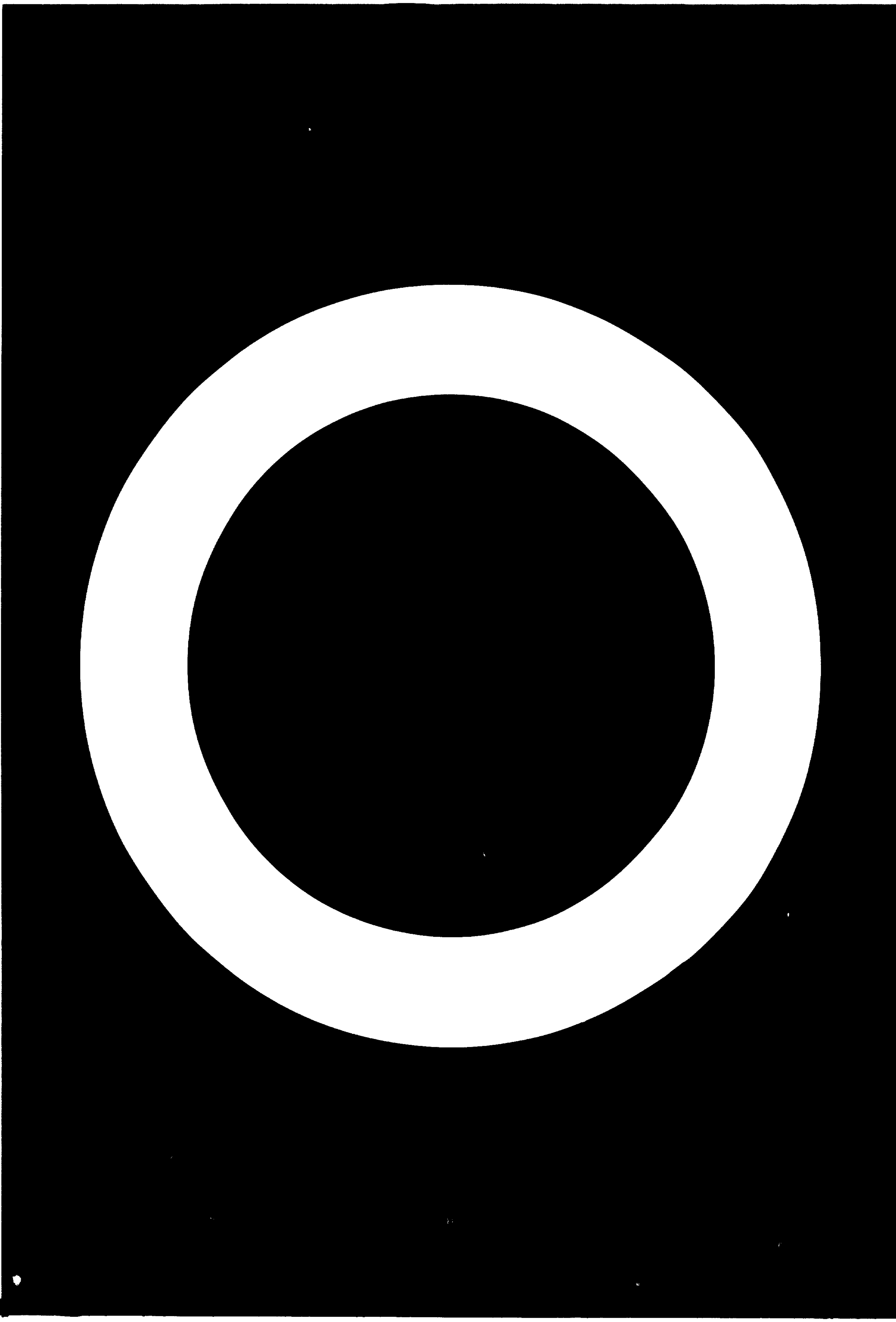
In order to extend the scope of its training and consultancy services, the Hong Kong Productivity Centre (HKPC) intended to add heat treatment to the services already offered by its Technology Division. The Government of Hong Kong therefore requested assistance in the establishment of a heat treatment unit with HKPC and the project "Hong Kong Productivity Centre - technical assistance in heat treatment" (DP/HOK/76/006) was duly approved by the United Nations Development Programme (UNDP) in June 1978, the United Nations Industrial Development Organization (UNIDO) being designated executing agency.

The project document originally provided for a mission of six months of one expert in heat treatment. This period was later split into two missions of three months each, to be carried out by different experts. The present report covers the first expert's assignment from June to September 1979. The expert visited a wide range of local factories to assess the type of heat treatment required in Hong Kong and initiated a survey of the heat treatment industry by sending a questionnaire to approximately 2,400 companies and by analysing the replies received. He further conducted seminars on heat treatment, advised the counterpart staff on establishing training courses in heat treatment, prepared a list of equipment to be purchased for the new heat treatment unit and suggested books to be bought for its library.

The expert found that with few exceptions, heat treatment practice in Hong Kong operates at a low level of understanding, with inadequate furnaces and with insufficient control.

He concludes that an improvement may be achieved in the long term by the provision of a heat treatment unit which would be used to demonstrate proper heat treatment practice and to offer a service not otherwise available to the industry. This would be linked with properly structured courses of instruction for shop floor operatives, technicians and managerial staff.

The Hong Kong Productivity Centre has both, staff and basic facilities to undertake this. With the provision of extra equipment, staff training via fellowship schemes and the development of a comprehensive heat treatment advisory service, the Centre should be in a position progressively to raise the level of heat treatment technology in Hong Kong.



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1. Introduction

1.1 Heat treatment is generally referred to as an operation or combination of operations in which metal in the solid state is carried through cycles of heating and cooling for the purpose of obtaining certain desired conditions or properties. In the manufacturing industries, components which normally require heat treatment are metal parts, dies and moulds. A properly heat treated die or mould can prolong its service life and thus improve the accuracy of the product as well as the quantity produced per die set. Furthermore downtime for changing die sets can be reduced. For component parts, correct heat treatment means better properties. Also, in some cases, heat treatment is inevitably at the intermediate stage of a successful forming process, e.g., intermediate annealing in a multi-stage drawing process.

1.2 The development of a heat treatment unit within the Hong Kong Productivity Centre had been accepted by the Productivity Council as part of the Third Five-Year Policy Plan and it was envisaged that the functions of the Heat Treatment Unit would be to:

(a) Conduct seminars and courses concerning the technology of heat treatment;

(b) Provide heat treatment and consultancy services to local industries in this field;

(c) Organize a heat treatment committee among local heat treatment factories and users.

1.3 The total development of the Heat Treatment Unit was planned in three phases. Phase I covered the provision of a laboratory based service and the establishment of courses and seminars. Phase II would require the provision of commercial scale heat treatment equipment and details of this would depend on advice of a visiting expert and the outcome of a market/technical needs survey in 1980. Phase III planned for 1981 onwards would require larger facilities than in Phase II where the need could be justified, together with specialised facilities that would be available to local industry but unlikely to be justified financially by many companies because of insufficient job loading.

1.4 The original proposals for funding were approved in June 1976 and are set out in Tables (1) and (2). The UNDP input was to be US$72,500 whilst the Hong Kong Government contribution via HKPC amounted to HK$360,930. The proposal included provision for technical assistance from an Heat Treatment Expert, the availability of Fellowships for HKPC staff and funds for the purchase of equipment. Authorization of the project was given on 29th April 1978 and the starting and completion dates were originally scheduled for January 1979 and March 1980 respectively.

1.5 During 1978/79, in consultation with the writer and Mr. H.C. Child (Director, Wolfson Heat Treatment Centre, University of Aston, U.K.) it was agreed by UNDP that the following programme of Expert visits and Fellowship training should be adopted.

(a) A visit of three months duration by an Heat Treatment Expert to be followed immediately by

(b) Fellowships to be based at the Wolfson Heat Treatment Centre, U.K., to be followed immediately by

(c) A visit of three months duration by a second Heat Treatment Expert.

1.6 The duties agreed for the two Experts are set out below:

(a) First Expert (Mr. B.J. Meadows) - 3 months from June 1979

i. Visiting a wide range of local factories to assess the type of heat treatment required in Hong Kong and outlining a 'state-of-the-art' report to be produced after the visit of the second expert.

ii. Conduct of a seminar(s) on Heat Treatment and advice to local counterpart on establishing heat treatment training courses.

iii. Advising the Centre on purchasing equipment suitable for the Unit to provide future service to industry.

iv. Assisting the staff of the Unit in rendering trouble shooting services in heat treatment.

v. Consider need for a regular communication on heat treatment technology in Hong Kong.

TABLE 1.

United Nations Development Programme

Project Budget Covering UNDP Contribution

(in U.S. Dollars)

Country: Hong Kong

Project No.: HOK/76/006/A/01/37

Project Title: Hong Kong Productivity Centre - Technical Assistance in Heat Treatment

Code	Item	Total m/m	Total $	1979 m/m	1979 $	1980 m/m	1980 $
10	PROJECT PERSONNEL COMPONENT						
11	Experts						
11-01	Heat Treatment Expert	6	39,000	6	39,000		-
19	Component Total	6	39,000	6	39,000		-
30	TRAINING COMPONENT						
31	Fellowships						
31-01	Heat Treatment	3	4,500		-	3	4,500
31-02	Industrial Engineering	6	9,000		-	6	9,000
39	Component Total	9	13,500		-	9	13,500
40	EQUIPMENT COMPONENT						
41	Equipment		20,000		20,000		-
49	Component Total		20,000		20,000		-
99	GRAND TOTAL		72,500		59,000		13,500

TABLE 2.

PROJECT BUDGET COVERING GOVERNMENT CONTRIBUTION IN KIND

(in H.K. Dollars)

Country: Hong Kong

Project Number: HOK/76/006/A/01/37

Project Title : Hong Kong Productivity Centre - Technical Assistance in Heat Treatment

		Total		1979		1980	
		m/m	HK$	m/m	HK$	m/m	HK$
10	PROJECT PERSONNEL						
11-01	Counterpart to the UNIDO Heat Treatment Expert	6	45,960	6	45,960		-
11-02	Consultant	6	46,440	6	46,440		-
11-03	Junior Consultant	6	30,030	6	30,030		-
11-99	Sub-total	18	122,430	18	122,430		-
13	Administrative Support Personnel (proportion only)		18,840		18,840		-
19	Component Total		141,270		141,270		-
30	TRAINING						
31	Maintenance of Trainees		69,660		-		69,660
39	Component Total		69,660		-		69,660
40	EQUIPMENT						
11	Equipment		150,000		150,000		-
49	Component Total		150,000		150,000		-
50	MISCELLANEOUS						
51	Miscellaneous		-		-		-
59	Component Total		-		-		-
99	GRAND TOTAL		360,930		291,270		69,660

(b) Second Expert (Mr. H.C. Child) - 3 months from December 1979

i. Assist the Centre in installing equipment in the Heat Treatment Laboratory and getting the Unit operational.

ii. Draft standard heat treatment practices for typical Hong Kong needs and launch the day-to-day operation of the Unit.

iii. Conduct seminars and training course(s) on heat treatment for local industries.

iv. Assist the Centre's staff in rendering consultancy services in Heat Treatment.

v. Finalize the 'state-of-the-art' review, report on the likely future market for heat treatment in Hong Kong and decide on the form (if any) of a regular communication on heat treatment.

The visit by the first Expert (the writer) started on June 17th 1979 with the normal briefings in Vienna and Bangkok and work commenced in Hong Kong on June 22nd 1979.

1.7 The description of the Fellowships was:-

(a) Familiarization with the day-to-day work of the Wolfson Heat Treatment Centre.

(b) Visiting a wide range of heat treatment and other related companies. These include companies with various types of heat treatment processes such as flame hardening, carburising, nitriding, nitro-carburising, sub-zero treatment and vacuum heat treatment.

(c) Collect together information, catalogues, visual aids, lecture materials, demonstration materials for later use by the Hong Kong Unit.

In the light of briefings held in Vienna and Bangkok and discussions by the writer in Hong Kong during his visit a revision of the Fellowship Training Programme was submitted. This is described in detail in Sections 7.3 and 7.4.

2. Industrial Heat Treatment in Hong Kong

One of the major tasks undertaken at the beginning of the visit was a study of the Hong Kong heat treatment industry. This was achieved by means of visits arranged by HKPC and the first part of a two-stage survey. The impressions gained from this study profoundly affected the rest of the project and a detailed description is therefore set out of the state of the heat treatment industry as it exists in Hong Kong in 1979.

3. Visits to Companies and Other Institutions

3.1 The heat treatment industry may be divided into three main groups:

(a) Manufacturing companies with their own in-house heat treatment. As indicated later in the survey section this group covers a very large number of firms ranging from metal product manufacturers (screws, stoves, watches, forgings etc.) to the plastics industry using metal dies. The total number of companies in this group is probably unknown and the vast majority employ 10 or less people.

(b) Manufacturing companies who sub-contract work elsewhere for heat treatment. This also represents a wide range of industries, again small in terms of numbers employed.

(c) Contract heat treatment firms. There are three of these in Hong Kong.

There are no furnace manufacturers although a number of overseas companies have branches or agencies in Hong Kong. Furnace instrumentation and control equipment is also not directly available in Hong Kong.

3.2 The visits that were made are listed in Appendix A. In discussing the industry it will best be done in terms of range of equipment used, extent of instrumentation and control, level of understanding shown and level of back-up metallurgical support.

3.3 The equipment used for heat treatment varies from the most simple (coke fire or blow torch) to reasonably modern furnaces as seen at Sidchrome (S.E. Asia) Ltd. (a sealed quench furnace), Hong Kong Precision

Screws Manufacturing Ltd. (a belt conveyor furnace used with an atmosphere generator) and O'Bailee Co. Ltd. (a vacuum furnace). In spite of evidence of some good equipment too many examples were seen of unsuitable furnaces being improperly used. Instances were regularly noted of high temperature muffle furnaces being used for (low temperature) tempering and of these furnaces being overloaded without reference to temperature gradients existing within the muffle. Where modern furnaces were being used they were not always the most suitable for the particular product being processed and several examples were noted where the capital investment could not have been justified in terms of the production throughput. The small size of so many of the companies is necessarily restricting capital investment in furnace equipment and this in itself strengthens the case for HKPC having the facilities which may be used by industry.

3.4 As regards control, it was rare to see a satisfactory level of instrumentation, properly used and maintained. In some factories no attempt was made to measure temperature (except by "eye"). Those companies having temperature controllers/indicators did not normally have the laboratory and technician support to check regularly on accuracy or to sustain a proper level of maintenance. Rarely was furnace atmosphere monitored nor was it customary to control quenching oil temperature.

3.5 The level of understanding of the heat treatment process, with one or two exceptions, was minimal. Operators will slavishly follow the instructions set out in brochures published by steel suppliers. As the equipment is so often unsuitable and control is lacking it is not surprising that erratic results are achieved. Many reports were received of companies having to heat treat up to ten dies in order to obtain three or four satisfactory ones. No clear picture emerged regarding responsibility for heat treatment specification when work is sent to a contract heat treater. The main criterion that is met is that of hardness and little responsibility seems to be accepted for distortional features so commonly caused by heat treatment.

3.6 It is rare to find back-up metallurgical support for the heat treatment process. In Hong Kong there are probably seven or eight professionally qualified metallurgists and an unknown number of Chinese educated metallurgists. Again the smallness of size of so many companies effectively acts as a barrier to a metallurgical input. A further constraint is the lack of training currently available in Hong Kong in the metallurgical field. This will be referred to in detail in section 8.1.

3.7 In spite of the obvious deficiencies in the industry, rarely was concern expressed by companies themselves.* This, in part, is due to the fact that heat treatment of general engineering steels is not so critical as tool steels and for many of the components, quality does not have to be high. Where heat treatment is critical, there is not in Hong Kong any norm with which to compare. Companies do not keep records of forging die life and do not therefore know whether a die heat treated in one way is better or worse than any other. Certainly as labour costs rise, and as higher quality, higher technology products are made the need for better heat treatment will become self apparent.

4. Postal Survey

4.1 In order to provide an in-depth study of the heat treatment industry a survey was initiated which will span the visit of both UNDP Experts. The survey will be in two parts. The first stage which covered the July/August 1979 period was a simple questionnaire sent out to approximately 2,400 companies. The second section will enable a detailed study to be made of approximately 100 companies.

4.2 The simple questionnaire is given as Appendix B, together with tables summarising the results obtained.

* In the postal survey, a high level of dissatisfaction (55%) was recorded.... see section 4.3 (vii), and 80% admitted having heat treatment problems.....see section 4.3(viii).

4.? The salient features emerging from the survey may be listed as follows:

(i) of the firms replying, 50% heat treat components within their own works (in-house), the other 50% using one of the three contract heat treatment firms referred to in section 3.1c and Appendix A.

(ii) analysis of replies regarding the heat treatment of tools/dies/moulds shows approximately one third of the companies using in-house heat treatment exclusively, one third relying entirely on contract heat treaters and a third using both in-house and contract heat treatment.

(iii) 56% of the heat treatment operations listed involved a hardening process. Normal correct practice is for tempering to follow hardening. The number of tempering operations was less than the hardening operations indicating that:

a) tempering is not always used, or

b) tempering is being incorrectly described as, for example, annealing, or

c) companies do not understand the term or

d) tempering is being performed on all hardened components without some companies realising it.

(iv) 63 companies performing their own in-house heat treatment possessed 84 heating facilities ("furnaces"). 38 of these "furnaces" were simply torches and coke fires - completely unsuitable for heat treatment. Only six of the companies possessed a forced air circulating furnace, the unit most suitable for tempering.

(v) of the 63 companies performing their own heat treatment, 21 had no control or testing equipment. 33 of the companies had no temperature measuring device and 38 had no hardness testing machine. Five possessed some means of atmosphere control, three had a metallurgical microscope.

(vi) 71 steel "specifications" were being heat treated. Of these 18 were described vaguely ("carbon steel" "alloy steel", "soft steel", "ordinary steel" etc.). 11 companies failed to reply to the question seeking information on the steels heat treated.

(vii) When asked if they were satisfied with the quality of heat treatment, more than 55% stated they were not satisfied.

(viii) significantly more than 55% (namely 80%) admitted to having heat treatment problems.

(ix) of a total of 132 heat treatment problems reported, 45 were associated with distortion and 55 with too high/too low hardness.

(x) of those companies replying to the question asking if they would like help from HKPC in solving these problems, 80% said "yes".

5.0 <u>Conclusions from Company Visits (para. 3.0 - 3.7) and from Postal Survey (para. 4.0 - 4.3)</u>

5.1 Both the subjective views formed during visits to companies and the more analytical postal survey clearly reveal:

(i) a technologically backward industry with inadequate and improperly used furnaces

(ii) an absence of control on most heat treatment processes

(iii) an absence of testing equipment

(iv) inadequate understanding at all levels of the principles of heat treatment practice

(v) a serious dissatisfaction with the quality of heat treated parts

(vi) a high concentration of problems associated with hardness and distortion

(vii) a very positive statement that help is required from HKPC.

5.2 In order that HKPC can take positive steps to provide this help and so improve the standard of heat treatment in Hong Kong consideration was given to the further development of heat treatment facilities within the Centre, to the training of HKPC staff, the development of educational and instructional courses, the creation of an heat treatment information service and the need for an heat treatment publication. These items are discussed in the following sections 6.0 - 10.0.

6.0 HKPC Equipment Requirements and Costs

6.1 The visits to companies and the survey results clearly indicated the inadequacy of the equipment in many factories, and of the lack of control and instrumentation. In particular the major difficulties which were experienced were in tool and die heat treatment requiring more complex heating/cooling cycles and more control than for general engineering steels.

6.2 During the course of the visit, a statement and recommendations regarding further equipment purchases was made. This statement is set out as Appendix C. Summarised, the requirements for additional equipment are as follows:

(i)	a high temperature (1300°C) electrode salt bath furnace	estimated cost	US$ 27,000
(ii)	interrupted quench (martemper) furnace	estimated cost	US$ 9,500
(iii)	"Tufftride" salt bath furnace	estimated cost	US$ 14,500
(iv)	intermediate temperature (950-1000°C) electrode salt bath furnace for preheating with spare pot for carburising	estimated cost	US$ 15,000
(v)	control and measuring equipment	estimated cost	US$ 15,000

6.3 The high temperature furnace can be purchased from funds already available. A strong case exists for the martemper and Tufftride furnace to be purchased from UNDP unallocated funds and the intermediate temperature furnace and control/measuring equipment will be obtained from Hong Kong Government funds. The total money spent on equipment would then be:

UNDP	US$ 44,000	
HK Govt.	US$ 59,000	approx.
	US$ 103,000	

ABSTRACT

In order to extend the scope of its training and consultancy services, the Hong Kong Productivity Centre (HKPC) intended to add heat treatment to the services already offered by its Technology Division. The Government of Hong Kong therefore requested assistance in the establishment of a heat treatment unit with HKPC and the project "Hong Kong Productivity Centre - technical assistance in heat treatment" (DP/HOK/76/006) was duly approved by the United Nations Development Programme (UNDP) in June 1978, the United Nations Industrial Development Organization (UNIDO) being designated executing agency.

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The expert found that with few exceptions, heat treatment practice in Hong Kong operates at a low level of understanding, with inadequate furnaces and with insufficient control.

He concludes that an improvement may be achieved in the long term by the provision of a heat treatment unit which would be used to demonstrate proper heat treatment practice and to offer a service not otherwise available to the industry. This would be linked with properly structured courses of instruction for shop floor operatives, technicians and managerial staff.

The Hong Kong Productivity Centre has both, staff and basic facilities to undertake this. With the provision of extra equipment, staff training via fellowship schemes and the development of a comprehensive heat treatment advisory service, the Centre should be in a position progressively to raise the level of heat treatment technology in Hong Kong.

6.4 In considering heat treatment costs and the charges that might be made to industry, it is necessary to establish a distinction between the provision by HKPC of a consultancy/training service and the provision of what might be regarded as a contract heat treatment service.

6.5 In the early stages the Heat Treatment Unit will provide a comprehensive range of technical assistance, training and information services. Although cost recovery is important it is unreasonable to expect commercial viability of these services as they form part of the Centre's total on-going programme of assistance to industry. The laboratory facilities will be used to a large extent to support these programmes.

6.6 In the later stages of its development the Heat Treatment Unit would be offering specialist contract heat treatment services in which case the possibility of cost recovery becomes significant.

6.7 It is reasonable to calculate costs on the basis of energy used, capital depreciation and direct labour (with an allowance for some direct overheads). The unit costs are dependant on the pattern and level of demand and the weight of charge loaded into the furnaces. Appendix D shows costing for four different types of heat treatment processes each with a varying furnace load. For the treatment of cold work steel (O [illegible]), hot work steel (H 13) and high speed steel (M [illegible]) income has been based on charges currently made by Hong Kong Contract Heat Treaters. For the "Tufftride" process of heat treatment this is not commercially available in Hong Kong and HKPC would therefore be offering it as a unique specialist service.

6.8 On the basis of the exercises set out in Appendix D it may be seen that:

(i) % cost recovery increases as weight charged into the furnace increases;

(ii) 100% cost recovery for hardening and tempering of tool steels could be possible with furnace loadings of between 25 and 50 lb. weight;

(iii) for specialist processes such as the "Tufftride" type of heat treatment the charge made to industry can be related to expenditure incurred in order to ensure adequate cost recovery.

7.0 UNDP Fellowships

7.1 Further training of HKPC staff can be achieved by means of UNDP fellowships schemes. Under the UNDP budget proposals for Technical Assistance in Heat Treatment to Hong Kong, provision was made for two fellowships (see Table 1).

31-01 Heat Treatment	3 m/m;	US$4,500
31-02 Industrial Engineering	6 m/m;	US$9,000
		US$13,500

7.2 During the course of briefing sessions in Vienna and Bangkok in mid-June 1979 I was asked to resolve as quickly as possible the job descriptions for these two fellowships and urge with the Hong Kong Government their implementation in 1979. Following discussions with HKPC and the Government Economic Secretariat, the following recommendations were made to HKPC and forwarded to Government on 6th July 1979.

7.3 Heat Treatment Fellowship

The heat treatment fellowship should be of 3 months duration commencing on October 1st, 1979. The work that would be undertaken will be metallurgical in nature and would enable the nominated person to:-

(i) familiarise himself in a detailed manner with the day to day work of the Wolfson Heat Treatment Centre (WHTC);

(ii) obtain a detailed understanding of all relevant heat treatment processes and their effect on metallurgical structure and properties. This will be achieved by work within the WHTC and the metallurgical laboratories of the University of Aston, and by visits to appropriate companies;

(iii) collect information (particularly from WHTC), lecture material, visual aids, demonstration pieces and metallurgical specimens for use in HKPC.

7.4 Industrial Engineering Fellowship

The industrial engineering fellowship should also be of 3 months duration and run concurrently with that of the heat treatment fellowship from October 1st 1979. The work undertaken would be concerned with the engineering aspects of heat treatment and the nominated person would involve himself with a detailed study of:-

(i) day to day work of WHTC;

(ii) engineering aspects of heat treatment, particularly concerned with furnace construction and maintenance, plant layout, temperature measurement and control, furnace atmosphere generation and control, and other aspects of instrumentation;

(iii) engineering design considerations compatible with subsequent heat treatment, with particular reference to the avoidance of distoration, warpage and cracking.

7.5 A charge will be made by the Wolfson Heat Treatment Centre for the services that they will provide to the nominated fellows. It is proposed that a sum of £ 2,000 be allocated for this purpose from the budget. This charge together with the cost of 2 x 3 months fellowships should still come within the previously agreed budget figure of US$13,500.

7.6 For the Heat Treatment Fellowship, HKPC have nominated Mr. Peter Yau and for the Industrial Engineering Fellowship Mr. Wing-ching Keung. Both these nominations have my full approval and arrangements should be made for them to commence on October 1st 1979.

8.0 Courses

8.1 No formal training to produce professional graduate metallurgists or metallurgical technicians exists in Hong Kong and with the present state of development of the metallurgical industry and the size of individual companies it is doubtful if a purely metallurgical training could be justified. What is required in Hong Kong is a greater supply of general engineering graduates and technicians who have have received a significant metallurgical engineering input to their training and educational programme. Both the Polytechnic and H.K. University include some metallurgical teaching in their course structures but the evidence is that it is insufficient to provide the expertise required by industry even now.

8.2 It is certainly beyond the scope of the work of HKPC to undertake such a broad task and Government should give consideration to the further development of technician and graduate courses at the Polytechnic and the University in order that engineers may be produced with a better understanding of metallurgical control and principles.

8.3 In the more limited context of heat treatment the Productivity Centre has a very positive role to play. The lack of understanding and of control has already been referred to in sections 3.4, 3.5 and 4.3, and the establishment of educational courses by HKPC would help to remedy this situation. In the early stages very considerable efforts may have to be made to convince industry of their need for such courses and much public relations work will have to be done by the staff of the Centre in general, and those involved with the Heat Treatment Unit in particular. Three levels of instruction have been identified, namely:-

(i) A course for Operatives in Heat Treatment Practice;

(ii) A course for Technicians in Heat Treatment Control;

(iii) A course for Management in Heat Treatment Technology.

8.4 For both the Operatives and the Technicians, it is proposed that a Certificate should be awarded for satisfactory completion of the course. At Management level, a proposal has been made that there should be both a Certificate, and an Advanced Certificate Course.

8.5 The detailed proposals for all courses including syllabuses are set out in Appendices E, F and G.

8.6 The timing, phasing and demand for these courses needs to be assessed and this will form part of the second stage survey referred to in section 4.1.

8.7 However if completion of equipment requirements can be achieved by early 1980 one or more of these courses could be offered from September/October 1980.

9.0 Information Facilities

9.1 A library is operated by HKPC from its Mongkok branch. Currently there are only a limited number of books dealing with metallurgy and more specifically with heat treatment. A full list of necessary purchases has been recommended to HKPC - this list is set out as Appendix H.

9.2 As the Heat Treatment Unit is to be based in a separate building at Kowloon City, it would be advisable for all heat treatment literature to be based in this building on permanent loan to the Unit.

9.3 Both before and during my visit, HKPC commenced collection of information guides, catalogues and brochures on steels, and heat treatment. A properly organised, efficient information retrieval system needs to be developed as part of the general advisory service that the Heat Treatment Unit will provide. Part of the Fellowship schemes (sections 7.3 and 7.4) will be concerned with a study of the system operating in the Wolfson Heat Treatment Centre at the University of Aston, U.K. On the return of the Fellows, and under the guidance of the second Expert, it will be necessary for a proper organisation of information to be established.

10.0 Publications

10.1 Consideration has been given to the need for a regular communication on heat treatment technology in Hong Kong. Currently HKPC publishes a monthly bulletin "Productivity News" and this has been used to give publicity coverage to the Heat Treatment Unit.

10.2 As the Unit develops and the equipment recommended in section 6.2 is installed the Productivity News may be utilized to further the work of the Productivity Centre in the heat treatment field. Recommendations have been made to the Centre that a regular one column feature should appear dealing with heat treatment enquiries and/or describing a simple aspect of the technology.

10.3 In the long term there will be a need for a quarterly publication of 4 - 8 pages, for circulation specifically to those in the heat treatment industry. Similar bulletins are put out by HKPC for the furniture and plastics industries and have met with great success. It is envisaged that in about one year the Centre would be in a position to publish an heat treatment bulletin and the visit of the second expert, Mr. H.C. Child, in January 1980 could be used to advance this part of the project. Mr. Child would also discuss with HKPC the extent to which material published in the U.K. by the Wolfson Heat Treatment Centre (WHTC) could be reprinted by HKPC. (Mr. Child is Director of WHTC).

11.0 Other Aspects

11.1 During the course of the vist attention was given to a number of other matters. These included seminars, consultancy and liaison with other organisations. A brief statement of these is made in paragraph 12, 13 and 14.

12.0 Seminars

12.1 During the visit three seminars were given:

(i) on Saturday, 4th August for HKPC staff;

(ii) on Saturday, 25th August for HKPC staff;

(iii) on Wednesday, 5th September for representatives from industry. The topic was "Problems in the Heat Treatment of Tool Steels". A copy of the text is attached as Appendix

12.2 In addition on Saturday, August 18, the expert participated in a meeting of the HKPC Heat Treatment Consultative Committee addressed them on state of the Hong Kong industry and the future role of the Heat Treatment Unit.

12.3 In correspondence with Mr. H.C. Child, the second Expert scheduled to be in Hong Kong from January 1980, arrangements have been made for him to give seminars on:

(i) Improved service life for tool steels;

(ii) Salt bath heat treatment;

(iii) The right furnace for the right job.

12.4 Consultation with Degussa (China) Limited, Associated Swedish Steels AB, Eagle and Globe (HK) Limited, the University and the Polytechnic has shown the willingness of these organisations to assist in seminars.

13.0 Consultancy

13.1 The HKPC is regularly asked to undertake both major and minor consultancy projects. During the course of my visit, I was asked specifically to involve myself with a number of "trouble-shooting" problems emanating from the heat treatment industry. Details of these are set out in Appendix J.

13.2 Reference to the results of the postal survey (paragraphs 4.3 (ix) and 4.3 (x) clearly shows the nature of the problems) and the demand for assistance from HKPC. There is little doubt that a significant increase in requests for help from the heat treatment industry will be made. If this help is to be forthcoming it is imperative that there be no delay to the purchase of the necessary facilities for the Heat Treatment Unit and that the remainder of the UNDP programme (Fellowship training and visit by second Expert) be speedily implemented.

14.0 Other Facilities Available to HKPC

14.1 Other equipment which the Heat Treatment Unit may ultimately need in phases II and III of its development could in the short term be made available by other organisations in Hong Kong.

(i) Detailed discussions have taken place with the Kowloon Motor Bus Company (KMB) concerning use by HKPC of the gas nitriding furnace. A formal proposal has been made to KMB for mutual co-operation between the company and HKPC.

(ii) Small fluidised bed furnaces are available in Hong Kong University and in the Polytechnic. Good relationships exist between these institutions and HKPC Heat Treatment Unit staff which should allow use of these specialised units if required.

(iii) Other larger scale industrial furnaces (vacuum, sealed quenched, belt conveyor) exist and could probably be used by HKPC staff, in conjunction with control instruments provided by HKPC.

15.0 Conclusions

15.1 With few exceptions, the Hong Kong Heat Treatment Industry is technologically backward, lacking suitable equipment, control and trained personnel.

15.2 Industry would welcome assistance from HKPC in the heat treatment area.

15.3 The establishment of an Heat Treatment Unit within HKPC, with expertise, an information retrieval system and specialist equipment could make a positive and dramatic impact on the heat treatment industry.

15.4 The Heat Treatment Unit as presently established is not in a position to offer the services requested by industry. Further training by means of UNDP fellowship schemes is necessary and additional funds are needed to complete phase I of the equipment requirements.

16.0 Recommendations

16.1 Immediate approval should be given for the authorisation of UNDP Fellowships to Mr. Wing-ching Keung and Mr. Peter Yau, to be operative from 1st October 1979.

16.2 Additional funds should be made available for equipment purchases, US$24,000 to come from UNDP 1980 unallocated funds and US$30,000 from Hong Kong Government.

16.3 Arrangements should be put in hand immediately for the visit by the second Expert, Mr. H.C. Child, commencing December 1979 or January 1980.

Acknowledgements

The writer wishes to acknowledge the various staff members of UNIDO and UNDP who assisted with the numerous administrative arrangements associated with the visit. Gratitude must also be expressed to the staff of the Hong Kong Productivity Centre for the co-operation they provided and for their friendliness. Particular thanks are due to Dr. J.C. Wright, Mr. S.K. Chan, Dr. L.T. Chan, Mr. W.C. Keung, and to Ms Mimi Leung who had the unenviable task of typing this report from hand written notes.

Appendix A

Companies/Institutions Visited

a). Contract Heat Treatment Companies

(i) Forest Industrial Company

Contact: Mr. S.L. Fok - Manager

Facilities: Three salt bath furnaces for carburising and hardening.
Muffle Furnaces for tempering.
Oil tanks - five different oils.
Hardness Tester.

Comment: No control on salt bath furnace temperature. Very cramped. A company working at full capacity and able to give service based on long practical experience. Allegedly obtains about 60% of contract heat treatment market.

(ii) Chung Tin Precision Machine Tool and Heat Treatment Company

Contact: Mr. F. Ma - Managing Director
Mrs. Choi, Ho Chi - General Manager/Mechanical Engineer

Facilities: Three salt bath furances.
Two Muffle furnaces.
Quenching tanks.
Hardness tester.

Comment: Temperature recorders installed. High level of consciousness of need for control. Well laid out plant. Reported that a better class of operator was required to ensure high quality of work. Insufficient order book to justify more than two days work per week. Takes about 30% of market.

(iii) O' Bailee Company Limited

Contact: Mr. Michael Lam - Sales Representative
Mr. Y.K. Poon

Facilities: Degussa Vacuum Furance.
Muffle furnace
Forced Air Circulating furnace
Facility for Nitrogen quenching.
Facility for sub-zero treatment.
Hardness tester.

Comment: Good control panel on vacuum furnace if used properly. Temperature measuring devices on other furnaces. Company deals mainly with tool steels and heat treats only to an agreed hardness. Production amounts to two charges per day (for 5 - 6 days). Probably only economic because furnace is second hand and was purchased cheaply.

b) Metal Product Manufacturers

(i) Hong Kong Precision Screws Manufacturing Company Limited

Contact: Mr. P.K. Tang - Vice President
Mr. Tang To - Assistant Manager

Facilities: Belt Conveyor furnace, with atmosphere from Endothermic Generator (Propane - Air)
Three Muffle furnaces

Comment: Conveyor furnace used for carburising. Properly instrumented and working well, if not profitably. Muffle furnaces used for hardening/tempering tools. Company experience difficulty in achieving consistency of hardness, and with distortion. Possibly due to operator inexperience of proper heat treatment practice.

(ii) Man Fung Metal Works Factory

Contact: Mr. Chan Siu Wah - Owner

Facilities: One homemade salt bath furnace.
One muffle.
Digital temperature meter.
Hardness tester.

Comments: The company hot forges watch cases and heat treats its own dies. The salt-bath furnace is too small, no control of temperature except by hand operation of burner. Pre-heating of dies on top of furnace is practiced and a wide temperature variation was observed. No control on oil temperature. Both salt bath, and muffle used for tempering were being overloaded. Little wonder die life was variable.

Owner very enthusiastic to improve set-up - showed some technical understanding of structural changes within steel.

(iii) Union Metal Works Ltd.

Contact: Mr. Samuel H.W. Sung - Director

Facilities: Oxy-butane blow torch (for heating small tools to hardening temperature). One muffle furnace - thermcouple broken.

Comments: Most heat treatment is performed by the Forest Industrial Company. Some small parts are heat treated in the works with a blow torch and muffle furnace. The tools (cold work tool steel) are not normally subjected to arduous conditions and few if any problems can be attributed to faulty heat treatment.

(iv) Sidchrome (S.E. Asia) Limited

Contacts: Mr. Daryl J. Esler - Director & Operations Manager

Facilities: Sealed Quench furnace.
Atmosphere Generator.
Air Circulating Furnace.

Comments: Heat treats is own products(spanners) but contracts out tooling to Chung Tin. If demand was big enough would prefer to do all heat treatment in-house. Australian input has created a proper understanding of need for control in heat treatment which is being well done.

(v) Shackman Limited

Contacts: Mr. Daniel W.Y. Hui - Technical Manager
Mr. Bill S.T. Keung - Production Engineer

Facilities: Muffle furnace.
Belt conveyor furnace.
Blow torch.
Bottled nitrogen and hydrogen.
Ammonia.

Comments: A good modern belt conveyor furnace with a cracked ammonia atmosphere. Tools heat treated either in muffle furnace, or with blow torch. Company accept that they have no temperature control and that this is the cause of many tooling problems.

(vi) Sonca Industries Limited

Contacts: Mr. Y.K. Chow - Technology Manager

Mr. K.C. Leung - Divisional Manager

Facilities: Two Muffle furnaces.

Forced air circulating furnace.

Comments: A good modern air circulating furnace. Muffle furnaces not being properly used, and evidence of significant temperature gradient within one furnace.

(vii) Advanced Semi-conductor Materials Asia Ltd.

Contacts: Mr. P.S.P. Lam - General Manager

Mr. A.C.F. Wong - Mechanical Engineer

Mr. C.D. Au - Mechanical Engineer

Facilities: Two muffle furnaces for heating up to 1,200°C and 300°C. Both with temperature indicators.

Comments: An attempt to heat treat intelligently but problems regarding hardness experienced because of thermal gradients, lack of atmosphere control, heating time. HKPC services to be provided.

(viii) Chia-Hua Comalco Ltd.

Contacts: Mr. Pak-Lau So - Production Manager

Mr. Poon Wai Ying - Engineer

Facilities: Large muffle furnace.

Forced air circulating furnace.

Tufftride salt bath furnace.

Comments: Used for heat treating extrusion dies. Although no atmosphere control on muffle furnace dies are packed in spent charcoal. Otherwise an excellent plant with all the necessary controls.

c) Machinery Manufacturers

(i) Hung Sang Engineering Works Limited

Contact: Mr. Poon Lun - General Director

Facilities: None

Comments: A company making die casting machines. Sends all work to be heat treated to sub-contractors (Forest Industrial Co.). Experience problems from time to time attributable to steel selection and/or heat treatment. Will require periodic help from HKPC.

d) Academic Institutions

(i) Hong Kong Polytechnic

Contacts: Dr. C. Irving - Principal Lecturer
Mr. B. Lee - Lecturer
Mr. N. Langdale - Consultant

Facilities:		
	Four Muffle furnaces (carbolite)	Dept. of Production and Industrial Engineering
	Fluidised bed furnace	
	Forced air furnace	
	Degussa sintering furnace	
	Kasenite muffle	Industrial Centre
	Heraeus tempering furnace	

Comment: Significant back-up support in terms of metallographic and testing laboratories. Fluidised bed and sintering furnaces are specialist ones that might occasionally be used by HKPC. Kasenite muffle furnace is semi-production size used for tool heat treatment. Some atmosphere is achieved but without control.

(ii) Hong Kong University

Contacts: Dr. G. Green
Dr. B. Duggan

Facilities: Three muffles (small)
Fluidised bed furnace (600°C)
Two salt baths (for 1000°C and 650°C max.)
- purchased awaiting delivery

e) Others

(i) Kowloon Motor Bus Co. (KMB)

Contacts: Mr. Wong - Engineer

Mr. Lui - Plant Manager

Facility: Gas Nitriding furnace

Comment: This furnace was purchased 1 - 2 years ago but has never been commissioned. It is unlikely that the company will now use it more than a few times per year. A proposal has been made by the expert for co-operation between KMB and HKPC which would allow KMB to utilise HKPC expertise in running the furnace and give access to HKPC for the use of the furnace.

(ii) Haeco Limited

Contact: Mr. R. Clarke - Senior Engineer

Facilities: Large muffle-type furnaces

Comment: A specialist company performing maintenance work. Furnaces used for sizing and aluminising. No conventional heat treatment being performed.

Appendix B

HEAT TREATMENT SURVEY

A. Questionnaire (circulated in Cantonese)

HEAT TREATMENT OF METAL SURVEY

A considerable quantity of metal parts is used by Hong Kong industry and many tools, dies and mould are required to make these and other non-metallic components. Both the life of the tools and the quality of the components produced may be very considerably influenced by the heat treatment to which the metal has been subjected.

To assist industry, HKPC is establishing a heat treatment unit which will provide training and technical consultation, and it is hoped that local companies will make increasing use of the facilities that will be available in the Centre. The development of this unit is being helped by United Nations (UNDP) funds and two experts from England will be in Hong Kong for six months to assist in this work. One of these experts, Mr. B. J. Meadows is currently with us until mid-September.

In order that unit can be most effective the cooperation of companies is invited in the completion of a survey. The object of this survey is to provide an over-all view of the extent of the heat treatment industry in Hong Kong, the types of treatment being used, the steels being processed and the difficulties encountered. Most questions merely require a yes or no answer, or just a ✓ and completion of the survey form should take you no more than five minutes.

Your cooperation in completing the attached questionnaire will be very much appreciated.

Please return it before August 17 to:-

Mr. W. C. Keung
Hong Kong Productivity Centre
Mongkok Branch
Bank Centre, 13th Floor
636 Nathan Road
Mongkok
Kowloon

Hong Kong Productivity Centre

SURVEY OF HEAT TREATMENT INDUSTRY

NAME OF COMPANY ____________________________________

ADDRESS ____________________________________

____

____

1. What is your main field of business?

____

2. Do you use or make any component, tool die or mould that requires heat treatment?

Yes ☐ No ☐

3. If "yes" which parts are heat treated and where are they treated?

Component		Tool/Die/Mould	
In your own plant	Sub-contracted	In your own plant	Sub-contracted

tick (✓) appropriate box

4. Which heat treatments are required?

	Component	Tool/Die/Mould
Stress Relieving/Annealing		
Hardening		
Tempering		
Surface Hardening		

tick (✓) appropriate box

5. What type of furnace do you possess?

Salt Bath	________	tick (✓) if appropriate
Muffle	________	
Forced Air	________	
Torch	________	
Coke Fire	________	

6. What steels do you heat treat? (list specifications, if known)

____

____

____

____

____

7. Have you any of the following control or testing equipment?

Temperature Measuring Device	________
Atmosphere Control Device	________
Hardness Testing Machine	________
Metallurgical Microscope	________

8. Are you satisfied with the quality of the work heat treated?

Yes ☐ No ☐

9. Do you encounter any of the following problems?

Hardness too high	______
Hardness too low	______
Distortion	______
Cracking	______
Others (please specify)	______

10. Would you like assistance from HKPC Heat Treatment Unit in solving these problems?

Yes ☐ No ☐

Thank you. Please return before 17th August to:

Mr. W. C. Keung,
Hong Kong Productivity Centre,
Bank Centre,
630-636 Nathan Road, 13th Floor,
Kowloon.

B. Analysis of Replies to Survey

The Hong Kong Government Imports and Exports Classification List classifies commodities by sections, divisions, groups and items. This method of classification is similar to one operated internally by HKPC and was used to establish those industrial sectors who would be approached for the survey. Companies on HKPC files were then circulated with the questionnaire.

The following list represents the major industrial groupings who were asked to assist in the survey.

Industry	No. of Replies
Fabricated Metal Products	55
Plastic Products	9
Watches and Clocks	7
Machinery and Equipment	6
Electronics	5
Electrical Products	3
Dies and Moulds *	2
Basic Metal Industries	1
Furniture	1
Footwear	0

Up to and including August 25th a total of 89 firms had replied to the questionnaire. All but four stated the need for heat treatment.

Table B1 - B8 set out the results obtained.

* not contained within the H.K. Government classification but separately classified by HKPC.

Table B1: Relationship between Source of Heat Treatment and Type of Product (Question 3)

Heat Treatment of	Exclusively In-house	Exclusively by Sub-contracting	In-house and Sub-contracting
Components	19	17	2
Tools/Dies/ Moulds	28	24	25

Table B2: Analysis of Type of Heat Treatment being Practised (Question 4)

Product Type	Stress Relief and Annealing	Hardening	Tempering	Surface Hardening
Component	16	18	11	13
Tool/Die/ Mould	30	70	48	32

Table B3: Analysis of Heating Method used by those 63 Companies Performing their Own Heat Treatment (Question 5)

Salt Bath	Muffle	Forced Air	Torch	Coke Fire
6	34	6	19	19

Table B4: Analysis of Control and Testing Equipment possessed by 63 Companies with their own Heat Treatment Facility (Questions 3, 5 and 7)

Temperature Measuring Device	Atmosphere Control Device	Hardness Testing Machine	Metallurgical Microscope	None
30	5	25	3	21

Table B5: Analysis of Problems Encountered by 66 Firms (Question 9)

Problem Type	Hardness Too High	Hardness Too Low	Distor tion	Cracking	Others
Frequency	23	32	44	17	16

Table B6: Analysis of 71 Steel "Specifications" Quoted (Question 6)

	National Specification	Suppliers Specifications	Not Identified	Inadequate or Vague
Frequency	23	23	7	18

Table B7: Analysis of 47 National or Suppliers Specifications by Area of Use

	Cold Work Tool Steels	Hot Work or Plastic Mould Steels	High Speed Steels	Others
Frequency	20	19	3	4

Table B8: Analysis of Frequency of Usage of Steel Specifications

Steel Type/Specification	Frequency
Hot Work	
Specification H13 or equivalent	20
Specification H10A or equivalent	4
Four other clearly defined specifications	5
Cold Work	
Specification 01 or equivalent	51
Specificiation D6 or equivalent	19
Specification D2	4
Specification D3	3
Specification W1	3
Six other clearly defined specifications	6

Appendix C

PROPOSALS FOR EQUIPMENT PURCHASE FOR THE HEAT TREATMENT UNIT

Summary

Analysis is made of the expenditure to date on equipment for the HKPC Heat Treatment Unit. Outstanding funds for 1979/80 will enable the Productivity Centre to purchase a high temperature (1300°C) furnace. In order to complete phase I of the development and to provide HKPC with essential facilities for assisting the tool and die industry, it will be necessary to purchase further equipment in 1980 at a total cost of US$54,000. It is strongly recommended that US$24,000 of this sum should be made available from UNDP unallocated funds, the remainder, US$30,000, coming from HKPC.

Introduction

The original proposal for heat treatment equipment to be funded by UNDP was US$20,000 and was contained in a project document dated 24th June 1976. The Hong Kong Government contribution towards equipment was set at HK$150,000. It was subsequently determined that out of the total funds available some equipment would be purchased in advance of the visit of the first Heat Treatment Expert. This was done in late 1978/early 1979.

On my arrival in Hong Kong on 22nd June 1979, the position was as follows:-

(a)	UNDP Input	US$ 20,000	
	of which	6,791	had been spent
	leaving	US$ 13,209	
(b)	HK Government Input	HK$150,000	
	of which	73,228	had been spent on equipment
	leaving approxi.	HK$ 76,772	equivalent to about US$15,000

The equipment purchased is listed in the appendix. I have been shown this equipment and fully endorse the necessity of having it as fundamental to the proper future working of the Heat Treatment Unit.

Current Situation

During my first five weeks in Hong Kong I have carried out a sufficiently detailed study of the Hong Kong industry to reveal very serious inadequacies in the heat treatment of tool and die steels. The strictest control needs to be exercised when heat treating such steels and particular attention has to be paid to the following parameters:-

(i) rate of heating (achieved by one or two preheating stages)

(ii) hardening temperature, and time at temperature

(iii) furnace atmosphere

(iv) cooling rate including possible use of interrupted quenching methods and proper selection and control of quenching oil

(v) tempering temperature and number of tempering treatments.

The equipment already purchased by the Productivity Centre is ideal for the treatment of general engineering steels but will meet only <u>some</u> of the requirements when hardening tool steels. It is therefore essential that the additional equipment should enable the Heat Treatment Unit to:

(i) perform the basic heat treatment of tool steels under properly controlled conditions representative of normal good practice. It would enable the Productivity Centre to set a standard for Hong Kong industry and could be offered to companies for use on a commercial basis.

(ii) provide the current modern processes by which tool steels may be treated. Thus the use of interrupted quenching ("martempering") should lead to less distortion/cracking, and the "Tufftride" process should considerably enhance tool life.

(iii) control and monitor (a) quality of in-coming material, (b) heat treatment conditions, (c) properties of heat treated steels.

I have therefore set out in the next section my proposals for the purchase of the equipment necessary to complete the first phase in the development of the Heat Treatment Unit. Failure to purchase, in particular, the furnaces would make the Unit completely ineffective as regards giving assistance to the Hong Kong tool and die industry.

Proposals

The proposals have been set out in the full realisation of the funds still currently available in 1979/80 (see introduction), in anticipation of Government funding in 1980/81, and in anticipation that money can be obtained from the UNDP "unallocated funds" for 1980.

For the furnaces, prices are based on quotation received about 8 months ago from a Germany company. Up-to-date quotations have been requested from manufacturers both in Germany and elsewhere. Currency exchange rates operating at the end of July 1979 have been used for conversion from DM and HK$ to US$.

	1979/80	
	US$	Source
High temperature (1300°C) Electrode Salt Bath	13,209	UNDP balance
	13,791	HKPC balance
	27,000	
	1980/81	
Interrupted quench (martemper) furnace	9,500	
"Tufftride" salt bath furnace	14,500	
	24,000	UNDP 1980 unallocated funds
Intermediate temperature (950 -1000°C) electrode salt bath furnace with spare pot	15,000	HKPC 1980/81 funds
Control and measuring equipment, including Vickers machine, Dew-point tester, temperature indicator, quenchometer, analytical apparatus, quenching tanks and oils, sub-zero equipment, bench microscopes, time-temperature recorder/controller, grit blaster	15,000	HKPC 1980/81 funds

Specifications

Specifications for all equipment with firm prices can be obtained during August-September. However as it is necessary for more detailed cases to be made now for the Interrupted Quench furnace and for the "Tufftride" salt bath, a statement concerning these is set out below:

(a) Interrupted Quench (martemper) Furnace

The hardening of tool steels requires eventual heating to temperatures between 1000°C and 1300°C depending on the steel in question, followed by rapid cooling. Unfortunately a side effect of rapid cooling (quenching) is to cause distortion of the steel and possibly even cracking. This can only be avoided either by the use of more expensive steels which may be cooled more slowly, or by interrupting the quench at 300-400°C in a carefully controlled manner - a process referred to as martempering.

For Hong Kong, having to import all its steels and having only a limited range of steels to select, the interrupted quench provides the best solution to the problems inherent in hardening. A specification for a German furnace is set out below based on information supplied in December 1978. It may be regarded as typical of the requirements.

Pot dimensions:	diameter	350 mm
	depth	500 mm
Rated temperature:		650°C
Rated Voltage, 3 phase a.c.		380 v
Rated Power		24 kw
Heating time (20-600°C)		3½ h
No load consumption at 560°C		6 kwh/h
Quenching capacity from 1250 to 560°C		50 kg/h
Heating capacity from 20 to 560°C		160 kg/h
Max. permissible load when quenching		12 kg

(b) "Tufftride" Furnace

The service life of conventionally hardened tool steels may be considerably enhanced by a short term treatment known as the Tufftride Process. A specially aerated salt bath operating at 570°C allows diffusion into the surface of the steel of between 7 and 9% of nitrogen and minor amounts of carbon.

This surface treatment has the following effects:

a significant increase in wear resistance, development of very good anti-friction properties, increased resistance to fatigue failure, increased resistance to corrosion.

The Tufftride process is now a well established part of European and American heat treatment practice. In the present state of development of Hong Kong industry, the process needs to be used and could be made available by HKPC to individual companies with significant benefits to them in terms of tool life.

A typical specification is as follows:-

Pot dimensions:	diameter	350 mm
	depth	500 mm
Rated Temperature		650°C
Rated Voltage, 3 phase a.c.		380 v
Rated Power		24 kw
Time to heat to 570°C		2 h
No load consumption at 570°C		5 kwh/h
Heating capacity 20°C - 570°C		160 kg/h

Conclusions

(1) To date the following funds have been spent on heat treatment and ancillary equipment:

from UNDP US$6,791

from HKPC US$14,082

(2) In the current financial year, a high temperature (1300°C) furnace should be purchased, funded jointly by UNDP (US$13,209) and HKPC (US$13,791), a total of US$27,000.

(3) In order to complete phase I, a total further funding of US$54,000 is required and it is proposed that of this HKPC should provide US$30,000.

(4) The strongest possible case exists for the balance, US$24,000, to be made available from UNDP 1980 unallocated funds in order to secure the purchase of an interrupted quench furnace and a Tufftride furnace.

List of Equipments Purchased for Heat Treatment Unit

			Amount HK$
1977/78			
1 set	Microsectioning equipment	$12,149.00	
1 "	'Olympus' inverted metallurgical microscope model PME, AC220V, 50 cycles complete with standard accessories	12,890.00	
1 "	'Olympus' micrometer eyepiece with digital counter, model OSM-D2, AC220V, 50 cycles	8,850.00	
1 "	'Olympus' Palaroid camera back 3¼ x 4¼ model PME-PA-P for metallurgical microscope	1,320.00	
1 pc.	'Olympus' M plan 100X objective, OI 1	1,470.00	$36,679.00
1978/79			
1 pc.	'Osmund' forced air circulation furnace type LKUC-3/4	$24,610.00*	
1 "	'Naber' high temp. muffle furnace, model M41/SH with additional sic plate	15,200.00	
1 "	Rockwell hardness tester model 4TT completed with standard accessories	14,000.00*	
1 set	'Metaserv' C200 RP Rotary pregrinder & accessory	9,152.94	
1 "	Tube type resistance furnace, model RJK-2-13	3,100.00	
1 "	'Omega' electronic digital thermometer, model 2160 A-K, 200-1360°C	1,794.00	
	Thermocouple probes	936.00	
1 "	'Metaserv' introductory practical metallography & foundry metallography	851.35	
1 "	'Olympus' 35 mm camera back for heat treatment unit	310.00	
2 units	Solid carbide square die drill 3/16" x 3/8"	202.73	
-	Glasswares & glasstubing	181.30	
1 pc.	'Sentry' introductory assortment heat treating container	140.00	
	Tongs for heat treatment	63.00	
5 set	'Chino' CA type lead wire meters @ $13.00	65.00	70,606.32
			HK$107,285.32

* Purchases funded by UNDP

SUMMARY

HKPC	HK$ 73,228.32
UNDP (US$6,731)	34,057.00
	HK$107,285.32

Heat Treatment Cost Exercises

1. Hardening and Tempering of Cold Work Tool Steel (01)

Estimated Costs (HK$) of	Weight of Steel Charged into Furnace (lbs)					
	5	10	25	50	75	100
Energy at 30c/kWh	30	31	32	51	80	105
Direct Labour *	60	60	60	90	140	170
Depreciation **	58	58	58	58	70	70
Direct Overheads***	30	30	30	45	70	85
Total	178	179	180	244	360	430
Income at HK$5 per lb. ****	25	50	125	250	375	500
% Cost Recovery $= \frac{100 \times \text{Income}}{\text{Expenditure}}$	14	28	69	102	104	116

* Technician II rate

** Based on an initial capital investment of HK$115,000 with a 2 000 day write-off period

*** Analysis of Direct Overheads of Heat Treatment Unit reveals that they would be approximately 50% of Direct Labour Costs

**** Current price charged by Contract Heat Treatment Companies in Hong Kong for this steel is between HK$3 and HK$5 per lb.

Costing based on a furnace loading shown on page D5

2. <u>Hardening and Tempering of Hot Work Tool Steel (H13)</u>

Estimated Costs (HK$) of	Weight of Steel Charged into Furnace (lbs)					
	5	10	25	50	75	100
Energy at 30c/kWh	80	82	84	122	201	236
Direct Labour *	110	110	110	140	220	250
Depreciation **	110	110	110	123	220	233
Direct Overhead***	55	55	55	70	110	125
Total	355	357	359	455	751	844
Income at HK$10 per lb.****	50	100	250	500	750	1000
% Cost Recovery = 100 x Income / Expenditure	14	28	70	110	100	118

* Technician II rate

** Based on initial capital investment of HK$220,000 with a 2 000 day write-off period

*** Analysis of Direct Overheads of Heat Tratment Unit reveals that they would be approximately 50% of Direct Labour costs

**** Current price charged by Contract Heat Treatment companies in Hong Kong for this steel is between HK$6 and HK$10 per lb.

Costing based on a furnace loading shown on page D6

3. Hardening and Tempering of High Speed Steel (M2)

Estimated Cost (HK$) of	Weight of Steel Charged into Furance (lbs)				
	1	2	5	10	25
Energy at 30c/kWh	96	97	99	104	110
Direct Labour *	110	110	110	110	110
Depreciation **	110	110	110	110	110
Direct Overheads***	55	55	55	55	55
Total	371	372	374	379	385
Income at HK$20 per lb.	20	40	100	200	500
% Cost Recovery $= \frac{100 \times \text{Income}}{\text{Expenditure}}$	5	11	27	53	130

* Technician II rate

** Based on an initial capital investment of HK$220,000 with a 2 000 day write-off period

*** Analysis of Direct Overheads of Heat Treatment Unit reveal, they would be approximately 50% of Direct Labour Cost

**** Current price charged by Contract Heat Treatment Companies in Hong Kong for this steel is approximately HK$20 per lb.

Costing based on a furnace loading shown on page D7

4. "Tufftriding" of Steel

Estimated Costs (HK$) of	Weight of Steel Charged into Furnace (lb.)					
	5	10	25	50	75	100
Energy at 30c/kWh	26	27	29	43	58	87
Direct Labour *	110	110	110	110	110	165
Depreciation **	35	35	35	35	35	70
Direct Overheads***	55	55	55	55	55	82
Total	226	227	229	233	258	404

Charged HK$ per lb. to ensure 100% cost recovery****	45	23	9	5	3	4

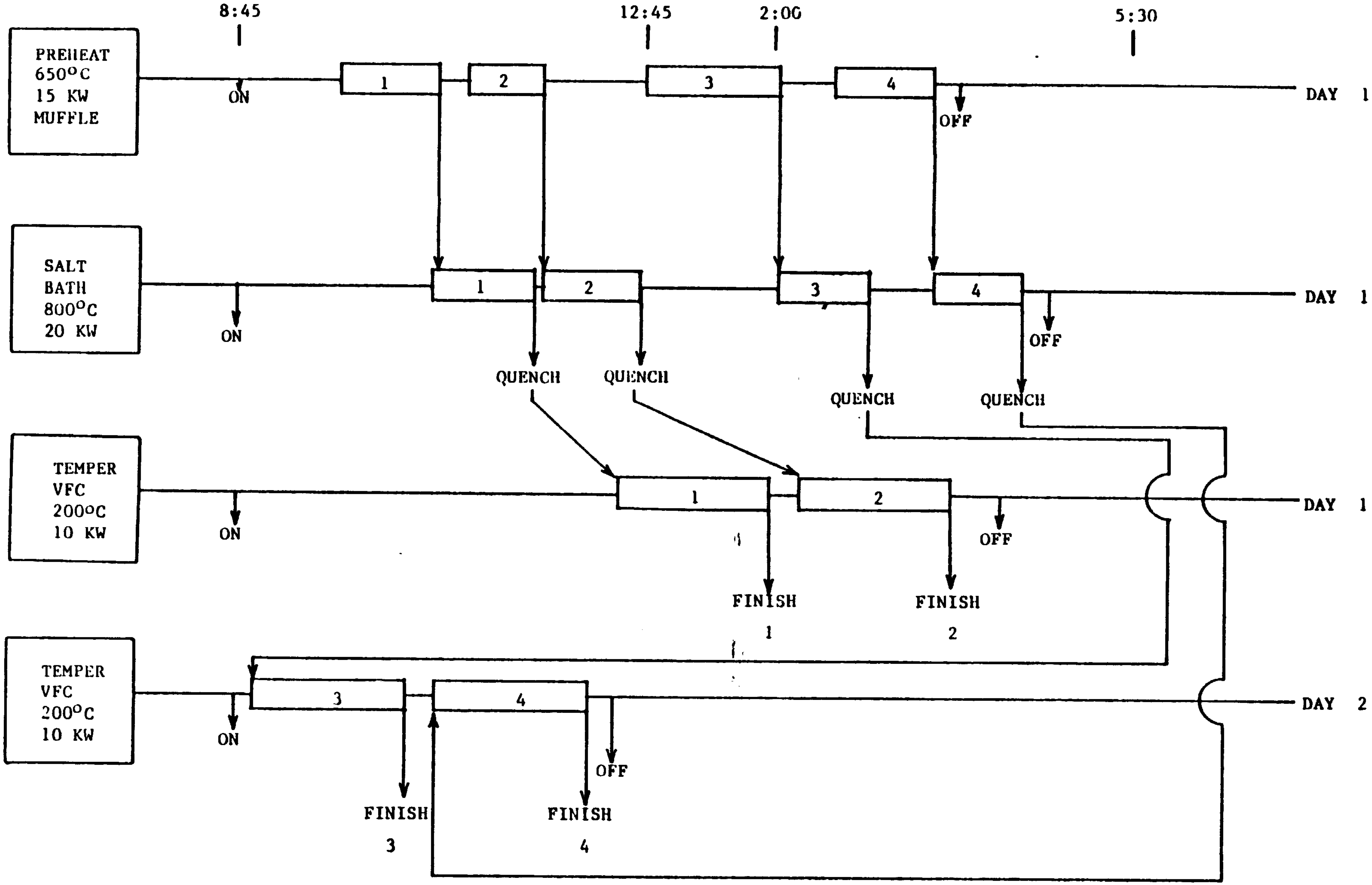
* Technician II rate

** Based on an initial capital investment of HK$70,000 with a 2 000 day write-off period

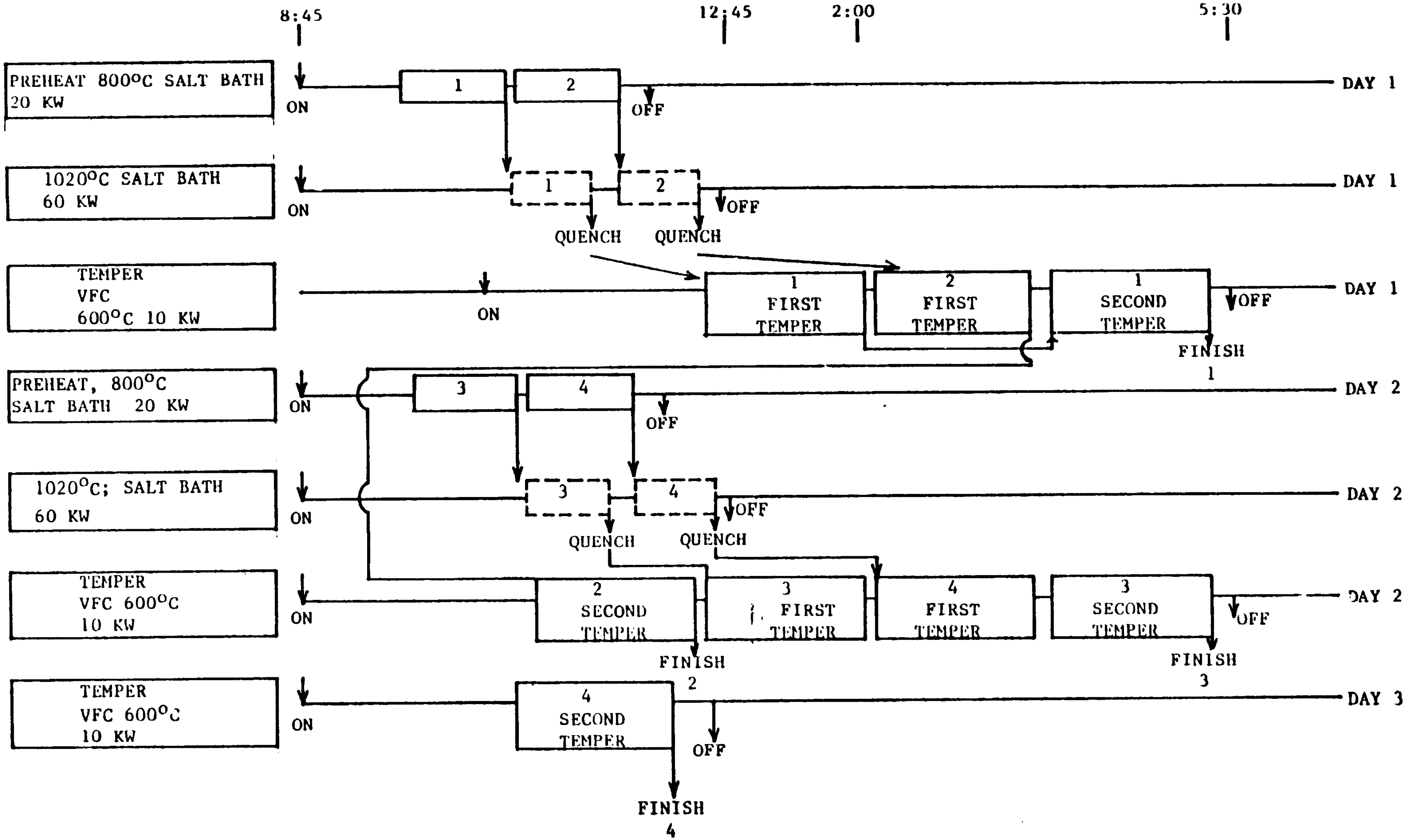
*** Analysis of Direct Overheads of Heat Treatment Unit reveals that they would be approximately 50% of Direct Labour Cost

**** Not available in Hong Kong - no price norm.

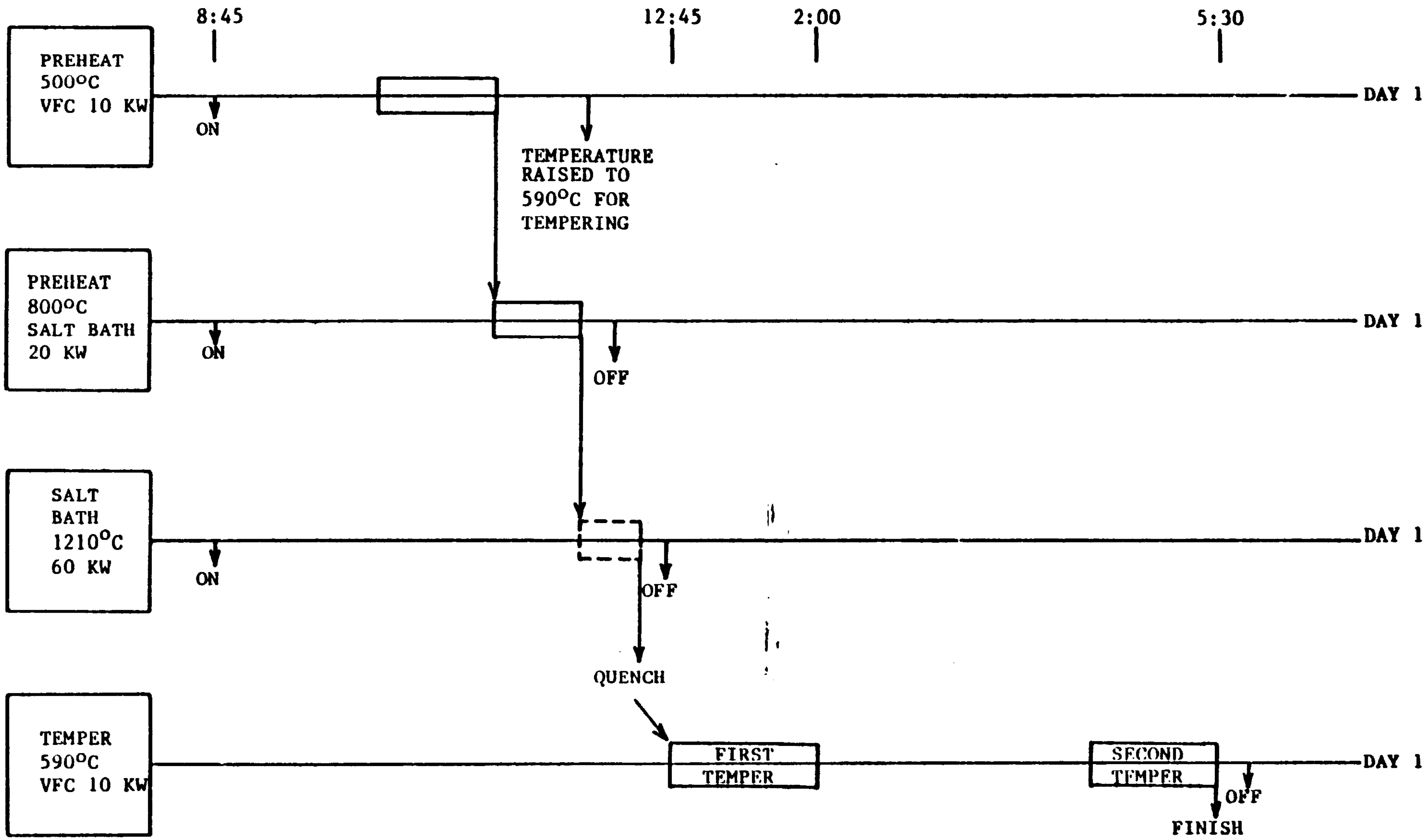
Costing based on a furnace loading shown on page D8



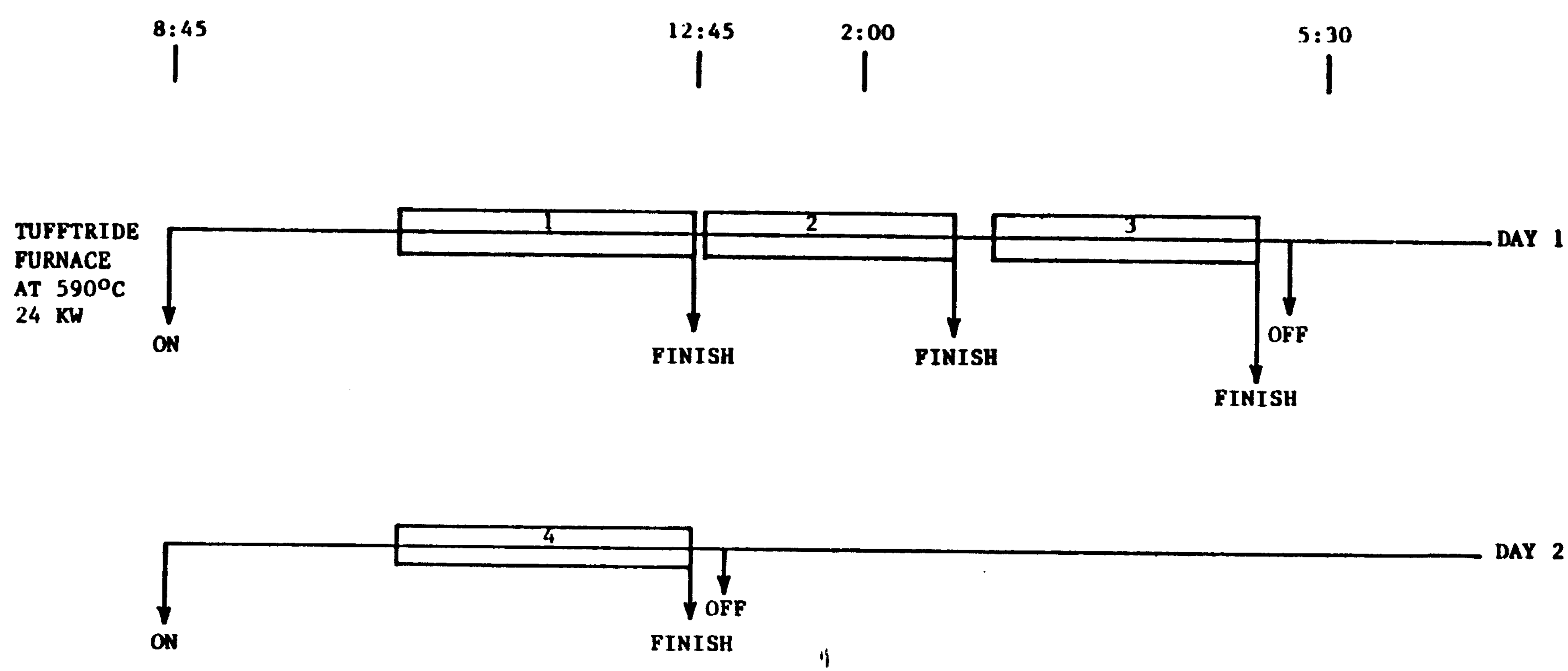
D5 SCHEME FOR HARDENING AND TEMPERING STEEL 01, UP TO 100 lb WEIGHT IN



D6 SCHEME FOR HARDENING AND TEMPERING STEEL H13, UP TO 100 lb WEIGHT
IN 4 x 25 lb CHARGES



D7 SCHEME FOR HARDENING AND TEMPERING STEEL M2 IN WEIGHTS UP TO 25 lb.



D8 SCHEME FOR TUFFTRIDE PROCESS, APPROXIMATELY 1½ HOURS at TEMPERATURE; STEEL UP TO 100 lb WEIGHT IN 4 x 25 lb CHARGE.

Appendix E

Proposal for Operatives Certificate Course in Heat Treatment Practice

The course would be for heat treatment operatives engaged in shop floor operations. The emphasis would be almost entirely on heat treatment practice and the way this may influence quality of the work. The course would cover six training periods, two of which would include laboratory-demonstration time.*

Syllabus

1. Important properties of metals - hardness, strength, toughness at room temperature. Red hardness, wear resistance.
   Dependance of these properties on composition (specification) of material and its heat treatment. Examples of heat treated materials - cold work tool steels, hot work tool steels, high speed cutting steels, carbon and low alloy steels for general engineering applications, (case study approach to all these to demonstrate particular requirements). Types of heat treatment: hardening, tempering, annealing, stress relief, carburising, nitriding.

2. Importance of rate of heating. Expansion of metals. Temperature gradients within metals caused by different heating rates. Differential expansion brought about by temperature gradients. Distortion. Importance of heating rate with reference to carbon and low alloy steels, and high alloy steels. Use of pre-heat temperatures. Practice for commonly used Hong Kong steels. Influence of size and shape of component.

3. Significance of hardening temperature. Elementary reference to structural changes in steel. Influence of composition on temperature at which change occurs. Reference to varying groups of steel previously discussed and the hardening temperatures used. Effect of both under-heating and over-heating on properties.
   * Elementary description/demonstration of metallurgical microscope and hardness testing machine. Laboratory demonstration of effect on hardenss and structure of quenching from 700°C, 750°C, 800°C, 850°C and 900°C for an 0.3% carbon steel.

4. Significance of cooling rate. Elementary reference to structural changes
   * in steel when being cooled from correct hardening temperature. Laboratory demonstration of these structures together with corresponding hardness

../2

values. Annealing. Importance of chemical composition in establishing proper cooling rate to achieve either an annealed or an hardened steel. Types of quenches available, brine, water, oil, air. Different types of quenching oil. Distortion arising from cooling.

5. (a) Tempering. Effect on properties of reheating an hardened steel. Elementary references to structural changes. Laboratory demonstration of this with corresponding hardness measurements. Need for accurate temperature control. Relationship of tempering temperature to operating service temperature. Elementary explanation of double and triple tempering.
(b) Surface effects. Oxidation of iron and of carbon. Carburising and Nitriding. Importance of control.

6. Problems in heat treatment. Incorrect hardness (too hard, too soft). Distortion, cracking.
Case study approach referring to cold work tool steels, hot work and high speed tool steels, and to general engineering (carbon, low alloy) steels.

Appendix F

Proposal for Technicans Certificate Course in Heat Treatment Control

The course is designed for technicians who would be expected to undertake the appropriate control, calibration and maintenance of equipment and instrumentation necessary in good heat treatment practice. The emphasis would be on practical control aspects and a significant training in the use of control and measuring instruments would take place in the HKPC laboratories.*

1. Types of steel heat treated. Particular importance of % carbon. Need for specifications and material identification.
   Types of heat treatment: annealing, normalising, hardening, tempering, surface treatments. Importance of control of heating rate, temperature, time at temperature, furnace atmosphere, cooling rate, reheating temperatures and times.

2. * Temperature measurement. Principle of thermo-couples, types and uses. Potentiometric box. Digital temperature indicators. Calibration. Radiation pyrometers.
   * Temperature variation within furnaces. Temperature control and indicating/ recording equipment accuracy.

3. Surface reactions when heat treating steel. Carburising, Nitriding, decarburisation, scaling. Identification of oxidising gases (oxygen, water vapour, carbon dioxide). Importance in control of carbon monoxide,
   * hydrogen and hydro-carbons. Measuring instruments, principles and uses. Dew-point meter, infra-red analyser, oxygen probe.

4. * Mechanical testing methods. Theory of hardness testing. Use of Rockwell machine for different materials utilising different indentors and loads. Surface hardness measurements on case hardened components.
   Tensile testing - load v elongation relationship. Calculation of yield stress, ultimate tensile strength, % elongation and reduction in area.
   Impact testing.

5. The metallurgical microscope. Preparation of specimens. Etching.
   * Examination of heat treatment structures under the microscope (annealed, hardened, hardened and fully tempered, low alloy steel and high alloy steel) and the relationship of structure to hardness.
   Measurement of case depth in carburised and nitrided steels. Demonstration.

6. * Practical laboratory period to demonstrate influence of different hardening temperatures on structure and hardness. Establishment of a tempering curve.

7. Furnace maintenance. Control in salt baths. Quenching, oil selection, use and control. Measurement of quenching oil characteristics. Quenchometer. Safety aspects in heat treatment.

8. Problems in heat treatment, cause and effects. Quality control. Charts.

Appendix G

Proposal for Certificate, and Advanced Certificate Courses in Heat Treatment Technology

The two courses would be for middle and top management involved in or requiring heat treatment. Each course would be of eight sessions duration and applicants for the Advanced Certificate Course would be expected to have undertaken the Certificate Course. Together the two courses will provide a comprehensive survey of the science and practice of heat treatment which will clearly demonstrate the need for appropriate equipment and proper control. There will be a detailed discussion of the heat treatment of particular groups of steel including hot and cold work tool steels, high speed cutting steels and general engineering steels. Quality control and the costing of heat treatment will be discussed together with recent developments in heat treatment processes and instrumentation. Where appropriate laboratory-demonstration work will be included.*

Syllabus

Certificate Course

1. Introduction - reasons for heat treatment. Types of heat treatment.
   * Influence of structure on properties. Simple explanation of structure of steel and use of the metallurgical microscope. Significance of structures including ferrite, carbide, martensite and austenite. Influence of carbon on hardness of steel. Use of alloy steels.

2. Hardening of steel. Need for control of heating rate, hardening temperature,
   * time at temperature and cooling rate. Effect of using different steels on these parameters. Significance and use of TTT diagram and influence of alloying elements on it. Decarburisation. Tempering of steel - effect on properties. Reasons for double and triple tempering. Sub-zero treatment.

3. Surface Hardening of steel. Chemical reactions at surface. Carburising by pack method, in gaseous atmosphere and in salt bath. Nitriding in gaseous atmosphere and in salt bath.

4. Other heat treatment processes. Annealing, normalising, stress relieving, age (precipitation) hardening.

5. Heat Treatment of general engineering steels (carbon and low alloy).

6. Heat treatment of hot work tool steels.

7. Heat treatment of high speed cutting steels.

8. Heat treatment of cold work tool steels.

Advanced Certificate Course

1. Furnace types - batch and continuous. Muffle, Sealed Quench, Shaker Hearth, Belt. Salt Bath. Furnace atmospheres - generators. Endothermic and Exothermi Nitrogen base atmospheres.

2. Quenchants. Theory of quenching with reference to TTT diagram. Brine, water, oils, air. Quenchometer. Heat treatment instrumentation. Thermocouples. Atmosphere control measurement. Dew point meters. Infrared analyser oxygen probe.

3. Quality control in heat treatment. Statistical approach. Mean and standard deviation, Quality Control charts.

4. Problems in heat treatment. Reasons for failure to attain correct hardness as related to structure. Causes of failure related to temperature, time, cooling rate, atmosphere control and tempering practice. Distortion and cracking in heat treatment.

5. Steel selection for heat treatment. Properties required (room temperature hardness, hot hardness, wear resistance, toughness).
   Alloying elements used (Ni, Cr, Mo, W, V, Co). Effect on TTT curve.
   Jominy test and significance.

6. Use and interpretation of trade literature. Explanation of graphs in manufacturers brochures. Case study on furnace selection using brochures.

7. Costing of heat treatment. Direct costs and overheads. Particular reference to energy costs and future trends. Significance of labour costs and balance between labour and other costs.
   Capital costs and investment appraisal.
   Tool costs. Significance of steel price in context of tool life.

8. Modern Developments in heat treatment. Vacuum furnaces. Induction heating. Tufftride process. Developments in instrumentation and control.

Appendix H

Recommended Library Purchases for Heat Treatment Unit

1. Metallurgy and Heat Treatment of Tool Steels
   R. Wilson
   McGraw-Hill Book Co. (UK) Ltd.

2. Heat Treatment for Beginners
   Part 1. Introduction; Processes; Materials; Furnaces
   Part 2. Atmospheres; Quench and Draw Heat Treating
   Part 3. Carburising; Carbonitriding
   L.J. Haga
   State Heat Inc.

3. Glossary of Heat Treatment
   Publication No. TNC 57E, Swedish Centre of Technical Terminology

4. Heat Treatment of Spheroidal Graphite S.G. Cast Iron
   British Cast Iron Research Association.

5. Surface Hardening of S.G. Iron
   British Cast Iron Research Association

6. Heat Treatment of Steel
   B.P. Oil Ltd.

7. Introduction to Practical Heat Treating
   Resources Development Corporation.

8. Heat Treatment of Welded Structures
   F.M. Burdekin
   The Welding Institute.

9. Principles of Heat Treating
   Resources Development Corp.

10. Induction Hardening and Tempering
    A.S.M. Monograph on Heat Treating.

11. Quenching and Martempering
    A.S.M. Monograph on Heat Treating.

12. Furnace Atmospheres and Carbon Control
    A.S.M. Monograph on Heat Treating.

13. Gas Carburising
    A.S.M. Monograph on Heat Treating.

14. Principles of Heat Treatment
    M.A. Grossman and E.C. Bain
    American Society for Metals.

15. "Cassel" Manual of Heat Treatment and Case Hardening
    Imperial Chemical Industries Ltd.

16. Heat Treatment of Metals
B. Zakharov
Peace Publishers.

17 Heat Treatment of Metals
P.S. Houghton
The Machinery Publishing Co. Ltd.

18. Heat Treatment of Steel
E. Gregory and E.N. Simons
Sir Isaac Pitman & Sons Ltd.

19. Protective Atmospheres
A.G. Hotchkiss and H.M. Webber
John Wiley & Sons Ltd.

20. Elements of Hardenability
M.A. Grossman
American Society for Metals

21. Controlled Atmospheres for the Heat Treatment of Metals
I. Jenkins
Chapman & Hall Ltd.

22. The Selection and Hardening of Tool Steels
L.H. Seabright
McGraw-Hill Book Co. (UK) Ltd.

23. Hardenability and Steel Selection
W. Crafts and J.L. Lamont
Sir Isaac Pitman & Sons Ltd.

24. Metal Working and Heat Treatment Manual
F. Johnson
Vol. 1: Carbon Steels
Vol. 2: Alloy Steels, Cast Irons and Non-Ferrous Metals
Vol. 3: Surface Hardening Processes
Vol. 4: Furnaces and Pyrometry
Paul Elek Books Ltd.

25. Steel and Its Heat Treatment
D.K. Bullens
Vol. 1: Principles
Vol. 2: Tooks Processes, Control
Vol. 3: Engineering and Special Purpose Steels
John Wiley & Sons Ltd.

26. Heat Treatment: A Handbook
I. Kamenichny
Central Books Ltd.

27. Phase Transformation Kinetics and Hardenability of Medium-Carbon
Alloy Steels
W.W. Cias
Climax Molybdenum Co.

28. Metal Progress Databook
American Society for Metals.

29. The Mechanical and Physical Properties of the British Standard En Steels
J. Woolman and R.A. Mottram
Vol. 1: En 1 -En 20
Vol. 2: En 21-En 39
Vol. 3: En 40-En 363
Pergamon Presss Limited

30. De Ferri Metallographia Vol. 2: Structure of Steels
A. Schrader and A. Rose
Verlag Stahleisen m.b.H.

31. Isothermal Transformation Diagrams
United States Steel Corp.

32. Alloy Steels
Samual Fox & Co. Ltd.

33. The Transformation of Austenite in the Continuous Cooling of Steel (An Atlas of Thermo-kinetic Diagrams)
P.V. Romanov and R.P. Radchenko
State Publishing House

34. Atlas: Hardenability of Carburised Steels
Climax Molybdenum Company Ltd.

35. Transformation Characteristics of Direct Hardening Nickel Alloy Steels
The International Nickel Co. (Mond) Ltd.

36. Atlas of Isothermal Transformation Diagrams of B.S. En Steels
I.S.I. Special Report 56.
The Metals Society.

37. Atlas of Isothermal Transofrmation Diagrams
United States Steel Corp.

38. The Hardenability of Steels
C.A. Siebert, D.V. Doane and D.H. Breen
American Society of Metals

39. Source Book on Nitriding
American Society for Metals 1977

40. Carburizing and Carbonitriding
American Society for Metals 1977

41. Atlas of Continuous Cooling Transformation Diagrams for Engineering Steels
M. Atkins,
British Steel Corporation 1977

42. Heat Treatment 73
The Metals Society 1975

43. Steel and its Heat Treatment: Bofors Handbook
K.E. Thelning
Butterworth & Co. Ltd. 1975

44. Combustion Technology Manual
Industrial Heating Equipment Association 1974.

PROBLEMS IN THE HEAT TREATMENT OF TOOL STEELS

INTRODUCTION

The generic phrase, tool steels, covers a very wide range of compositions and uses. A previous seminar given by Wilkins[(1)] outlined the different types of tool steels available, broadly dividing them into high speed cutting steels, hot work steels, and cold work steels. More comprehensive texts deal in greater length with the influence of composition on service behaviour but in the content of this seminar consideration will be given to the types of steel listed in Table I.

General Types	C (%)	Cr	Mo	V	Co	W
High Speed Steels	0.7-1.2	4	0 or 5-9	1-2	0 or 5-12	1-20
Hot Work Steels	0.3-0.4	3-5	2	0.3-1	0 or 3	0-9
Cold Work Steels	0.3-2.0	1-12	0-1	0-1	0 or 3	0-2

In terms of choice, the cold work group provides the biggest range. The properties that are sought have been generally described as wear resistance, red hardness, toughness, dimensional stability and machinability. These properties, however defined, are generally achieved by the creation within the steel of the correct structural condition and in order that the problems of heat treatment may be better understood a brief statement of the micro-structural constituents found in steel needs to be given.

MICROSTRUCTURAL CONSTITUENTS IN STEEL

Iron is the major constituent of any steel and pure iron exists in two forms. At room temperature and up to about 900°C it is referred to as alpha (α)-iron whilst above 900°C up to nearly 1500°C it is called gamma (γ)-iron. In steels whether carbon or alloy, the α constituent is called "ferrite" and the γ constituent is referred to as "austenite". However, the temperature at which one changes to the other will depend on the carbon and alloy content. In addition to ferrite and austenite, a carbide

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(1) Paper given by Trevor Wilkins at HKPC on 21.2.79

phase may exist. In plain carbon steels the carbon may be chemically bonded to the iron and iron carbide may be formed. In alloy steels the carbon may be combined with, for example, chromium, or tungsten or vanadium or molybdenum.

From Room Temperature Up To Approximately 700°C

In steel at temperatures between 20°C and about 700°C the normal "equilibrium" structure will be of ferrite and carbide. Ferrite is soft, the carbides hard, but overall the hardness of the steel will be relatively low. An annealed or normalised steel should consist of ferrite and carbide, although the form of the carbide may be affected by the actual heat treatment condition.

Above 700°C

Above 700°C the structure increasingly consists of austenite and as the temperature increases there will be fewer and fewer carbides. In a medium carbon steel all carbide should have disappeared by dissolving in the austenite at 723°C. However with very highly alloyed tool steels some alloy carbides will still exist at 1200 - 1300°C.

Cooling Down

If a steel is cooled down from a high temperature its structure will be determined by the rate of cooling. At "slow" rates of cooling the high temperature constituent, austenite, will eventually revert back to the normal low temperature ferrite + carbide. At faster rates of cooling ("quenching") this reversion is prevented and another constituent is formed.

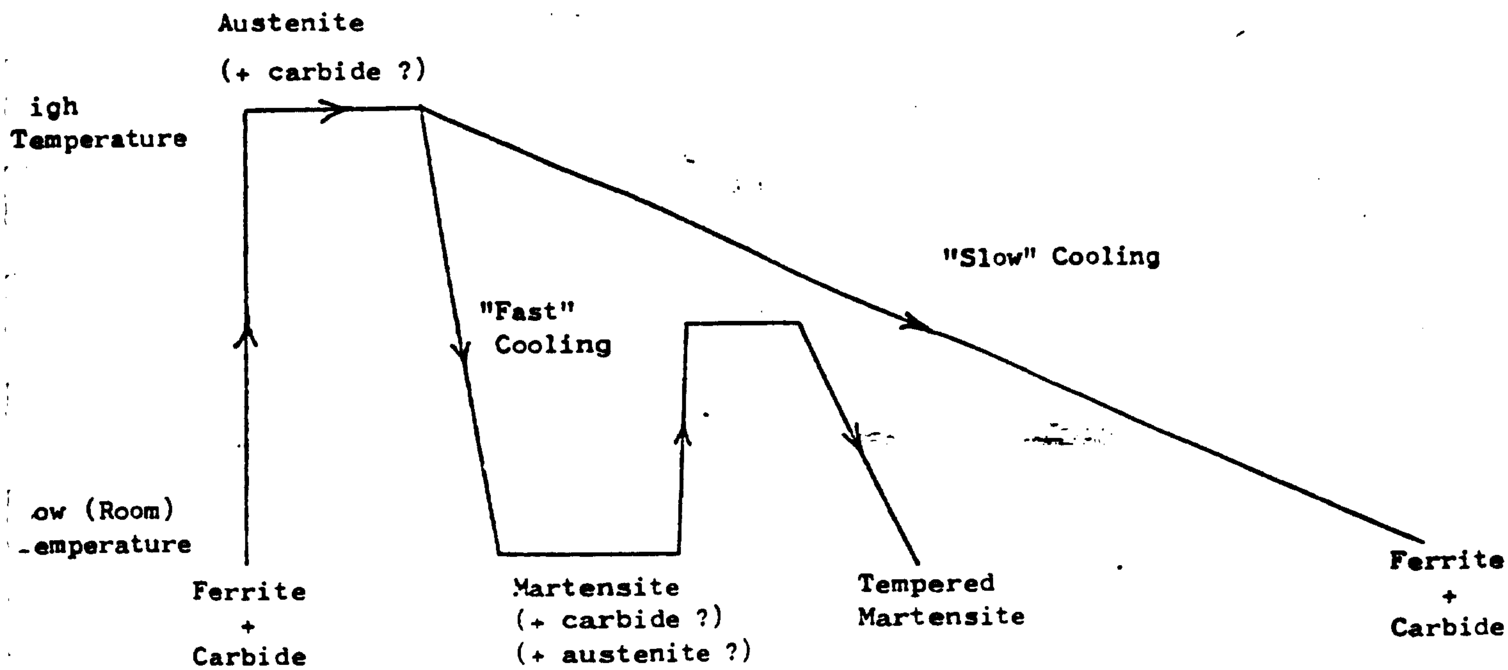
Martensite

Martensite is a very hard constituent in steel created by the cooling of a hot steel at a rate sufficiently fast to prevent the normal structure developing. It is a product of the transformation of austenite and the hardening of steel requires martensite formation. The hardness of the martensite is principally determined by the carbon content of the steel.

Reheating Martensite

The reheating of martensite up to about 700°C is referred to as tempering. It normally gives rise to a reduction in hardness and if the steel was heated for a sufficiently long time at, say 650°C the martensite structure would revert to the normal equilibrium one of ferrite plus carbide.

Heating of the martensite above 700°C will cause the reformation of austenite. The sequence of events in heating, cooling and rehoating may be shown schematically:



Such a diagram seriously over simplifies the subject and, of course, temperatures (whether "high" or "low") will vary according to the composition of steel being considered.

Structural Requirements In Tool Steels

In order that a tool steel may perform satisfactorily it needs to be hardened and tempered. Its structure should consist essentially of tempered martensite, i.e. the very hard constituent martensite produced by "fast" cooling but with a toughness created by controlled reheating - tempering. Depending on the steel being considered the structure may additionally contain alloy carbides. What should not be present are the soft phases ferrite or austenite. In order to understand the problem that occur with tool steels, and the causes and cures of these problems, reference inevitably has to be made to the micro-structural constituents described above.

Too Hard

A tool steel that is too hard will probably be brittle and prone to fracture. It is likely that such a condition has been brought about either by omission of the tempering treatment or by tempering at too low a temperature. The change in hardness with tempering temperature is shown in Fig.1. Certainly at the higher temperature where the rate of change of hardness increases, the control of tempering temperature is vitally important and, as for any heat treatment operations, proper control instrumentation should be used.

A possible cause of excess hardness may be an incorrect chemical composition - particularly the % carbon. The as quenched hardness of the martensite is very significantly affected by the carbon level and this influence of carbon will still be apparent even after tempering. Thus an 0.4% carbon steel such as may be used for hot working tools, should produce a hardness after quenching of about Rc52. If inadvertantly a carbon level of 0.5% is supplied the hardness will rise to about Rc60.

Too Soft

(a) Just as too high a carbon content can produce steel that is too hard, so a lower than specified level of carbon will lead to a lower level of hardness.

(b) Associated with this is the phenomenon of surface decarburisation. If a medium to high carbon steel is heated in air to a temperature at which austenite forms (in practice probably 850°C upwards) then some of the carbon at the surface of the steel will react with oxygen in the air and thus cause a depletion in the surface carbon content. This is referred to as decarburisation. The effect on the surface hardness is just the same as if a lower carbon steel had been used. To prevent this it is normal practice to use a controlled gaseous atmosphere or heat treat in a salt bath.

(c) The quenching rate down to room temperature (but particularly between 700°C and 400°C) has an influence on the hardness. The rate of cooling has got to be sufficiently fast to prevent the high temperature constituent austenite transforming to ferrite and carbide, and allow, instead, the transformation of austenite to hard martensite.

The rate of cooling required to achieve the martensite structure depends on the size and alloy content of the steel, and with many tool steels it may be sufficient to air cool. However if the cooling rate is insufficient for the steel and tool in question some ferrite may form, perhaps together with martensite, and give rise to an inadequately hardened steel.

(d) The temperature to which the steel is heated prior to quenching, if not correctly achieved can produce a tool that is too soft. The steel needs to be heated to a temperature sufficiently high to have removed all ferrite from the structure and for austenite to be present. Martensite can only be formed from austenite and so a structure of ferrite plus austenite on quenching will change to ferrite plus martensite. Such a steel containing some (soft) ferrite cannot be as hard as one containing only martensite.

(e) For some steels softness may result after quenching because too high a heating temperature has been used. As the temperature is increased more and more alloy carbides will dissolve in the austenite, effectively enriching it in alloy content. On cooling, perhaps even in air, down to room temperature not all the austenite will necessarily transform to martensite and the structure containing some austenite will be softer than if complete transformation had occured. There are some steels where even with the correct hardening temperature this will happen but such steels are further treated by refrigeration or double or triple tempering in order to allow the retained austenite to transform to martensite. This will be referred to later.

(f) The time for which a steel is held at its hardening temperature prior to quenching may be critical. Particularly for the highly alloyed steels, the amount of alloy carbide that dissolves in the austenite is a function of time at temperature. In such steels the desired ultimate structure is one of tempered martensite plus alloy carbides. Thus not all the carbides should be dissolved on heating. If an excessive amount is taken into solution in the austenite then on quenching some austenite may be retained with a corresponding decrease in hardness.

Distortion

Distortion of tool steels arises from one or more of the following:-

(i) non-uniform heating or cooling

(ii) inadequate support to thinner sections at high temperatures

(iii) volume changes which occurs as a result of the previously described structural changes.

In common with most other materials steels expand on heating up and contract on cooling down. With an infinitely slow rate of heating or cooling all parts of the steel would be at the same temperature at any one time and expansion/contraction would be uniform. No distortion would result. In practice whether on heating or cooling, some parts will be hotter than others and there will therefore be different dimensional changes as one section will have expanded/contracted more than another.

Another cause of dimensional change may be due to a sagging of thinner sections at elevated temperature when strength is reduced.

Particularly significant when hardening is being carried out is the distortion brought about when the austenite changes on quenching to martensite. This transformation is accompanied by a volume increase. The increase cannot be avoided but its effect may be controlled by control of the quenching rate, endeavouring to use the slowest possible cooling rate through the temperature range when martensite is forming.

Cracking

The expansion/contraction effects and volume changes referred to above will most often occur to differing extents in different sections of a tool. Inevitably this gives rise to stresses which may be of such a magnitude as to cause cracking. Control over this may be exercised by careful design and proper selection of the correct quenchant.

Short Service Life

In a brief review it would be impossible to give a comprehensive and authoritative summary of the causes of service life being shorter than anticipated. It should not be assumed that, when this problem is encountered, the fault is always to be found in the heat treatment. Other reasons why service life may be short are:-

(a) bad tool design

(b) wrong material

(c) misuse after heat treatment (e.g. bad grinding)

(d) improper use in service.

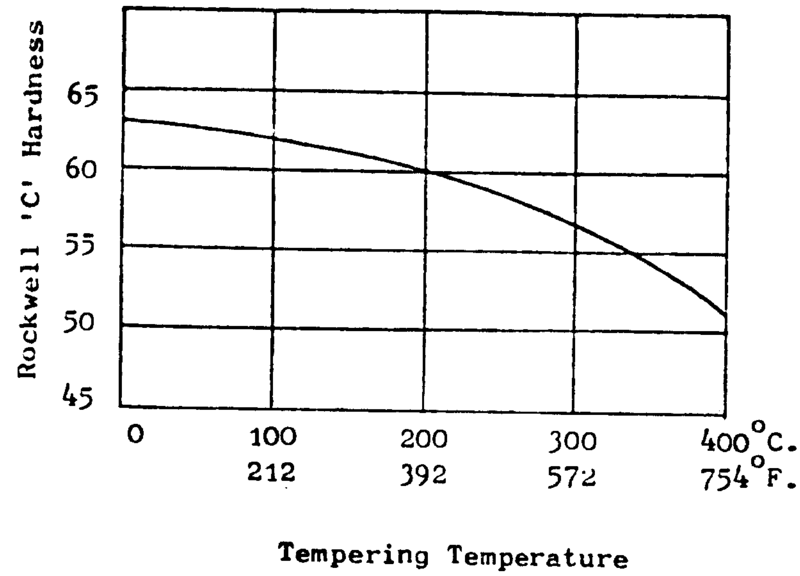
Where the heat treatment is felt to be at fault, consideration will firstly be given to the tool being too hard or too soft and to the underlying structural effect associated with this. Failure to observe the proper tempering treatment can lead to premature wear. A tool steel requiring double or triple tempering may undergo structural changes in service if only one temper had been performed and these changes could be the cause of tool failure. Any particular tool failure does however need to be considered on its own merits and the professional advice of a metallurgist sought.

Summary

The heat treatment of tool steels is not an easy matter. Complex structural changes are taking place within a steel during an heat treatment operation such as hardening, and many problems can arise. If these problems are to be avoided the structural changes taking place must be understood and controlled. This control can only come about by attention to:-

- furnace loading
- furnace temperature (preheat, hardening and tempering)
- time at temperature (in all furnaces)
- furnace atmosphere
- cooling rate
- tool design

If good and consistant quality is to be achieved a proper standard practice needs to be established, adhered to and monitored by control equipment. Failure to do this must inevitably lead to some of the problems described.



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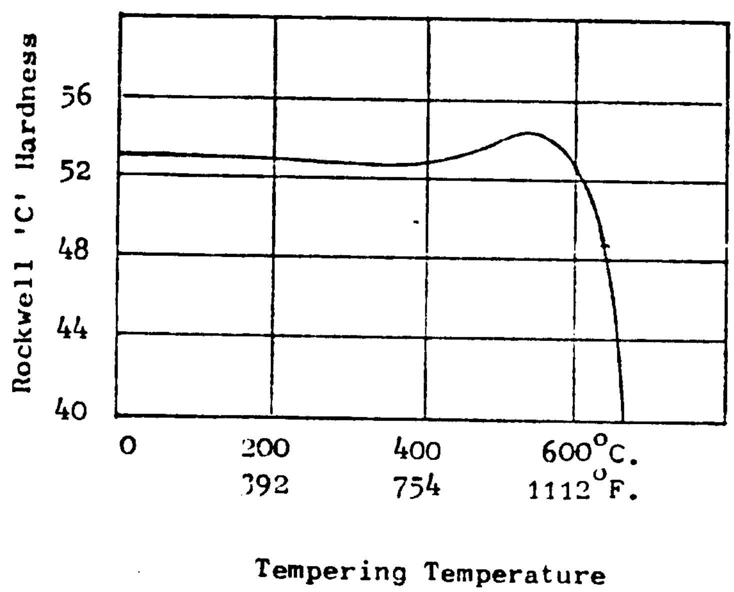

H13

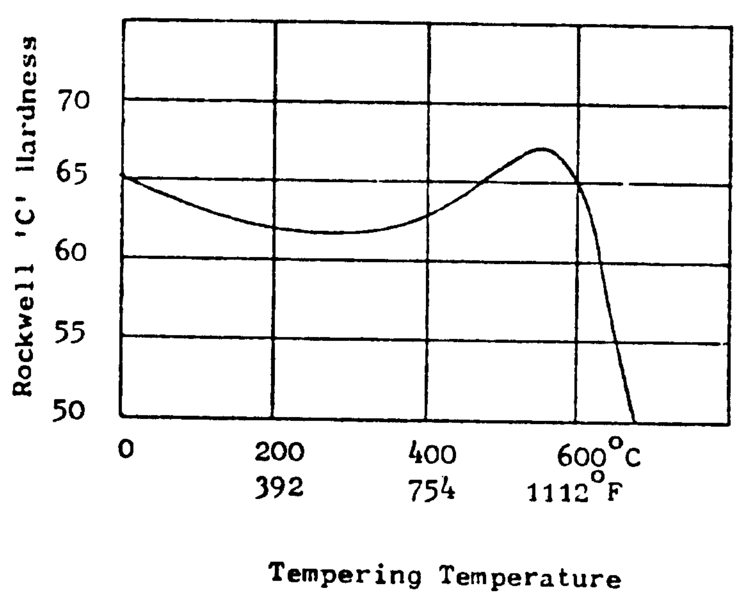

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Figure 1 [illegible]

Appendix J

Consultancy Work Undertaken

1. Man Fung Metal Works Factory

   Problem: Cracking of some dies in heat treatment and short service life of others

   Assistance: Recommendations regarding improvements to heat treatment facilities and practice. Suggestions made regarding interrupted quenching and alternative quenching oil.

2. Kowloon Motor Bus Company

   Problem: Commissioning and future use of gas nitriding furnace

   Assistance: Expert and HKPC staff to be present when furnace manufacturers commission equipment.
   Technical input by HKPC staff whenever furnace is used.
   Availability of furnace to HKPC proposed.

3. Hong Kong Precision Screws Manufacturing Limited

   Problem: (a) Distortion of dies
   (b) Distortion of long screws

   Assistance: Proposals made regarding normal preheating/heating/quenching practice for dies. Advice to be passed onto furnace operator. Advised that screw distortion was probably an inherent feature with furnace and quenching method being used.

4. Hung Sang Engineering Works Limited

   Problem: (a) Material specification for die casting machine
   (b) Plunger ring life

   Assistance: (a) Advised to use H13 tool steel
   (b) Advised on steel selection and heat treatment.

5. Shackman Limited

   Two problems: (a) erratic tool life
   (b) rigidity of watch straps

   Assistance and advice was offered

   (a) to calibrate furnace instrumentation and determine temperature profile in furnace; to make available HKPC equipment as required.

   (b) rigidity was due either to engineering design and manufacture which could be demonstrated by examination of strap profile, or due to metallurgical effects which would require microscopical examination.

6. Johnson Electric Co. Ltd.

   Problem: lack of springiness in beryllium - copper clips.

   Advice given on specification of grade of material required, its heat treatment and furnace facilities needed. Samples taken away for testing. Advice given on furnaces manufacturers.

7. Triocean Enterprises Limited

   Problem: lack of flatness of blanked steel discs and problems on availability of raw materials.

   Advice given on cause of "bad shape". Contact to be make with British Steel Corporation.

8. Sonca Industries Limited

   Problem: Information required on Tufftride Process.
   Furnaces manufacturers for normalising process.
   Furnace types and manufacturers for hardening extrusion punches.
   Advice provided.

9. Hong Kong Precision Screws Manufacturing Co. Ltd.

   Problem: Complaint from customer concerning too high hardness at surface and in core.

   Assistance: Microscopical examination carried out and hardness measurements obtained. Advice given on possible methods of achieving correct result.

10. Kowloon Motor Bus Co. Ltd.

    Problem: Effectiveness of surface cleaning of steel parts prior to nitriding.

    Assistance: Hardness plot performed. Miscroscopical examination carried out.

B-365

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