Introducing Cost-Effective Technology into a Small New Zealand Manufacturing Company

A Thesis presented in partial fulfilment of the
requirements for the degree of
Master of Technology in
Manufacturing and Industrial Technology at
Massey University

Mark Caukill
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Abstract

Precision Manufacturing Limited (PML) is a small general engineering firm in Feilding, New Zealand. It is a general job shop (with a few specialty products) well known in the region for producing timely, high quality results.

Southchain Conveying Systems Limited was purchased in November of 1998 and is the only conveyor chain manufacturer in New Zealand. Soon after taking over Southchain, the company found it difficult to compete against chain imports in the New Zealand conveyor chain market with a manual operation. At this point in time Precision Manufacturing owner, Garth Thelin, contacted Massey University and the idea of a GRIF project was introduced.

The project commenced on November 1 1999 and ran for 14 months. The technical goals of the project were to reduce manufacturing costs by 30% and limit capital expenditure to $100,000.

A numerical process model was built using Microsoft Excel based around a combination of a Bill of Materials model and a Route Sheet model. After completing the process model, it was then analysed to obtain a list of first order savings projects in the company. Dollar savings vs. the estimated cost of implementation, as well as interdependencies between the issues, was used as a criteria to rank projects as first order.

Two projects were then chosen to be pursued: pin induction automation and roller induction heat treatment. The induction automation project covered the design of the mechanical apparatus, building and testing of working models, building of the production machinery, and the industrial control systems to integrate the mechanics to the induction heater. The roller induction heat treatment project investigated using the in-house induction heater to case harden the chain rollers and divest the company of a high external expense.

Six months after the project was completed the company had reduced its costs considerably and as a result, was more profitable. The key to this was the reduction in

roller costs. With better margins the company has been able to increase its sales and hence boost production levels. Being more profitable also means the company is in a better position to implement more cost saving measures and become more competitive in the market place.

Acknowledgements

I would like to acknowledge the staff and management of Precision Manufacturing Limited and Southchain Conveying Systems Limited. Every person in these companies always had both a smile and a helping hand for the scarfi in their midst.

My supervisors, Harvey Barraclough and Ralph Ball, have imparted to me their considerable knowledge and guidance over the two years since the beginning of the project. This project would not have been as successful, nor as enjoyable, as it was without their support and encouragement.

To my family - Nicky, Aleisha, Vanessa and Hamish: all these pages contain part of you too. Thanks for giving me the support, and the space, to do this.

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Background and Introduction
PML
Precision Manufacturing Limited (PML) is a small general engineering firm in Feilding, New Zealand (Figure 1). It employs between 20 and 30 fabricators, turner/fitters and

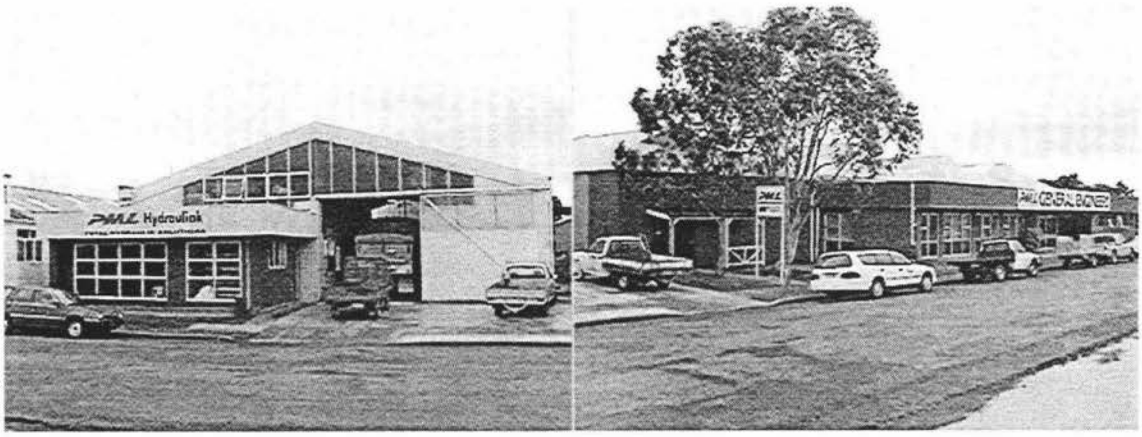

Figure 1: Precision Manufacturing Ltd and Southchain Conveying Systems Ltd site in Feilding, NZ.

general labourers. It currently has two subsidiary companies: Bettany Gears Ltd and Southchain Conveying Systems Ltd. It is a general job shop with several specialties such as Jack Flash bins, Mini-hoists, rubbish bin lifters. They are well known in the region for producing timely, high quality results.

Garth and Barbara Thelin purchased PML in 1990. At this stage PML's primary focus was manufacturing sprockets for end user companies. Over the years sprocket manufacturing went from being 80% of their business to only 10%. The reduction of sprocket business stemmed from other manufacturers importing sprockets and undercutting the price. A decision was made by PML to stay in the sprocket business, but knowing it couldn't compete with the imports, started importing sprockets themselves. The manufacture of specialist sprockets would then complement the importing sector.

Keeping in line with sprockets, PML purchased Bettany Gears Ltd in 1996 to expand its customer base as well as complement the sprockets business.

Southchain

As PML had always been in the sprocket market, and the profile cut conveyor chain sprocket market, it made sense to look to conveyor chain as the next point of expansion.

It would fit in well with PML's planning and operations and would also once again expand its customer base as well as complement the parent company sprockets business. Having seen an ad in the newspaper that McLay Industries of Invercargill was divesting itself of its conveying chain operations, Garth went down to Invercargill to check out the company.

The McLay family business trust wanted to get out of the general engineering business, part of which was Southchain Conveying Systems. It was being offered for sale as a separate going concern. As there were no separate profit and loss figures for the chain division and the equipment was somewhat run down, Garth suspected the business was not going well. Even so, an opportunity was seen and in November of 1998 PML purchased Southchain Conveying Systems Limited chain manufacturing business.

Six container loads of plant and equipment, including punches and dies were trucked up to Feilding. The two large presses were laid down on their backs on open flat-deck trailer units to get them to PML. One of the McLay management was employed as a consultant to assist with the setting up of all the manufacturing plant. As soon as the plant and equipment was set up, two orders of chain had to be manufactured for waiting customers!

Difficulties

Initially there were some problems with the manufacturing of the chain. PML had not anticipated the technical expertise that was required to make conveyor chain and the fact that there was literally no room for errors. Garth believes it would have been better to have one of the McLay/Southchain manufacturing staff come up to Feilding and work with PML instead of a management person. This would have facilitated a knowledge transfer to the new Southchain staff and management and made the new factory less prone to problems.

Southchain staff had 'come up to speed' very quickly and was producing good quality chain some 12 months later. Over that first year the major difficulty in operations was costs. The company was finding it difficult to compete in the New Zealand conveyor chain market with a manual operation, that was the same at that point, as it had been for years in Invercargill. At this point in time Garth contacted Massey University and the idea of a GRIF project was introduced. The project is discussed fully in the chapter on The Project.

Competition

Southchain Conveying Systems is the only conveyor chain manufacturer in New Zealand. The nearest manufacturing competitors are Ace Chains and Reynolds Chains in Australia. A large amount of chain comes into the Australasian region from the UK, US and Asia.

Company Aims

Since the project has finished the company has become more competitive and stronger. As such it is planning for the future with certain aims in mind.

They are starting to get into partnerships with clients to give them an edge against overseas competitors. Personal service is to become a hallmark of Southchain's. With this in mind they are actively searching out new clients instead of the usual advertising.

They are now putting 'Made in new Zealand' on their chain so end users can find out who made the chain and can contact them directly regardless of how they came to purchase the chain.

Management are currently working on a co-operative benchmarking project and are soon to meet with the Australian conveyor chain manufacturers to discuss improving business and reducing imports in the Australasian market.

Southchain is again investigating further development funding and are looking to the government technology funding bodies and Massey University.

They are aiming at becoming more competitive on the pricing of the stock chains. It is seen that the company doesn't have to have a better price, just better supply (i.e. immediate supply of goods) It is accepted that they can't compete against the bigger players on large orders of stock standard chain but can supply lengths to order instead of standard basic lengths. As such they are going to start stocking 4" 6/7.5K and 6" 12/15K chain, as they are most popular.

The next point of cost reduction is seen as being volume production. Plans are being considered to take on another shift to produce stock chain in the evenings. This would facilitate increased availability of stock chain without interfering with the production of specials chains during the day.

The Project

The project commenced on November 1 1999 and was to run for 12 months. It was extended by mutual consent between the company, Massey University and the GRIF fellow until January 2001.

Aims and Objectives

The technical goals of the project were listed as:

Factor	Goal
Manufactured Cost	Reduce by 30%
Capital Cost	Limit capital expenditure to $100,000

The following section is from the Technology New Zealand Contract for Education Fellowship Project Plan (full version in Appendix A). It defines what the project was to be about and how the goals were to be accomplished. It was used for the project as a guideline with due consideration to the practicalities of an engineering project.

Introduction

Literature Review

- Current methods of conveyor chain manufacture employed overseas
- Other similar flexible automation projects
- Tool design, multi-stage transfer tool design, indexing mechanisms, automatic feed techniques, commercially available automation components and systems
- Process automation – PLC control etc
- Process evaluation methods – simulation software etc

Introduction to the Industry

- Conveyor chain manufacture
- Use of conveyor chain in industry, range of products

Analyse Current Process

The current production system for conveyor chain manufacture is the starting point for this project. The goal is to upgrade this process so as to reduce manufactured cost of conveyor chain. The Fellow will analyse the current system – he will:

- Work hands-on at each station to compile a process flow diagram for conveyor chain manufacture
- Perform method study to identify whether all unit functions are necessary
- Measure the resource costs (labour, material, capital) for each workstation and transfer between operations and determine inherent variability
- Simulate the production system using SIMULINK software, confirm predictions and use this technology to rank stations and transfer steps in order of resource use
- Identify immediate ('first order') savings gained from better process layout, and improved transfer between operations (i.e. using methods that preserve spatial relationship between parts)
- PML staff will introduce these first-order improvements

Improved Process

Conceptual Design

The fellow will develop potential solutions for the priority (high resource use) workstations. Consideration will be given to combining operations where resource use is reduced. We expect he will put forward two or three solutions that will be evaluated using the process simulation software that will identify unit cost from labour, throughput and set-up times.

Decision Point

The twelve-month GRIF timeframe will not permit all workstations to be improved and evaluated. We will sit down with the GRIF Fellow and Massey supervisors to identify several upgrades that fit the time frame. It is likely that we will go with two significant upgrades in this project.

Selected Workstation Upgrades

The fellow will complete the detailed design of the new workstations assisted by our design staff. On completion they will be signed off by the Project Manager and then manufactured in our workshop.

Assess

Once the workstations are operational the fellow will measure resource use to confirm that we have met our goals for labour, throughput and set-up times.

Document – Thesis and Works Documentation

Document Preferred Solution

Within this project several workstations will have been upgraded. PML will continue this work after the GRIF project has been completed. The Fellow will prepare an implementation report that:

- Prioritises workstations upgrades
- Presents a layout design
- Estimates resource savings and upgrade cost and impact on manufactured cost

Submit Thesis

Masters thesis written and submitted to Massey University

The Cost Reduction Process

Initially the project followed the plan of the project contract above. After some weeks it became obvious that practical issues and limitations would dictate the true path of this undertaking. For this reason, the process of improving the company, loosely followed the plan given in the project contract.

Analyse Current Processes

The first two months of the project concentrated on learning how to manufacture chain and the associated processes. In these initial weeks the company was extremely busy producing a large order specialist chain, and as such, the focus was mainly on that contract. This proved to be of benefit as the project fellow was treated as 'part of the crew' and hence had a practical need to learn in great detail how conveyor chain was made.

Throughout the project, meetings were held on a weekly (or 'as needed') basis between company management, thesis supervisors, and the GRIF fellow. Minutes of these meetings can be found in Appendix B.

During the initial induction into the methods of conveyor chain manufacturing, action research was being undertaken and many issues were discovered in the general manufacturing environment where changes and improvements could be made. Issues such as factory layout, materials handling, occupational safety, and others were considered and improvements implemented. These are discussed in more detail in the chapter – Improving the General Manufacturing Environment.

Early in the new year of 2000, process flow diagrams were drawn up for the chain manufacturing procedures (Appendix C). Resource costings of the processes, including labour and materials, were then measured.

A numerical process model was built using Microsoft Excel (Appendix D). It was based around a combination of a Bill of Materials model and a Route Sheet model. Both of these practical manufacturing methods tools, when combined, fitted the requirements for the process analysis. The way in which this manufacturing model was built, focused on providing the company with a useful tool to cost chain and quote for business, after the project was complete.

After completing the process model, it was then analysed to obtain a list of first order savings projects in the company. A basic analysis of the model was done, calculating the ratio of dollar savings vs. the estimated cost of implementation, but this was not the only criteria used to rank a project as first order. The interdependencies between the issues considered was also thought-out and used to weight the decisions.

Two projects were then chosen to be pursued: pin induction automation and roller induction heat treatment. In the case of the induction automation, it was not the savings of the project that caused it to be chosen as a project, but its inter-dependence with the induction heat treatment of the rollers.

The induction automation was a large project, covering the design of the mechanical apparatus (bulk components to singular components), building and testing of working models, building of the production machinery, and the industrial control systems to integrate the mechanics to the induction heater. The roller induction heat treatment project attempted to use the induction equipment in a manner that has not been tried by other manufacturers (according to public records). It did not produce any implemented solutions, but was successful from the point of view that the company then knew that this in-house process was not an option.

These subjects are covered in detail in the chapter on - Induction Automation and chapter on - In-house Roller Heat Treatment Investigation.

Simulate Production Systems

The purpose of simulating the production systems was two-fold. Firstly, to understand and document the chain manufacturing process, and secondly to explain the effects of proposed changes of methods and materials prior to actual implementation.

It rapidly became apparent that the main benefit of a "model" of the system would be in the fields of costing and estimating / quoting. This fact had a great influence on the modeling method chosen.

The original project plan contract stated that this topic be done in the mathematical and graphical modeling package SIMULINK.

Simulation Options

Two categories of models were available for the analysis: numerical and graphical. Consideration of these model types was made, taking into account conditions and interactions in the factory process that were present. The relevance of the chosen method/model to the process flow understanding (purely project focused) was important but more so was the factor of providing a tool that factory staff could use.

Discussion groups were formed on each of these overview topics to consider the status of, model evaluation, and roles in process and observational studies.

The 'start - stop' nature of the chain manufacturing process in this company meant a graphical simulation would have been very inaccurate. Batch sizes and times were difficult to estimate as they were wholly dependant on customer orders, due dates, and the commonality of components used for the manufacture of any one particular chain. Also, due to the relatively large number of 'specials' chains the company does, a fixed simulation would have had no easy method of inclusion into a graphical simulation.

An important requirement of the model was to leave Southchain management with an effective tool to continue accurately modelling the system. This model would enable management to quickly and accurately estimate / quote on chain enquiries as well as provide the main method of tracking chain costing. Being spreadsheet based means that it is within the capabilities of the management to gain knowledge of the spreadsheet and maintain / alter it when necessary.

The spreadsheet model was also designed to enable the company to use it for any product manufactured by the parent company as a whole, not just chains. It was based on a three tier cost rollup (as compared to the two tier rollup actually necessary) which enabled additional products to be modelled.

After consideration, it was deemed wholly unsuitable to use a graphical simulation based on the requirements of the company and so a more practical method of modelling was chosen. A spreadsheet based bill of materials and route sheet combination analysis was developed (Appendix D).

Process Flow Diagrams

Simple, generic process flow diagrams were drawn up for individual components and final assembly to determine the modelling requirements of the manufacturing and assembly processes taking place in the original regime.

Each component process was initially diagrammed separately for consideration and understanding of its movement through the factory. An overall flow diagram pulled together the interactions of the components and final assembly process.

Process flow diagrams were compiled for the conveyor chain manufacturing process as well as route diagrams for the componentry and sub-assemblies. These functional diagrams assisted in the development of the spreadsheet based process model (see Appendix C).

Analyse Current Processes

The first two months of the project concentrated on learning how to manufacture chain and the associated processes. Resource costings of the processes, including labour and materials, were then measured. The amount of labour in any one process was measured by timing several 'runs' of the process and averaging out the time. Short time duration measurements were therefore used in the process analysis with the understanding that the process model would have to be updated by the company with more accurate figures as time went on.

Non-specific Chain Component Diagram

This diagram (Figure 2) was created in an attempt to simplify and standardise the component naming convention that was being used. The component and chain identifiers being used at the time were basically sufficient but had never been shown in

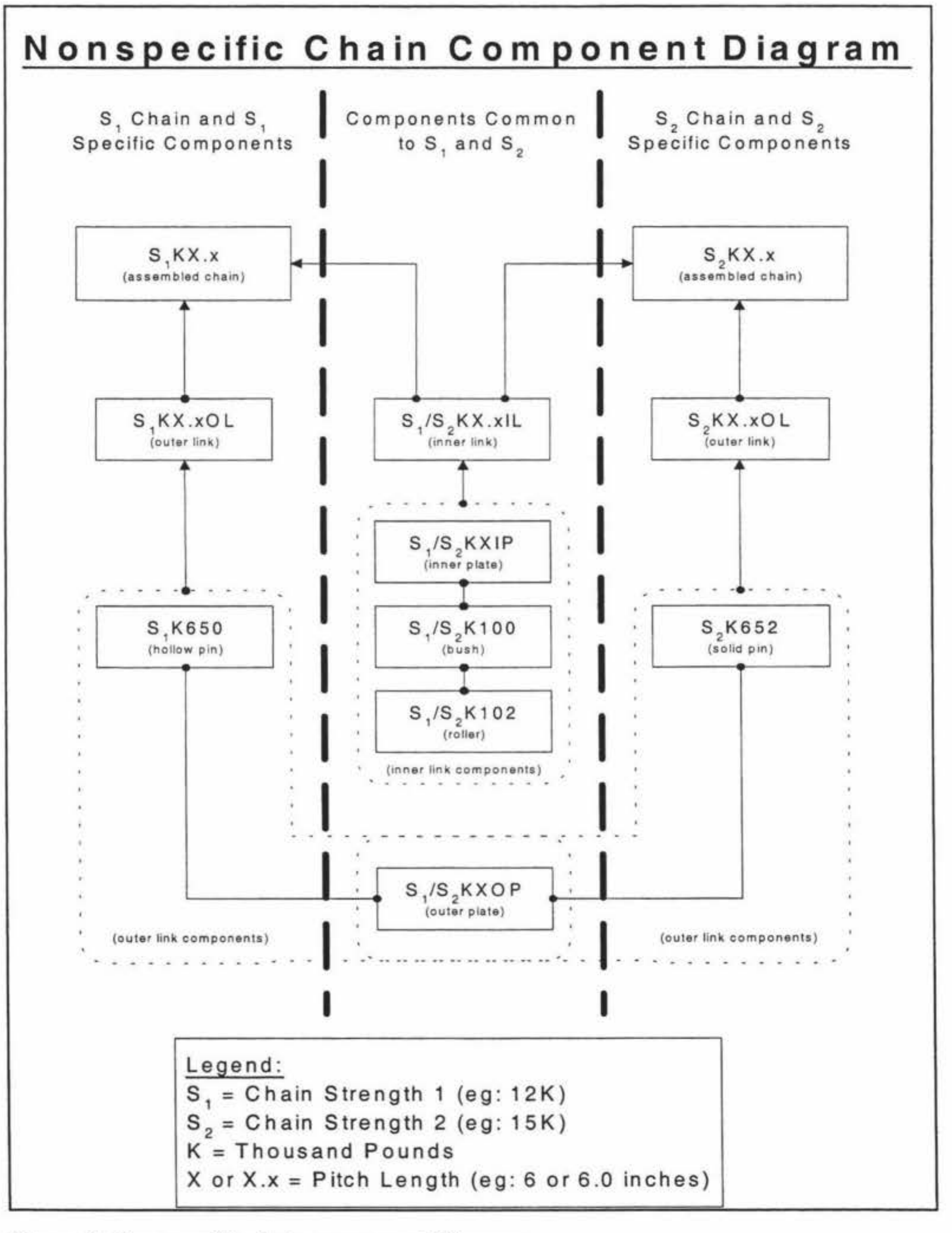

Figure 2: Non-specific chain component diagram.

a graphical format. This diagramming had a beneficial outcome, being the understanding that any chain of any specific size/pitch had two strength regimes and within those two strengths there were a number of components that were common to both.

This issue of commonality was a key factor in forecasting production levels for stock. and orders assembly. In essence, if a particular standard pitch was ordered by two different customers, each a different strength for that standard pitch, it was practical to combine production runs for those components common to the two orders.

Although combining the common component manufacturing was commonly being actioned by management, the understanding of this matter was significant in the development of the process model.

Bill of Material / Route Sheet

As stated above, the process analysis / simulation was done using a spreadsheet format. In specific, Microsoft Excel was used. Multiple sheets were set up, each with a specific function in the model.

It was decided that the best method of analysing the manufacturing system within the constraints of a spreadsheet was to combine a bill of materials model with a route sheet model. A bill of materials (BOM) to list the components (including quantities) needed to manufacture the final product and show how the product is fabricated and assembled; and a route sheet to determine the sequence of manufacturing operations, listing the operations and machine centres through which the component must go. This combination would take into account the relevant information needed to accurately calculate costings in the chain manufacturing process.

The analysis was begun by using the information gathered in the first few months of the project as stated above. The requirements of the 'front end' of the spreadsheet were determined in terms of what information was necessary to the project and also be of long-term value as a tool to the company. To represent all the chains produced by the company in the analysis would have made the spreadsheet too unweildy, so certain products had to be chosen for investigation. At the beginning of the project, the 1999 sales figures (including footage sold) had been determined (Table 1).

Stock Chain Details

Chain	1999 (ft)	% of Production
4.5K3.0	103	1.4%
4.5K4.0	160	2.1%
6K3.0	405	5.4%
6K4.0	1210	16.2%
6K6.0	583	7.8%
7.5K3.0	1396	18.7%
7.5K4.0	1223	16.4%
7.5K6.0	847	11.4%
12K4.0	578	7.7%
12K6.0	100	1.3%
15K4.0	566	7.6%
15K6.0	288	3.9%
Totals	7459	

%Total production stock chain	
3/4.5K	3.5%
6/7.5K	76%
12/15K	21%

NB: These chain production figures are standard chains only and DO NOT include specials chains.

Table 1

As can be seen from the production figures, the majority of stock chain production was the 6/7.5K and 12/15K chains. As this was from the beginning of trading of the company it was decided to include the larger chains (24/30K) in the analysis and drop the smaller chains (3/4.5K) as they had done many more quotes for the larger chain than the small ones.

Two modules (sheets in the workbook) of the analysis used purely manual input, two contained manual input fields and calculated fields, and one sheet was solely a calculated sheet necessary for the correct functioning of the lookup functions in Excel. See Figure 3 on the next page for the module interdependencies.

Once these requirements were established, the supporting data sheets were designed and developed. The following is an explanation of each of the sheets within the analysis.

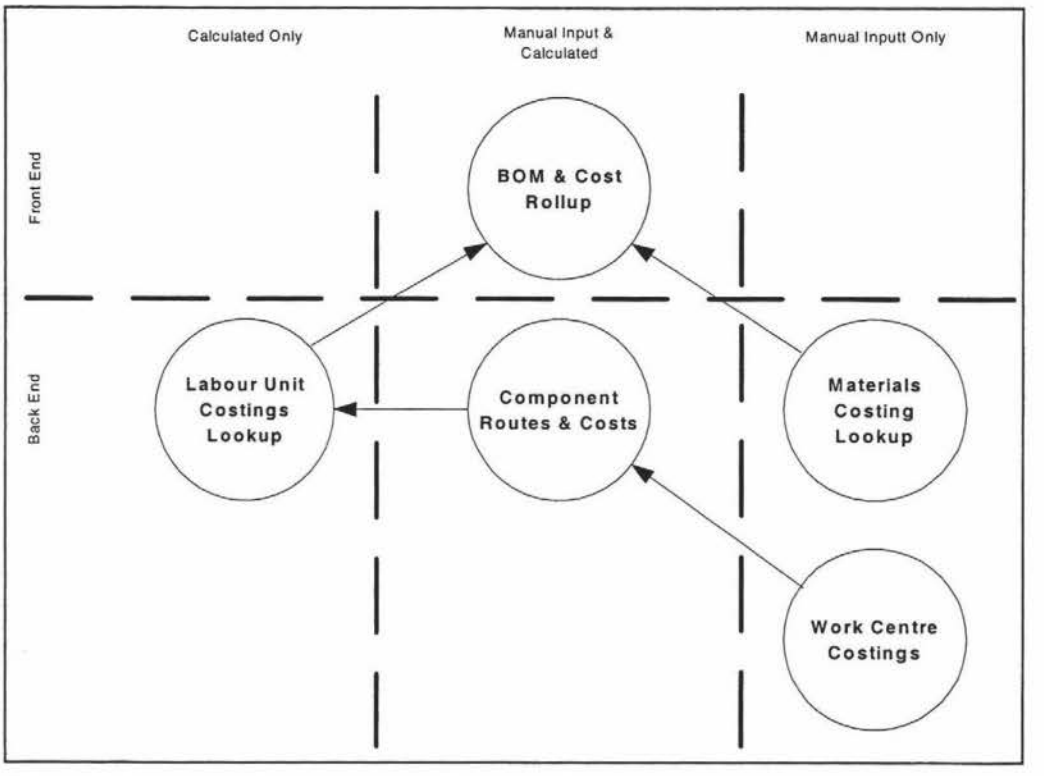

Figure 3: Process model module interdependencies.

Materials Costing Lookup

At the core of a bill of materials is the record of all raw materials used in the manufacture of the products in the analysis. This sheet included:

- Material codes

  The material code applied the stock codes already in use by Southchain for the raw materials purchased.

- Cost per raw material unit

  The buy price (excluding GST) of the materials purchased, based on the physical format of the delivered goods. There were two basic formats of materials: bar stock and sheets. This format made for easy entry of new materials and maintenance of existing items.

- Unit descriptor

  Showed the measurements of the purchased raw stock such as specific lengths or sheet dimensions.

- Description

  A meaningful description of the material.

All details in this sheet were manually entered and there were no external references to any other sheets.

An array was set up (MaterialsArray) which was comprised of the material code and cost of raw material unit. This was for referencing in the appropriate BOM & Cost Rollup sheets.

Work Center Costings Lookup

This sheet was to list all operations that occurred for components and was manual input only. It was separated into two sections: internal operations and external operations. This was necessary as they were costed in differing manners.

Internal Operations

The internal operations section of the sheet was to take into account the costs of the various processes internal to the company. These "per hour" costs were calculated by the company accountant and included fixed overheads. The fields used were: work centre/machine/operator, setup charge rate, and processing charge rate.

- Work centre / machine / operator

  The code for the various internal processes. It was essentially a list of short names or codes of the machine centres or mechanisms involved in the processing of the component parts.

- Setup costs /hr

  The cost to set up the work centre on an hourly basis.

- Processing costs /hr

  The cost to operate the work centre in production on an hourly basis.

External Operations

The external operations section of the sheet was to cost the processes that were external to the company. These included value added processes such as case hardening, electroplating, guillotining, and laser cutting. Issues such as freight, that were intermediary, and added outlay but no direct value to the component, were included here as well. The fields used were: external sub-contractor work centre/operation, costings charge rate /unit, charge description.

- External sub contractor work center/operation
  A short name list of all external operations carried out on components.
- Costings charge rate /unit
  The dollar value charge of the external process. It was based on the format the external charging company invoiced for the raw materials. Examples were per kilogram, per hour, per metre, etc.
- Charge description
  A description of the basis of the charge rate / costing used.

Component Routes and Costs

This sheet catalogued all the components and sub-assemblies of the chosen chains, their associated processes and then priced the total processes on these parts. It involved both manual input and calculated fields. Each component section had the calculated fields totaled for the part.

- Part number
  The standard inventory number used by the company (manual input).
- Standard batch quantity
  For setting the batch size of the components and sub-assemblies processed. It was averaged at a size of 1000. This field was meant to be manipulated by the company on a batch basis for assessing chain cost for both quoting purposes and stock valuation (manual input).
- Operation number
  A numerical list. A number was applied to each process in reference only to the specific component. The numbers were incremented by ten to allow for easy insertion of extra steps in the process (manual input).

- Description

  A meaningful description of the work carried out at each work centre or machine listed (manual input).

- Work centre / machine / operator

  The codes for the work centres each process went through. These codes were exactly those listed in Work Centre Costings sheet and were used to look up setup and processing costs (manual input). Input errors in this field caused flow-through calculation batch pricing errors.

- Batch setup time

  This field had two types of manual input. If the process was internal, this field was the time (in hours) spent by the operator setting up the work centre to production readiness. If the process was external, this field was an 'x'. This represented 'external' and influenced the batch setup cost.

- Batch setup cost

  There were two calculated outcomes of this field. For internal processes the field used the work centre code to obtain the batch setup cost from the InternalOpsArray (Work Centre Costings Lookup sheet) and multiplied it by the batch setup time.

$$\boxed{Batch\ Setup\ Cost = Batch\ Setup\ Charge\ Rate \times Batch\ Setup\ Time}$$

  An 'x' in the batch setup time caused this field to be a zero value as it was an external process.

- Internal unit production time or External unit measurement

  This field had differing manual inputs for internal versus external processes. Internal processes required a time (in minutes) that the component or sub-assembly spent being produced at the work centre specified. An external process required the numerical unit measurement to be manually input. The unit measurement (kg, hour, etc) was dependent on the external process the component went through. For example, any external process charged on a weight basis would have had a number representing the mass of the component entered into the field. For time based external processes, the time charged for the batch invoiced, was divided by the number of components treated or created externally.

The total for this field of each section was meaningless if there were any external processes involved, as each external process could be different from the next and certainly had no similarity to the time measurement of any internal processes. This summation was set up mainly for looking at the total internal operations processing time for the component.

- Batch processing cost

  This field had a differing calculated result for internal and external processes. Internal operations looked up the InternalOpsArray (Work Centre Costings Lookup sheet) to determine the hourly production cost, divided it by 60 to get a per minute equivalent, multiplied the result by the internal production time input, and finally multiplied this by the batch size.

$$Internal\ Batch\ Processing\ Cost = ((Hourly\ Production\ Charge\ Rate \div 60) \times Internal\ Production\ Time) \times BatchSize$$

For external operations the formulae looked to the ExternalOpArray (Work Centre Costings Lookup sheet) for the external operation cost, multiplied it by the unit measurement, and the result was multiplied by the batch size.

$$External\ Batch\ Processing\ Cost = (External\ Operation\ Cost \times Unit\ Measurement) \times Batch\ Size$$

- Standard batch cost

  The batch setup cost summed with the batch processing cost.

$$Standard\ Batch\ Cost = Batch\ Setup\ Cost + Batch\ Processing\ Cost$$

- Standard unit labour cost

  The standard batch cost divided by the batch size.

$$\text{Standard Unit Labour Cost} = \text{Standard Batch Cost} \div \text{Batch Size}$$

Labour Unit Costings Lookup

This sheet contained calculated fields only and was created to allow the correct performance of the 'vlookup' function used in parts of the analysis. It was a table consisting of the component or sub-assembly part number and its standard unit labour cost from the Component Routes & Costs sheet. The table was sorted on the part number to allow the 'vlookup' function to avoid possible lookup errors. Sorting maintenance of this sheet would be necessary when additional products were added to or deleted from the analysis.

BOM & Cost Rollup (Final product and component costing)

This section was the 'front end' of the analysis. It was from here that management would interface with the analysis, obtaining information regarding the cost of the various chains. There were multiple sheets, one for each type (strength) of chain. Each chain type BOM & Cost Rollup sheet contained multiple sections with every section representing the breakdown of each pitch of chain.

It was built with a 'three-tier quantity structure' with the purpose of being used for products the company may produce other than chain. The term 'three-tier quantity structure' refers to the use of three quantity fields, one each for the sub-assembly level, component level, and materials level. See Figure 4 on the next page for the basic structure of the analysis interface sheets. The currently manufactured conveyor chain required only a 'two-tier quantity breakdown' (being components and materials), as there were only ever one of each of the two sub-assemblies per standard unit of chain. Hence, with this three-level configuration, any product included in the analysis can contain more than one of any sub-assembly.

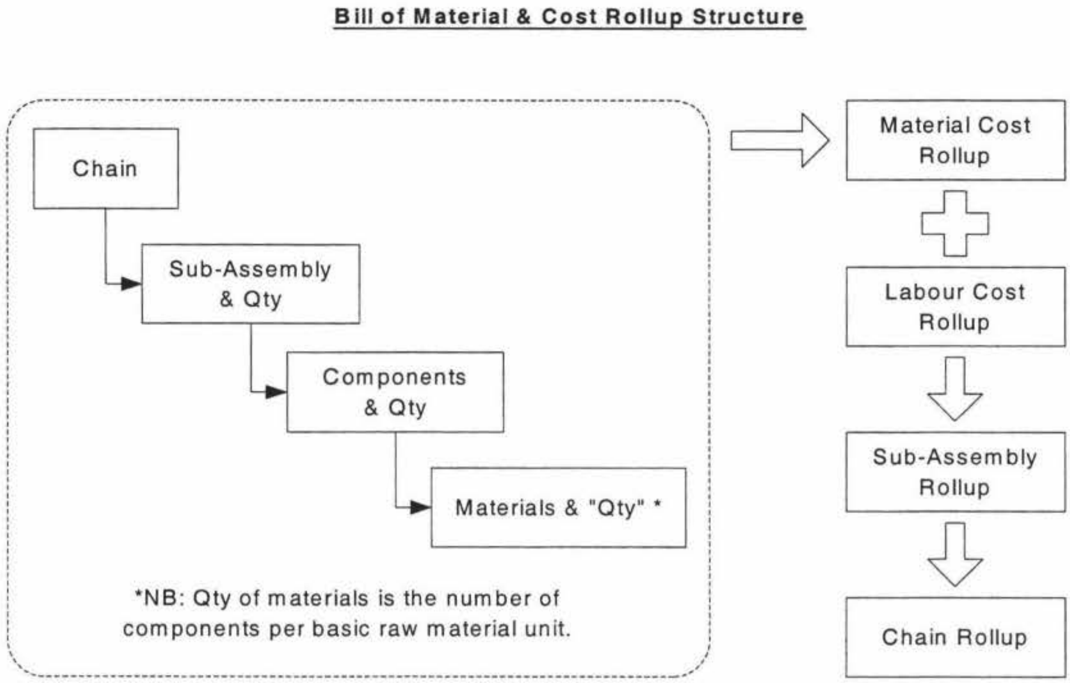

Figure 4: The structure of the Bill of Material and Cost Rollup sheets.

As many different pitches of chain were to be included in the analysis, a specific linear measurement could not be used. Different pitches would have dissimilar numbers of components in any one length. In order to overcome this problem, a standard unit of chain was devised. It comprised of a complete inner link, coupled with a complete outer link (Figure 5).

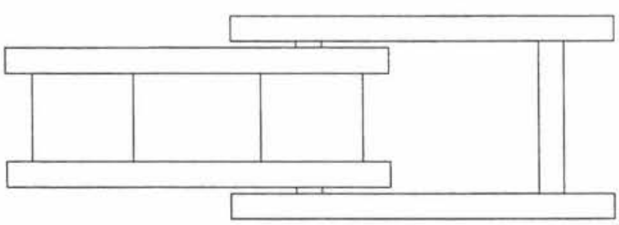

Figure 5: Diagram of a 'standard unit' of chain.

This unit of chain is not normally employed when considering chain production and would never be implemented on its own for several reasons. It is an impractically short length, customers think in specific lengths of chain required, and the final outer link pin in any chain provided is a special connector pin (non-standard). For the purposes of this analysis, this unit length suits the requirements and is easily translated to linear measurements.

The following is an explanation of the fields used in the BOM & Cost Rollup sheets.

- Chain

  The standard unit chain code (manual entry).
- Sub-assembly

  The sub-assembly inventory code (manual entry).
- SA-Qty

  The quantities of sub-assemblies in a standard unit of chain (manual entry). As stated above, there are only ever one of each of the two sub-assemblies per standard unit of chain. Hence the default value of this field is one (1).
- Components

  The list of component codes used in the sub-assembly they are owned by (manual entry).
- C-Qty

  The number of components in the sub-assembly they were owned by (manual entry).
- Materials

  The list of material codes used by the components (manual entry).
- No. Components per basic Raw Material Unit

  The number of components available from a raw material unit (manual entry). The raw material unit was the physical form that the raw materials were purchased in. This field was the number of components that were obtained (cut, punched, etc) out of the purchased format of the raw material. For instance, there would be a certain number of rollers machined from a standard length section of bar-stock that was bought into the company.
- Mat'l Unit Cost

  The materials code was used to look up the raw material unit cost, which is then divided by the number of components per basic raw material unit.

$$\text{Material Unit Cost} = \text{Raw Material Unit Cost} \div \text{No.Components per Basic Raw Material Unit}$$

- Material Cost Rollup

  This calculated field had two purposes. It represented the total materials value for each type of component in the sub-assembly. Material unit cost times the component quantity. At the sub-assembly and final product level it was solely a sum of the cost of all the materials used in all the components for that sub-assembly and product.

$$\text{Material Cost Rollup} = \text{Material Unit Cost} \times \text{Component Quantity}$$

- Labour Cost Rollup

  The result of this field was the cost of labour contained in producing each the components, sub-assembly, and final product. Using the component code, the formula looked to the LabourUnitCostArray (Labour Unit Costings Lookup sheet) to determine the constituent labour cost of each component, sub-assembly, and product then multiplied the result by the value in the quantity field relevant to the level. In the case of the final product, it simply returned the labour cost of a single standard unit of chain.

$$\text{Labour Cost Rollup} = \text{Component Labour Cost} \times \text{Quantity of Parts}$$

- Subtotals

  Two differing calculations took place in this field. At the component level, the subtotal was the material cost of all the parts used in the sub-assembly plus the labour cost of all the parts used in the sub-assembly. At both the sub-assembly level and product level, it was wholly labour cost as there were no additional materials used at this level.

$$\text{Subtotal} = \text{Material Cost Rollup} + \text{Labour Cost Rollup}$$

- Sub-Assembly Rollup

  The total materials and labour used in the production of the sub-assembly was summed into this field.

- Chain Rollup

  This was the sum of the sub-assemblies rollup fields and represented the total costing of a single standard unit of chain.

- Cost per Foot

  This field was calculated by taking the standard unit cost (chain rollup field) and dividing it by two, multiplying the result by 12 divided by the pitch. An explanation of this is seen in the equation below.

$$\left(\frac{chain\ std\ unit\ \cos t\ (\$\ per\ std\ unit)}{2\ pitches\ per\ std\ unit)}\right)\times\left(\frac{12\,inches\ per\ foot}{chain\ pitch\,(inches\ per\ pitch)}\right)=\left(\frac{chain\ \cos t\times 6}{chain\ pitch}\right)\times {}^{1}\!/_{foot}$$

- Cost per Metre

  This field was calculated by multiplying the cost per foot by the number of feet per metre (3.28).

Model Updating Requirements

Several areas of potential inaccuracies exist within the existing model. To become more accurate and hence more useable, the company must be continuously updating key areas of the spreadsheet. They include:

- Batch sizes – batching was not necessarily appropriate for some operations and batch sizes used were arbitrary, although loosely based on average approximate throughput of orders. These batch size figures need to be reviewed on a consistent basis and refined for better accuracy with each production run.
- Work centre times – as with any finite time measurement of a process, it is only as accurate as the situation it is measured from. A few timed runs of a production process is not necessarily an accurate representation of the actual time required for the process over a longer considered period. The company

needs to revise all the time measurements as often as is practical to improve the accuracy of the model.

- Materials costs – as materials purchase prices change, they need to be reflected in the analysis to ensure an accurate representation of the bill of materials aspect of the model.
- External / Internal process costs – process costs may change with the introduction of skilled staff, etc and especially external costs may alter drastically. These also need to be taken into account for the route sheet aspects of the model.

The updating functions outlined above would be normal in any ongoing manufacturing system, manual or computerised. They are not specific to this model, or to Excel.

Identify First Order Savings

Process Model Outcome

Once the process analysis model was completed, the manufacturing processes were ranked and savings were identified.

The bill-of-materials and cost rollup sheets (Appendix D) were examined for the various chains (with special emphasis on the top production chains) from the component level, then sub-assembly level. The material portion of each component was not a focus of this particular scrutiny as even with the existing manual systems, materials use and wastage was under constant revision. The labour portion (both internal & external processes) of the costs was examined for possible reduction by automation and/or the introduction of practical technology.

Each component was assessed for potential savings:

- Inner Plates

  The inner plates were blanked and pierced on the presses then rumbled. As rumbling is an unmanned process it was deemed to have little savings value. Rumbling improvements are discussed later in this document. Press automation was seen to hold large savings for the company.
- Bushings

There were three types of bushings to consider for a reduction in labour content: split - rolled, split - pressed, and machined. The machined bushes (for 24/30K chain) were done on a semi-automated machine centre and were for a chain that represented a small percentage of production. As such they were not considered for savings. The split – rolled bushes (for 6/7.5K chain) were already being done on a semi-automated rolling machine and required little interaction, so were not considered. The split – pressed bushes (for 12/15K chain) were being done in an extremely manual and slow press tool. The quality of this process was also an issue as the press tool had an inclination to 'chewing' pieces periodically. The split – pressed bushes were included for consideration of savings.

- Rollers

The manufacturing of the majority of the rollers was done on the automated Mori-Seiki lathe and hence the manufacture of the raw rollers was not up for savings improvements. However, the case hardening of all the rollers used by the company was done in an external gas carburising process in Auckland. The hardening process and freight was charged for by the kilogram and as the rollers were a large mass item, this process was deemed high on the list of priorities for investigation.

- Outer Plates

These components are processed in a similar fashion to the inner plates except for the addition of the company logo/identifier stamp on the plate. This stamping process was deemed a reasonably simple procedure to improve and was included in the savings considerations.

- Pins

The company produced two types of pins: hollow, and solid. Produced on the automated Mori-Seiki lathe, the manufacture of the raw pins was not considered. However, both types of pins are processed similarly in the in-house induction heater. The manual method of feeding the heater (with resulting quality fluctuations) and the unpleasantness of the job made this step in pin production prime for automation.

The assembly of the sub-assemblies and final product assembly were next considered for savings from applied technology. The assembly of the inner links was a process considered to be simple enough to be included in the savings investigation.

Prediction of Savings

A spreadsheet (Appendix E) was done covering the estimated possible cost savings of:

- logo stamp automation
- 12/15K bush roller automation
- 75T press automation
- 150T press automation
- inner link assembly automation
- pin induction automation
- in-house roller induction heat treatment

The savings analysis (summary in Table 2 below) of the above issues considered the savings as a percentage of per foot cost of each process, and its overall labour saving per annum (based on the current labour content). It must be noted that capital expenditure and labour savings were 'ball-park' figures and based on knowledgeable conjecture.

		Weighted Average across all chains	Estimated Capital Expenditure	Estimated Potential per annum Labour Savings
Percentage Savings per Foot after ...	Induction Automation	1.22%	\$10K	\$5K - \$10K
	Logo Stamp Automation	2.09%	\$3K - \$5K PLUS repair & assembly of 30T press	\$5K - \$10K
	12/15K Bush Roller Automation	2.51%*	\$5K - \$8K PLUS redesign of mechanism	\$3K - \$4K
	75T Press Automation	5.73%	\$30K - \$50K+ NOT including new automation ready tooling.	?
	150T Press Automation	6.91%*	\$30K - \$50K+ NOT including new automation ready tooling.	?
	Inner Link Assembly Automation	3.09%	\$30K - \$50K	\$10K - \$15K

		Weighted Average across all chains	Estimated Capital Expenditure	Estimated Potential per annum Labour Savings
	In-house Roller Induction Heat Treatment	10.01%	12/15K manual setup: $2K / full auto: $10K semi-auto 6/7.5K setup: $2K / full auto:$5K	?
*Savings apply only to 12/15K chain				

Table 2

Logo Stamp Automation

The company logo stamping was being done on the 75T press at the time of the project as the smaller 30T press was out of commission. The automation of this particular process would be relatively easy using a pneumatic system but hinges on using the 30T press as a permanent station. The repair of this machine was not considered an easy task. It was an old press and there was no manual, parts were missing, and no one within the company had had experience with repair and maintenance at the required level, nor was there labour to spare. Although there were reasonable labour savings to be had ($5K-$10K) with automating the stamping process, due to the difficulties in getting this press working, logo stamp automation was not chosen as a project. Stamping the company logo is applied to ALL chains produced and as such this project should be considered in the future once the 30T press is repaired.

12/15K Bush Roller Automation

These bushings were being done on the 75T press, as the 30T press was not running. The idea for this process was to duplicate that of the smaller bushing (6/7.5K) roller which was an effective semi-automatic process. The savings for eliminating the manual press rolling of these bushes was about 2.51% but taken over the whole range of stock chain, savings amounted to approximately 0.54%. As these weights of chain are growing in demand for the company, it would be prudent to keep this project in mind for the future.

75T Press Automation and 150T Press Automation

As all chain plates, with the exception of some specials chains, are done on the 75T and 150T presses, press operations represent a considerable proportion of the labour input to any stock chain. It would seem then, that the almost 6% savings (possibly representing a total labour unit per year) in automating the presses should be considered a valid project.. Automating the presses themselves would not be a difficult or particularly expensive project using pneumatics, but there are several other issues that contraindicate its validity. Firstly, the existing tooling is totally manual and would be extremely difficult and costly to automate. Cost prohibitive new tooling, automation ready, would be required for the presses to be efficiently automated. Secondly, there are raw material considerations. Bar stock is not particularly suited for automatic feeding, so coiled strip would be superior. This creates further issues of necessary equipment and stock on hand. Decoiling machinery is expensive and meant for large runs, and the amount of raw material in a single coil is a profligately large amount of stock for the production levels of the company. A minor third consideration is that these are the wrong type of press for the process. These two presses are long stroke presses whereas short stroke presses are superior for this type of work. For the above reasons, press automation was not considered for a project and the company was advised to stay away from this issue.

Inner Link Assembly Automation

Inner link assembly was considered as a possible source of savings due to its inter-relation to any two chains. This means that one inner link assembly will be used on two different weight chains of the same pitch, and hence could be batch processed regardless of customer orders. Also, the manual assembly of these sub-assemblies is a relatively straightforward affair, with little intricate work being done. It's half labour unit savings is good but the cost of automating this process prohibitive. There were other, less capital-intensive projects to be done before this project should be undertaken.

In-house Roller Induction Heat Treatment

The model also pointed out that the chain rollers were a very expensive component in the manufacturing process. The basis of this was twofold. The rollers are a heavy component and the heat treatment process is external to the company and was charged for by the kilogram. Approximately 11% to 23% of the cost of a foot of chain was directly caused by case hardening costs. Table 3 below shows a summary of case hardening for the high production chains.

Chain	1999 (ft)	cost/ft	HTAuck/ft (incl freight)	Percentage of Case Hardening per Foot
12K4.0	578	$ 19.10	$ 4.09	21%
12K6.0	100	$ 13.28	$ 2.73	21%
15K4.0	566	$ 17.99	$ 4.09	23%
15K6.0	288	$ 12.54	$ 2.73	22%
4.5K3.0	103	not avail	not avail	not avail
4.5K4.0	160	not avail	not avail	not avail
6K3.0	405	$ 14.99	$ 1.74	12%
6K4.0	1210	$ 11.55	$ 1.31	11%
6K6.0	583	$ 7.96	$ 0.87	11%
7.5K3.0	1396	$ 12.95	$ 1.74	13%
7.5K4.0	1223	$ 10.02	$ 1.31	13%
7.5K6.0	847	$ 6.94	$ 0.87	13%
	7459			

Table 3

As this project represented major savings for the company it was decided to investigate alternative methods of heat treating the chain rollers. Various methods were considered until the concept of an induction heating trial was settled on.

Pin Induction Automation

The induction heater was identified as an important area for consideration. At only 1.22% weighted savings per foot it was the lowest rated savings, but it was not chosen purely for the savings it represented. The issue of induction automation was intrinsically tied up with the possibility of heat treating the rollers on the induction heater. With the concept of greatly reducing the roller costs by making their case hardening an in-house induction treatment, the forecast use of the induction heater was significantly higher than the levels of use from manual pin treatment. The single resource of the induction heater would theoretically become the bottleneck in the chain manufacturing process if both rollers and pins were treated manually on it. Therefore it was imperative that the pin treatment be automated to reduce, as much as possible, the time the induction heater was engaged in pin production.

Three other basic reasons indicated it was a wise choice for inclusion in the project. One reason being the fact that automation could be introduced on this device without any capital expenditure to prepare the machine. The second reason was that the job of treating the pins manually was unpleasant (due to the burning cutting oil coming off the pins during the heating cycle), and boring (hence hard on staff morale). A third unquantifiable reason was that the staff were concerned with the issue of being constantly exposed in close proximity to the undesirable effects of radio frequency electromagnetic fields. For all the above reasons, automating the induction heater was chosen as a significant project.

Recommended Actions for Improvement

As mentioned in the subjects above, there were two project outcomes from the analysis. There was to be an investigation and trial of case hardening the rollers. This project is covered fully in the chapter on In-house Roller Heat Treatment Investigation. Running concurrently was the project to automate the induction heater for the production of pins. The induction heater automation is covered in the chapter on Induction Heater Automation.

Noddy's Guides

Noddy's Guide to Induction Heating

Southchain's Induction Heater

The induction heater used by the company was purchased as part of the chattels when Precision Manufacturing bought the going concern Southchain (see Background and Introduction). It was a Raydyne design, built under license in New Zealand by Northern Electronics around 1975. The specifications of the heater were as follows:

- Power (kW): 15 kW
- Output Frequency (kHz): 450 kHz
- Input Voltage (V): Three phase, 220 / 440 V
- Cooling: Water
- Variable Output Transformer

This induction heater comes under the general heading of a Vacuum Tube unit. It consists of a power supply section and an oscillator section. The power section provides the high voltage for the triode. The oscillator section is made up of a triode and a tank circuit (a matched inductor coil and capacitor). The triode controls the amount of electrical energy delivered to the tank circuit from which the energy is removed by the coupled load (the work piece). The frequency developed in the system is determined by the inductance of the tank coil and the capacitor, which form a parallel tuned circuit.(ASM Committee of Induction Hardening, p168-p183) See Appendix F Induction and Flame Hardening for a full article.

This machine was somewhat different from the general design of its day (above) in that it has a variable output transformer (primary and secondary) on the DC/oscillator side of the system. Normally, for this design, the tank circuit is fixed and load-matching is accomplished by adjusting the coil (tuning) until the appropriate impedance for the work coil is achieved. For the company heater, load matching was achieved by manually adjusting the primary internal coil for each heating coil used until the appropriate impedance was met. From the operator's point of view, the power was turned up until the current flowing through the coil was a maximum. Usually this was accomplished by gradually bringing the power up until the tripout relay triggered, then the power adjustment was 'backed off' to just under the maximum current throughput. Figure 6 shows the induction heater used for the project.

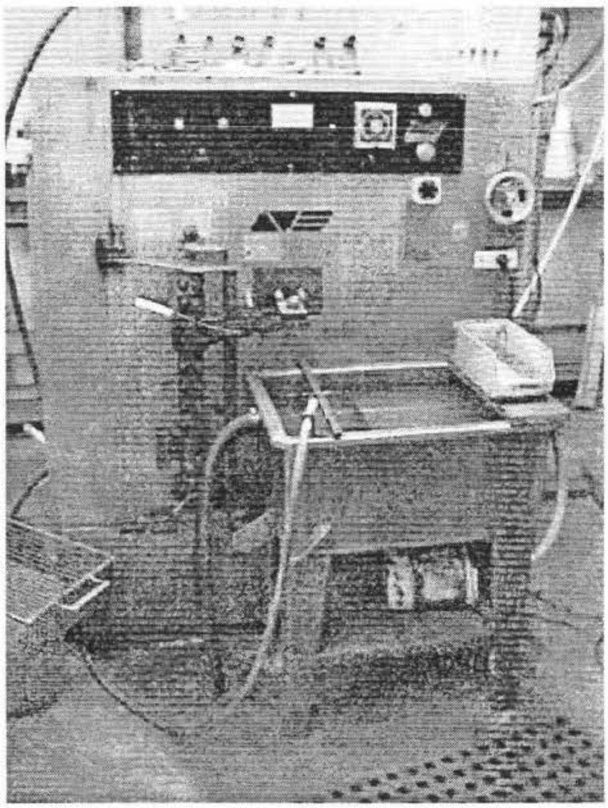

Figure 6: Southchain's Raydyne / Northern Electronics induction heater.

The suitability of this machine for various applications of induction heating can be seen in Table 4 on the next page.

Depth of Hardening (mm)	Section size (mm)	Rating for Frequencies over 200kHz
0.4 to 1.3	6.4 to 25.4	Good
1.3 to 2.5	11.1 to 15.9	Good
	15.9 to 25.4	Good
	25.4 to 50.8	Fair
	Over 50.8	Poor
Good indicates frequency that will most efficiently heat the material to austenitising temperature for the specified depth.		
Fair indicates a frequency that is lower than optimum but high enough to heat the material to austenitising temperature for the specified depth. With this frequency, the current penetration relative to the section size causes current cancellation and lowered efficiency.		
Poor indicates a frequency that will overheat the surface unless low-energy input is used. Efficiency and production are low.		

Table 4

Table 4 is adapted from Induction and Flame Hardening by the ASM Committee of Induction Hardening.

The company induction heater was used for components in the first category with a usual maximum of approximately 25mm. The length of any large section components was important as the power required to surface treat long components was not available. As such, large diameter (greater than 25mm) components over 75mm in length were rarely treated. To do so meant a greater depth of heating due to the low efficiency of the coil and hence slow heating.

This induction heater was inactive due to repairs for the first four months of the project. Pins were sent to Heat Treatments in Auckland to be induction hardened there. The triode in the heater was removed and sent away for testing and came back with no faults. The problem with the machine remained elusive until the whole machine was packed up and sent to High Frequency Electronics in Auckland. There they found a cracked solder joint in the coil feed line just behind the front panel. With this issue solved, the induction heater was then back into production as well as available for the project.

Induction Heating – A General Perspective

Induction hardening belongs to the case hardening category of heating treatment processes in that it treats only a very selective surface area of a work piece. It is generally found to be the most economic approach for selective hardening, especially if the part to be treated is symmetrical.

Induction heating occurs in an electrically conducting, not necessarily magnetic, object when it is placed in a varying magnetic field. When the work piece is placed in the coil and thus enters a rapidly varying magnetic field, eddy currents are induced within the work piece, generating precise amounts of clean, localized heat without any physical contact between the coil and the work piece. Induction heating also uses hysteresis losses for heating the material although it is not a major factor.

Eddy Currents

Eddy currents occur in any conducting materials (both magnetic and non-magnetic) and are responsible for the majority of heating in induction and the heat produced in a work piece via eddy currents comes through pure resistance heating. In the case of a cylindrical work piece in a solenoidal induction coil, eddy currents are localised areas of circumferential current loops induced by transformer action in the material. Eddy currents tend to be an image (although opposite in direction) to the coil current. The following diagram (Figure 7) illustrates eddy currents in a work piece.

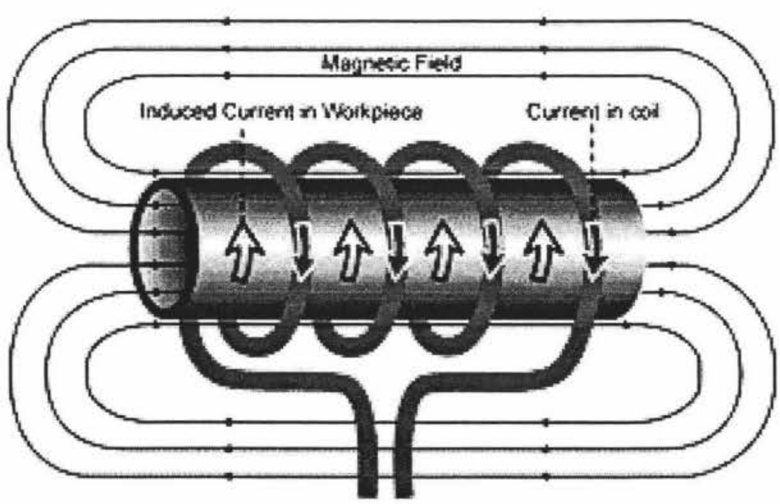

Figure 7: Illustration of eddy currents in a workpiece.

Eddy currents follow the basic rules of electricity. Ohm's Law $I = E/R$ (I is the current in amperes, E is the voltage in volts, R is the resistance in ohms) can be used to determine the induced current in a work piece. The resistance of the work piece to be used in Ohm's law can be found by $R = \rho L/A$ (R is the resistance in ohms, L is the length of the conductor in metres, A is the area of the cross section of the conductor in square metres, ρ is the resistivity of the work piece material in ohm-metres). The power (P) in a work piece due to eddy currents is I^2R (P is the power in watts, R is the resistance in ohms, I is the current in amperes) heating. The voltage induced in the work piece can be determined by $E = N\Phi/t \times 10^{-8}$ (where E is the induced voltage in volts, N is the number of turns in the circuit which are affected by the field, Φ/t is the rate at which the field is changing in lines per second) (Tudbury, 1960).

Hysteresis Losses

Hysteresis only occurs in magnetic materials and does not play a large part in induction heating. As a simple explanation of hysteresis losses, consider the molecules of metal as small magnets. When the material is exposed to the varying magnetic field, the molecules are magnetised in one direction, then the other. The friction between the molecules as they turn is overcome by adding energy via the magnetic field, which is converted into heat. The rate of energy outlay is dependant on the frequency of the magnetic field. Hysteresis losses become smaller as the material approaches the Curie temperature. The Curie temperature is a temperature above which ferromagnetism disappears in a substance. This disappearance of magnetism is temperature dependant and is very large (for iron) between 600°C and 780°C. The components treated in the induction heater are carbon steel (i.e. very similar to iron), and are heated to above 830°C, and as such hysteresis plays little part in their induction treatment.

Virtual Sleeves

To make the issue of dealing with eddy currents in a solid bar easier to understand, it is useful to envisage the bar as a number of concentric virtual sleeves, each sleeve a smaller counterpart of its outer mate (Figure 8 on the next page, adapted from Tudbury,1960, p1-24). It is now possible to understand the eddy currents running in each successive layer instead of as a whole. To obtain the total current induced in the bar one only has to sum the current in each sleeve.

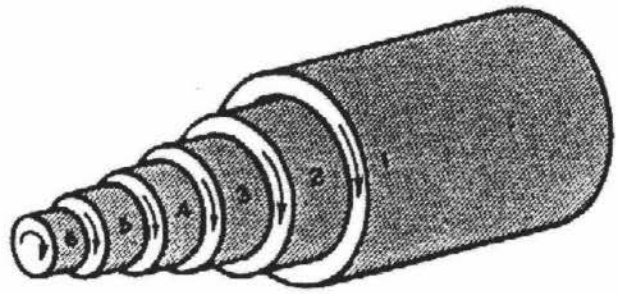

Figure 8: Diagram of 'virtual sleeves' used to simplify the understanding of eddy current flow in a solid workpiece.

To understand the usefulness of this model it is helpful to consider the eddy current workings in each sleeve. When a solid bar is placed in a coil emitting a rapidly varying magnetic field, the field links up with the outer virtual sleeve, voltage is induced, current flows and power is developed. Now consider the next sleeve in (sleeve #2). The process mentioned above also happens in this sleeve, but to a lesser extent. The outer sleeve has already interacted with the magnetic field and hence weakened it. The amount the field is weakened is dependant upon the frequency of the field and the properties of the bar. This process is the same for each successive virtual sleeve in the bar(Figure 9, adapted from Tudbury,1960, p1-25). With this visualisation one can see

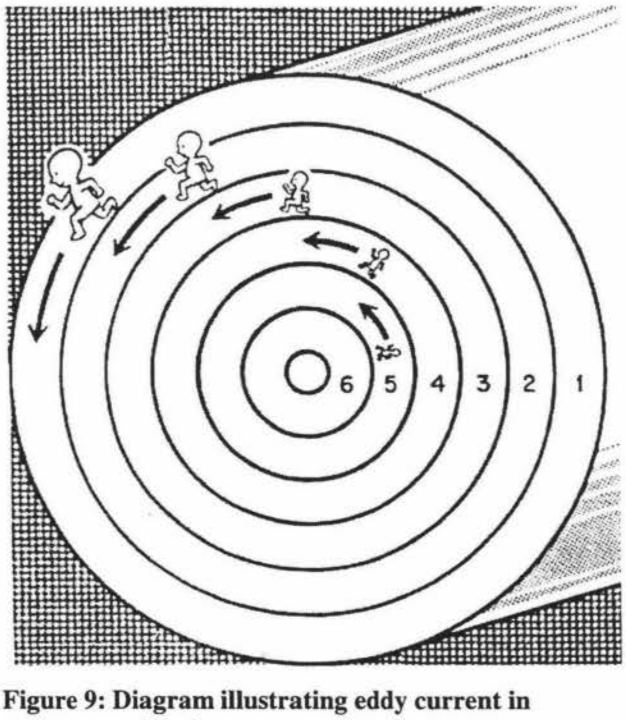

Figure 9: Diagram illustrating eddy current in each successive sleeve.

that the heavier current is induced on the surface of the solid bar and the current density, field strength, and power decrease as the depth into the bar increases. Note that at the centre of the bar the current is zero as the effective diameter is infinitely small.

Skin Effect

Now that a solid bar can be treated as a set of concentric sleeves, and it is seen that the outer sleeve has the highest current density and power. This is called the skin effect. This effect is dependent upon a number of issues: frequency of the magnetic field, size of the bar and its magnetic and electrical properties. In general, the higher the frequency of an induction heater, the shallower the skin effect is for any single work piece. Also, higher frequency heaters can process smaller diameter work pieces.

Power and Temperature Distribution

The power level used to treat a work piece does not alter the skin effect. Using a greater power level increases the amount of power in the outer sleeve of a bar, with corresponding increases in power in the inner sleeves, but the proportions are still the same. What this indicates is that a higher power setting can be used to heat a component more quickly. The skin effect and higher power are useful when shallow treatment of a component is required. Higher power allows the component surface to be heated to the required temperature (for the required phase change) before the remainder of the work piece becomes too hot via conduction and also changes phase. Power levels and heating times are closely related to the characteristics of the work piece and the design of the induction coil.

Depth of Hardening

As has been explained above, the extent of the skin effect into the work piece is dependant upon the frequency used, and the resistivity & permeability of the material used. But the temperature determines the resistivity and permeability of the material. From the two factors above the following approximate relationships (from 'Surface Hardening of Steel', 1980, HC Child) can be formed: $d_{800} = 500/\sqrt{f}$ (where d800 is the depth of penetration of current in mm at 800°C, and f is frequency of the power supply to the coil in Hz). Because conduction carries the heat into the work piece, the overall depth of heating is increased. The depth of penetration resulting from conduction is approximately given by $d_C = 0.2\sqrt{t}$ (where t is the heating time). Overall penetration, d0, is given by $d_0 = d_{800} + d_C$. Given the company has a fixed frequency with which to treat components, the depth of hardening can be controlled by adjusting heating time and power (Child, 1980, p26).

Coil Design

The induction heater coil is analogous to a transformer primary winding and the work piece similarly to a transformer secondary winding. Coils are normally made of copper with appropriate water cooling and vary considerably in shape according to the application. Coil efficiency is the ratio of power provided in the coil to that induced in the work piece.

A major factor in the efficiency of this equivalent transformer system is the coupling between the coil and work piece. The efficiency is inversely proportional to the square of the distance between them. As such it is important that the coil inside diameter be only slightly larger than the diameter of the work piece. The bulk of flux lines travel inside a round multiturn coil, close to the coil itself and hence a work piece must be placed in the centre of the coil for the greatest rate of heating.

For the most part, the company used round multiturn, single-place coils. It was necessary during the course of the roller treatment investigation to use internal coils. Due to the above explanation of flux lines, internal coils have a low level of efficiency. See Table 5 for a comparison of coupling efficiencies of various types of coil.

	Coupling efficiency at frequency of 450kHz	
Type of Coil	Magnetic Steel	Other Metals
Helical around work piece	0.80	0.60
Pancake	0.50	0.30
Hairpin	0.60	0.40
One turn around work piece	0.70	0.50
Channel	0.70	0.50
Internal	0.50	0.25
Zinn and Semiatin, 1988, p34		

Table 5

Coils used in the project included standard round, rectangular, pancake, internal and a combination of these (Figure 10).

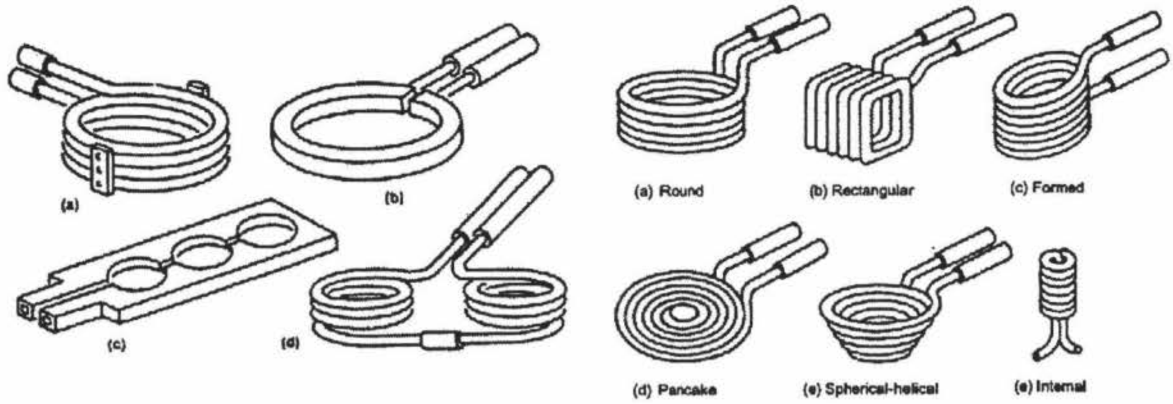

Figure 10: Basic types of coils (from Coil design and fabrication: Part 1).

For more in depth coverage of the fundamentals of induction heating see excerpts from Basics of Induction Heating, Chester A. Tudbury, in Appendix G. Further information on coil design can be seen in the articles Coil Design and Fabrication, Parts 1, 2, and 3 Appendix H.

Noddy's Guide to Surface Hardening of Steel

Many types of steel are treated with heat to be hardened, hence increasing toughness and resistance to wear. The hardness that can be imparted to steels is dependant upon the carbon content. Generally steels with a carbon content of less than 0.3% cannot be hardened and increasing carbon content beyond about 1% does not substantially increase the hardness. There are two general types of hardening processes: through hardening, which treats the entire part, and case hardening, which by and large treats the work piece surface area and only some of the interior area, according to the depth of hardening requirements for any one specific process.

Heat Treatment Greatly-Simplified

Plain carbon steels are malleable alloys of Iron (Fe) and Carbon (C) with a carbon content from a small fraction of a percent, up to approximately 1.5%. The carbon content heavily influences factors such as hardness, resistance to wear, toughness, hardenability, and malleability. In this greatly-simplified explanation of what happens to metal when heat treated, steel with a carbon content of 0.4% (1040) will be considered. This is the majority of steel used by the company for in-house induction heat treatment and was also used during the roller induction treatment investigation.

The principal effect of carbon in steel is the influence on its microstructure. At room temperature 1040 steel is made up of two main components: Ferrite and Pearlite. Ferrite is virtually pure iron with very little carbon. It is magnetic, soft and ductile. Pearlite is composed of an aggregate of Ferrite and Cementite. Cementite is iron carbide (Fe_3C), is magnetic and contains about 6.7% carbon. Note that steel with a wholly Pearlitic structure is a *eutectoid* steel.

When 1040 steel is heated, certain changes take place in its microstructure. By following the Iron-Carbon equilibrium diagram in Figure 11 (The Structure and Heat Treatment of Steel, p8), the change in make-up of the steel can be tracked.

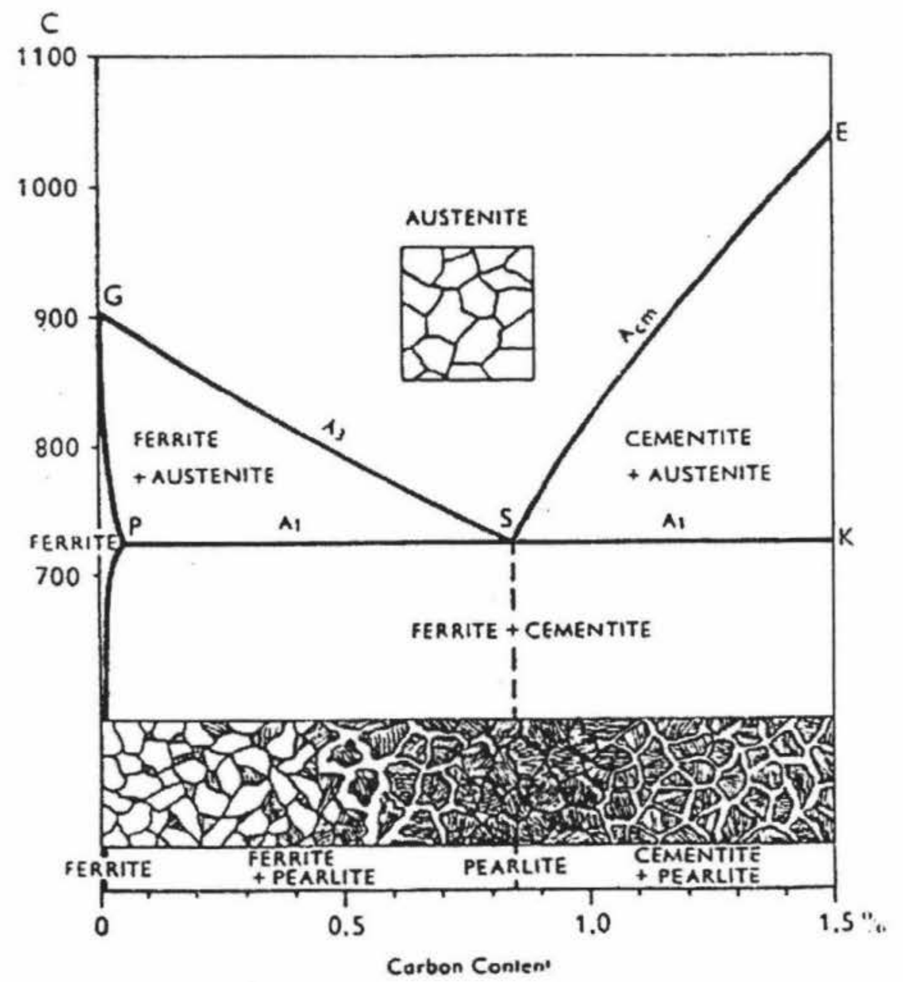

Figure 11: Carbon-Iron equilibrium diagram.

Heating this hypoeutectoid steel above approximately 725°C (the PK line on the equilibrium diagram) causes the Pearlite to disaggregate, with its components Cementite and Ferrite going into solution to form a new, stable phase called Austenite (which is non-magnetic). At this point the structure of the steel consists of Ferrite and Austenite. Taking the temperature above approximately 830°C (above the GS line on the equilibrium diagram) causes the remaining Ferrite to dissolve into Austenite. At this stage the metal is in a purely Austenitic phase structure.

At this high temperature (above 830°C) iron can dissolve more carbon than can iron formed by slow cooling to room temperature. Austenite therefore contains more carbon than Ferrite and due to its structure, is denser. The differences in the crystalline structure will not be discussed in this paper.

Austenite is the structure that is necessary for obtaining the appropriate level of hardness in the 1040 steel for the company manufacturing purposes. But if the metal is left for a period of time to cool slowly, the above process reverses and results in the steel being of the same microstructure (and hence hardness) as it was initially. To preserve the austenitic structure, the cooling process must be done over a very short period of time.

The amount of hardening achieved is greatly influenced by how the steel is cooled or "quenched". The cooling rate of any steel part depends on the rate of heat energy extraction (which is a function of the characteristics of the quenching medium). The three most common quenching media are water, oil and air with water being the chosen quenchant by the company. The effectiveness of the quench can be improved by increasing the rate of flow over the part.

Over time the scientific and engineering community have gained knowledge of the structural transformations that take place during the heat treatment of steels. Through experimentation and testing, the progress of the isothermal transformation has been determined and illustrated by means of Time-Temperature-Transformation (TTT) graphs (Figure 12 next page - The Structure and Heat Treatment of Steel, p13). The areas on either side of the curves on the diagram represents the basic three phases (microstructures) mentioned above. To the left of the left curve is Austenite. Between the two solid line curves is Austenite and Ferrite (in the case of 1040 steel), and to the right of the right curve is Ferrite and Cementite.

So if the initial cooling time is very short (less than approximately 0.6 seconds) the temperature of the steel will drop very steeply over time, miss the 'knee' of the left curve and retain a purely austenitic structure (until a certain point in the temperature of the work piece).

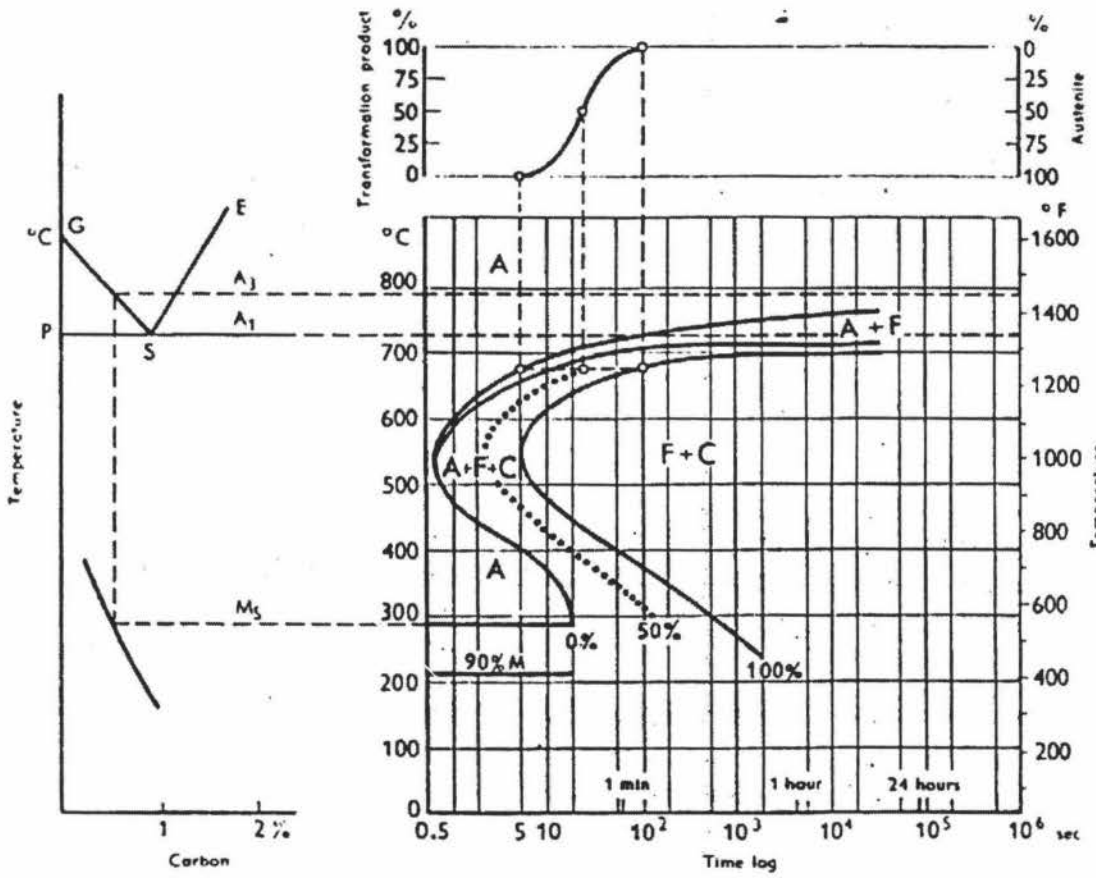

Figure 12: Time-Temperature-Transformation (TTT) graph.

At this point it is necessary to reconsider the transformation in the structural composition of the steel as it is cooled. In spite of rapid cooling, austenite undergoes a transformation at low temperature (≈280°C), forming a structural phase called martensite. Martensite has needle shaped grains and is extremely hard. This phase gives the required hardness of metal.

Note that the diagram represents a hypoeutectoid steel of about 0.5% carbon and the TTT diagram for 1040 steel would be slightly different.

In 'Strength of Materials' (1978, p83), Bela Sandor states "In general, resistance to deformation increases as the microstructure (sizes of grains) is made finer." It is this factor that was used to ascertain the hardened areas of metal versus untreated metal during the roller induction heating investigation. See Figure 13 for an example of both fine grain and coarse grain 1040 steel.

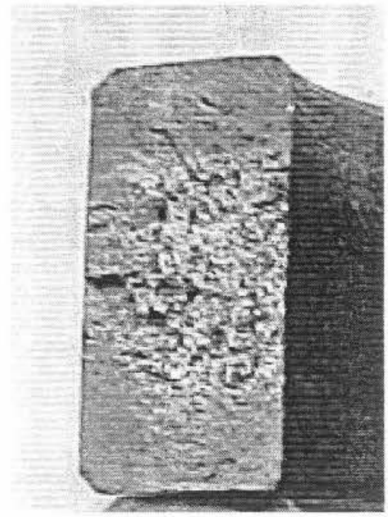

Figure 13: Example of coarse and fine grain microstructure in 1040 steel.

Noddy's Guide to Conveyor Chain

Conveyor chain comes within the 'roller chain' category of chains. The company normally only manufactures steel chain but has done cast iron chains. A roller chain consists of a number of the following components: plates (inner and outer), pins, bushes, and rollers. Conveyor chains are not used for power transmission, but as its name states, play the role of conveying items. The basic construction of conveyor chain can be seen in Figure 14 – U.S. Tsubaki Inc (1997). <u>The Complete Guide to Chain</u>.

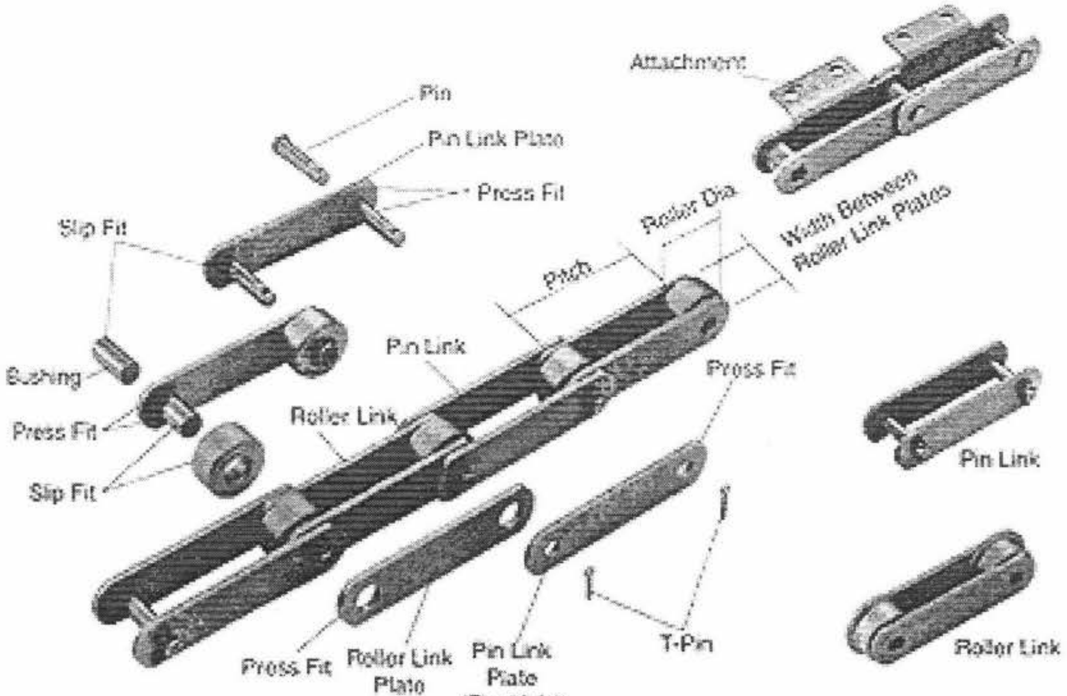

Figure 14: Exploded view of a conveyor chain from US Tsubaki.

The remainder of Noddy's guide to conveyor chain covers the basics of conveyor chain and has been taken directly from The Complete Guide to Chain, (1997), U.S. Tsubaki Inc, p4-p6. It is an excellent resource and so was thought to be worth including the relevant portion. It is also available online at http://www.ustsubaki.com/chainguide.html. The GRIF fellow has added some comments and additional material.

Plate

The plate is the component that bears the tension placed on the chain. Usually this is a repeated loading, sometimes accompanied by shock. Therefore, the plate must have not only great static tensile strength, but also must hold up to the dynamic forces of load and shock. Furthermore, the plate must meet environmental resistance requirements (for example corrosion, abrasion, etc). [Note here that the inner plate is the weak point in conveyor chain as the hole punched to fit the bushing creates a narrower cross section of metal in the plate.]

Pin

The pin is subject to shearing and bending forces transmitted by the plate. At the same time, it forms a load-bearing part, together with the bushing, when the chain flexes during sprocket engagement. Therefore, the pin needs high tensile and shear strength, resistance to bending, and also must have sufficient endurance against shock and wear. [Pins are induction treated by the project company.]

Bushing

The bushing is subject to shearing and bending stresses transmitted by the plate and roller, and also gets shock loads when the chain engages the sprocket. In addition, when the chain articulates, the inner surface forms a load-bearing part together with the pin. The outer surface also forms a load-bearing part with the roller's inner surface when the roller rotates on the rail or engages the sprocket. Therefore, it must have great tensile strength against shearing and be resistant to dynamic shock and wear.

Roller

The roller is subject to impact load as it strikes the sprocket teeth during the chain engagement with the sprocket. After engagement, the roller changes its point of contact and balance. It is held between the sprocket teeth and bushing, and moves on the tooth face while receiving a compression load. Furthermore, the roller's inner surface constitutes a bearing part together with the bushing's outer surface when the roller rotates on the rail. Therefore, it must be resistant to wear and still have strength against shock, fatigue, and compression.

Pin Riveting (non-Tsubaki)

This is the process that prevents the chain from falling apart at the point of connection. Unlike the conveyor chain diagram above, the company manufactures stock chains using spin riveting process that creates fewer problems than cotter pins, spring clips and T-pins used by Tsubaki. The company has found that these extra components are prone to wear as well as tend to catch and cause problems.

The following picture (Figure 15 – next page) shows the components used in the company's two most popular chains, the 4inch 6/7.5K and 6inch 12/15K chains.

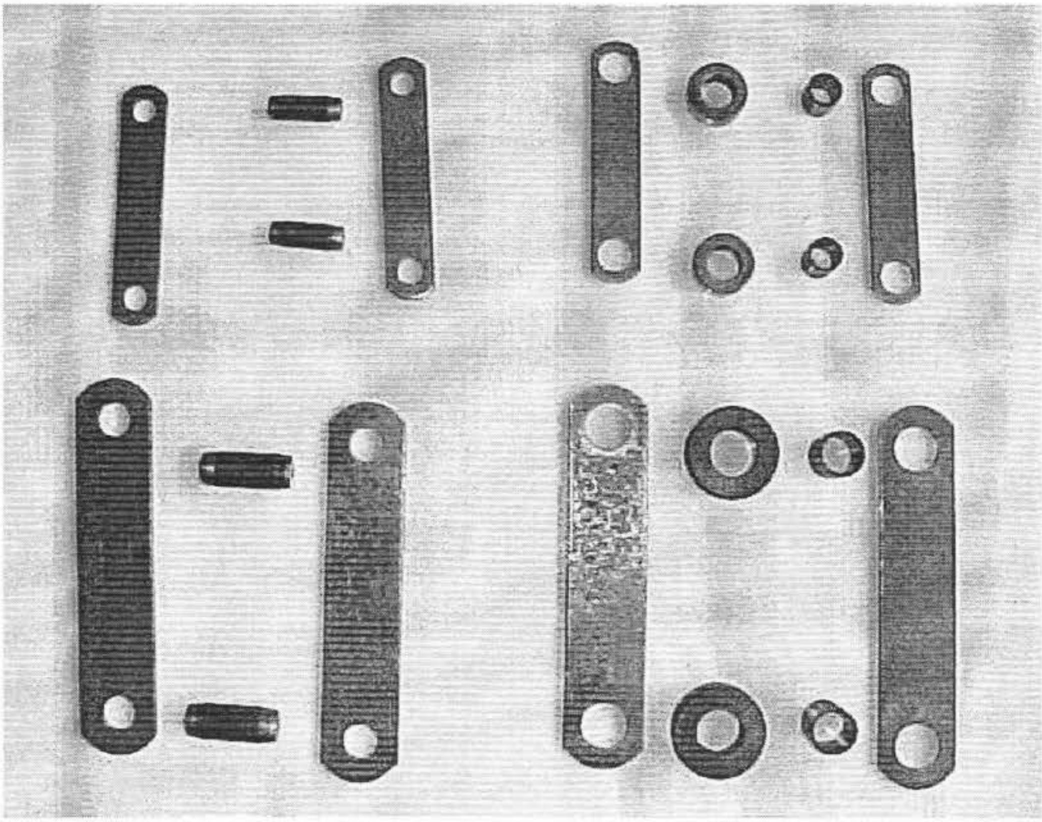

Figure 15: Components used in the company's two most popular chains.

In-house Roller Heat Treatment Investigation

As stated earlier, the process model showed a large proportion of the production cost of chain was caused by the external process of case hardening of the chain rollers. This particular point of investigation had the potential to save the company many tens of thousands of dollars in component treatment costs.

Several methods of in-house treatment were considered but all required much capital expenditure (see Table 6 on page 50). Considered methods were divided up into two categories: treatment methods the company was capable of at the time, and those methods that required capital expenditure.

Capital intensive methods taken into account included work hardening via peening and extrusion, gas carburising, pack carburising, salt bath carburising (cyaniding), and nitriding. The capital costs of these were researched and found to be between $20,000 for a small manual pack carburising plant, through to in excess of $250,000 for a small gas carburising plant.

In-house techniques that required no capital expenditure for equipment included: flame through hardening, surface work hardening via knurling, and induction heat treatment.

The most simple means of hardening steel immediately available to the company was flame hardening. Flame heating tests were carried out on the three size rollers and various methods trialled(Figure 16 next page). The rollers were taken above the phase change temperature (approximately 830°C) and quenched in oil, water, and brine in separate tests. Two rollers (quenched in water) were machined down using a diamond tip tool at high speed, and every two millimetres, hardness tests were done (Appendix I). The Rockwell C hardness throughout the thickness of the rollers was above that required just on the surface, and in shock tests it was established that the components were too brittle to continue considering this method of heat treatment.

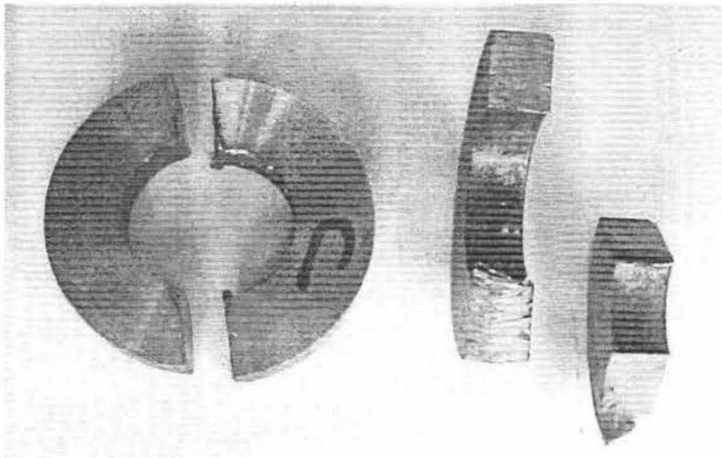

Figure 16: Through heated rollers cut away using high speed diamond tip cutter.

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	Pins	Rollers	Bushes
Induction Heating -no capital expenditure -R&D necessary -automation feasible -for >= 0.4% Carbon steel	-status quo -can easily double or triple production -option of coil improvements -option of quench improvements	-R&D necessary -need to change metal	-R&D necessary -need to change metal -case depth an issue (milder quenching?) -split bushes may not harden due to open circuit
Work Hardening (incl. knurling, shot peening, extrusion) -no large capital expenditure for knurling -case depth an issue (shallow, ~0.1mm?) -shot peening & extrusion require large capital expenditure -R&D necessary - mat'l selection issue	-R&D necessary	-R&D necessary	-R&D necessary -rolling machine could be altered to work the bushes more
Gas Carburising -capital expenditure ~$250,000	-must selectively plate ends	-status quo ($$$)	-status quo ($)
Pack Carburising -capital expenditure ~$20,000 (minimum) -no control over carbon content - >= 2.5mm case depth -small batch size (50kg) for min end cap-ex -long batch processing times (~24+ hours) -automation not feasible	-must selectively plate ends	-possible -R&D necessary	-case depth too great
Salt Bath Carburising (Cyaniding) -dangerous chemicals -capital expenditure ~$50,000 -components require post treatment cleaning -automation not feasible	-must selectively plate ends	-not considered wise for health & safety and disposal of waste issues	
Nitriding (incl. Plasma, salt bath, gas) -capital expenditure prohibitive -case very hard but shallow	-must selectively plate ends		
Flame Hardening -low capital expenditure -automation feasible -R&D necessary	-R&D necessary	-R&D necessary	-R&D necessary

1. We have knowledge and experience with induction heating. All other hardening processes are effectively new and untested inhouse.
2. The status quo with induction heating is very well suited to the hardening of pins. All other case hardening processes (except flame hardening) involve coating the ends of the pins to avoid hardening the worked ends.
3. Even if the more expensive alternative is opted for, due to the material handling requirements mentioned above the induction heater would continue operating for pins
4. Getting the induction heater to process at least 50% to 75% (dollar expenditure) of the current externally hardened components means that even without automation, induction heating saves considerable money.
4a. Adding automation to the induction heater improves the savings even more.
5. For the alternatives, automation is only feasible for the high end $$ options
6. The least expensive and safest way forward is to investigate the full utilisation of the induction heater and only outlay capital if it is warranted.

Those processes above that required large amounts of capital, required no research and development as they were tried and true methods being employed by many companies worldwide. The second category of treatment methods needed much investigation and development.

Essentially, high capital investment methods had a low return on investment for a company of this size. So as the company owned an induction heater and was practiced at working with this method of heat treatment, it was decided to attempt to use the existing induction heat treatment equipment in a novel fashion to harden roller components. The GRIF fellow did not discover any manufacturers carrying out a process of induction heating all surfaces on a profile such as a conveyor chain roller.

Choice of Rollers

The rollers were shipped to Auckland where they were gas carburised and shipped back. Both the treatment and the freight were charged by weight. Dependant upon which chain is in question, roller case hardening accounted for between 11% and 23% of the cost of a foot of chain (see Identifying First Order Savings chapter). As per the chapter on process simulation, the 6/7.5K and 12/15K chains represented over 95% of chain sold (1999 figures) and hence the greatest expenditure on case hardening. As such, these chains were chosen for roller induction investigation.

An estimation of percentage of case hardening for the larger chains shows the value of the external process including freight to be immense (Table 7).

Chain	Cost/ft		HTAuck/ft (incl freight)	Percentage of Case Hardening per Foot
24K6.0	$ 23.74		$ 5.90	25%
24K8.0	$ 19.08		$ 4.43	23%
30K6.0	$ 23.11		$ 5.90	26%
30K8.0	$ 18.61		$ 4.43	24%

Table 7

These chains, at the time of the analysis, did not represent a large proportion of production. But given the size of the rollers in these chains and their external heat treatment costs, there would only need to be a small to moderate production run of this size before the external costs became a significant issue. It is for this reason that the 24/30K chain rollers were included in the inhouse heat treatment investigation.

Rollers sent away for case hardening were fabricated from 1020 (0.02% Carbon) steel. As stated previously (Noddy's Guide to Induction Heating chapter), this is not enough carbon content to effectively induction heat treat. The low carbon content does not allow the appropriate molecular structure for acceptable hardness. Hence, test rollers were manufactured from 1040 (0.04% Carbon) steel to allow for satisfactory induction heating and quenching.

There were four surfaces on the roller which were attempted to be hardened. These were the inner circumference, the outer circumference, and the two flat faces on either side of the roller (Figure 17). Note that each circumference and face had a 'sister' surface that was parallel to it.

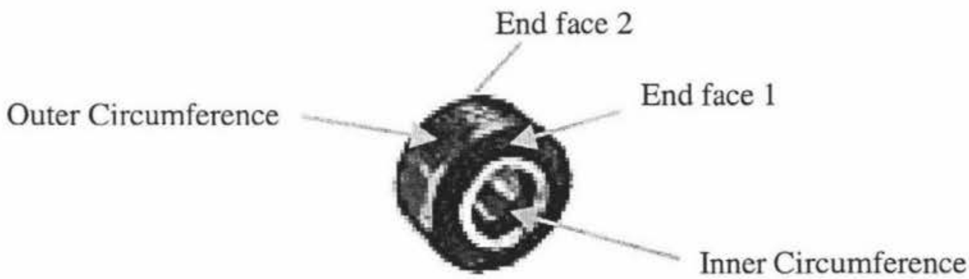


Figure 17: Explanation of the surfaces available on a roller.

At this juncture, the company had been using the induction heater to harden pin components. This necessitated only placing a cylindrical metal component into a vertical helical coil to treat the outer circumference of the pin. By implication, treating the outer circumference of the rollers would not be any different except for the diameter of the part to be treated.

What was to be attempted was the hardening of all four surfaces of the roller. The gas carburising being done externally was able to accomplish this in one process as the parts were immersed in the treatment environment. Induction heat treatment though (as the explained in Noddy's Guide to Induction Heating chapter) requires an induction coil that comes into close proximity to the surface to be treated. Treating each of the surfaces separately, or in conjunction to its parallel 'sister' surface, was feasible. Complications of multiple steps included the problem that each additional heat process would anneal/temper the previous one.

Treating all four surfaces simultaneously was not attempted as it was considered to be impossible with the technology and equipment available to the company. The core reasoning of the infeasibility of a simultaneous process was the physics behind induction heating. Certain coil configurations cause a cancellation of the required magnetic fields and a coil intended for executing this would by necessity include such configurations. Even considering that such a coil was possible, the physical limitations in entirely surrounding a component (ensuring coverage of all surfaces) with an induction coil would make insertion and removal of components very difficult and not readily implemented in a manufacturing process.

The trials of induction heating rollers were carried out in three parts (one for each size of roller) and the investigations were carried through to a conclusion before the next size roller was dealt with.

Testing of Roller Results

After heating and quenching each roller, a diamond tip Rockwell C (R_C) hardness testing regime was carried out. Up to 42 positions (see example hardness map, Figure 18) on each roller were hardness tested. The roller was mapped out in four quadrants (North, South, East, West) around the outer circumference. Three tests were done

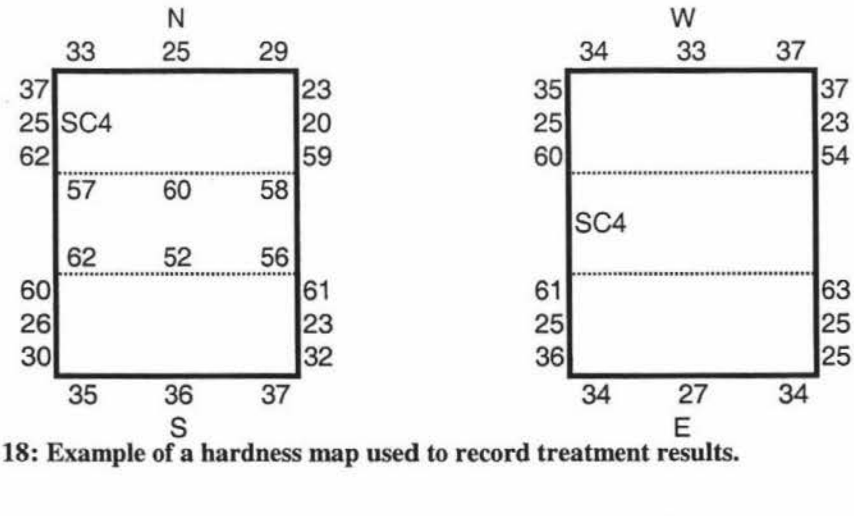


Figure 18: Example of a hardness map used to record treatment results.

across each available surface. The inner circumference surface was tested once the roller was broken in shock testing. The inner surface along the break was not tested (note the lack of measurements on the E/W quadrants diagram above).

The aim of the hardness testing was to ensure the trial process results matched (or came close to) the case hardened (Heat Treatments Ltd, Auckland) rollers. Results were deemed satisfactory if within ±10% of the average R_C results of Heat Treatments results.

To simulate shock loading on the rollers, a crude but effective test was devised. A 'hammer test' was done to get a feel for the brittleness of the roller and view of internal crystal structure (fine vs. coarse structure). After hardness testing the rollers were held by vice-grips and placed on an anvil. The roller was then pounded with a hammer until it broke. Brittle and unacceptable rollers broke on the first hit (first few hits) and were not misshapen by the striking process. Rollers that malformed and did not break were deemed too soft and also unacceptable. Satisfactory results were achieved when the roller took severe 'punishment' before breaking and was slightly out of round due to the hammering. Rollers that had satisfactory results were of good durability.

In-situ testing of the rollers was not carried out in the company consumer environments. It was regarded as too risky to introduce a product (albeit a trial one) that may have transpired to be substandard, with the result that customer confidence in the company would decrease.

12/15K Trials

These rollers measured approximately 46mm outer diameter, 24mm inner diameter, 17mm wide and weighed 0.200kg (see Appendix I for 12/15K trial results).

External Coil for Treating a Single Outer Surface

As with standard pin treatment, a multiturn, single position coil was all that was needed to treat the outer circumference of the rollers (Figure 19 next page). It only remained to be seen if the company induction heater had enough power to bring the intended surface up to the required temperature quickly enough for a shallow treatment. A coil was built for this purpose and worked successfully. Hardness results were satisfactory but shock durability testing was not done.

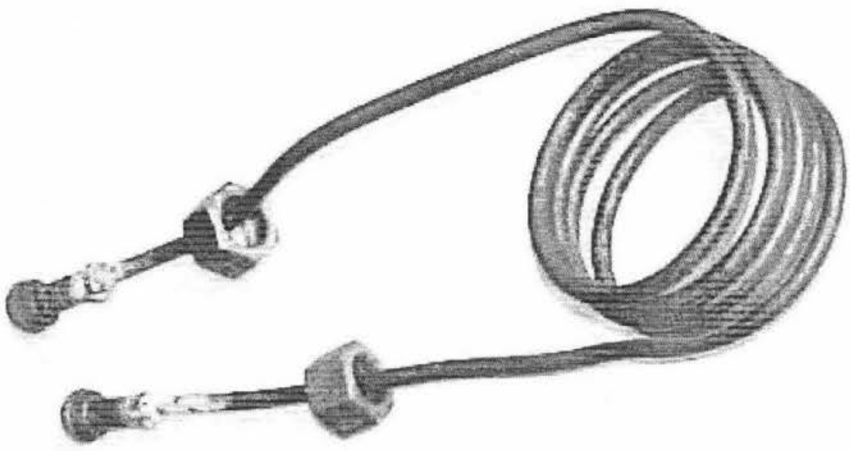


Figure 19: Multiturn, single place coil used for 12/15K outer circumference surface.

Twin Pancake Coils for Treating Two Parallel End Faces Simultaneously

The second trial was to heat both faces of the roller simultaneously. A multiturn, twin-position pancake coil was constructed for this purpose. This coil was a single element, turned into two opposingly wound pancake coils, with each pancake placed parallel to its opposite (similarly to Figure 20). The roller was then placed into the space between

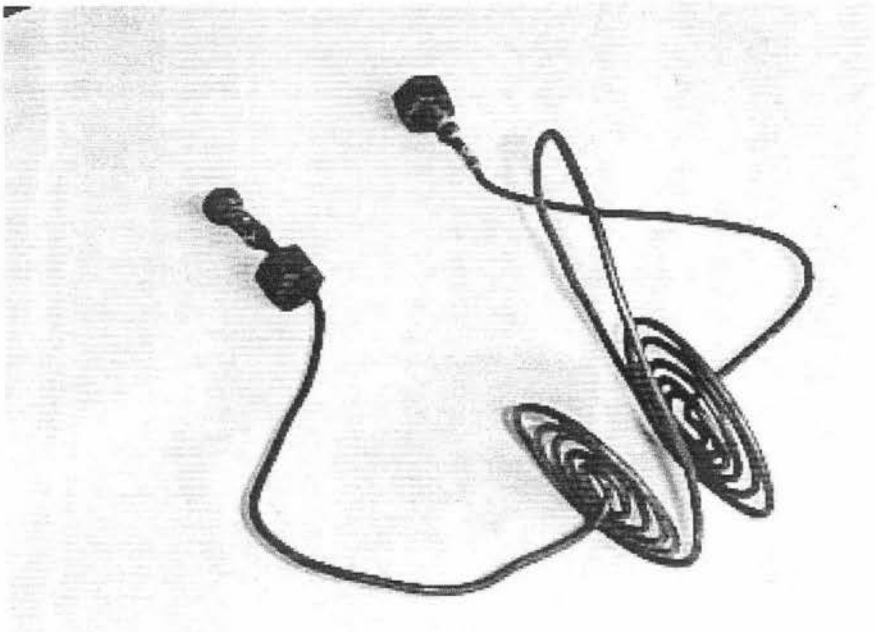


Figure 20: Double pancake coil used for end face treatment.

the pancakes and held manually (with non-inductive, non-conductive tools) whilst the heating cycle took place. At the end of the cycle, the roller was dropped into a quench bath for hardening.

Hardness results were satisfactory on the two faces as well as on the face edges of the outer and inner circumference. No hardening occurred on the majority of the outer and inner circumferences. Shock durability testing of the roller was satisfactory.

Dual Coil for Treating Two Parallel Circumferential Surfaces

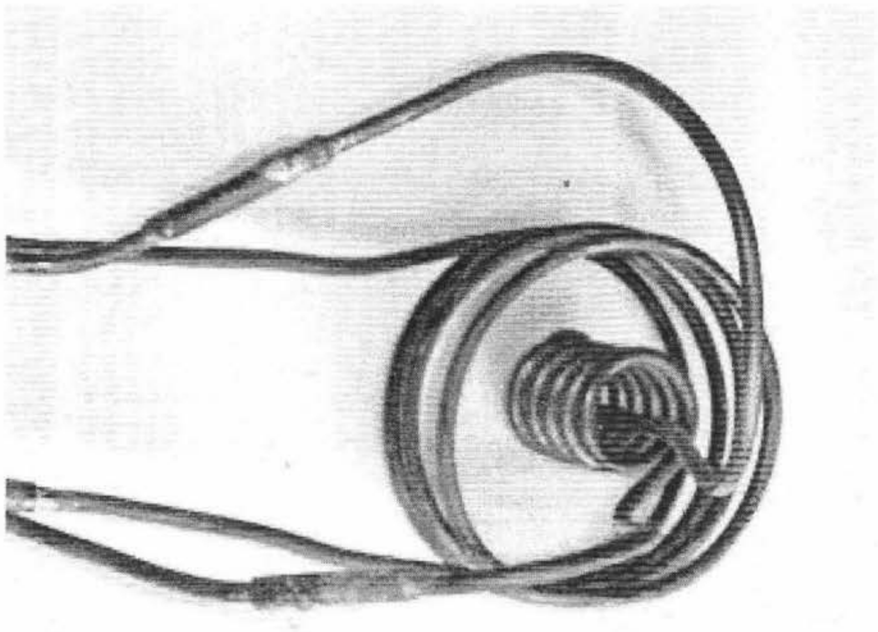


Figure 21: Dual coil (inner & outer) used in trialing simultaneously treating the inner and outer circumferential surfaces.

Simultaneously

The next experiment attempted to treat the inner and outer circumferences simultaneously. A double element, multiturn, single-place combination coil was constructed by making a multiturn, single place external coil and a multiturn, internal coil and brazing the leads together so the coils were in parallel with each other (Figure 21 above). As explained in Noddy's Guide to induction heating, the internal adjustment of the Raydyne heater had to be adjusted for each coil and work piece (and their particular efficiency together). The predicament with this situation was that there were two differing coils, with differing efficiencies. Matching the impedance of the two coils in parallel meant that neither was set correctly. Setting the heater for the external coil meant the internal coil did not have enough power to heat the inner surface. Attempting to increase the power to the dual system to resolve this caused an over-current tripout due to the outer coil.

Still keeping with the idea of a dual internal / external coil configuration, a single element multiturn single place coil was built. A single copper tube was wound for the external surface then lead to an internal coil. The same power per coil problems was encountered. Enough power to drive the internal coil meant an over-current tripout and the correct power setting for the external coil had the effect of under-powering the internal coil.

This coil configuration was abandoned as no treated rollers were successfully produced with this method.

Internal Coil for Treating a Single Inner Surface

Leading on from the unsuccessful dual coil trials, it was necessary to prove that the internal circumference of the rollers could be effectively treated. A multiturn internal coil was formed (Figure 22) and was successful at treating this surface.

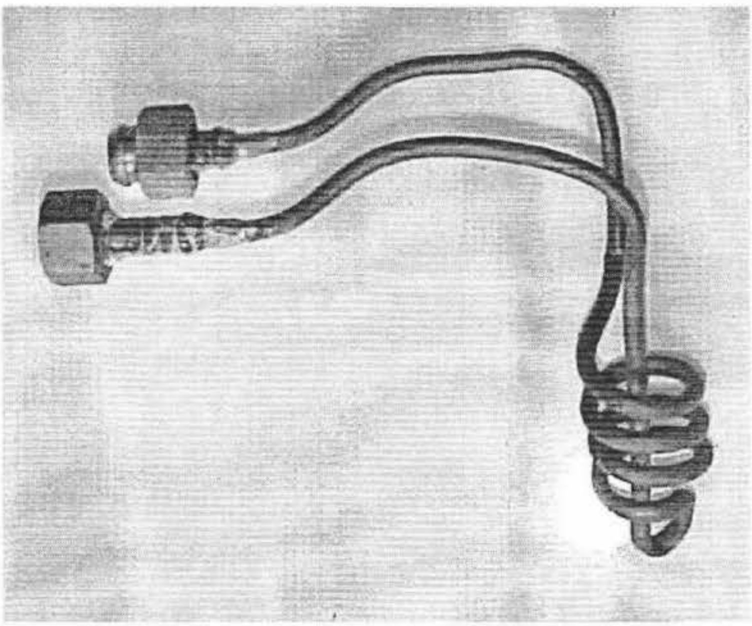


Figure 22: An internal coil.

External then Internal Heat Treatment Process

Knowing that both circumferences could not be treated concurrently, it was decided to approach treating the circumferential contact surfaces of the roller in succession. The previously constructed external and internal coils were used one after the other to treat the roller. Firstly the outer circumference was dealt with. Hardness tests were then conducted on the treated surface and satisfactory hardness was achieved. The internal circumference was heat treated next.

Whilst treating the inner surface, the occurrence of a 'heat wave' was observed. Once the bore coil was active, the inner surface began (as expected) to heat and become red. It was noticed at the point of just turning red, that a 'wave' of colour change traversed the face surface of the roller, passing from inner edge to outer edge. At the time deemed sufficient to treat the inner surface effectively, this wave had since reached the outer limits of the roller. Once quenched, the roller was hardness tested on the outer circumference and was found to have been tempered back to an unacceptably low level of hardness. After breaking the softened roller apart, the inner circumference was hardness tested with satisfactory hardness levels.

It was then attempted to treat the inner surface without tempering the outer surface by restricting the heating time to the time it took the 'colour wave' to travel the radial distance but not quite reach the outer edge of the roller. These tests were unsuccessful as all rollers tested soft on the external circumference after bore heating and the internal circumferential surface had not obtained the appropriate hardness level.

Internal then External Heat Treatment Process

The opposite of the above two stage heat treatment process was then trialed. The inner circumference was treated and tested successfully. The outer circumference was then treated with the same effect as before – the previously treated surface was tempered back to an unacceptably low level of hardness.

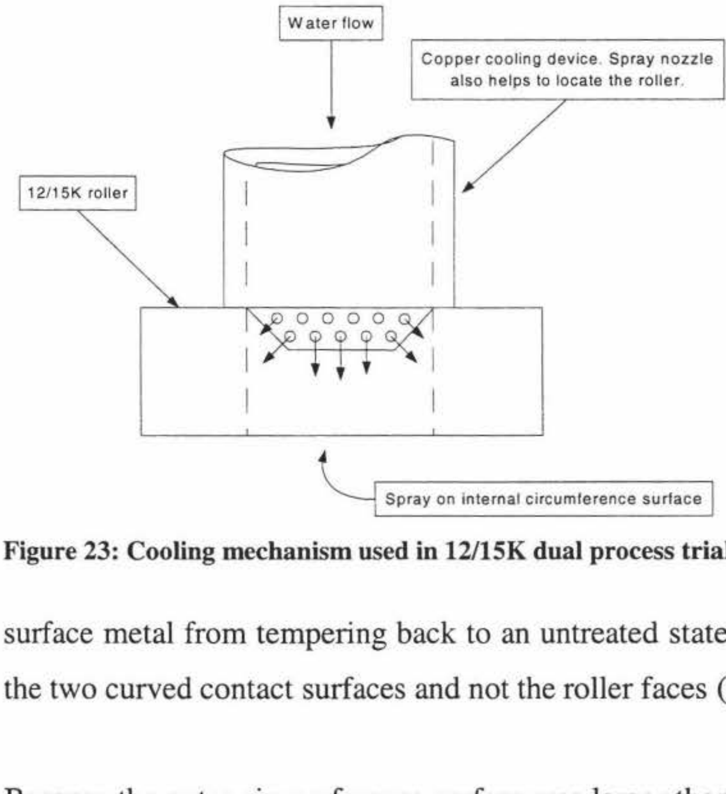
Internal then External with Internal Cooling

The knowledge that the inner and outer circumference surfaces of the roller were the important contact surfaces and the lessons of the previous trials led to the following points:

- at a minimum, the inner and outer circumference surfaces must be of acceptable hardness
- the inner and outer circumference surfaces cannot be treated simultaneously using the dual coil configuration above
- the inner and outer circumference surfaces cannot be treated in succession by the above methods without the second process destroying the results of the initial process

A method to achieve good results, at the same time keeping within the bounds of the above line of reasoning, was necessary. The conclusion was to create a composite roller with a hard outer circumference surface, an essentially untreated 'central' circumference and a hardened inner circumference surface.

It was decided the solution for the 12/15K rollers involved undergoing a modified version of the double treatment process above. Firstly the inner circumference surface was heat-treated (heated and quenched), then secondly the outer circumference surface was heated whilst the inner circumference surface was water-cooled. See Figure 23 for a diagram and picture of the cooling mechanism. The inner cooling stopped the inner



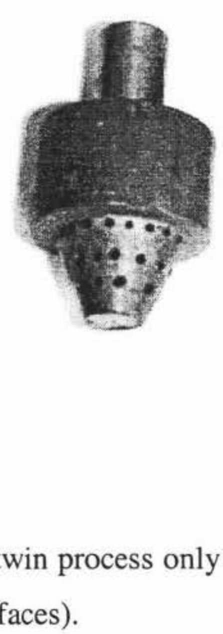


Figure 23: Cooling mechanism used in 12/15K dual process trials.

surface metal from tempering back to an untreated state. This twin process only treated the two curved contact surfaces and not the roller faces (flat surfaces).

Because the outer circumference surface was larger than that of the inner circumference surface, more power was required to heat it. This being the case, more heat than the inner alternative would have been generated in the part, therefore requiring greater cooling. It would have made sense, therefore, to have treated the outer surface first, followed by the inner surface to have a lesser amount of heat to eliminate. Although this was quite feasible, time constraints dictated otherwise and the more easily constructed inner circumference surface cooling solution was produced. This mechanism also assisted with ease of location of the roller in the coil.

End Results

Results of this roller showed very satisfactory hardness on both inner and outer circumference surfaces and the durability of the roller was good. The cross-section of roller was examined to verify the hardness tests and demonstrate the composite nature of the roller (Figure 24). Note the fine crystal structure on the inner and outer circumferences and the coarse crystalline structure on the inner portion.

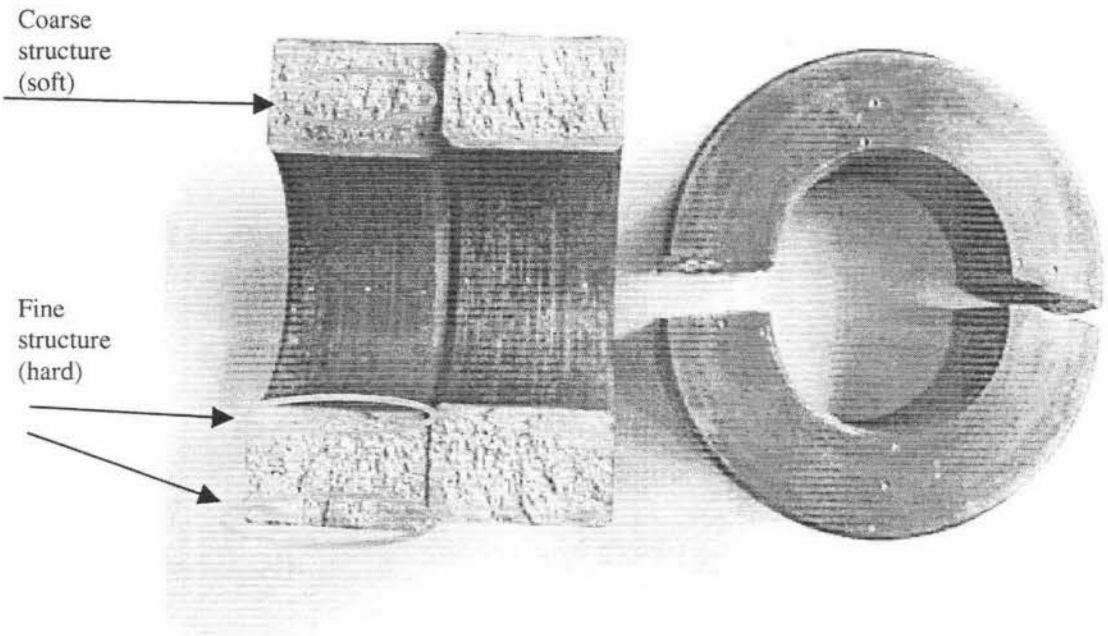


Figure 24: Composite 12/15K roller treated in dual process trials - including inner cooling.

The twin process with cooling on the second phase produced good results but because the complete surface of the roller was not hardened this solution was not deemed of high enough quality. There was the potential for 12/15K rollers to become rolling cutting edges due to soft faces and hard inner and outer circumferences. If the faces of the rollers were to (as would be expected) come into contact with the inner link side plates, the softer material in the central circumference could wear away, leaving the inner and outer hard edges to cut or wear into the side plate. This scenario would cause premature failure in the chain.

Untested Possible Solutions

There were considered solutions not implemented in the 12/15K trials. These solutions were regarded as being feasible but not workable within the time frame of the project. They included:

- Heat treat both faces, then heat the external circumference with face cooling, then the inner circumference with external and face cooling.
- A channel coil could have been constructed to treat a wedge shaped portion of both faces and the outer circumference, simultaneously an internal bore coil would have heated a section of the inner circumference. The roller would have been rotated during the heating cycle whilst quenching sprays mounted just below the treating coils would be active as the roller rotated. As such, heating and quenching are done as a single process. Although possible, this may have been a complicated, mechanically demanding solution.

6/7.5K Trials

These rollers measured approximately 31mm outer diameter, 18mm inner diameter, 14mm wide and weighed 0.059kg.

External Coil for Treating a Single Outer Surface

As with the larger 12/15K rollers, a multiturn, single place coil was all that was needed to treat the outer circumference of the rollers. Quick trials were done and the outer circumference surface had sufficient hardness. This on its own was inadequate as the inner circumference surface was in its 'raw' state.

Internal Coil for Treating a Single Inner Surface

An internal coil for the 6/7.5K rollers was not constructed due to the small diameter of the inner bore. It was possible to build an inner coil this small with narrow gauge copper tubing, but the coil would have been so small that the inefficiencies of this type of coil would have made heating inner circumference surface, to a sufficient level, difficult.

Twin Pancake Coils for Treating Two Parallel Face Surfaces Simultaneously

Following the pancake trials of the larger rollers above, it was also attempted to heat both faces of the roller simultaneously. A multiturn, twin-position pancake coil of the appropriate size was constructed for this purpose. Trials were run and the result was a composite roller with hard faces and a centre toroid that was left in its raw, untreated state. This was unacceptable as the majority of the curved contact surfaces (inner and outer) were left untreated and would wear very quickly

Rectangular Coil

As above, the knowledge that the inner and outer circumference surfaces of the roller were the important contact surfaces and the lessons of the previous trials led to the following points:

- at a minimum, the inner and outer circumference surfaces must be of acceptable hardness
- the inner circumference surface cannot be treated
- the faces cannot be the only surfaces hardened

A method to increase the treatment coverage on the inner circumference surface as well on the outer circumference was needed. A process of rolling the roller down a ceramic channel, through a rectangularly wrapped coil (Figure 25 on next page) was developed. This would theoretically treat both faces, as well as heat the outer circumference surface

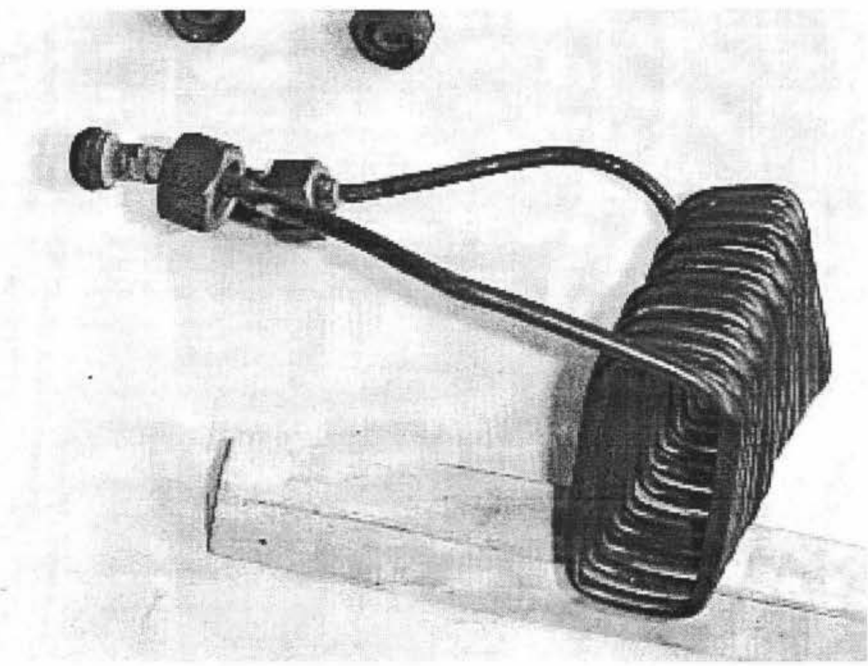


Figure 25: Rectangular coil used to treat the 6/7.5K rollers.

as it traveled down the coil.

End Results

Results of this roller showed satisfactory hardness on both faces with a tendency for hardness on the edges of the curved surfaces. Durability of the roller was good. The cross-section of roller was examined to verify the hardness tests and demonstrate the composite nature of the roller (Figure 26 – next page). Notice the fine crystal structure on the heat treated surfaces (hardened material) and the coarse crystalline structure in the centre (softer material). Also note the tendency of the fine crystalline structure to 'curve over' to the outer circumference surface due to its rolling exposure to the top and bottom of the induction coil.

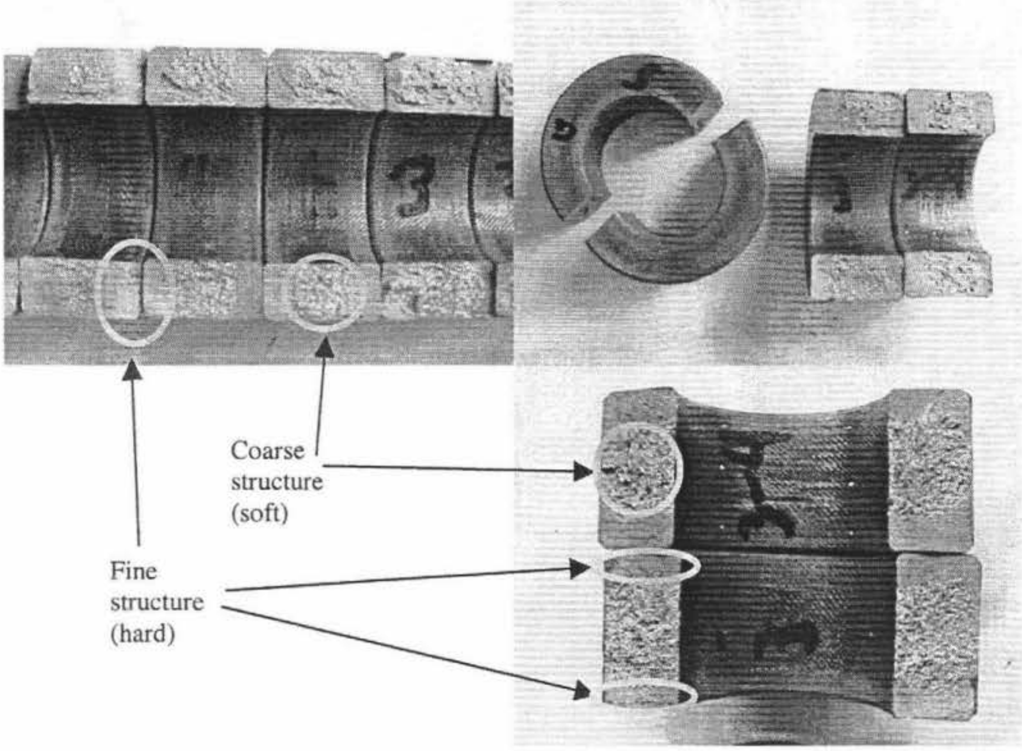


Figure 26: Composite 6/7.5K rollers rolled through rectangular coil.

As originally, this process had been done by hand, a pneumatic feed device (Figure 27) was built to ensure that further runs could be done and produce consistent results. The idea was to produce enough of these rollers to trial in a 'live' environment. This was

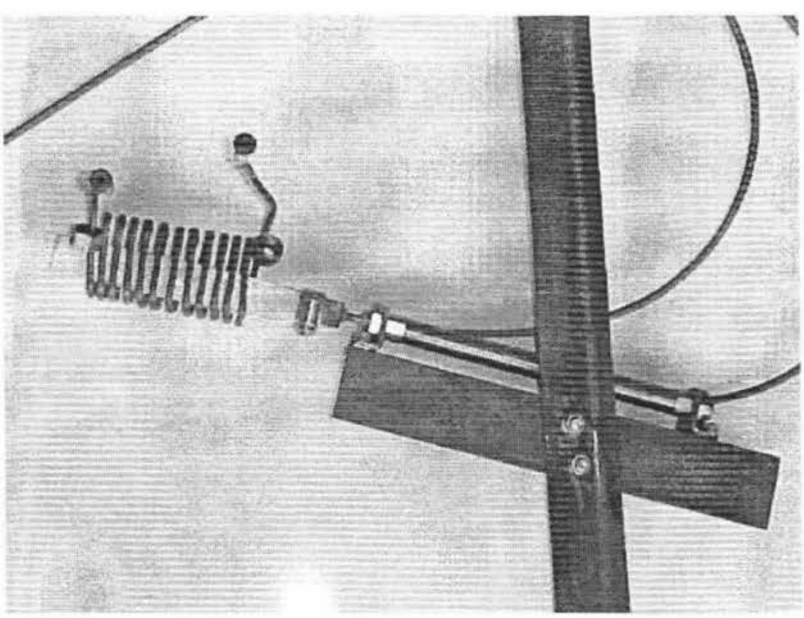


Figure 27: Pneumatic system for consistent rolling results.

never carried out as there was the potential for the 6/7.5K rollers to become 'pizza cutters' due to the hard faces and soft outer and inner circumferences. This was more of a problem for the inner surface due to wear against the bush whereas the outer circumference rolls along so is not so prone to wear.

24/30K Trials

These rollers measured approximately 66mm outer diameter, 32mm inner diameter, 24mm wide and weighed 0.500kg.

External Coil for Treating a Single Outer Surface

Only a single trial set was done for this size of roller. Due to the large magnitude of the roller and the power limits of the induction heater, these were unsuccessful. The coil configuration of simple multiturn, single place was capable of heating the outer circumference surface, but only very slowly. This meant that a large proportion of the roller was heated to above the phase change point, much the same as a directed flame through heated roller.

Further thoughts of using the induction heater for this roller type were therefore abandoned.

Potential of In-house Induction Heating Rollers

Estimated costings were done on the possible savings of 12/15K roller in-house induction heating using the twin process with cooling on the second phase (see Appendix J – Internal vs. External Roller Hardening Costs). Based on a throughput of between 60 to 120 rollers per hour, in a totally manual operation, there were potential savings of between 60% to 80% per roller. This was a multi-step process and as such, labour costs could possibly exceed that of external case hardening with a lower quality result.

Although the results of this roller were not what was absolutely required, costings were done on the possible savings of in-house induction heating of 6/7.5K rollers (Appendix J – Internal vs. External Roller Hardening Costs). Based on a totally manual throughput of between 120 to 240 rollers per hour, there were potential savings of between 32% to 66% per roller.

Summary of Roller Results

Table 8 below summarises the results obtained in the roller induction heat treatment trials.

	Inner Circumference Surface	Outer Circumference Surface	End Face Surfaces	All Surfaces
6/7.5K Rollers	Not Possible.	Slightly treated due to surface proximity to rectangular coil top & bottom.	Results good by rolling component through a rectangular coil. Gives composite hardness.	Not Possible.
12/15K Rollers	Done with inner coil. Results affected (reduced) by outer circumference treatment unless cooling used – then results good.	Done with multiturn-single place coil. Results on this surface good.	Possible but not done. Would affect curved surface results without cooling.	Possible using a mechanically demanding and complicated process.
24/30K Rollers	Feasible – not trialed.	Trial results unsatisfactory as roller is too large for the available power.	Feasible using a single pancake coil, treating each face separately with cooling – not trialed.	Possible using a mechanically demanding and complicated process.

Table 8

Neither of the roller induction heat treatment processes was deemed acceptable by management although field trials were never done. Lack of customer acceptance of 'incompletely' surface hardened rollers (if they find out/told) was perceived to be too big a risk to take the rollers out of the initial research and development phase. At the time of writing, the company is successfully importing complete rollers from overseas to keep these component costs down.

Induction Heater Automation

General Requirements

Once the induction heater had been chosen as a first order savings project, it was necessary to determine the basic requirements of the automation system before any detailed work began. This approach was important in clearly defining the material parameters of the project that would influence the final outcome.

The following aspects were deemed necessary in the development of the automatic system:

- There should be minimal spacing between the work piece and inner diameter of the induction coil. As small a gap as is workable is necessary to keep the flux lines as concentrated on the work piece as possible. A large gap may allow easier component flow through the coil but would degrade the power transfer to the work piece by a substantial amount (see Noddy's Guide to Induction Heating).
- There must be NO electrical contact between the induction coil and work piece. If ANY contact were made, the coil circuit would short and destroy the induction coil, as well as allow the cooling water to spray about.
- Materials near the induction coil must be non-inductive. Any materials near the induction coil (and hence in its magnetic field) would pick up the magnetic flux lines and heat up. In addition, inductive materials near the coil would influence the magnetic field and possibly detract from the power transferred to the work piece.
- Heat resistant materials must be used for contact with work piece and the near work piece. As the metal component in the coil is heated above 800C°, any parts in contact with, and near, the work piece must be extremely heat resistant.
- The material used to isolate the induction coil from the work piece is cooled on the outer surface (inside diameter of the copper tube induction coil) and heated on the inner surface (by the induced current on the work piece) so the thermal shock resistance of the insulation material must be high.

- Any materials used as part of the feeder system coming into contact with the work piece must be shock resistant.
- At the end of the heating cycle, the work piece must exit the induction coil as quickly as possible. For correct hardening to occur the work piece must not be allowed to cool below the phase change point and so must exit quickly into the quenching phase.
- The quenching system must be as close as possible to coil bottom. As stated above, immediate quenching is necessary.
- The quenching system should take the part away. To keep the system free of open water, the quenching system should move the part away from the coil and feeder.
- Low cost. This system had to be within the bounds of financial viability in terms of an appropriate payback period and available funding.
- Minimal disruption of the induction heater. The induction heater must be able to be run fully manually and as such, any automatic interfacing must be non-disruptive/intrusive.
- The operation of the induction system must be largely an unmanned operation. Reducing labour content in the components was a core reason for this project.

Planning & Design of Automation System

The planning and design of the induction heater automation was broken down into three distinct units: the feeder mechanism, the hopper and the control system.

Feeder

Coil Feed & Exit Mechanism

Many different solutions to inserting and removing the work piece were available but additional feed/exit constraints were added and had to be considered. They included:

- A low level of complexity.
- If at all possible the work pieces should exit and enter in one motion (or motion – counter motion) to simplify any mechanisms used.
- The feed/exit mechanism must be able to cope with several component sizes. As several 'stock' components were put through the induction heater manually, the feeder should be able to handle the 20% of components that represent 80% of the components induction heat treated. This represented three components: 6/7.5K, 12/15K, 24/30K pins (although the 24/30K pins were chosen for their

mass and treatment cost). It was not necessary to have a single mechanism to cope with all different component sizes but any mechanism designed should have the capability to interchange parts dependant upon the component being treated.

Moving coil

As explained earlier, the existing induction heater had limitations caused by a fixed coil configuration. This limited the length of 25mm diameter pins that could be treated to 75mm-100mm, as the coil configuration is limited by the power of the heater.

To enable the system to treat longer pins (and other cylindrical components such as hydraulic cylinders) as well as to be automated, a moving coil configuration was considered.

A moving coil would consist of a single 'turn' coil made of 3mm to 5mm copper approximately for power, and a quenching sprayer underneath the coil (Figure 28).

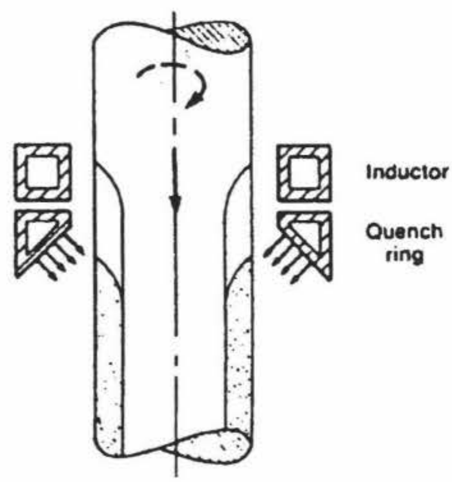


Figure 28: An example of a moving coil configuration.

Transfer of power and coolant to the coil could be accomplished by using a high frequency braided copper, water cooled cable. This would allow the head to raise and lower along the axis of the article to be induction treated. These conduits, due to the nature of their construction are very lossy and hence would deduct from the available working power. An alternative for flexible power delivery was to use multiple strips of thin copper bolted together at both the fixed and moving ends. Cooling would be provided to the coil in a separate water tube. This unconventional solution leaves large amounts of electrically live metal exposed so the potential for harm is too great. It also is subject to power losses.

The mounting and travelling mechanism of this method was costly and complicated as was any automation method. This approach was discarded for these reasons.

Horizontal vs. Vertical

Once a decision had been made to move the work piece through the induction coil (as compared to remaining in place and being scanned) consideration had to be given to the orientation of the fixed coil. The coil could be positioned anywhere between vertical and horizontal and the two extremes were deemed the only viable choices.

Horizontal Push Rod

This mechanism meant the work piece would have a horizontal orientation. The work piece would have to slide along a channel/track through the induction coil with the track at the point of the coil being non-conductive, non-inductive, and very heat resistant.

The proposed method of propelling the work piece through the coil was a simple ram, driven either by a rotating wheel with the ram offset or an air ram. The ram would push the work piece into the coil, pause during the heating cycle, continue forward immediately after completion of the heating cycle (expelling the hot work piece), and withdraw far enough to allow a queued pin to fall into place in front of the ram. The cycle would then repeat. This method required the pins to be queued laterally (i.e. side by side).

The requirement of the work piece exiting the coil as rapidly as possible meant that the expulsion force may be large enough to 'launch' the component through the air at speed. This was not an unsolvable problem but added unnecessary complications to the issue.

Air Burst

For this design, the work piece would have to travel along a horizontal track similar in nature to the design above. The method of exiting would be a simple jet burst of air to 'blast' the component out of the coil. In addition to the challenges mentioned above, there was little or no control with this form of expulsion so it was discarded.

Vertical Six Shooter

This mechanism had the pins queued in a vertically linear fashion (i.e. end to end) and simply uses gravity to both insert and expel the work piece from the induction coil. The name 'six shooter' was derived from its similarity to the six-barrelled chamber of a revolver although the final form of this mechanism had twelve chambers.

This feed mechanism consisted of three main parts: a rotating chamber plate, a scrape plate, and a 'finger' plate. The rotating chamber plate (Figure 29) consisted of a disc lying horizontally, with a central aperture for an axle and holes for the work pieces

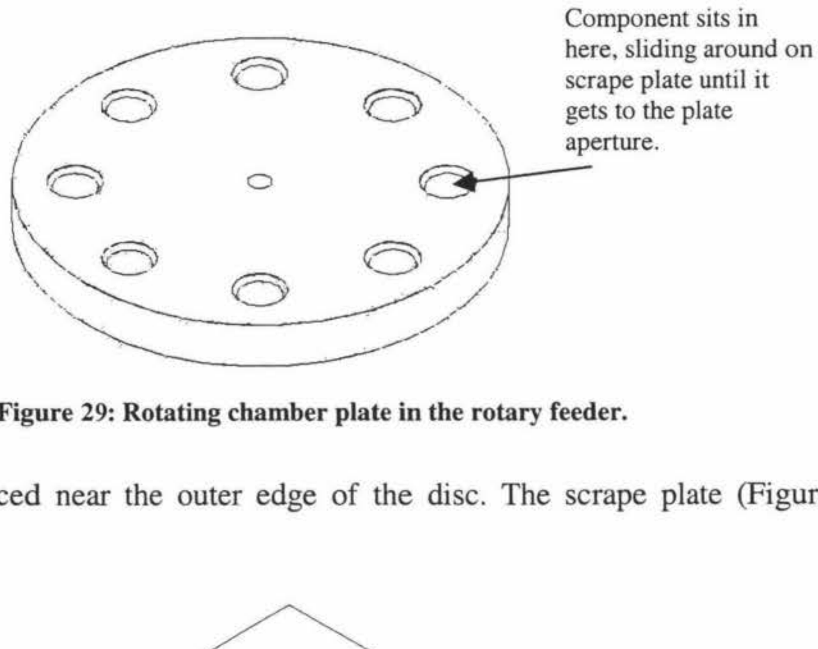


Figure 29: Rotating chamber plate in the rotary feeder.

equally spaced near the outer edge of the disc. The scrape plate (Figure 30) was a

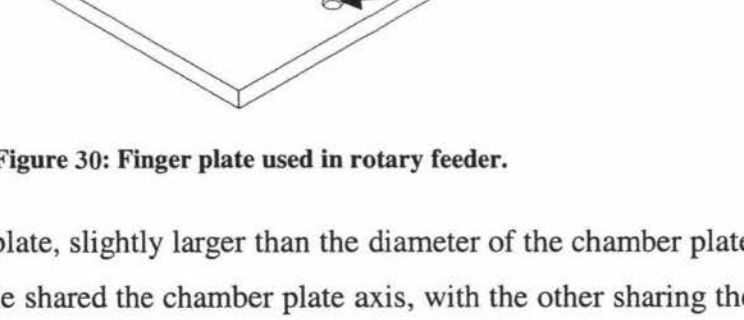


Figure 30: Finger plate used in rotary feeder.

square, solid plate, slightly larger than the diameter of the chamber plate with two holes through it. One shared the chamber plate axis, with the other sharing the same radius as the outer holes of the chamber plate. The 'finger' plate (Figure 31) was a disc of the

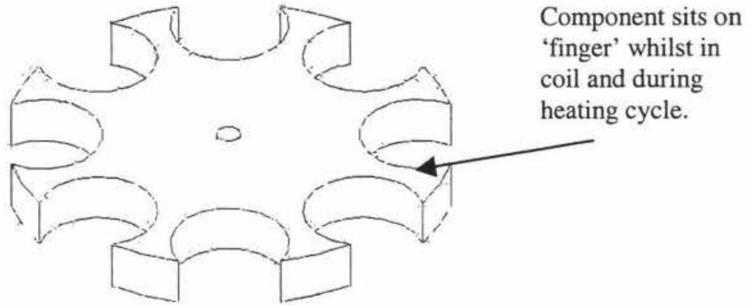


Figure 31: An early version of the finger plate used in the rotary feeder. Later designs did not have the flaired finger ends.

same dimensions as the chamber plate (including the axis aperture) but instead of holes at equal intervals there were radial 'fingers.' The 'fingers' were placed at the same points along the circumference as the chamber holes.

The three elements of the feed/exit mechanism were assembled on an axle in the order of chamber plate, scrape plate and finger plate. The scrape plate allowed the axle to turn

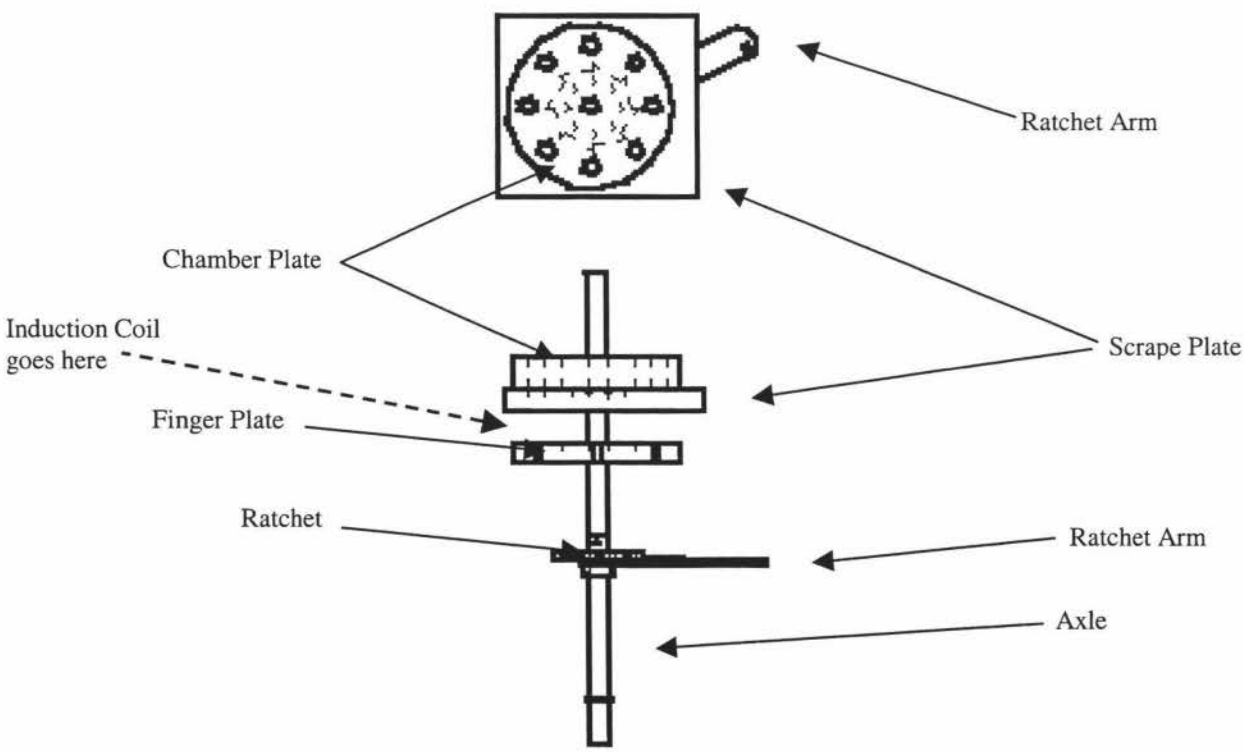


Figure 32: View of assembled components of the rotary feeder.

freely but was fixed to the feeder frame. The chamber and finger plates were fixed to the axis out of phase to each other, meaning each chamber aperture matched exactly a finger below it. The chamber plate sat upon (or fractionally above) the scrape plate with the two surfaces in mobile, near friction free contact. The finger plate was placed below the scrape plate leaving enough space for the height of the induction coil between the bottom of the scrape plate and the top of the fingers. See Figure 32 above.

The work piece enters an outer edge hole in the chamber plate from the vertical queue and sits on the scrape plate. As the chamber plate is advanced, the components slide or scrape along the scrape plate, eventually reaching the hole in the plate. At this point gravity drives the component down through the plate hole and into the coil, sitting on one of the finger plate fingers.

In one movement at each advance, both the chamber plate and the finger plate rotate on the single axis, sliding the work piece off the finger (which was holding it up in the coil) and then dropping the next component out of the chamber plate, into the coil and onto the finger below.

Due to its simple design and the fact that it met with multiple criteria (including easy component entry/exit, easily indexed, easily driven, etc), this design was chosen as the method of component feed and exit. See Figure 33 for a side view of the end result.

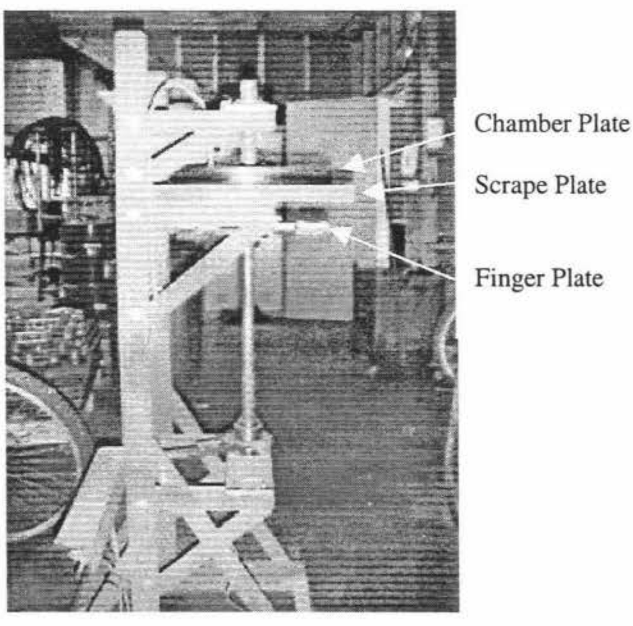


Figure 33: The final production version of the rotary feeder.

Coil Protection

As stated in the first six *general requirements* above, there can be no work piece contact with the induction coil during the heating cycle. Otherwise, severe damage can occur to both the work piece and the coil, hence causing a halt to production and downtime for repairs.

Clamping

The manual method of preventing electrical contact between the work piece and the induction coil was to place the component in the coil, clamp it between non-conductive, non-inductive 'jaws' and then release the piece upon completion of the heating cycle. This relied on a pair of jaws above the coil (the operator's fingers) working synchronously with mechanical jaws underneath the coil. Automating this form of device was deemed both complex and expensive and so was abandoned.

Fingers between Coil Windings

As there are small spaces between the induction coil windings, non-conductive, non-inductive material could be inserted into the coil radially, just far enough to stop the work piece from touching the inside diameter of the coil.

Due to the inserted material by necessity being very thin, this solution would most probably not be robust enough to endure the impact of steel components.

Ceramic beads

Slipping ceramic beads onto the coil would also stop contact between the coil and component, but as above, would give no robustness due to the small thickness' involved.

Coating

The concept of coating the coil in a non-conductive, non-inductive material was considered. The commercially available coating processes researched were plastics based and did not give a high enough temperature rating.

A simple ceramic coating was trialled by dipping the coil in ceramic slurry and firing the coated coil at 900°C. It was believed that this process would run into problems because ceramic is fired at between 1100°C to 1300°C and copper melts at approximately 1080°C. The actual trouble with this method was due to the copper expanding in the furnace (and hence also the ceramic coating). Upon cooling after withdrawal from the furnace the ceramic coating crumbled and flaked off the copper tubing.

Without relying on high-tech, expensive commercial methods (if available) this approach was not feasible.

A basic protective glass coating was trialled by winding fibreglass matting around the coil tubing to form a glass jacket over the copper. This method worked for only a few component heating cycles before the glass melted and the component contacted the coil.

Sleeve

A simple liner inside the coil was deemed the best solution for this problem. The challenge here was to determine a suitable material for a sleeve.

A borosilicate tube was given a trial and successfully protected the coil from the work piece in manual runs. This material was too expensive to be considered for production purposes as well as requiring a method of holding the tube in place.

Next, ceramic as a material was tested. Initially a ceramic insulator from an electric bar heater was turned down to the required dimensions and a manual trial run of components was made. The resulting pins were of good quality (appropriate hardness

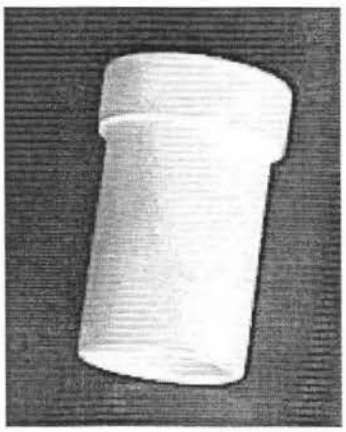


Figure 34: Ceramic sleeve used to stop contact between the coil and component.

via Rockwell C hardness tests) and no contact was made between coil and component. Hence the temporary ceramic sleeve was successful albeit somewhat flimsy in nature.

Ceramic tubing was then purchased and turned down to the required dimensions including a flange so the sleeve would sit on the coil and add additional strength to the structure (Figure 34 on previous page). This device worked in all the model feeder trials and was implemented in the final mechanism.

Indexing Mechanism

Some method of rotating the feed/exit mechanism had to be contrived to advance the feeder in a timely and accurate fashion. The following systems were considered.

Electric Motor

Using the simple rotation of an electric motor was deemed a very good idea, as it was uncomplicated and inexpensive. However consideration had to be made that the feed/exit mechanism was not constantly moving but stopping and starting intermittently. Turning a standard electric motor off and on was an option but positioning the feed/exit mechanism consistently accurately was difficult. Also taken into account was the negative effect of (what can be) a wet environment on an electric motor in the proximity.

Stepper Motor

The stepper motor was considered briefly. The stumbling block with this solution was one of cost. Stepper motors and the associated controls were expensive and complicated, and hence deemed outside of the useful bounds of this project.

Variable Speed Continuous Drive

With this solution, a motor would continuously turn the rotary feed/exit mechanism. The rate of rotation (time between the holes on the chamber plate being directly above the coil) would have to match when the cycle was on and off. As described above, this particular induction heater used had an external and manual time setting, so the potential for mismatching component feed to 'cycle on' and component exit to 'cycle end' was high. Interfacing this method to the heater to drive the feed/exit mechanism continuously but at a rate matching that of the heating cycle was considered possible but too invasive, too complicated and too expensive.

Geneva indexing

Continuous drive and intermittent (indexed) movement can be done using a Geneva indexing mechanism (Figure 35).

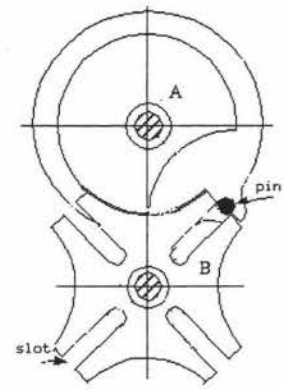


Figure 35: Illustration of a Geneva indexing mechanism.

This would have been the solution of choice for a continuous drive method. It would have provided the appropriate matching of rotation to heat cycle but was still a complex method of obtaining the required start/stop system.

Ratchet and Pawl

The final method of interfacing the manual induction heater cycles was a simple ratchet and pawl system. The indexed movements required of the feeder were coarse enough to allow a ratchet system to work. The end result is similar to that shown in Figure 36.

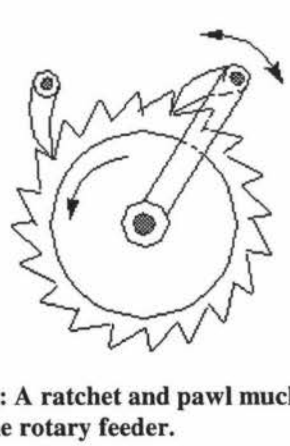


Figure 36: A ratchet and pawl much like that used in the rotary feeder.

This choice made driving the feeder a much simpler challenge.

Drive Method

Once an indexing method had been chosen, it was a relatively simple matter to decide on a drive method. Both rotary cams and pneumatic rams were considered.

Rotary Cam System

A standard cam on an electric motor was briefly considered for this task. Without going to stepper or variable speed motors it wasn't judged feasible to accurately trigger the ratchet between cycles. A cam is also more complex than necessary.

Pneumatic Ram System

The ratchet and pawl system chosen for indexing was a design that lent itself to being driven by a simple air cylinder. As the only forces on the feed/exit mechanism necessary to overcome were the frictional forces of rotation, only a low powered pneumatic cylinder was required. A simple and inexpensive solution (see Figure 37) as

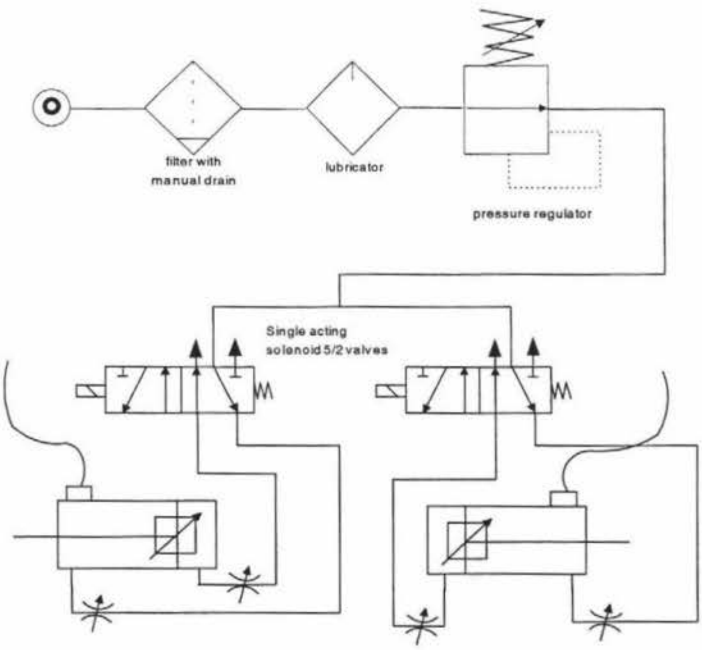


Figure 37: Pneumatic schematic of the system used.

it was air driven (pressurised air was readily available throughout the plant), and the sensors and actuators were relatively inexpensive and easily interfaced. See Appendix K for a full size pneumatic diagram.

Frame

The frame of the feed mechanism had to be stable under operating conditions (i.e. not move) yet be mobile enough to be easily taken away from the induction heater to allow manual operations. Due to the distance of any part of frame being outside of the influence of the induction field, it was not restricted to non-inductive, non-conductive materials, and so could be made of steel; making manufacturing straightforward.

Hopper

Now that a method of automatically supplying the induction heater with components was established, the next challenge was to enable the components to progress from a bulk state to a singular state and get them into the correct orientation to enter the feeder mechanism.

Bulk to Singular Feed Mechanism

A variety of off-the-shelf systems were readily available but had several detracting features. Firstly, they were prohibitively expensive. Secondly, most commercial systems were custom designed to handle only a specific component (size, weight, profile, orientation, etc). Thirdly, the pin components treated in this process were generally too massive to be handled by all but the biggest bulk feed machinery.

Vibratory Systems

Two vibratory systems were available to be considered: bowl feeders and table feeders.

Bowl feeders in general are intended for lightweight components. They are expensive to tool up as both the vibrating base and the bowl have to be 'tuned' for the specific component to be fed. Vibratory bowls do not hold a large amount of bulk components as overloading the bowl detunes the system and stops it from functioning efficiently.

A table feeder would handle larger components and larger amounts of bulk components but feed small numbers of components at a time – not singularly. For these reasons vibratory feeders were discarded as viable options.

Reciprocating Blade Systems

For this type of delivery system, a blade reciprocates vertically through a hopper of bulk components. As the blade passes upward through the bulk has a propensity to retain a number of components on its top edge. Those not oriented correctly fall off the blade.

Owing to the components being symmetrical about all three axes', minimal component manipulation was necessary. It was sufficient to align the part along its long axis, without regard to a specific orientation of the part. Hence, two different approaches to a reciprocating blade hopper feeder system were considered.

The first design considered was a vertical blade with a fixed point, reciprocating through an arc (see Figure 38 'Automated Assembly' 1979). As the blade pushed up

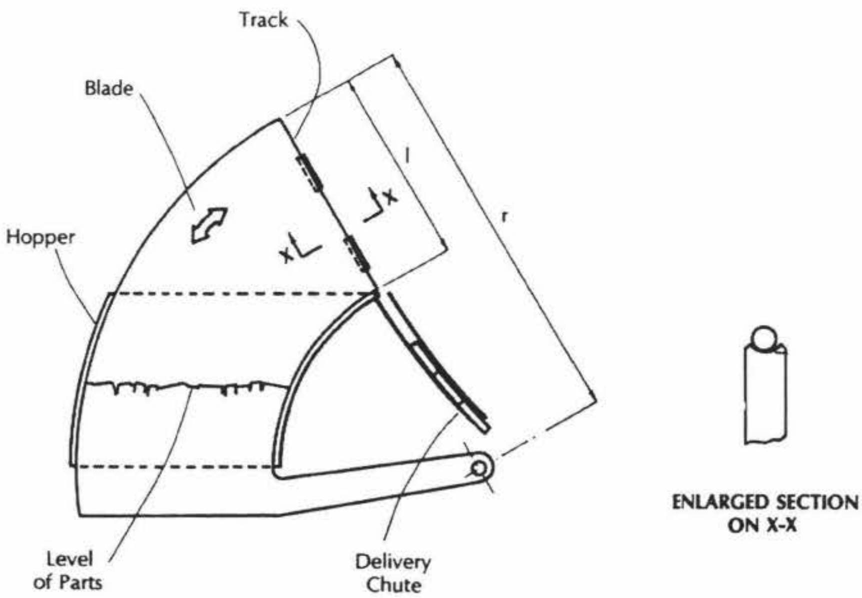


Figure 38: Arc reciprocating blade hopper feeder.

through the bulk components, several parts would rest on the upward travelling edge of the blade. Once the blade had reached it apex it would pause, allowing the components to slide down the concave edge of the blade into a chute. Once the upward travel was completed, the blade would withdraw so the top edge of the blade was below the surface of the pins. This arc-based blade gave differing impetus to the components dependant upon where they contacted the blade, how fast the blade was travelling through its arc and how far the blade moved through its arc.

Much more simple was a reciprocating blade moving linearly in a vertical path (Figure 39, 'Automated Assembling – Hopper Feeders, 1980). This was less complicated to

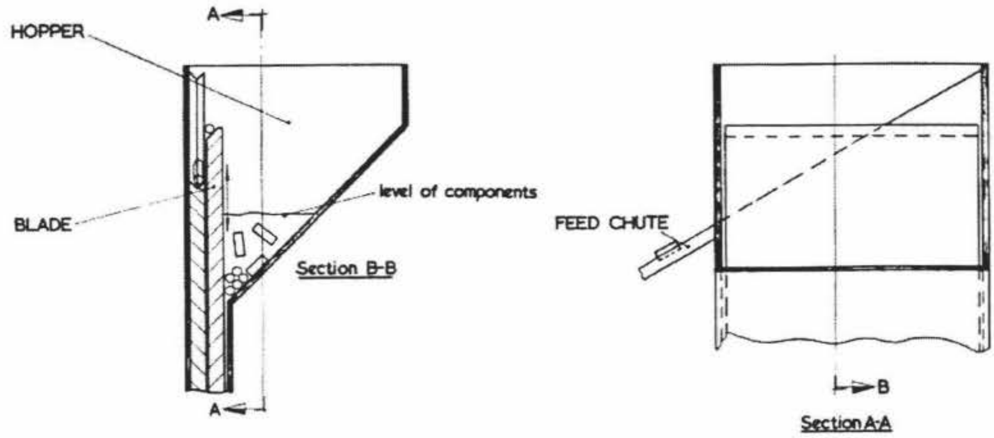


Figure 39: A vertical path reciprocating blade hopper feeder. This design was implemented.

design and implement, as the whole tip of the blade moved through the bulk parts at a steady speed.

The top edge of the blade was inclined towards the back of the hopper through the depth of the blade (see Figure 40 for cut-away view of hopper blade and chute) with the top edge along the width of the blade being horizontal. As the blade travelled upwards, it allowed pins to settle into the cleft created and be pushed up through the bulk of pins. A sloped, concave channel was built into the back of the hopper and as the blade came up with pins laying on the leading edge of the blade, they were forced into the channel by virtue of 'rolling' down and off the sloped blade edge face. Once in the channel,

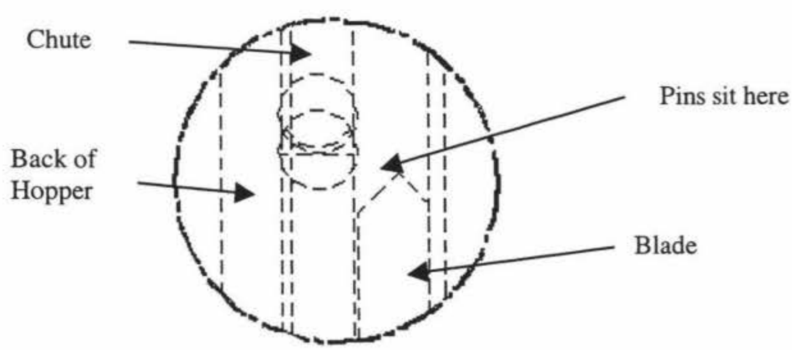


Figure 40: Cutaway of the blade tip showing where the pins sit as the blade pushes upward through the bulk components.

gravity caused the pins to slide down the chute into the feed tube (Appendix L).

Hopper to Rotary Feeder Feed

Once parts were extracted from the bulk bin and placed in a singular fashion, ready for the feeder, two decisions had to be made: work piece orientation and transport from hopper to feeder.

Work piece Orientation

There were two available component orientations for this process: side-by-side and end-to-end, only one of which was practical. So, the physical orientation of the pins for the automation was effectively already decided for this stage, as both the rotary feeder mechanism and the hopper feeder were already chosen and designed with specific requirements. The rotary feeder required a vertical, end-to-end presentation and the hopper feeder was designed to provide the same.

Work piece Transport – Tube or Track?

A method of transporting them from the hopper to the feeder was needed. Again, two gravity feed methods were available.

A 'track' or rail method gave the option of having the components travel either by sliding end to end or rolling side by side down the track. As explained above, only end presentation was needed. This method had the advantage of being able to see and clear any blockages in the track, hence reducing downtime and maintenance difficulties. A distinct disadvantage was the complexity and cost of building a track for the components to slide down effectively.

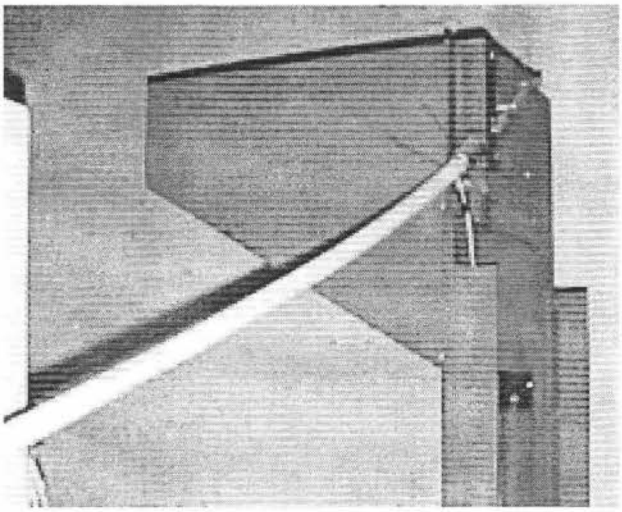


Figure 41: Hopper chute.

A tube method meant the components had to travel in an end-to-end fashion, which suited the requirements. Using electrical conduit provided a simple and cost effective solution. The possible disadvantages are the wearing out of the inside of the tube, eventually causing a rough surface and hence the possibility of blockages, which could not be seen and easily cleared. The tube method was chosen and implemented (Figure 41).

Drive Method – Cam or Ram?

A simple method of driving the reciprocating blade was required. Two were considered: a rotating cam and a pneumatic ram.

Rotating Cam

This system, albeit relatively simple, was impractical due to the required length of travel of the hopper blade. As the blade had to move through a distance of over half a metre, the cam would have to have been an impractical size (i.e. in excess of that distance at the maximum radius) and the clearances around the hopper too unmanageable.

Pneumatic Ram

The easiest and most practical solution for this situation was a pneumatic ram. As air was chosen for driving the rotary feeder, it was also a sensible choice for the hopper as well. A potential maximum mass of the components above the blade was calculated by setting a worst-case scenario assumption of the blade being under a full hopper of pins.

This 'best guess' calculation plus the mass of the blade was the basis for the choice of force capability of the ram used. A double acting ram was chosen, as the blade would have to be driven both up through the bulk pins and pulled down through the remaining volume of pins (see Appendix K for pneumatic schematic).

Frame

The frame holding the hopper feeder was left to the final stages of the build stage. There were no 'extra' requirements of the frame above that of being stable with a full hopper of components and high enough to enable the blade to reciprocate clear of the ground and feed the components down into the rotary feeder.

Quenching System

The existing manual quenching system was the simplest of designs. A stainless steel tank full of water into which the hot components dropped was sufficient (Figure 42). The disadvantage of the tank for the automatic system was its size. It was too big to fit

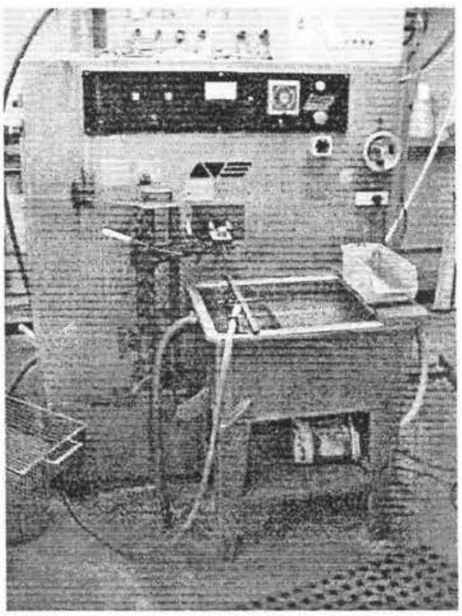


Figure 42: The old quench bath.

between the induction heater and the immediately adjacent rotary feeder. The requirements of the new system were for a compact quenching system to fit just beneath the finger plate, which would cool the component quickly enough to effect hardening, and carry parts away from the feeder and heater with little or no water splashing the equipment.

Sluice

A sluice method was deemed to be the most efficient method of matching the quenching requirements. Due to the spatial requirements, other methods (such as conveyor systems) were only briefly considered.

The system devised had a quenching sleeve, an enclosed sluice, and a collector.

Quenching Sleeve

Just under the coil (below the finger plate) was a water quenching 'sleeve' (Figure 43) This was made up of a length of 50mm PVC pipe with 1mm holes drilled around its circumference and along its length. It was then fitted inside a slightly shorter length of 100mm PVC pipe. A small hole was drilled half way along the length of the outside pipe to allow a hose fitting to be mounted. The larger pipe had caps glued on either end with a central hole to allow for the 50mm pipe to fit through. Water was then supplied to the sleeve and sprayed inwards from the small inner pipe. The hot pin fell through this pressurised spray to be quenched. There was no problems with the hot pins melting the plastic as the water enveloped the part and moved it fast enough along the plastic surface so not to cause damage to the chute.

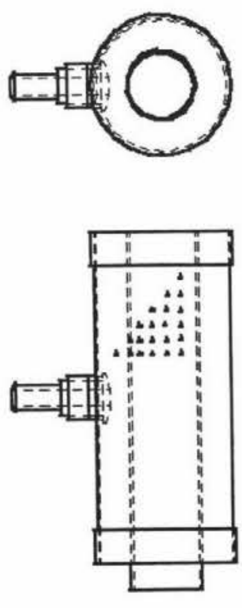


Figure 43: The queching sleeve.

Chute

The chute was a 100mm PVC pipe connected onto the bottom of the quenching sleeve. Water was directed down the chute to both continue cooling the component and carry it away to the collector bin. See Figure 44 below for the quenching sleeve and chute.

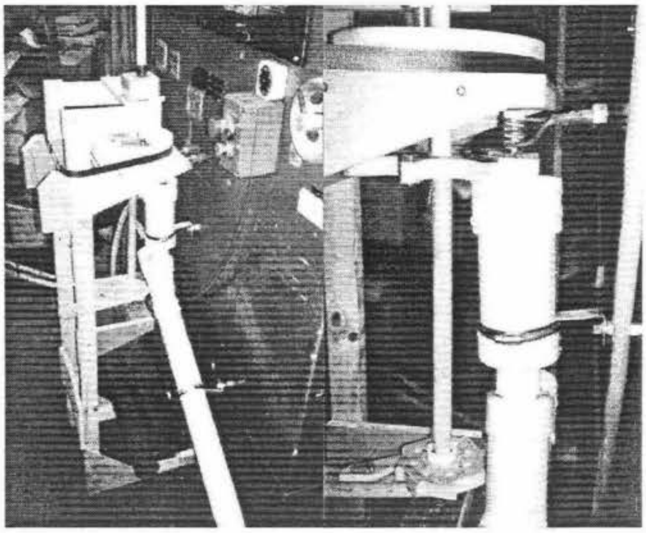


Figure 44: The quenching sleeve and carry chute in action.

Collector Bin

Water from the quenching sleeve and chute stream carried the component into a small bin. The pins were collected in a wire basket sitting in the water. The water was pumped out to the stormwater system initially but plans to recycle and cool the water were made. Periodically the components were emptied from the collector bin and dried.

Controller and Input Output

Controller

With the physical systems in place to provide components for induction heating, the logic controller was the next section to be designed. The processing requirements for this automation were deemed to be low so a 'low-end' controller with sufficient inputs/outputs could be used. Three different systems were considered: a personal computer, a programmable logic controller and a micro-controller.

PC

Due to the low processing requirements, a disused (and therefore no cost) 486 PC was considered for the controller. An ISA interface card with multiple I/O could have been used and the control actuated via a program written in QBasic or any simple programming language.

Several disadvantages were seen with this solution. They included:

- the computer would be unfit for the environment of the process or would need to be a distance away in an office which in itself could cause difficulties
- it was not robust enough as old hardware (hard-drive, power supply, etc) was liable to fail
- this solution was very proprietary (to the company) with no outside understanding of the system and hence no ongoing support for the logic control
- having a keyboard and monitor made the system easily interfered with by people that would not necessarily have an understanding of the system.

Therefore this option was not chosen.

PLC

Many suitable Programmable Logic Controllers were available 'off the shelf' for this project. Most basic controllers did not have enough available inputs and/or outputs, which meant purchasing a larger model and hence increased price. Price was the major factor in deciding not to choose a PLC.

Micro-controller

Micro-controllers are placed under PLC's in terms of cost, and in most cases capabilities. They do not normally have the industrial strength of PLC's (withstanding environment, electrical protection, etc) and as such are not used in 'heavy duty,' large industrial automation applications. They may also be implemented in large-scale OEM production, fitting within a product to be sold such as HVAC systems.

A micro-controller product was found that matched the cost, available I/O, and robustness requirements. The Australian SPLAT (http://www.splatco.com.au) SP10-8A micro-controller was the product of choice (specification sheet in Appendix M). It had

10 fully debounced 24VDC optically isolated inputs for contact closures, 8 relay outputs at 5A/240VAC resistive load rated 2500VA maximum, and used low cost

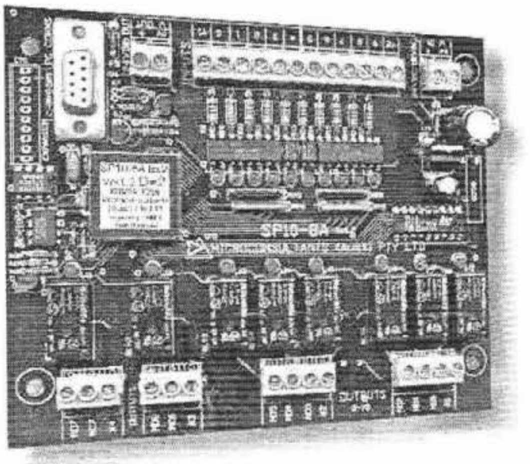


Figure 45: The Australian built SPLAT SP10-8A microcontroller.

24V/350mA unregulated power (Figure 45 above).

The programming requirements of this controller were not as satisfactory as the industry standard ladder logic of a PLC, but the language was deemed simple enough to be easily learned by the original programmer and the company electrician/technician for further support.

I/O (Sensors & Activators)

Interface with the Manual Induction Heater

As stated previously, any interfacing with the heater had to be done with a minimum of disruption to it. The induction heater was to be able to be run fully manually and as such, any automatic interfacing must be non-disruptive and non-intrusive.

There were only three points of interface with the heater: the emergency stop button (ESTOP), tripout relay, and a contactor relay. See Figure 46 for the controller cabinet.

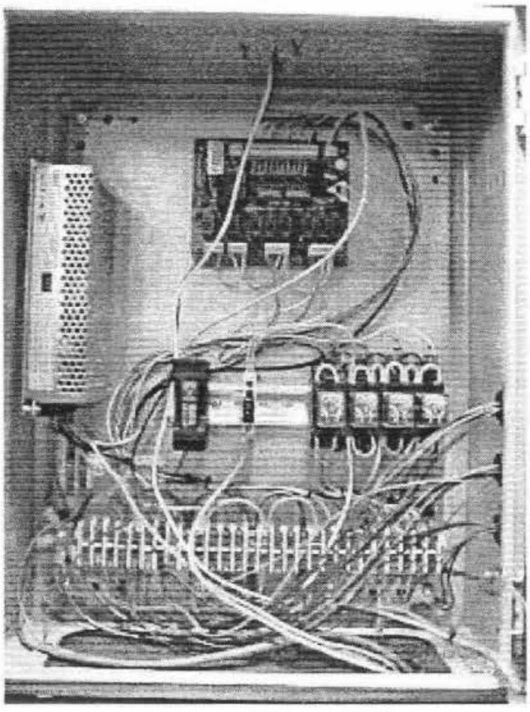


Figure 46: The induction automation control cabinet.

The existing ESTOP button had to be replaced with one that contained multiple poles. The button's main function was still that of halting ALL electrical power to the induction coil. In addition to this it had the new capability of disconnecting all the outputs from the controller. This was done for safety reasons. All automatic systems had to cease when the emergency stop button was pushed. The system could only start up again once the ESTOP button was reset by hand.

The heater had an existing overcurrent tripout relay to shut off the power to the coil should too much current be drawn by it. The two main causes of this situation were either the power settings (internal impedance settings) of the heater being set too high for the coil configuration in use or a work piece contacting the coil. This tripout relay was not changed but a relay for automation purposes was put in parallel with it. Hence, when the heater tripout relay was triggered, so was the automation relay.

To start the heater manually, a button was depressed by an operator, which in turn caused two relays to pull two contactors closed. An automation relay was put in parallel with the second contactor relay to both enable the system to start the heater automatically as well reveal when the power to the coil was on or off.

Having the logic watch the contactor relays had the benefit of being able to use the existing analogue timer on the induction heater. Timing control was therefore left on the heater and for this reason no timing input/output mechanism was needed on the controller.

The water flow cutout relay was not necessary to monitor. If there was no water flowing through the coil, there was no power supplied to the contactors and the automation could not cause any coil damage.

Controller Specific I/O

Two of the eight available inputs were specifically for the micro-controller. One was a 'pulse' start button to activate the logic within the controller and allow interaction between the heater and the controller. Without this button being pushed after powering up the induction system, the heater was totally in manual mode.

The second input was from a toggle switch, which allowed the operator to put the controller in run or setup mode. Setup mode allowed for over current situations without the logic triggering a warning and shutting down the outputs and requiring a reset. This normally happened when the operator set up a new coil configuration and a tuning of coil power was necessary. The operator had only to make sure there were pins in the rotary chamber and coil, then execute the heating cycle by pressing the manual 'go' button. The system would heat, then exit the pin and wait for another manual execute. This meant power adjustments could be made between heating cycles and pins could be quality tested. Run mode allowed the operator to start off the first heat cycle manually and the controller would continue automatically with the heating cycles.

A rotating amber warning light was mounted on the control box to draw attention to possible problems with the system. Once the operator was near the control box, three indicator lights were present to indicate the specific problem area. The pattern of indicator lights showed what subsystem required attention.

All cabling to and from the controller was double shielded twisted pair. This was to provide the system with good signal protection from RF & EMI.

Hopper Sensors/Actuators

The hopper had a total of three I/O points mounted on it. Two inputs monitored the extreme extent of the pneumatic cylinder. One was for "up", or extended to the correct point. This was the uppermost point in the stroke of the hopper blade, having pushed through the bin of components and moved past the exit chute, dumping the pins off. The other input was the low extreme of the blade. At this point the blade had retracted and was ready to extend.

The only output for the hopper was the solenoid for the air feed to the blade cylinder. This controlled the motion of the blade and was single acting. With the output "on", the cylinder was extending, with the output "off" the cylinder was retracted.

Feeder Sensors/Actuators

There were only two I/O points for the rotary feeder. One input combined from two magnetic reed switches on the ratchet driving cylinder and a single output for the actuating solenoid. Theoretically there should have been two inputs from the two reed switches on the feeder cylinder but there were not enough available inputs on the controller. It was decided that the rotary feeder had less chance of having problems with jamming (as compared to that of the hopper) such that we could adapt the logic to cope with a single input from the reeds placed at the end-points of the rotary feeder cylinder stroke.

As with the hopper, a single output was necessary to activate the air feed solenoid. Again, a single acting solenoid worked a double acting cylinder.

Chute Sensors

A third set of inputs was necessary to inform the system whether the chute feeding the rotary feeder was empty, full, or in between. Two proximity sensors were mounted on the chute. One was placed at the top of the chute, just outside of the hopper. This was the full proximity sensor. The second sensor was placed just before the rotary feeder. This was the empty proximity sensor.

The reasoning of the sensors was as follows: Neither sensor detecting metal meant the chute was totally empty. By implication this meant that the hopper was either empty or had a jam above the feed chute in the hopper. Both of these circumstances required attention. So after a heating-cycle count equal to the buffer in the rotary feeder, if the empty proximity sensor had not registered metal (i.e. the chute had not started to fill up), the whole system would be stopped. If the empty proximity sensor was detecting metal and the full was not, the chute was either filling or emptying but did not require attention. If the both the empty and full proximity sensors were detecting metal, the chute was full and the hopper blade could be stopped. If the empty proximity sensor detected nothing and the full sensor detected metal, the system would be stopped as this would indicate a jam situation in the feed chute.

What It Didn't Have

There were at least two sensors that were desirable on the system but were not included due to the lack of controller I/O and it was feasible to leave them out of the design. Neither the hopper nor rotary feeder had force sensors to detect jamming of the mechanisms. Timers in the controller were used instead. Once actuated, the system allowed a specific time for the cylinder pistons to reach the other end of travel. It was sufficient to detect any jamming problems by time-out, before end-of-travel was reached.

The rotary feeder had no sensors to indicate whether there was a component in the coil or not. Having the heater cycle with no pin in the induction coil caused no damage and therefore was not an issue. It would have been advantageous to determine if a component had exited the coil before another dropped in to avoid a damaging 'melt-down' in the coil.

More sensors and inputs would have allowed a 100% coverage of the system. Two optical sensors and their corresponding inputs in addition to the existing I/O would have completed the system nicely.

Control Code

Coding Tools

Flow Charts

Four basic flow charts were drawn up: top level, feeder setup, feeder run and hopper run. The top level chart was derived by considering the interaction of each part of the mechanism with the induction heater and each other. The lower level charts were devised by considering the detail of the required workings of the particular mechanism and its interaction with the appropriate sensors and actuators. They set out what needed to happen, in the appropriate sequence and as such were a logical aid to coding (see Appendix N).

Sequential Truth Tables

A table of all the inputs and outputs versus the 'state' of the automation system was drawn up (see Appendix O). Each line represented the status of all the inputs and outputs at any particular point in the running of the automation. This was done initially to assist with the understanding of the interactions of the various mechanisms but was abandoned when only partly completed.

I/O Map

A standard document in automation programming, an input / output map was created. It lists the numbers, names, and purpose descriptions of all the inputs and outputs of the controller as well as what the I/O is connected to or from. (see Appendix P for i/o map)

Controller Simulator & Debugger

As stated earlier, the microPLC used was SPLat SP10-8A. It used a proprietary programming language with a structure somewhat like BASIC. As with most controllers, a PC programming interface, in which all the code was written, was included. To assist with implementation of the code, a simulator and debugger was also available. They allowed code to be tested and syntax checked before being downloaded to the controller. Not only does this make code development easier but allows programming and testing to be done away from the controller.

Code Design

To allow development of the code to written and tested, on a mechanism by mechanism, basis (i.e. hopper, then feeder, chute proximities) it was written in a 'piecemeal' fashion. Each device had code written for it, and then tested in isolation to the other components of the automation. Once the mechanisms worked to specification whilst segregated, their code was slowly integrated. The disparate parts were brought together step by step, checking for successful and safe interaction until all the mechanisms behaved as a single system.

The code itself was written in a modular fashion, with as many reusable, independent subroutines as was feasible. It was also fully commented to accommodate maintenance and troubleshooting in the future (see Appendix Q for code).

Work Piece Considerations

Problems with production automation can be put into two categories. The first category are those of the automation system itself, such as bad design or fabrication, etc. The second category of automation hindrance is that of component or material input. Automation systems are usually designed with specific component dimensions/proportions in mind and hence are inherently inflexible. Material quality, variability and defects can therefore stop and even damage well designed and built production automation systems.

This induction automation system was designed with the idea of flexibility in mind such that the various mechanisms (hopper blade, chute, rotary feeder) had interchangeable parts to allow for a range of component sizes. Accommodation of this type was never meant to allow for substandard components however.

There were two key issues with the components fed to the induction system. One issue was quality of the components themselves, the second being a presentation matter. A significant percentage of the 6/7.5K652 pins had a thin protrusion (approximately 2 - 5mm long) on one end. This was caused by incomplete parting-off in the Mori Seiki automatic lathe. This imperfection could not be ignored as it could affect the placement of the pin in the induction coil and consequently spoil the product. Altering the cutting tool and speed reduced this fault to an acceptable level. Manual inspection was also implemented.

The presentation issue was that of swarf being included in the bulk pins delivered to the automation system, from the parent company PML. Although not serious for a manual treatment system, this problem had the potential of jamming the hopper, the delivery chute and the feeder. Probable outcomes of this ranged from production downtime, to the more serious matter of damage to the machinery. Swarf was eliminated by improving the removal mechanism of the lathe, and both the operators of the lathe and induction heater carried out manual inspection of the components.

Working Models & Tests

At the end of the design stage for each of the two major mechanisms of the system, a working, scale model of the device was built and tested.

Rotary Feeder Model

The rotary feeder chamber plate, scrape plate, finger plate, ratchet and pawl were manufactured from 18mm MDF (Figure 47). Dowel was used for the axle and scrap

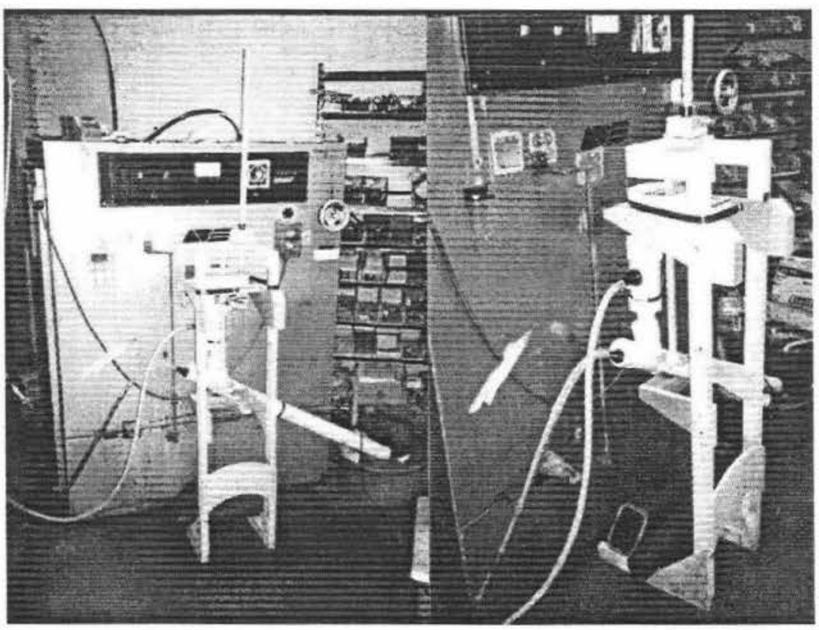


Figure 47: Rotary feeder model at work.

timber for the frame. The model was driven by hand and successful production tests were accomplished. From the outcome of these tests it was decided that the rotary feeder design was satisfactory but it needed to be larger to allow for more room between the induction heater and the feeder. Specifically, the diameter of the rotational elements was increased by a factor of approximately two.

Hopper Model

Again, 18mm medium density fibre-board was used to create a working prototype of the hopper feeder (Figure 48). A timber frame was constructed to raise the hopper to an

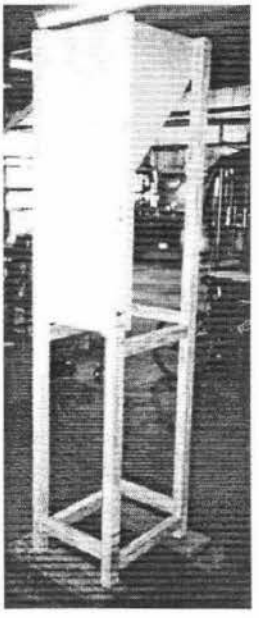


Figure 48: Model hopper feeder.

appropriate height. The blade was raised and lowered by muscle power. This allowed the effects of blade speed to be observed. Successful trials were run, easily emptying out the sample 100 pins. Jamming soon became a problem with the model as the steel pins scored the soft wooden composite. This was not seen as a problem that would happen with the genuine hopper blade made of plate steel.

Chute Tests

The rotary feeder and the hopper feeder were then positioned together, to simulate their interaction. A length of 25mm PVC electrical conduit was cut and shaped to connect the hopper chute to the feeder. The system was manually driven and performed very well.

Quenching Tests

Part of the rotary feeder test was using the quenching system (Figure 49). Hardness tests indicated quenching was adequate

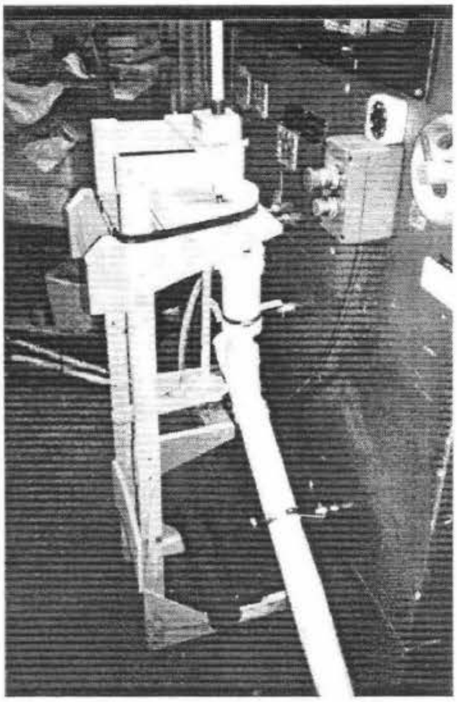


Figure 49: Quenching system on working rotary feeder model.

Machine Manufacture and Assembly

Materials

For the most part, the induction automation mechanisms were built with standard materials (steel), using standard fabrication methods (welding, bolting, gluing, etc). However, several components within the feeder were to be exposed to extreme environments and as such required special materials. All three plates (chamber, scrape, finger) had to be non-conductive, and non-inductive as well as heat resistant. The material chosen for this role was industrial Formica. It matched the above criteria and was suitably strong with good machining properties. At any point close to the coil where the Formica required bonding, nylon screws were used. As these were not adjacent to any thermal activity, heat resistance was not important.

Formica was unsatisfactory in only one position on the rotary feeder. Each finger on the finger plate supported a pin being heated to over 800°C. Although the end of the pin seated on the finger did not reach this temperature it was well above the rated heat resistance (140°C) of the phenolic impregnated cellulose paper (Formica) used. To solve this problem, small ceramic blocks were bonded with epoxy glue to each finger at the point the pin would sit.

High quality ceramic was also used to create a sleeve inside the induction coil to protect the coil from contact with the components.

From Plans to Practical

As with most projects, the final outcome is rarely as designs indicate and models show.

The rotary feeder originally started out as a six buffer chamber, but when it was discovered that there was not enough room between the feeder and induction heater, plans had to change. So the 'six shooter' became a twelve.

System Modularity

After the basic functional design of each mechanism was complete, an attempt was made to plan the specifics of each device. Matters such as blade width, blade channelling, etc, were drawn up to 'best effort'. Unfortunately, when it came to applying the available materials to the designs, it became overly complicated. This is where the practical input of the toolmaker (seconded from within the company for the construction of the project) was particularly valuable. As an example, where the designs called for thicknesses of metal that were not available off the shelf, the plans were queried. Instead of merely following them without question, he worked with the designer to modify the plans to increase practicality.

He was key to the implementation of a practical, modular design that was relatively easy to construct and allowed for easy maintenance and repairs. For each part of the system, he made sure the mechanisms could be stripped down using only basic tools. Interchangeable parts such as the hopper blade tip, the rotary feed chamber, and the scrape plate 'drop hole' were included in the design of the system but were implemented in a practical, modular manner by the fabricator.

Observing these construction issues was one of the most valuable lessons the writer received.

Production Trial

Mechanically, there were few problems with the initial production testing of the finished automation system. The foremost problems were with the hopper feeder where pins would block the exit chute and the blade would sometimes jam when retracting through the bulk pins.

The components were behaving in two ways that caused problems. They would stand on-end and ride up double layered on the tip of the blade. These situations did not allow the pins to transfer correctly to the concave channel to the exit chute and hence would block egress of the parts. Various spring type mechanisms inside the blade track, and on the back wall of the chute, were experimented with, but none worked with any consistent success. The profile of the blade tip was altered, also with no acceptable results. The idea was then struck upon to use a brush to push off all incorrectly poised pins. The solution consisted of a row of nylon brush bristle approximately one and a half pin diameters above the concave hopper chute.

The hopper blade retraction problem was overcome by providing more air pressure to the blade cylinder, thereby giving it more power to pull through the bulk pins.

The controller code required altering several times to correct problems such as the transition from 'setup' to 'run' of the system and the times allowed for cylinders to extend and retract required adjustment (in conjunction with the speeds of the cylinders).

The biggest obstruction to a very successful automation project came in the form of the ceramic sleeve breaking. The short run tests done on the system were never enough to show this problem, but once a longer run production trial was attempted, a fault became evident. As more pins cycled through the coil, the ceramic sleeve became hotter and more brittle. Little heat was dissipated into the water cooled coil. It was determined that the heat factor, together with pins being dropped into the sleeve and imparting shock energy to the ceramic was the cause of the breakage. Once the sleeve had broken, the loose sections of ceramic caused blockages and jammed the hot pin in the coil. Figure 50 below shows a standard sleeve with a failed sleeve and the consequences of this particular failure.

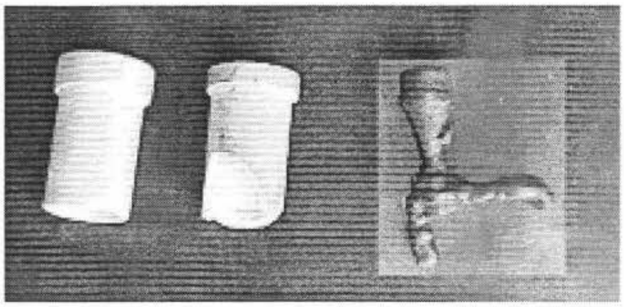


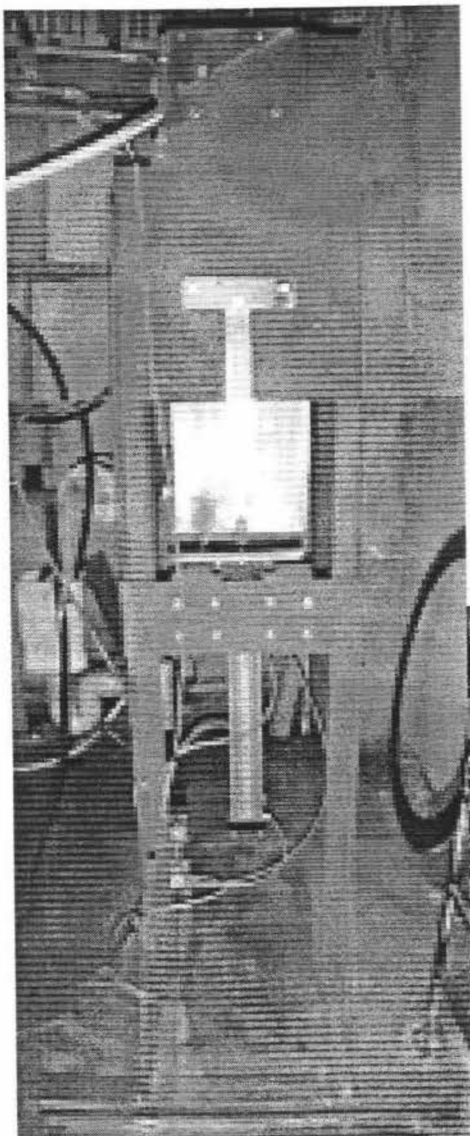
Figure 50: A failed sleeve and its consequences.

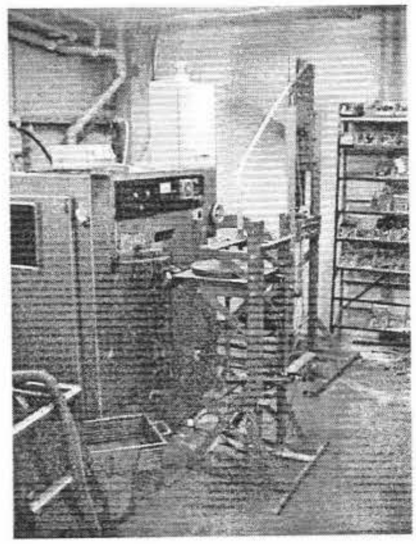
A more robust material was needed to safeguard the coil from contact with components. Ceramic specialists in Auckland (Certec Ltd.) were consulted and the problem resolved. A fused silica ceramic would be a sufficiently robust material for the requirements of the automation system. This solution was not implemented before the end of the project.

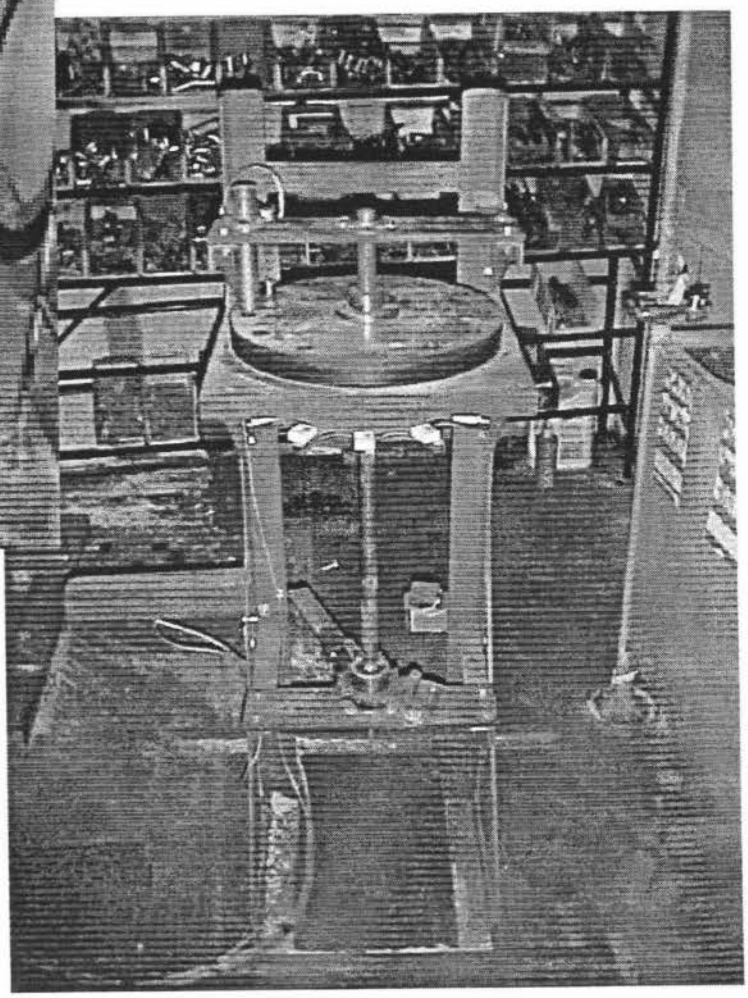
Conclusion

The end result of automating a manual induction heater was very respectable. The automated system could be used to produce large quantities of treated pins with only a small amount of labour content. The savings involved were in the region of at least one labour unit per year whilst the cost of the automation amounted to less than a years labour value.

The heater was also still able to be used in a totally manual mode as well. This flexible system allowed for other components that did not suit the automation system, to be treated by hand. See Figures on page 101 for the resulting system.







Improving the General Manufacturing Environment

Throughout the project attention was also paid to the general manufacturing environment for worthwhile secondary issues. An approach of questioning current methods was taken with the idea of improvement if possible. When an issue was discovered that merited further investigation, it was examined, improved, and if beneficial (cost effective), implemented. In most cases these secondary improvements cost the company very little money for reasonable improvements.

Improved Factory Layout

Soon after the project started it was obvious that the existing layout of the assembly line was not conducive to an efficient flow. The presses and assembly equipment had been placed in much the same format as it had been in Invercargill. Just before the Christmas break of 1999, the assembly area was reorganised. The assembly line presses and machinery was repositioned to a linear layout (Figure 51) to create more space in the factory and attain a more efficient flow of components for assembly.

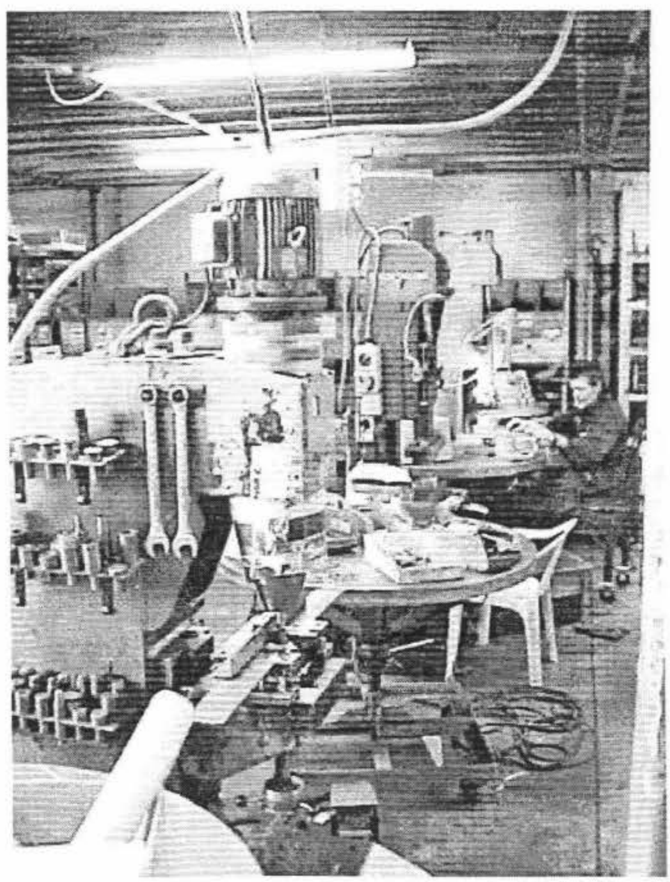


Figure 51: The assembly presses (red and grey - background) and spin riveter (blue - foreground) in-line for easier, more efficient production.

Improved Materials Handling

For assembling the various sub-assemblies it was necessary to take batches of components to the appropriate hydraulic assembly press. This was being done using cardboard boxes, rubbish tins, and sacks. A better method of moving components around the factory floor was required and so was developed. A simple bin and trolley method (Figure 52) was implemented which saved time and was easier on the employee's backs.

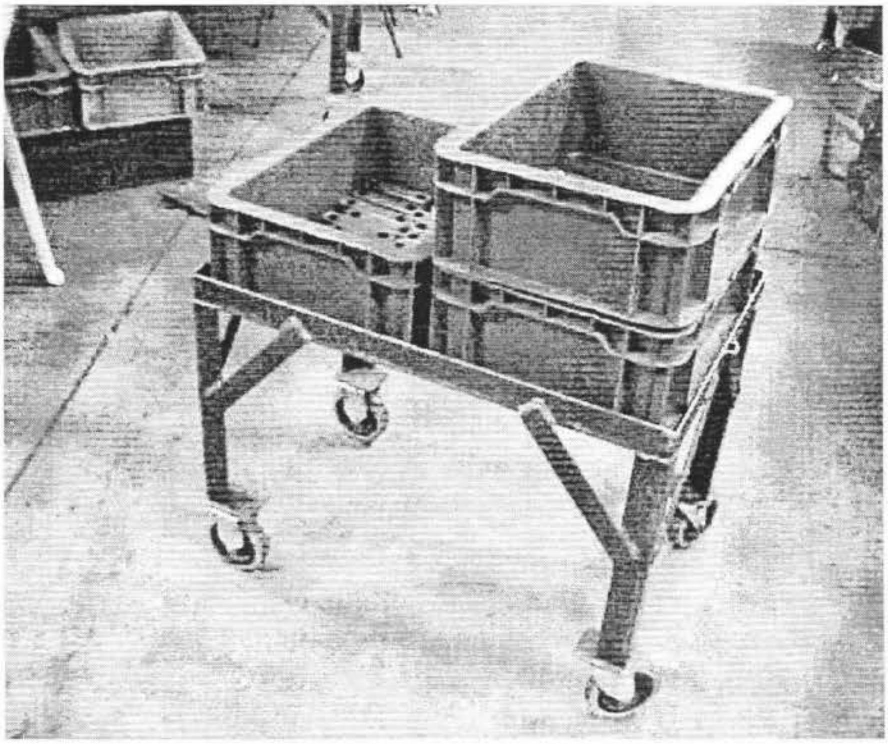


Figure 52: Material trolley and bins.

Rumbler Improvements

After the side plates were punched, they went into the rumbler for deburring and cleaning. The rumbler lid was a heavy, unsafe and cumbersome piece of the machinery. It had to be unbolted then lifted off with the forklift – a dangerous process at the best of times. Staff suggested it be changed from being detachable to being hinged (Figure 53 next page). This was designed and implemented easily and saves approximately 10 - 15 minutes each time the rumbler is loaded. It has also become a much safer process.

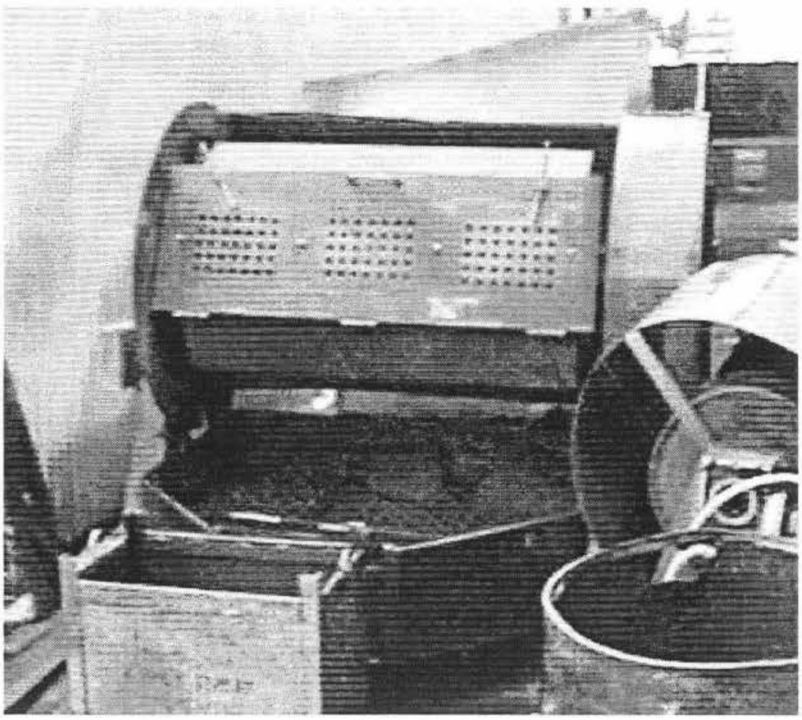


Figure 53: Rumbler with hinged lid.

Office Networked

The company manager had no computer access to the accounting systems used for both PML and the company. Time was wasted by having to go over to the PML offices to do any accounting task. Hence, the factory manager's office was networked to enable access to the company server and the relevant creditors, debtors, billing, and stock systems.

Occupational Safety

The seating at the assembly stations consisted of wire kitchen chairs and plastic garden furniture. This was not a dangerous situation but had a direct impact on the ergonomics of the assembly process. Staff could not adjust the height of the chair to suit themselves at the station and there was no back support. This issue directly affected the efficiency of assembly and hence throughput. It was agreed to abandon the unsuitable chairs and purchase proper seating for the assembly stations.

Project Results

Six months after the project was completed the company had reduced its costs considerably and as a result, was more profitable. The key to this was the reduction in roller costs. The rollers were not being case hardened in-house on the induction heater as a result of the trials carried out, but were being imported from overseas.

This seemed a disappointment at first consideration until it was realised that good quality finished rollers were being landed at the company premises for less than the cost of the raw material stock could be purchased in New Zealand. This solution was a direct result of the project. It was not an intended solution, but it was a good outcome for the company. As a direct result of doing a manufacturing process analysis, the company realised its chain cost structure and further from that, specifically the high cost of the rollers.

With better margins the company has been able to increase its sales and hence boost production levels. Being more profitable also means the company is in a better position to implement more cost saving measures and become more competitive in the market place.

Recommendations for Future Work

There are several matters remaining that could easily be implemented by the company to continue making advances in the cost savings exercise. See Appendix R for a full succession planning list.

Logo Stamp Automation

As discussed earlier, this particular project could be done with minimal capital but hinges on repairing the 30T press. The tooling used with the stamp requires redesigning for ease of automation and greater throughput but is deemed not to be a difficult issue. Ideas for this project have been passed to the company.

12/15K Bushing Roller

It would be beneficial to the company on two fronts to complete this project. There would be a cost involved but possibly more importantly, automated rolling of the 12/15K bushes would not tie up either of the presses. As the company production increases, the press resource usage will increase from the plate production. Leaving the 12/15K bushes to be press rolled may in the near future cause a bottleneck at the presses and delay production.

'Magazine-ing' Press Output

Presently all components produced on the presses are dropped off the press into a bin, losing all orientation. Parts such as bushing blanks and outer plates must then be handled again to orient them for the next process such as bush forming (both rolled and press) and stamping. It is imperative for these parts to be specifically oriented as they are not perfectly symmetrical between front and back due to the punching process.

It is suggested that the company look at the cost benefit of automating the output aspect of the presses to keep the components in their original orientation out of the press tool and then stack them into a storage magazine, ready for input into the next process.

Transfer Bins

The bins used for material handling (discussed in Improving the General Manufacturing Environment) should be used to create a 'Kan-Ban' system of stock control. This would improve stock control and components would not have to be double-handled when taken from storage to assembly.

Chain In Stock

As discussed in the aims of the company, it would be beneficial to start stocking lengths of the most popular chains. Response time to customer orders would improve, and as the company knows to a greater degree the amount of chain they will sell in a year, this would represent only a small risk in money tied up in unsold stock.

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Appendix A

Project Plan

The Project will commence on 1 October 1999 and run for twelve months terminating on 30 September 2000. Our technical goals in this project are

Factor	Goal
Manufactured cost	Reduce by 30%
Capital cost	Limit capital expenditure to $100,000

The main reason for the lack of profit in standard conveyor chain is the high cost of the current method of manufacture. The main processes are:

1. Turning of pins and rollers.
2. Heat treatment of pins and rollers.
3. Pressing of side-plates.
4. Assembly of pins and plates.
5. Riveting of pin ends, to retain plates.

The manufacture of the pins and rollers is now done on PML's CNC lathes, very competitively, but all the other operations work as individual processes, and all are fully-manned operations. The machine operator manually feeds a part (or assembly) into the process machine (press tool etc). After that operation the machine operator manually moves parts to the next process and performs the next operation. There is huge scope for full or partial automation, to greatly reduce the cost of manufacture (and increase profitability) while maintaining flexibility for the range of chain sizes and customised chain. However, the automation must be introduced cost-effectively. It is intended that PML and the GRIF fellow will design and build much of the improved system.

1. Introduction

Literature review
- Current methods of conveyor chain manufacture employed overseas
- Other similar flexible automation projects
- Tool design, multi-stage transfer tool design, indexing mechanisms, automatic feed techniques, commercially available automation components and systems
- Process automation – PLC control etc
- Process evaluation methods – simulation software etc.

Introduction to the Industry
- Conveyor chain manufacture
- Use of conveyor chain in industry, range of products.

Duration	4 Months	
Time	1.5 Months	
Location	25% PML	75% Massey University
Milestone	By 30 January 2000:	

- GRIF Fellow is up to speed with technology associated with conveyor chain manufacture and automation options,

2. Analyse Current Process

The current production system for conveyor chain manufacture is the starting point for this project. The goal is to upgrade this process so as to reduce manufactured cost of conveyor chain. The Fellow will analyse the current system - he will:

- work hands-on at each station to compile a process flow diagram for conveyor chain manufacture.
- Perform method study to identify whether all unit functions are necessary
- measure the resource costs (labour, material, capital) for each workstation and transfer between operations and determine inherent variability
- simulate the production system using SIMULINK software, confirm predictions and use this technology to rank stations and transfer steps in order of resource use
- Identify immediate ('first-order') savings gained from better process layout, and improved transfer between operations (i.e. using methods that preserve spatial relationship between parts) .
- PML staff will introduce these first-order improvements.

Duration	3 Months	
Time	2.5 Months	
Location	75% PML	25% Massey University
Milestone	By 30 January 2000:	

- Model of chain manufacturing process shown to predict resource use, (labour, throughput, set up times), unit costs for each operation and overall cost within measured process variability,
- Processes ranked in order of decreasing cost to identify those with highest potential cost savings
- First order process savings identified and specified.

3. Improved Process

Conceptual design. The fellow will develop potential solutions for the priority (high resource use) workstations. Consideration will be given to combining operations where resource use is reduced. We expect he will put forward two or three solutions that will be evaluated using the process simulation software that will identify unit cost from labour, throughput and set-up times.

Decision point. The twelve-month GRIF timeframe will not permit all workstations to be improved and evaluated. We will sit down with the GRIF Fellow and Massey supervisors to identify several upgrades that fit the time frame. It is likely that we will go with two significant upgrades in this project.

Selected workstation upgrades. The fellow will complete the detailed design of the new workstations assisted by our design staff. On completion they will be signed off by the Project Manager and then manufactured in our workshop.

Assess. Once the workstations are operational the fellow will measure resource use to confirm that we have met our goals for labour, throughput and set up times.

Duration	6.5 month	
Time	6.5 months	
Location	80% PML	20% Massey University
Milestones	By 30 April 2000:	

- Conceptual design for improved manufacturing process that meets the target cost; labour, throughput and set-up time as predicted by simulation model, completed.
- Two improved workstations meeting target labour, throughput and set-up times designed manufactured and operational.

By 15 August 2000:

- Confirmation in practice that unit manufactured cost – labour, throughput and set-up time, over two workstations meets model predictions.
- Quality of manufactured chain confirmed in tensile and hardness tests

4. Document - Thesis and works documentation

Document preferred solution

Within this project several workstations will have been upgraded. PML will continue this work after the GRIF project has been completed. The Fellow will prepare an implementation report that:

- prioritises workstation upgrades,
- presents a layout design
- estimates resource savings and upgrade cost and impact on manufactured cost

Submit thesis.

Masters thesis written and submitted to Massey University

Duration	1.5 months	
Time	1.5 months	
Location	25% PML	75% Massey University
Milestone	Automation plan for all workstations (including transfers) that reduces overall manufactured cost by 30% documented, by 30 September 2000.	

Milestone events for process automation project at PML, Feilding.

Stage 2. Existing process analysis.

At the end of Stage 2, the company will have a lsit of all activities involved in making its products. The list will show, for each activity, all items affecting the cost, e.g. machine time, direct labour, material, power and other services, etc. These items will be costed at current rates, to give the total cost of the activity per unit.

The list will be ranked in decreasing order of cost. The items at the top of the list will be obvious targets for cost reduction. Once these have been identified the GRIF Fellow will be able to prepare plans for process improvements which may involve new tooling, automation, process elimination/amalgamation, or any other technique which will result in a worthwhile cost saving.

Stage 3. Implementation of improvements.

As each process improvement is defined PML production staff will estimate a cost-of-implementation. This will be compared with the potential savings, to yield a measure of cost effectiveness. A new list, in decreasing rank of cost effectiveness, would be prepared and become the priority list for implementation.

The number of process improvement projects actually implemented from this list will be determined by the budget available. However, as savings accrue, projects further down the list will become possible.

Stages 2 and 3 would be, to some extent, concurrent. Outline designs for, e.g. six projects, would be required for the implementation priority study to commence. New projects would be added as designs became available.

Appendix B

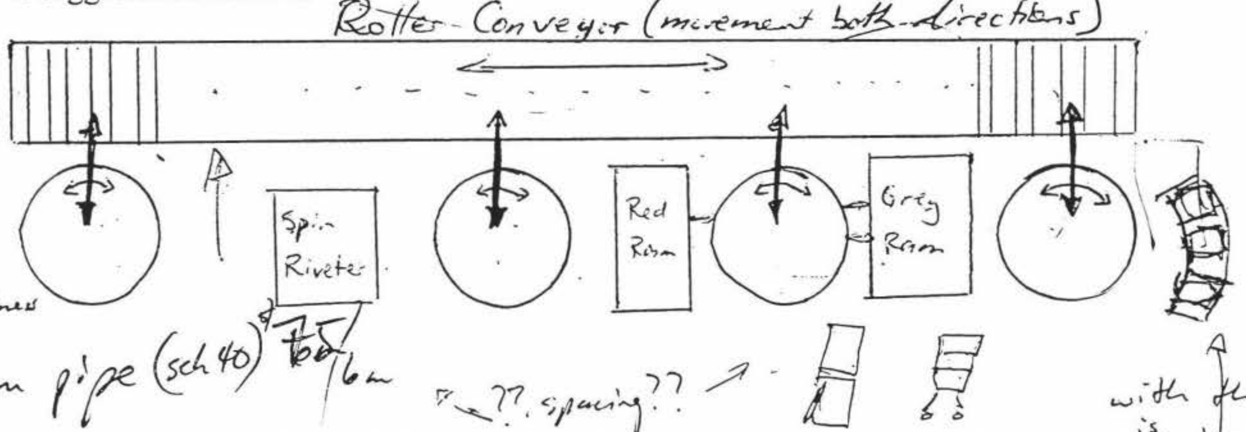
JMP ??

List of Immediately Doable Ideas @ 13 December, 1999

1. Assembly Line Rearranged

The current arrangement of assembly equipment is not optimum. A simple arrangement is suggested as follows:

Look for rollable roller conveyor.



0.3 OD

50 mm pipe (sch 40) 7.5/6m

The order of the equipment is just a straitened version of what is currently there. The spin riveter would be furthest from the presses. The position of this could be straight out from the C-Press as it has material fed in from the side (ie: perpendicular to this assembly line). This arrangement also alleviates material from the 150 ton press intruding into the assembly line. I have not included the air ram into this as I don't know at this stage where it is used.

with the is the conveyor.

2. Shelves and Small Easily Handled & Stackable Bins

I think the current method of storing components is inefficient and costly. The components require triple or quadruple handling. Blanked into a bucket or blue bin, moved to the rumbler, manually moved from there to stock bin or assembly area. From stock bin, pulled out manually (by the handfuls) and again put into a bucket or bin or assembly 'pile.'

Small tough stackable plastic containers (with moulded handles) could be used for the complete life cycle of the parts. All components would be kept in these bins making sure that not too much was put in them so they could be picked up and transported around by hand. Kept on shelves (suggest max two deep - unless rollers used - and max two high per shelf) that are marked (as oranges bins are presently) with the part names and numbers. High shelves could be accessed by a portable step. Stock levels could be quickly approximated by simply looking at the shelves. No containers present - no stock. Assembly would be made easier by making up (Tristan's good idea) a 'rack' (maybe on wheels) that would hold three or four bins in a semi-circle; thereby having easy access to the components. Two or three full containers could be moved with a standard dolly instead of wheels on the blue bins or a specialised trolley for the blue bins. This system eliminates the oversize blue bins and makes overall parts management easier. Orange bins could be sold or used by PML.

3. Rumbler System Improved

Unloading components into the rumbler is time consuming. I would like to add a more efficient sawdust removal system in conjunction with an easier method of getting parts from the rumbler into the sawdust removal. An idea would be to modify a 'domestic' electric concrete mixer by removing the barrel and building a screen barrel. Air jets could also be mounted for cleaning. Once clean, the blanks are tipped into the appropriate container. A belt conveyor going from under the rumbler to the mixer would easily carry the parts up and in. Fraser suggested that we also put the rumbler lid on hinges with large wing nuts to secure it closed which is a good idea.

4. <u>Computer for Greg</u>
Greg needs to have spreadsheeting and job costing/quoting available at his desk immediately. With an up to date job costing system he could do quick, accurate quotes and have a tidy method of presentation for faxing away. Non-standard jobs could be done on a spreadsheet from templates made up previously. A clone Celeron333 with 32Mb RAM, 4Gb HDD, keyboard & mouse was recently costed at $799 + GST. Adding a legal copy of Win98 adds approx $200 to this price. There are presently spare monitors and network cards available in the office. I would do the networking. Materials to network at about $200 + GST.

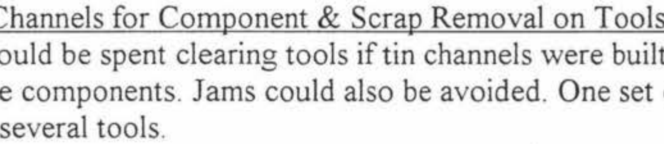
5. <u>Long Reach Cordless Phone for Greg</u>
Presently staff are interrupted from manufacturing activities several times a day to answer the phone which is for Greg about 90% of the time. He needs a phone that will reach as far as the NC's so he can take these calls. This will save time for all involved.

6. <u>Proper Seating at Assembly Stations</u>
Proper seating is necessary at the assembly stations. The existing seating is makeshift at best. Adjustable seating needs to be purchased promptly.

7. <u>Ramps/Channels for Component & Scrap Removal on Tools</u>
Less time would be spent clearing tools if tin channels were built to carry away the scrap and the components. Jams could also be avoided. One set of channels could be used across several tools.

8. <u>Southchain Logo Stamp</u>
The Southchain logo/name is presently manually stamped on all outside links adding time and extra cost (and errors) to the manufacture of chain. We could get the logo spark eroded onto the existing tooling to emboss the link on the appropriate side whilst blanking it and hence remove a step in the process. This could be done even though the tools may be replaced in the future although maybe it should be delayed until the tool replacement issue is considered.

9. <u>Manual Large Bush Roller</u>
We should consider making a manual bush roller to trial rolling the bigger bushes. If it is successful then we can essentially copy the existing roller. If the driver wheels are put on adjustable axis and made wide enough initially, as well as the roller wheel is changeable, we can accommodate a variety of different bushing sizes and diameters.



10. <u>Wellington Factory Visit</u>
I would like to have the core team of Greg, Fraser, and Tristan go for a tour of both

Interlock and Tilleys down in Wellington soon after Christmas. Interlock would give them a look at another assembly plant not so different to Southchain as well as the presswork and press tooling. Tilleys has a press similar to ours that they have automated.

11. Auckland Visit

I would like to visit Heat Treatments in Auckland to see their induction heater and how they have automated it. I would also take advantage of being in Auckland to visit Fisher and Paykel Healthcare where I would get a chance to see automated machinery.

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Telephone 0-6-323-6072, Fax 0-6-323-6212
E-mail garth@precisionman.co.nz

TO: Greg/Mark **DATE: 31 January 2000**

FROM: Garth

SUBJECT: Meeting on Marks Progress

1. After our initial meeting it was decided that regular meetings will be held every 2nd Wednesday at 9 am.

2. Harvey and Ralph will be invited to attend any one of the meetings.

3. The meetings in future will be more structured:
   A) Report from Mark on Progress
   B) Input from Greg and Garth
   C) Expected progress

4. Mark is to provide a weekly report on progress.

5. Mark will keep a record of the minutes of the meeting.

Next meeting Wednesday 2nd Feb

FAXED

Southchain Conveying Systems MTech Progress Report for 26/01/00 – 01/02/00

(1) Mori Seiki RS232 interface: Machine Tool Specialists (Chch) aware of our requirements and are supposed to be getting back to me with a quotation for the job.

(2) Induction Heater Automation

a Pin sorter table: The basics of the vibration table are ready to test. To test & modify to working level. Then will start developing the coil feed mechanism.

b Hardness testing of pins heated in ceramic sleeve: On hold until recently due to technical difficulties. To test ASAP.

c Ceramic sleeves: Have a working sleeve. Certec Engineering (Auck) are to get back with a quote for building a more robust model for inclusion into automation assembly.

(3) Rumbler lid: No progress. Will bring up a job number and initiate this project this following week.

(4) Bushing roller prototype: To do dimensioned drawings then will initiate job.

(5) Wellington visit: Have arranged for Greg, Fraser, Tristan, myself to go down to Wngtn to visit A.E. Tilley Ltd. and The Interlock Group. We will view an automated 75 ton press similar in age to ours (+ laser cutting facilities, etc) and assembly processes, automated presses, automatic feed mechanisms, tool making, speaking with tool makers, etc.

✓ (6) Chain CAD drawings: All existing chain drawings have been done in Claris CAD which does not exist now. There are commercial packages that will read and convert them but we are trying to track down an old copy of ClarisCAD or find a free conversion program. Next option is to suggest this as a forth year project and have all the relevant drawings re-drawn.

(7) Network: cable laid and terminated.

(8) Computer/printer: still awaiting.

(9) Bolt boxes: We have trialed some high-density plastic boxes for using in the assembly process. A total of seven are ordered to now build trial trolleys for them.

(10) Australian chain manufacturing contacts: – Garth?

(11) Flow charts / BOM / route sheets: generic flow charts are done for componentry. Bills of material and route sheets are being developed. These are also to be used for my first Technology NZ output.

(12) Auckland heat treatment visit: Greg & myself to visit Heat Treatments.

✓ (13) Solid Edge: being appraised by Harvey & Ralph before purchase.

(14) Process line rearrangement: before Christmas the assembly line was rearranged into a more workable format. Changes are still being made. Chain assembly table to be constructed as is a press tool bench. The press tool bench may have an I-beam above it with a pulley system on it for working on the press tooling. The large press needs to be rotated slightly so bar stock feeding into the machine does not interfere with working areas.

Minutes of meeting 16/02/00

Present: Harvey, Ralph, Garth, Greg, and Mark

1. Progress the last couple of weeks has been slow due to MTC being away for childcare issues and illness.

2. Induction heater went to Auckland. High Frequency Electronics think they have found the problem. Outer coil making/breaking connection. Should be back soon.

3. Garth hasn't yet made it to Australia regarding chain-manufacturing contacts – visit delayed about three weeks.

4. No computer in Greg's office yet. MTC to speak with Darren Lucinsky at Massey about a loaner.

5. MTech fees not paid and Massey has revoked Mark's uni services. Garth to take care of that today.

6. Solid Edge software a no-goer. Southchain will stick with using the free 2D package though.

7. ClarisCAD drawings being converted by Steelfort Engineering. They will put them across to DWG and DXF formats.

8. Technology NZ outputs for end of February. These are the BOM and Route Sheets.

9. Tooling – Greg is looking at new tooling and will talk with the people in Wellington on our visit to Interlock and Tilley's. New tooling should make the process faster but we are not sure to what extent the side plate will be processed – ie: blanked / pierced / bent / etc. Better, more efficient tooling would make the production of components less of an obstacle for staff. MTC to bring in book on tool making for Greg.

10. There is a question of the hardness variation along the length and around the circumference of the pins. MTC to harden solid pins and test.

11. Awaiting ceramic from Certec Engineering. MTC to chase up.

12. Induction coil could be dipped to insulate pins from coil. MTC & GE to speak with a company in Wellington that does lost wax process about the possibility of dipping coil. Harvey to look into borosilicate glass for sleeve.

13. Meeting minutes to be out ASAP or at least on the Monday before the next meeting.

14. Next meeting Wednesday, March 01, 2000.

Mark MTC

Helmholtds. coil.

Minutes of meeting 01/03/00

Present: Harvey, Ralph, Garth, Greg, and Mark

1. Induction Heater: Seems OK now except for the odd glitch, but when reset is OK. Mark and Greg have been looking at different coils recently to improve the uniformity of hardness. Harvey & Ralph suggested MTC look into Helmholtz coil for ideas of winding.

Mark is to send some raw pins to Greg McLeay for hardness testing so we know what level we are starting at.

Pins must be above the critical temp and then quenched quickly. We should consider a brine solution to improve the hardness. Heat Treatments pins have a uniform hardness of 50 all along the wear surface of the pin but still rivet OK.

The issue of pin hardness is prime so the first order of business is to get the pins up to the appropriate hardness and then look at making sure the ends are soft enough to rivet. Possible solutions are: a) change the coil profile, b) use a scanning coil similar to Heat Treatments, c) heat the whole pin up to the appropriate level and then temper the ends, d) alter the cooling profile.

Get the metallurgical phase diagram for the pin material – MTC, GE
Get hold of the appropriate standards for conveyor chain - MTC
Try hardness testing on Tsubaki chain – MTC, GE

Southchain need access to a hardness tester for a period to enable us to immediately test the hardness and alter the treatment in a timely fashion. Massey may be able to lend us one either a) after the tester comes back from Albany or b) the one Massey is purchasing from Allflex.

2. Southchain computer: MTC is getting pricing on computers. Mark to check with Mike Stevens regarding desk space at Massey and the possible use of the computer that may go with the space.

3. Induction Coil coating: Forward to next meeting. No contact was made with the Wngtn company that does lost wax process. Harvey to look into borosilicate glass for sleeve.

4. Ceramic sleeve: we have the ceramic and it has been turned. It has not been used yet and shouldn't be as it is a secondary issue to getting the hardness correct. - potter

5. Mark brought up the issue of PML seemingly treating the Project jobs as secondary. Garth assured this is not the case, but that PML fabrication is very busy. Also, a fabricator that is more practical and can use their initiative is needed on Project jobs. Garth indicated to speak with Duncan but that we must be prepared to get results that are not exactly as we wanted due to leaving the parameters fairly loose. Mark indicated this shouldn't be a problem. Garth also suggested that Greg might have to step in on project jobs when Mark is not here to deal with questions.

6. Mark's childcare issues: This issue is OK to let slide for a couple of months until Hamish sees the urologist and the underlying problem is sorted out. If it goes beyond

this timeframe then the need will arise to consider the situation and its implications in more detail.

7. A general discussion was held on the direction and outcome of the project. Harvey asked what the gut feeling was on what specific areas really would improve the process speed and cut costs. One issue raised was that the variability in components could be reduced / ironed out to increase assembly speed and efficiency. Greg indicated that press tooling was a major issue that would greatly improve the situation as well – leading back into the subject of decreasing component variability.

8. Next meeting Wednesday, March 15, 2000.

Mark

- shaker table - drawing CAM
- dc motor control Karl.

- Mori Seiki

- Garth Ans. chain contacts.

- profile cutter.

Minutes of meeting 15/03/00

Present: Harvey, Ralph, Garth, Greg, and Mark

1. Meetings now 11am

2. Pin hardness now up to scratch with quenching in brine. Greg had Macleay's pins hardness tested with the results being bad (4 to 30). We know it is the quenching that is making the difference, as there have been no changes to the hardening process bar the quenching solution.

The brine solution will eventually heat up when larger numbers of pins are processed so a heat exchanger of some sort will be necessary.

We have some untreated pins away being tested presently to determine the datum point.

Another option for pin treatment is to alter the induction machine to scan the pins. This would allow treatment of longer lengths than is presently practical but would require approximately $5000 investment.

Greg is presently having some Renolds components tested at Heat Treatments in Auckland for hardness and depth of hardness. Material tests too expensive.

3. The loan of the hardness tester is still in the pipeline. Depends on the Allflex deal or on the return of the tester from Albany.

4. Standards: The cost of the relevant standards is in the hundreds of dollars. MTC to get them via the interloan system.

5. Induction Coil Sleeve: borosilicate is not the answer. Pure silicon is probably a better solution. Fibreglass braiding was trialed. OK for short duration heating but in longer times the pins melted the glass and the pins stuck to the braid. Harvey needs pins for sizing the silicon sleeve. We need to look at alternatives that are inexpensive, durable and have a low coefficient of expansion.

6. Project jobs & PML: Duncan simply needs some basic sketches so he can discuss with any of his staff and leave them with it. Greg can be more involved when Mark is away.

7. Tooling: Greg is presently having a popular chain tool (variable) made up to allow for multiple metric and standard pitches. It will be dowelled for accuracy and he is trying to incorporate stamping the Southchain logo into the tool. Harvey & Ralph queried the ability to match the required high tolerances necessary in constructing a press tool. Greg and Garth indicated it shouldn't be an issue.

8. Press Automation: Greg and Mark should visit Cranston's to view their bar feed solution at a later date.

9. Australian Chain Contacts: A discussion was held on this issue with the result being that it was not necessary to know how other companies are manufacturing chain but to focus on the directions we are going.

10. Quality Issues: Greg indicated a rep had mentioned previous quality issues with Southchain chain. He was going to speak with him for more details.

11. Automatic Profile Cutter: suggested my MTC as a fourth year project. It was looked into years ago at a cost of $30,000. Harvey will talk with Huub Bakker but presently there is no call for projects.

12. Next meeting Wednesday, March 29, 2000.

Mark

Minutes of meeting 29/03/00

Present: Harvey, Garth, Greg, and Mark

1. Pin Hardness

All is OK here. We are only improving upon a good situation by trialing issues such as optimising the brine concentration, trying different coil configurations, etc. We need to get a testing kit so we can find and maintain the appropriate salt concentration. Look in a hydroponics retailer and/or locate a scientific catalogue. –> Greg

2. Induction Coil

Still working on different issues from coil configuration to coating the copper tubing to a silicon sleeve.

3. Induction Coil Sleeve

Harvey is still trying to get hold of the individual supplying silicon tubing. Message has been left.

Ceramic slurry sleeve may have problems due to the ceramic being fired at approx. 1100C to 1300C whereas copper melts at 1083C.

4. Hardness Tester

Tester coming back from Albany soon which will be available 3 days a week immediately and 5 days a week in the not too distant future. Once the Allflex tester is secured we can have a lend if needed.

5. Chain Standards

Copies are available in NZ via Massey library on interloan. MTC to get forms in ASAP. Cost $5/standard. We are after ISO1275 and ISO1977/1~3.

6. Tooling

Coming along nicely!

7. Cooperative Benchmarking

This issue of working with other conveyor chain manufacturers in Australasia to improve the systems of those involved was discussed. Garth believes that there is enough market capacity (if imports could be replaced by local product) to cope with the three conveyor chain manufacturers increasing efficiencies and production capabilities. For this reason working in with the other manufacturers would not be detrimental to those involved. Garth explained one of these firms may have been bought out by a large chain producer and therefore would probably not want to be a part of any mutual exchange. This may make it even more beneficial for the remaining two companies to cooperate.

It was agreed that cooperative benchmarking is something to pursue with the qualification that ownership of the chain company or companies in Australia is an important issue with regards to disclosure of information. Showing too much to the wrong company could simply show our capacity. Garth to find contacts / names.

8. Southchain Imprint
The Southchain name / logo stamp should include "Made in New Zealand" on it. Harvey mentioned it could be a stumbling block with CER and the necessity for local content in Australia.

9. Profile Cutter
Harvey to hand the project idea to Engineering & Automation.

10. Tentative Project List
We discussed what the possible major projects that we are facing were. The consensus is the following projects:
A) Induction Hardening automation
B) Press Tooling } interlinked
C) Press automation }
D) Case Hardening

11. Case Hardening Plant
Garth wants to start moving on investigating a case hardening plant. The best way to begin would be to look at Heat Treatments in Auckland.

In-house case hardening is being considered as one of the major technology implementation issues as:

a) sub-contracting it out is expensive
b) it has a low labour component
c) eliminates transport costs
d) strategic reasons

12. Output for Next Meeting
MTC is to have the spreadsheet analysis (BOM/Route sheets) completed for next meeting. Will need to liase with Greg for process data (stock numbers, process steps, times, costs, etc) and Harvey for spreadsheet format.

This will allow us to see the high cost processes and discuss - at this meeting - the cost savings versus the implementation costs and decide on three or four specific projects to get under way.

13. Next meeting Wednesday, April 12, 2000.

Mark

Minutes of meeting 14/04/00

Present: Harvey, Ralph, Garth, Greg, and Mark

1. Quenching Brine

Brine too concentrated for hydroponics tester. Need to research another method of testing to maintain required concentration.

2. Pin Hardness

Hardness tester back at Massey. Testing results of various configurations can now continue.

3. Cooperative Benchmarking

Garth to investigate ownership (of Australian conveyor chain manufacturers) issues and report. In discussion management and supervisors decided that this should not be a focus until later in the project. MTC disagreed as he sees it as an opportunity to assist improvement.

4. Case Hardening

The priority of this issue should be raised as considerable money is spent on case hardening outside of the business. The Heat Treatments visit should be done before the next meeting.

As rollers have the highest case hardening cost per component we should look specifically at roller hardening. Test harden existing rollers to identify what level of hardness can be obtained using pure heat & quench treatment.

Case hardening technologies need to be investigated for a potential TBG grant. Need to identify a particular technical issue pertinent specifically to Southchain.

5. Southchain Imprint

Correction: the lack of "Made in NZ" on the stamp could be a stumbling block for CER issues.

6. New Tooling vs

Existing tooling would be difficult to automate. Must take automation into account when building new tooling.

7. Project Issues

a) Cam job sat for about three weeks before something was done.

b) Projects should run simultaneously but at different stages. A discussion was held as to the various pros & cons of complete design then build versus design and build in stages. The later method was preferred.

8. Southchain Imprint

The Southchain name / logo stamp should include "Made in New Zealand" on it. Harvey mentioned it could be a stumbling block with CER and the necessity for local content in Australia.

9. Donuts

All bets should be shaken on during the meeting to be valid. A donut is a circular piece of pastry with a hole in the middle, not an oblong piece of pastry with cream in the middle.

10. Next meeting 11am, Wednesday 10 May, 2000.

Mark

Minutes of meeting 10/05/00

Present: Harvey, Ralph, Garth, Greg, and Mark

1. Auckland Visit

Heat Treatments - no unmanned induction heating. All induction heating is done on spindles using scanning. Gas carburising furnaces VERY expensive (~$250K).
Electric Furnace Company - advised if we were spending less than $20Kpa on case hardening not to buy any plant.

- Pack hardening capital ~$20K for a 50kg batch size. Cannot control carbon content and must anneal in forced air furnace.
- Cyanide Salt bath capital ~$50K - advised not to go this way due to various complications due to using cyanide.
- Gas Carburising capital ~$200K to $250K.

2. Case Hardening

Southchain should speak with Heat Treatments in respect to pricing. The current pricing for case hardening bushes and especially rollers (+ freight) makes it uneconomical to use Heat Treatments. If they can drop their prices it may not be necessary to set up a case hardening plant in-house. Garth indicated that controlling the process ourselves is important enough of a strategic issue that investigation into in-house hardening should continue regardless. Initial information on case-hardening plant cap-ex indicates that maximising the products hardened by induction heating should be investigated thoroughly.

Rollers processed at Heat Treatments should be hardness tested to set a benchmark for in-house hardness levels. To date there is no external specifications known for hardness levels. The conveying chain standards have no hardness level requirements.

Mark to experiment with hardening the existing rollers via the furnace at Massey.

3. Quenching

A by-product of quenching in brine is rust. Components quenched in brine have sufficient hardness but rust at a much faster rate. Investigation into solutions needs to be done. Polymer quenchant is one direction, another is treating the pins (kerosene & oil bath?) post-quenching.

4. Project Direction

Due to the project end date drawing ever nearer we need to narrow the focus in order for Mark to be able to deliver a successful automation solution for a process.
Greg to continue with new tooling and press automation.
Mark to concentrate on hardening issues and investigate the potential for using the induction heater for a greater range of (if not all) components. Potentially pins, bushes and rollers.

5. Project Jobs

Jobs still sitting on Duncan's desk after two months. Garth needs to have feedback more frequently than each fortnightly meeting if there are problems. Also, purchasing issues need to be discussed with Garth when a solution is required.

6. Next meeting 11am, Wednesday 24 May, 2000.

Mark

Minutes of meeting 24/05/00

Present: Harvey, Ralph, Garth, Greg, and Mark

1. Process Model

The model represents full recovery costs at this stage as the work centre rates were done by Glennys and include overheads. We discussed putting in direct costs and then adding overhead coverage but it was felt simply adding a percentage to the costings did not accurately reflect recovering overheads. Ralph suggested a dollar figure be put into the system and overheads added using this. Another discussion must be held in future regarding the model.

Greg feels the prices are a bit high. It was suggested that actual sales volumes could be collated and material spending calculated then compared against the model. This was deemed not to work as the model only covers a fraction of all chain made. Spreadsheet should be progressively verified as actual costs are verified.

One important objective of the model was to confirm high cost processes. It has done this especially in the area of case hardening costs.

2. Heat Treatments

Components are treated months before chain is made and sold so cash flow is an issue.

Sales volume spreadsheet was discussed. Cost per foot includes overheads so percentages of case hardening at HT are minimums. Total theoretical HT costs are in question but Watties 1999 was approximately 15K worth of hardening. Include specials and the figure seems OK.

3. Heating Options Spreadsheet

The various options for case hardening components were discussed. Greg suggested MTC contact Radyne UK for help and information. He also made the suggested that rollers could be imported hardened.

Harvey and Ralph are to try and arrange the hardness tester for Southchain for six weeks so testing can be done as various prototypes are developed. MTC to hardness test the inside diameter of HT hardened rollers.

4. MTC to start experimenting with induction heating rollers and is to report on progress next meeting.

4. Next meeting 11am, Wednesday 7 June, 2000.

Mark

NB: Mark was sick the week of 5/6/00 to 9/6/00 so no meeting was held. Next meeting 11am, Wednesday 21 June 2000.

	Pins	Rollers	Bushes
Induction Heating -no capital expenditure -R&D necessary -automation feasible -for >= 0.4% Carbon steel	-status quo -can easily double or triple production -option of coil improvements -option of quench improvements	-R&D necessary -need to change metal	-R&D necessary -need to change metal -case depth an issue (milder quenching?) -split bushes may not harden due to open circuit
Work Hardening (incl. knurling, shot peening, extrusion) -no large capital expenditure for knurling -case depth an issue (shallow, ~0.1mm?) -shot peening & extrusion require capital expenditure -R&D necessary -mat'l selection issue.	-R&D necessary	-R&D necessary	-R&D necessary -rolling machine could be altered to work the bushes more
Gas Carburising -capital expenditure ~$250,000	-must selectively plate ends	-status quo $$$	-status quo $
Pack Carburising -capital expenditure ~$20,000 (low end) -no control over carbon content - >= 2.5mm case depth -small batch size (50kg) for low end cap-ex -long batch processing times (~24+ hours) -automation not feasible	-must selectively plate ends		-case depth too great
Salt Bath Carburising (Cyaniding) -dangerous chemicals -capital expenditure ~$50,000 -components require post treatment cleaning -automation not feasible	-must selectively plate ends		
Nitriding (incl. Plasma, salt bath, gas) -capital expenditure prohibitive -case very hard but shallow	-must selectively plate ends		
Flame Hardening -low capital expenditure -automation feasible -R&D necessary	-R&D necessary	-R&D necessary	-R&D necessary

1. We have knowledge and experience with induction heating. All other hardening processes are effectively new and untested inhouse.
2. The status quo with induction heating is very well suited to the hardening of pins. All other case hardening processes (except flame hardening) involve coating the ends of the pins to avoid hardening the worked ends.
3. Even if the more expensive alternative is opted for, due to the material handling requirements mentioned above the induction heater would continue operating for pins
4. Getting the induction heater to process at least 50% to 75% (dollar expenditure) of the current externally hardened components means that even without automation, induction heating saves considerable money.
4a. Adding automation to the induction heater improves the savings even more.
5. For the alternatives, automation is only feasible for the high end $$ options
6. The least expensive and safest way forward is to investigate the full utilisation of the induction heater and only outlay capital if it is warranted.

Sales Volumes (ft) by Calendar Year													
Chain	1999 (ft)	2000 to end April (ft)		cost/ft	Cost of Chain 1999	HTAuck/ft (incl freight)	Percentage of Case Hardening per Foot	1999 Theoretical Case Hardening Costs	Cold Cash Material costs/ft	Percentage of Material costs per Foot	HT Auck (incl freight) + Material Costs /ft	Percentage of Material + Hardening Costs /ft (job purchases)	Total 1999 Job Purchases
12K4.0	578			$ 19.21	$11,101.58	$ 4.09	21%	$ 2,365.45	$ 5.72	30%	$ 9.81	51%	$ 5,669.54
12K6.0	100	239		$ 13.35	$ 1,335.41	$ 2.73	20%	$ 272.83	$ 4.36	33%	$ 7.09	53%	$ 708.88
15K4.0	566			$ 18.10	$10,242.78	$ 4.09	23%	$ 2,316.34	$ 5.72	32%	$ 9.81	54%	$ 5,551.83
15K6.0	288			$ 12.61	$ 3,632.84	$ 2.73	22%	$ 785.76	$ 4.36	35%	$ 7.09	56%	$ 2,041.56
4.5K3.0	103			not avail		not avail	not avail	not avail	not avail	not avail	not avail	not avail	not avail
4.5K4.0	160			not avail		not avail	not avail	not avail	not avail	not avail	not avail	not avail	not avail
6K3.0	405	302		$ 15.13	$ 6,129.60	$ 1.74	11%	$ 704.89	$ 2.64	17%	$ 4.38	29%	$ 1,775.20
6K4.0	1210			$ 11.66	$14,108.35	$ 1.31	11%	$ 1,579.49	$ 2.29	20%	$ 3.60	31%	$ 4,351.27
6K6.0	583	670		$ 8.04	$ 4,684.81	$ 0.87	11%	$ 507.35	$ 1.79	22%	$ 2.66	33%	$ 1,550.72
7.5K3.0	1396	1022		$ 13.09	$18,280.35	$ 1.74	13%	$ 2,429.71	$ 2.64	20%	$ 4.38	33%	$ 6,118.96
7.5K4.0	1223	460		$ 10.13	$12,388.74	$ 1.31	13%	$ 1,596.46	$ 2.29	23%	$ 3.60	36%	$ 4,398.02
7.5K6.0	847			$ 7.02	$ 5,942.30	$ 0.87	12%	$ 737.09	$ 1.79	26%	$ 2.66	38%	$ 2,252.93
	7459				$87,846.76			$ 13,295.37					$34,418.92
	2273.50	m										Total Job Purchases as a percentage of 1999 Chain Cost	39.2%

Sales Volumes (ft) by Calendar Year						
Chain	1999 (ft)	2000 to end April (ft)	cost/ft	Cost of Chain 1999	HTAuck/ft (incl freight)	Percentage of Case Hardening per Foot
12K4.0	578		$ 19.10	$ 11,039.16	$ 4.09	21%
12K6.0	100	239	$ 13.28	$ 1,328.21	$ 2.73	21%
15K4.0	566		$ 17.99	$ 10,181.66	$ 4.09	23%
15K6.0	288		$ 12.54	$ 3,612.10	$ 2.73	22%
4.5K3.0	103		not avail		not avail	not avail
4.5K4.0	160		not avail		not avail	not avail
6K3.0	405	302	$ 14.99	$ 6,071.28	$ 1.74	12%
6K4.0	1210		$ 11.55	$ 13,977.67	$ 1.31	11%
6K6.0	583	670	$ 7.96	$ 4,642.84	$ 0.87	11%
7.5K3.0	1396	1022	$ 12.95	$ 18,079.33	$ 1.74	13%
7.5K4.0	1223	460	$ 10.02	$ 12,256.66	$ 1.31	13%
7.5K6.0	847		$ 6.94	$ 5,881.31	$ 0.87	13%
	7459			$ 87,070.20		
	2273.50	m				
3/4.5K	263	4%				
6/7.5K	5664	76%				
12/15K	1532	21%				

Minutes of meeting 21/06/00

Present: Harvey, Ralph, Garth, Greg, and Mark

1. Roller Induction Hardening

An update was given on the progress of testing the feasibility of heating rollers with the induction heater. To date a variety of coil designs incorporating both an inner bore coil and an outer diameter coil have been tested and failed. This is due to the greatly differing impedance of the two coils and the fact that they were in series. The outer diameter heats and the inner bore does nothing. Initially I thought the inner coil was not working due to the lack of space for the flux lines to run inside the coil. This was not the case as it was later proved that a single coil could heat the inner bore successfully using the maximum setting on the variable transformer on the heater.

A single outer coil was then used to try and through heat a 12/15K roller and the outside edge melted before the mass was heated to critical temperature. This configuration could be retried if necessary but the link to the working piece would require to be reduced by opening the coil up and reducing the efficiency of the coil.

A double pancake coil was next made up to heat both flanks of the 12/15K roller with the objective of surface treating the rollers in a series of processes; the flanks being one process. At the time of the meeting I had only tested surface heating the flanks of a 1040 steel roller. It was successful in that a Rockwell hardness of 55 was achieved. I am now confident of being able to harden the rollers via induction.

Harvey strongly recommended that a simpler method of hardening the rollers be used before setting up several steps for roller hardening. The technique of through heating the roller, then drop quenching and testing for hardness provides the simplest

Split bushes have not been fully tested in the heater. An earlier test was conducted in a standard helical coil configuration (a coil used for pin hardening) and the split bush melted at the point of the split. This melting is due to ineffective contact at the split edges, causing the eddy currents to arc-over at one point, hence melting the bush. A horizontal placement in a specially wound coil may be a possible solution. This will be tested after the roller testing has come to a conclusion.

A separate discussion between Ralph and myself led to the conclusion that a double coil may work if the coils are wound in parallel with each other. This configuration will be tested after a work-up on flange heating the rollers has been completed.

A few rollers case hardened by Heat Treatments Auckland should be hardness tested as soon as possible to give us a target to aim for.

Garth indicated that the importance of this investigation could not be over-rated as he feels that Southchain will struggle to make a profit if we cannot considerably reduce the heat treatment costs by treating components in-house. He will also approach Heat Treatments Auckland to see if a better pricing structure.

2. Induction Pin Automation

An informal presentation was made showing the current ideas chosen of the major components of the induction heater pin processing automation. A chamber and plate ('six shooter') feed mechanism has been designed for feeding the coil and a centreboard hopper feeder is the leading contender for supplying pins to the chamber.

It was suggested that the automation be designed and prototyped in stages. The chamber and plate system should be built and hand tested to ensure that it works properly before incorporating it into an automatic system.

Harvey's sage advice was to Keep It Simple!

3. Next meeting is tentatively set at 9am, Tuesday 4 July 2000. Please contact me if this is unsuitable and I will organise a more mutually convenient time.

Mark

PS: School holidays start on 1 July and I will be needed at home until we go over to Nelson on 5 July until 17 July to visit family and for a much need break together. My Mum and sister are coming over from Canada to visit from 11 July until 5 August and this will take up a large amount of my time. Effectively July will be a very thin month on the ground for me, but I will attempt to make as much time available as possible.

Minutes of meeting 13/09/00

Present: Harvey, Ralph, Garth, Greg, and Mark

1. Induction Automation

The rotary feeder (six shooter!) and the side blade hopper feeder models have been built and tested successfully. The performance of both was very good. The hopper feeder feed rate should be able to match or exceed that required by the rotary feeder. The diameter of the rotary feeder proved slightly too small as the ratchet wheel rubbed against the cooling sleeve. The production shooter will have a 160mm larger diameter to provide more room under the workings.

Manufacturing of the production versions is to begin today. I am aiming at the manufacturing stage being completed by the end of September with commissioning in the first two weeks of October.

Presently there is no jamming/problem sensing on the planned system. This will be added in the future if necessary. Jamming shouldn't be a problem on the shooter as the cylinder is rated at 25kg force. It was suggested that the empty / problem warning light should be a large amber rotating one sitting atop the heater, clearly visible.

As at meeting time the micro-controller and coolant pump were on the premises with other ordered components arriving soon. MTC has a meeting with Carl to discuss the hardware (power supply, relays, lights, etc) required as well as develop a wiring diagram and program plan.

2. Rollers

Through Heating: The results of the through heating test were discussed (data & graphs attached). It was discussed as to whether 40HRc is too hard for a roller centre of mass under normal operating conditions of a conveyor chain. Greg thinks it is OK, MTC believes it is too hard. MTC to organise 'hammer test' to see if rollers break. MTC to contact Ted Smith and a metallurgist to discuss. Greg will speak with Ken (Bettany Gears) about the core hardness. If it is not too hard then production heating of the rollers is possible with the currently tested flange pancake heater. An option of cutting down on flange heating time was suggested. It could lower internal hardness and yet still leave the middle of the outer circumference an acceptable hardness.

Regardless of the method of heat treating rollers, the costs must be deliberated and watched so as not to exceed those of external contract case hardening.

Surface Heating: Options for roller heating trials were set out by MTC as follows:

a) internal & external coils wired in parallel - mainly intended for surface heating but possibly through heating
b) external and flange coil (inverted cup) wired as one - through heating?
c) standard helical coil - trial heating 6/7.5K rollers as per pins
d) scanning external diameters is an option
e) staged heating processes for larger rollers
   i) - single process using internal/external parallel coil leaving flanges indirectly treated
   ii) - double process using double flange coil & external coil leaving inside diameter indirectly treated

iii) - triple process using double flange coil, external coil, then internal coil in succession. Only applicable to 12/15K and larger rollers.

3. Succession Planning

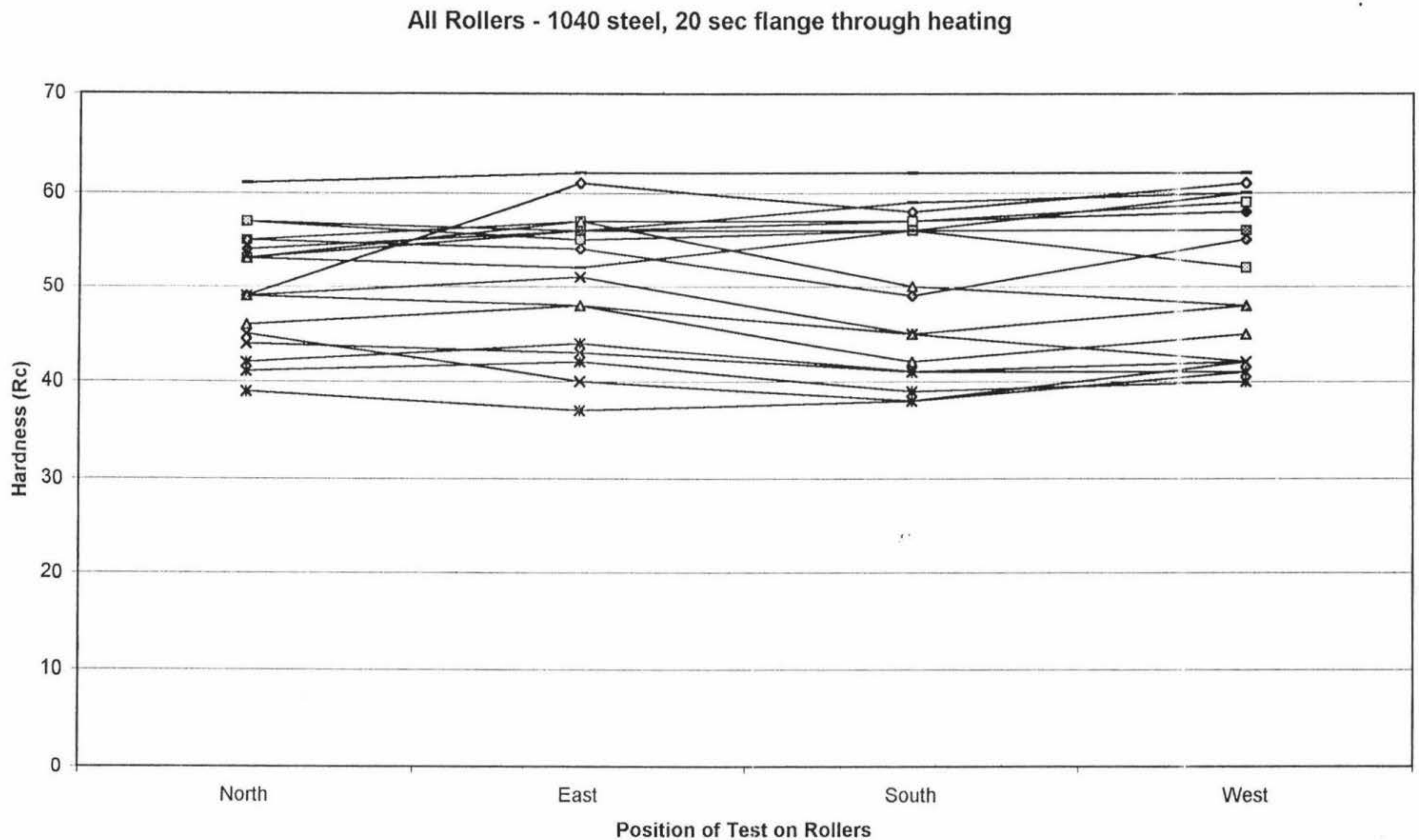
MTC to start some succession planning with Garth and Greg for cost reduction & process improvement after the project is over.

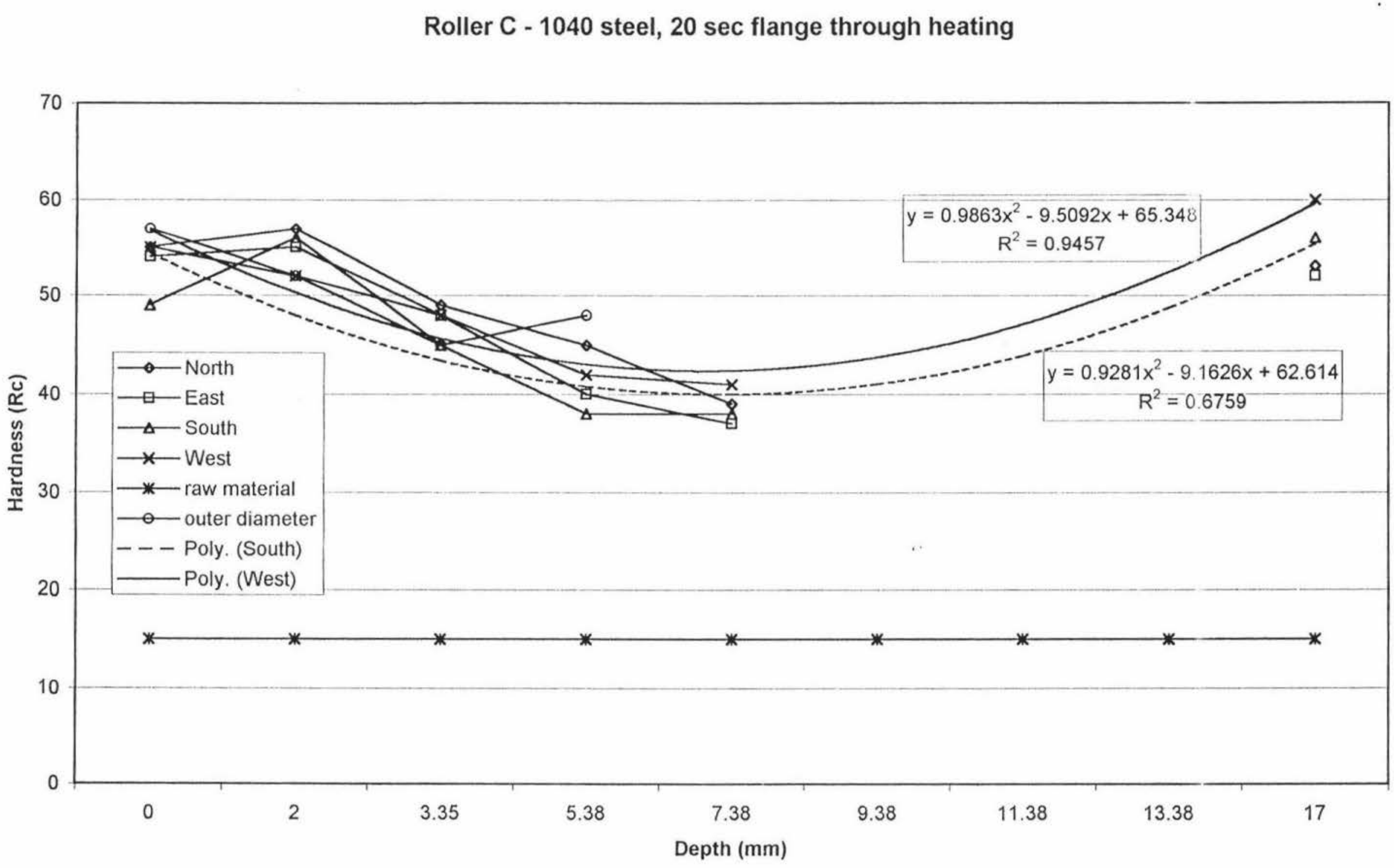
4. Reports

There are progress and annual reports due. MTC will contact Technology NZ & clarify what is necessary.

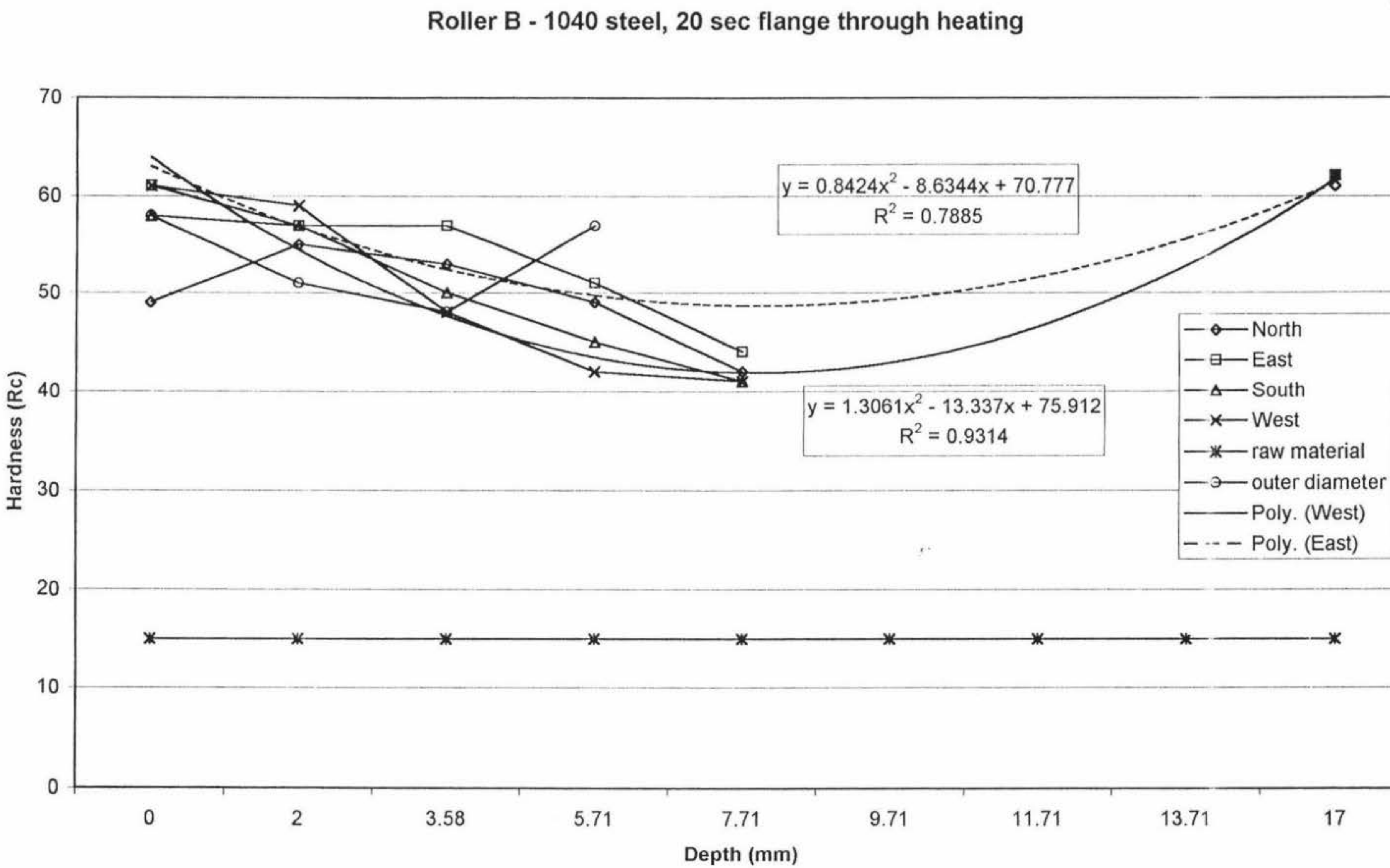
5. Next meeting is tentatively set at 9:30am, Wednesday 27 September 2000. Please contact me if this is unsuitable and I will organise a more mutually convenient time.

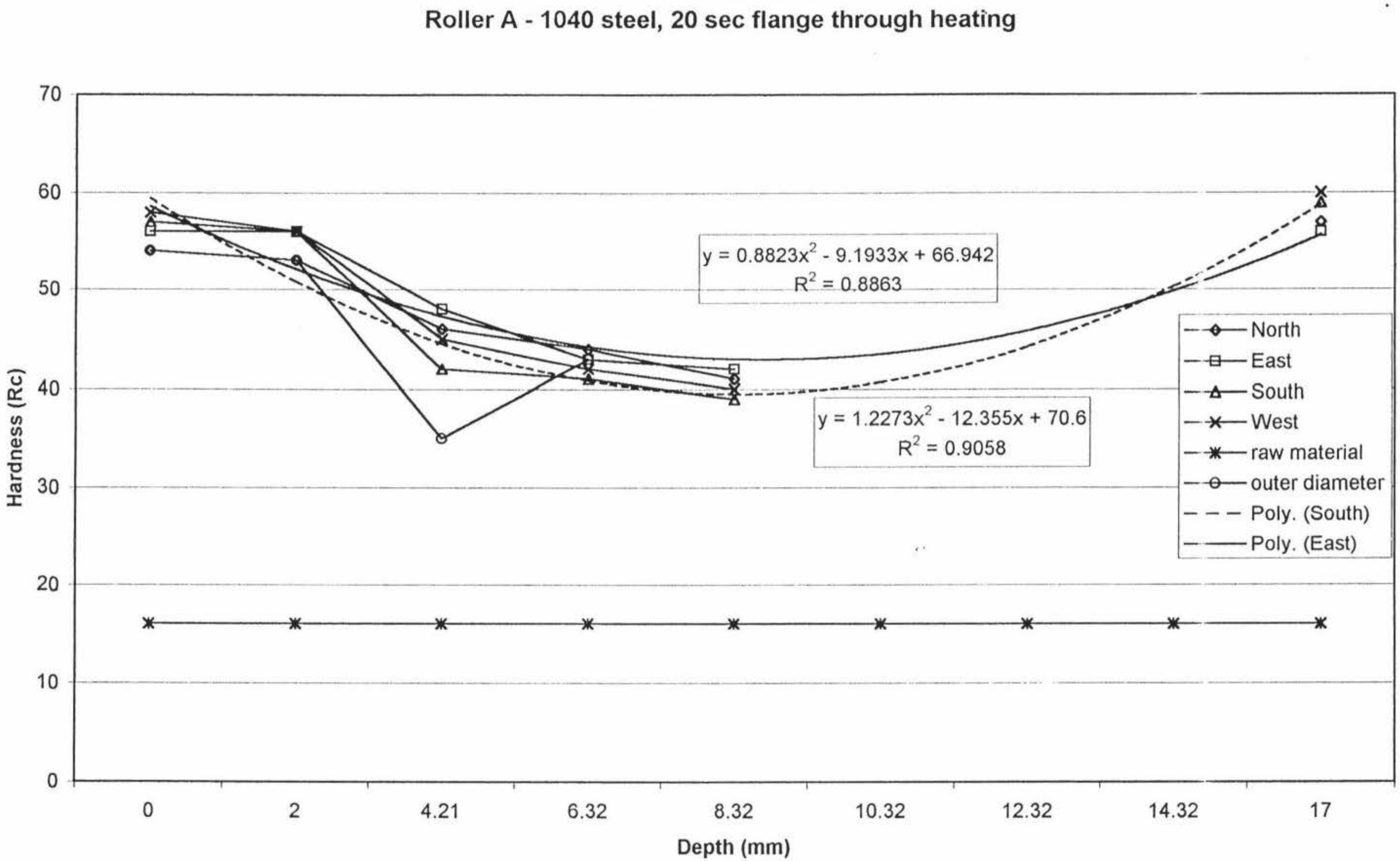
Mark Mark


All Rollers - 1040 steel, 20 sec flange through heating
70
60
50
40
30
20
10
0
Hardness (Rc)
North
East
South
West
Position of Test on Rollers



Roller C - 1040 steel, 20 sec flange through heating
Hardness (Rc)
Depth (mm)
70
60
50
40
30
20
10
0
0
2
3.35
5.38
7.38
9.38
11.38
13.38
17
North
East
South
West
raw material
outer diameter
Poly. (South)
Poly. (West)
y = 0.9863x² - 9.5092x + 65.348
R² = 0.9457
y = 0.9281x² - 9.1626x + 62.614
R² = 0.6759


Roller B - 1040 steel, 20 sec flange through heating
y = 0.8424x^2 - 8.6344x + 70.777
R^2 = 0.7885
y = 1.3061x^2 - 13.337x + 75.912
R^2 = 0.9314
North
East
South
West
raw material
outer diameter
Poly. (West)
Poly. (East)
Hardness (Rc)
70
60
50
40
30
20
10
0
0
2
3.58
5.71
7.71
9.71
11.71
13.71
17
Depth (mm)



Roller A - 1040 steel, 20 sec flange through heating
70
60
50
40
30
20
10
0
Hardness (Rc)
0
2
4.21
6.32
8.32
10.32
12.32
14.32
17
Depth (mm)
y = 0.8823x^2 - 9.1933x + 66.942
R^2 = 0.8863
y = 1.2273x^2 - 12.355x + 70.6
R^2 = 0.9058
North
East
South
West
raw material
outer diameter
Poly. (South)
Poly. (East)

Roller A

Approx Depth of Cut	thickness (mm)	depth (mm)	North	East	South	West	raw material
0	17	0	54	56	57	58	16
2	15	2	53	56	56	56	16
4	12.79	4.21	46	48	42	45	16
6	10.68	6.32	44	43	41	42	16
8	8.68	8.32	41	42	39	40	16
	6.68	10.32					16
	4.68	12.32					16
	2.68	14.32					16
	0	17	57	56	59	60	16
		outer diameter	54	53	35	43	

Roller B

Approx Depth of Cut	thickness (mm)	depth (mm)	North	East	South	West	raw material
0	17	0	49	61	58	61	15
2	15	2	55	57	57	59	15
4	13.42	3.58	53	57	50	48	15
6	11.29	5.71	49	51	45	42	15
8	9.29	7.71	42	44	41	41	15
	7.29	9.71					15
	5.29	11.71					15
	3.29	13.71					15
	0	17	61	62	62	62	15
		outer diameter	58	51	48	57	

Roller C

Approx Depth of Cut	thickness (mm)	depth (mm)	North	East	South	West	raw material
0	17	0	55	54	49	55	15
2	15	2	57	55	56	52	15
4	13.65	3.35	49	48	45	48	15
6	11.62	5.38	45	40	38	42	15
8	9.62	7.38	39	37	38	41	15
	7.62	9.38					15
	5.62	11.38					15
	3.62	13.38					15
	0	17	53	52	56	60	15
		outer diameter	57	52	45	48	

Minutes of meeting 04/10/00

Present: Harvey, Garth, Greg, and Mark

1. Tech NZ Reports

MTC to organise extension of reports and get them in to Technology NZ.

2. Succession Planning

Meetings must be held soon with Garth, Greg & MTC. Tentatively one during week of 23 - 29 Oct and the second and final during week of 13 - 19 Nov.

3. Induction Automation

Progress on the induction automation has been very slow. No fabricators have been available to date. Apologies were made by Garth and he indicated that two new fabricators would be starting soon and one of them would be put straight onto the job. He estimated three days to complete hopper and frames.

It was discussed that time was drawing to a close very quickly and we needed to get this done ASAP.

MTC is to do a costing on the savings of automatic pin hardening using a zero labour rate in the BOM-Route sheet spreadsheet. Due next meeting.

4. Roller Heat Treatment

MTC made a presentation (attached) of the latest 12/15K roller induction hardening results. Curved surface (inner and outer diameters) processes shown and discussed were:

- Single process / inner & outer coils in parallel
  - Results look OK but outside diameter middle needs improvement (possibly due to coil configuration). Centre of mass hardness tested to 35 HRc. This process may be successful but would be very difficult to execute in a high volume production situation.
- Two processes / outer first, inner second
  - Second process anneals the first process surface making this a non-viable option.
- Two processes / inner first, outer second
  - Second process anneals the first process surface making this a non-viable option.
- Heat Wave Test: heat wavefront not allowed to reach opposite diameter
  - Two processes / inner first, outer second
  - Heating times not sufficient to give full critical heating coverage over appropriate surfaces. Second process still annealed first process surface.
- Two processes / inner first, outer second / inner surface water cooled
  - This process was as done before but the inner diameter surface was partially cooled using a plugged bush and a small amount of water.
  - Results indicate that cooling the inner surface (albeit incompletely) had the effect of not annealing the first process surface as severely as the non-cooled roller. I feel if the inner was cooled properly (more water directly on the inner surface), results would be distinctly improved.

NB: Outliers were deemed to be a result of imperfections (bent, non-round, etc) in the coil windings.

MTC is to draw up a map of hardness on the cross section of the rollers.

The 1999 sales figures (including footage as a percentage, heat treatment costs as a percentage, etc) were presented (attached) to illustrate that at this stage the 24/30K rollers should not be pursued and that the 6/7.5K and 12/15K rollers represent the major bulk of production and heat treatment costs of standard chains (approximately 95%).

The 24/30K rollers are also too big a mass to be processed by our 15kWatt heater. It does not have the power to heat the surface quickly enough and as such the roller through heats. The 12/15K rollers are on the upper limits of surface heating on this induction heater. Even 25mm diameter x 100mm length pins are outside of the capabilities of this machine (from trials).

Through heating with oil quenching of the 24/30K rollers was trialed with poor results. All surfaces were in the range of 30 to 35 HRc.

5. Roller Heat Treatments Next Steps

Roller Type	**Ideal Results (curved surface heating)**	**30/40/30 layered (flange heating)**	**All Hard**
6/7.5K	Can't do - inner too small	To test	Too brittle
12/15K	OK using 1. Two stage heating + cooling the inner OR 2. Single stage heating (inner/outer in parallel)	To test	Too hard throughout (40+ HRc)
NB: All quenching done in cold town water supply.			

The above table shows the basic results to date of induction heating to date. The 30/40/30 layered approach is heating the roller via the flange but only hardening the outside (flanges) 30% leaving the inner 40% 'pancake' in an untreated state. This method was not well received by Greg and Mark as it leaves a large untreated surface in a position that receives much wear. This is not so much of an issue with the smaller rollers (there is also no choice) but is unacceptable in the 12/15K rollers. MTC is to trial the 30/40/30 flange method ASAP

MTC is also to trial through heating and oil quenching of the 6/7.5K rollers.

6. Next Meeting

The meeting is tentatively set at 1pm, Friday 20 October 2000. The 18th & 19th October is not suitable for me. Please contact me if the chosen date and/or time is unsuitable and I will organise a more mutually convenient time.

Mark

Sales Volumes (ft) by Calendar Year							
Chain	1999 (ft)	2000 to end April (ft)	cost/ft	Cost of Chain 1999	HTAuck/ft (incl freight)	Percentage of Case Hardening per Foot	1999 Theoretical Case Hardening Costs
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6K3.0	405	302	$ 14.99	$ 6,071.28	$ 1.74	12%	$ 704.89
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7.5K3.0	1396	1022	$ 12.95	$ 18,079.33	$ 1.74	13%	$ 2,429.71
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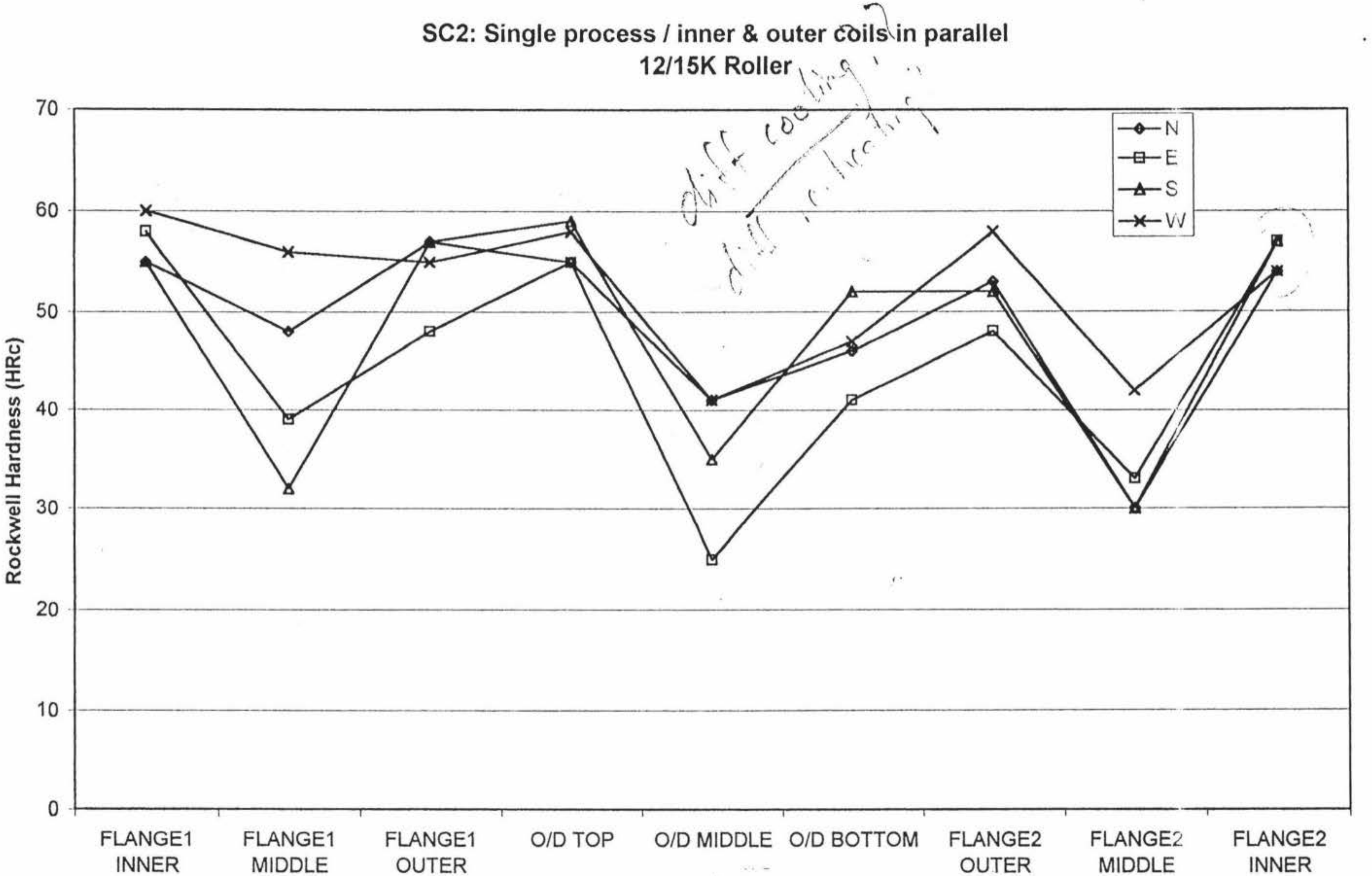
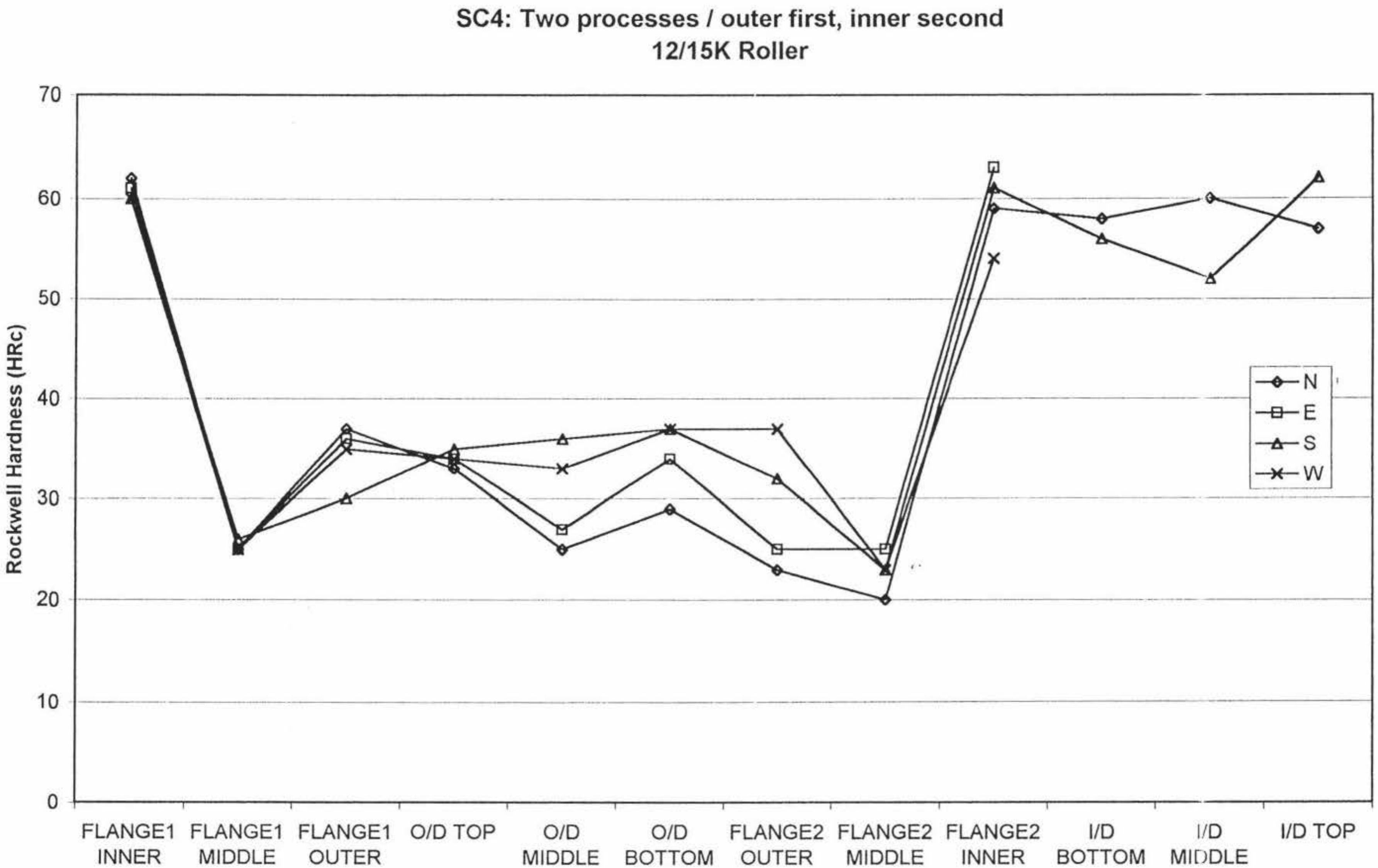
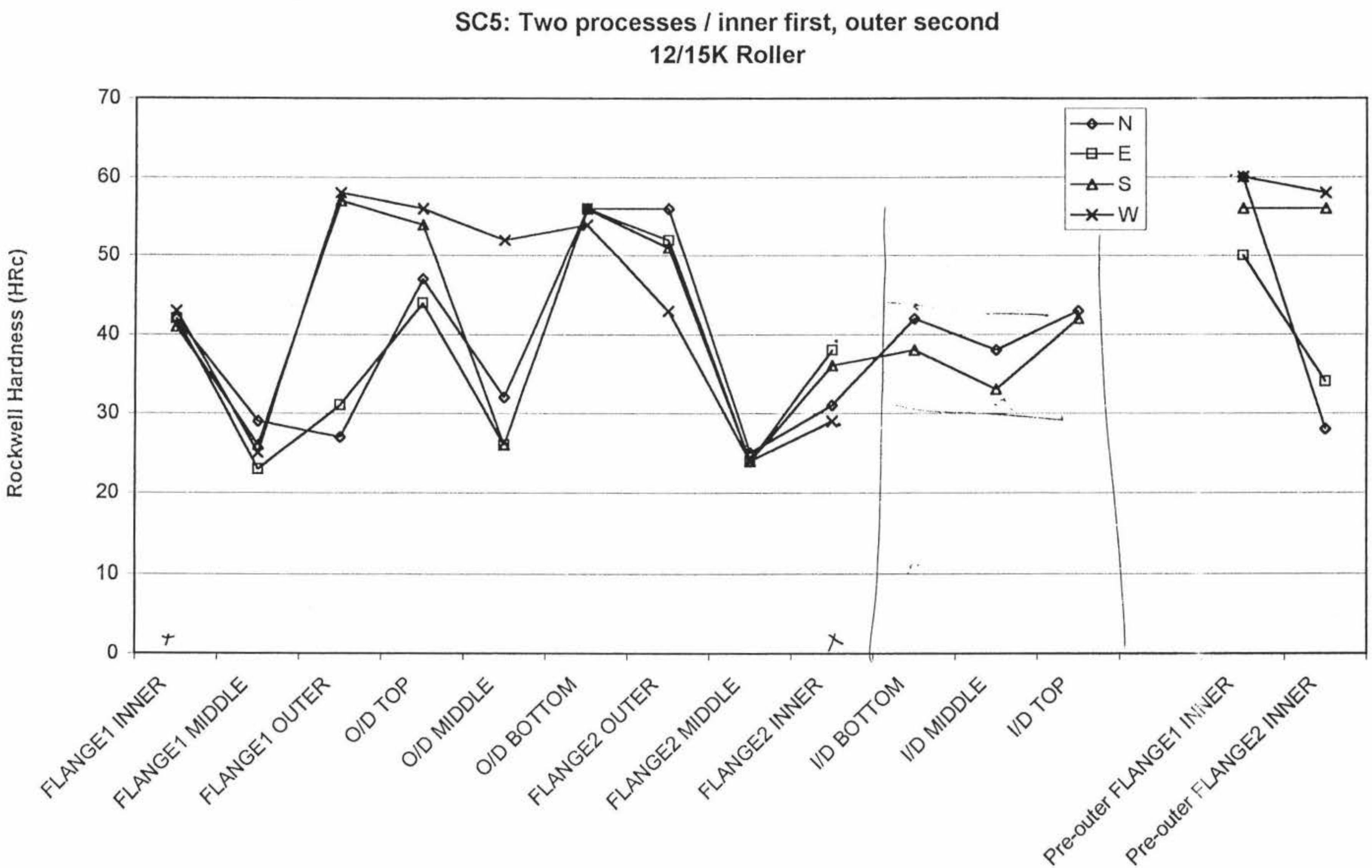
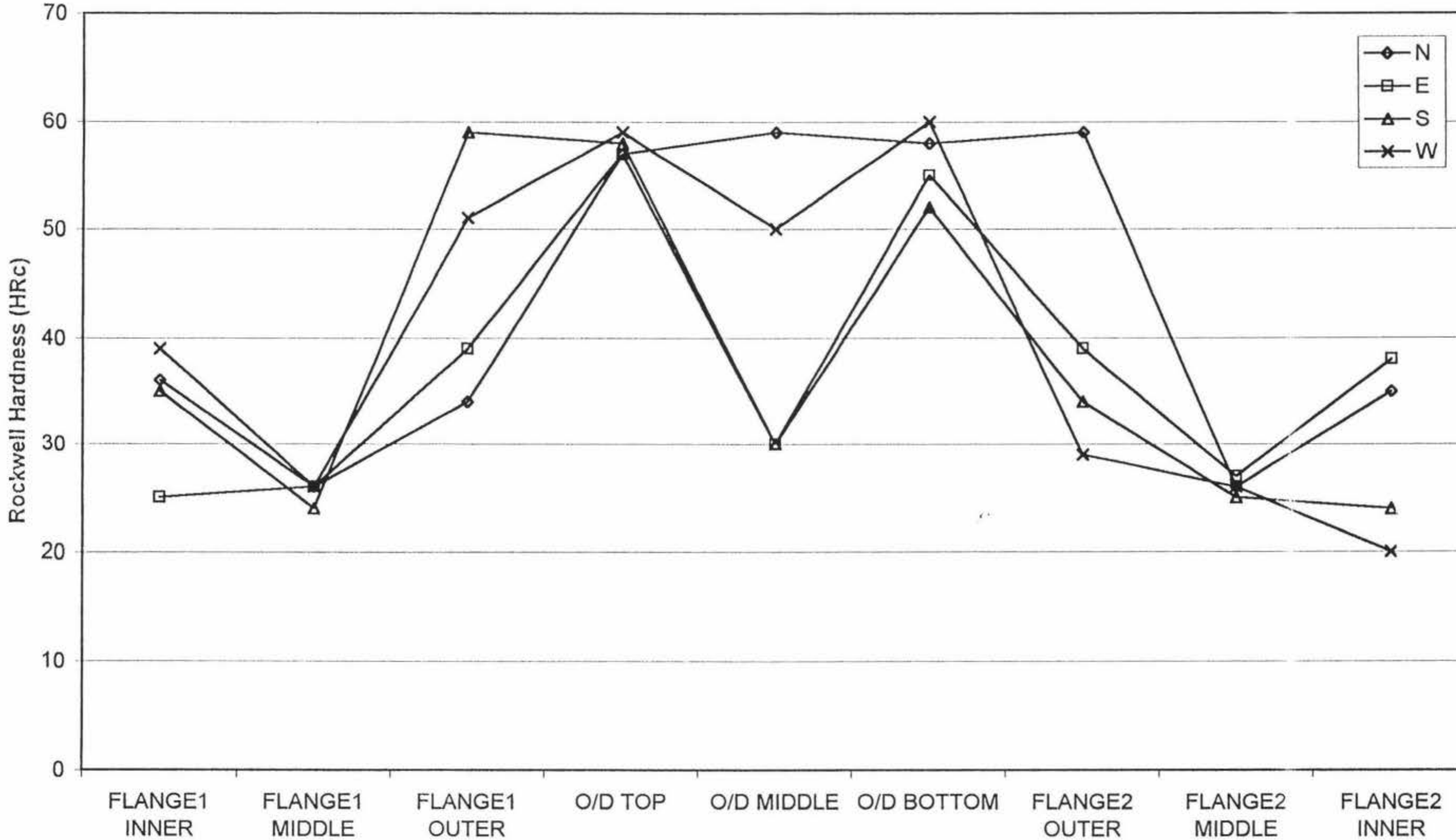
7.5K6.0	847		$ 6.94	$ 5,881.31	$ 0.87	13%	$ 737.09
	7459			$ 87,070.20			$ 13,295.37
24/30K6.0			$ 23.42	($/ft is approximate)	$ 7.04	30%	
	2273.50	m					
	1999			1999			
	footage	footage as %	$$	heat trtmnt costs as %		$ case hard/roller	$ case hard/bush
3/4.5K	263	4%	not avail	not avail		not avail	not avail
6/7.5K	5664	76%	$ 7,554.99	57%		$ 0.35	$ 0.09
12/15K	1532	21%	$ 5,740.39	43%		$ 1.18	$ 0.19
24/30K	NIL	NIL	NIL	NIL		$ 2.95	$ 0.57
NB: These costings include bushes and rollers.							
NB: Calc/ft = (((component costs * 2) * 6) / pitch)							

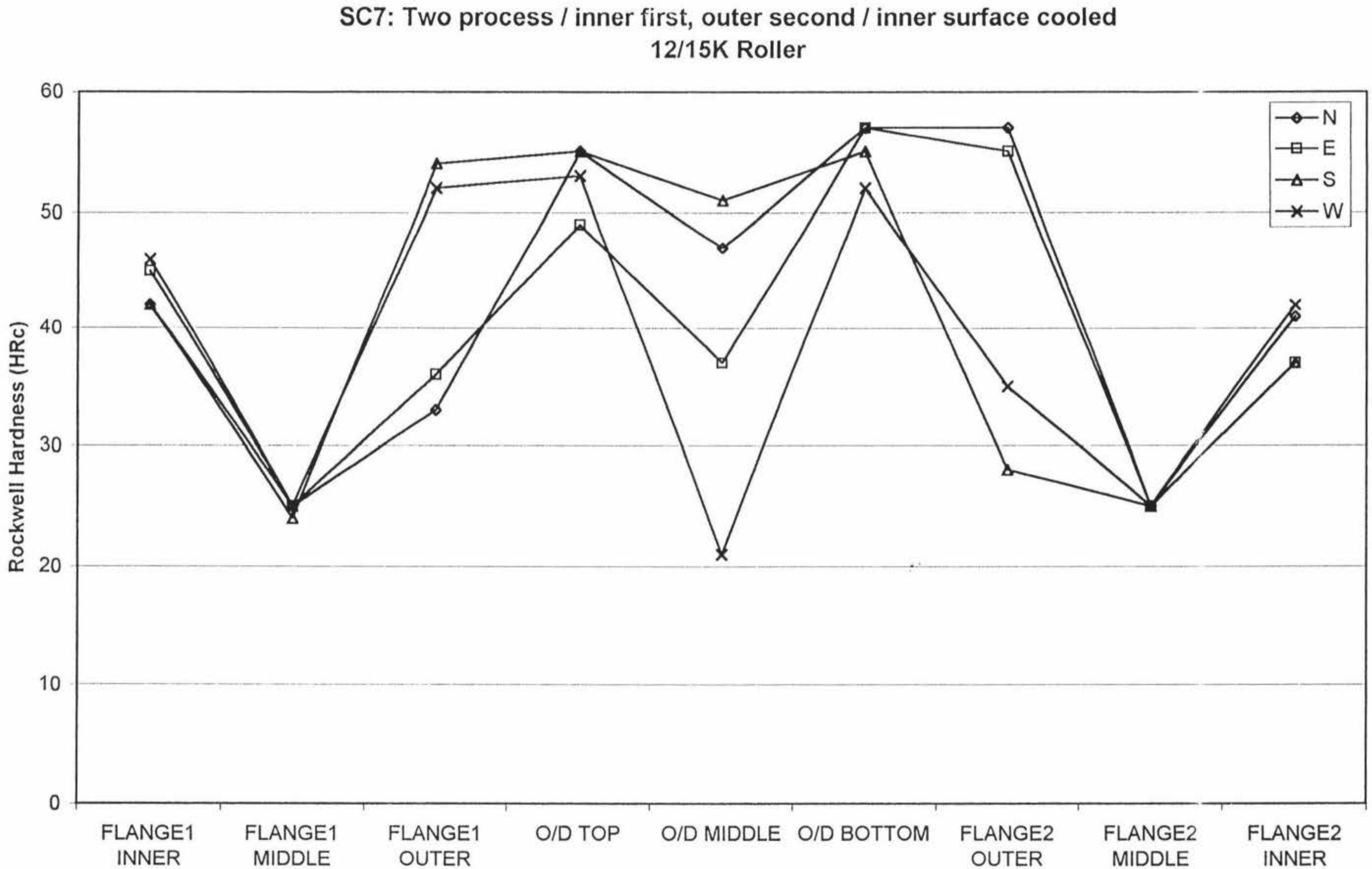

SC2: Single process / inner & outer coils in parallel
12/15K Roller
Rockwell Hardness (HRc)
70
60
50
40
30
20
10
0
N
E
S
W
FLANGE1 INNER
FLANGE1 MIDDLE
FLANGE1 OUTER
O/D TOP
O/D MIDDLE
O/D BOTTOM
FLANGE2 OUTER
FLANGE2 MIDDLE
FLANGE2 INNER


SC4: Two processes / outer first, inner second
12/15K Roller
Rockwell Hardness (HRc)
70
60
50
40
30
20
10
0
FLANGE1 INNER
FLANGE1 MIDDLE
FLANGE1 OUTER
O/D TOP
O/D MIDDLE
O/D BOTTOM
FLANGE2 OUTER
FLANGE2 MIDDLE
FLANGE2 INNER
I/D BOTTOM
I/D MIDDLE
I/D TOP
N
E
S
W


SC5: Two processes / inner first, outer second
12/15K Roller
Rockwell Hardness (HRc)
70
60
50
40
30
20
10
0
N
E
S
W
FLANGE1 INNER
FLANGE1 MIDDLE
FLANGE1 OUTER
O/D TOP
O/D MIDDLE
O/D BOTTOM
FLANGE2 OUTER
FLANGE2 MIDDLE
FLANGE2 INNER
I/D BOTTOM
I/D MIDDLE
I/D TOP
Pre-outer FLANGE1 INNER
Pre-outer FLANGE2 INNER

SC6: Heat Wave Test: Heat wavefront not allowed to reach opposite diameter
Two processes / inner first, outer second, 12/15K Roller




SC7: Two process / inner first, outer second / inner surface cooled
12/15K Roller
Rockwell Hardness (HRc)
60
50
40
30
20
10
0
N
E
S
W
FLANGE1 INNER
FLANGE1 MIDDLE
FLANGE1 OUTER
O/D TOP
O/D MIDDLE
O/D BOTTOM
FLANGE2 OUTER
FLANGE2 MIDDLE
FLANGE2 INNER

12/15K Roller Induction Heating Data

SC2 — Single process / inner & outer coils in parallel

	N	E	S	W
FLANGE1 INNER	55	58	55	60
FLANGE1 MIDDLE	48	39	32	56
FLANGE1 OUTER	57	48	57	55
O/D TOP	55	55	59	58
O/D MIDDLE	41	25	35	41
O/D BOTTOM	46	41	52	47
FLANGE2 OUTER	53	48	52	58
FLANGE2 MIDDLE	30	33	30	42
FLANGE2 INNER	54	57	57	54

SC4 — Two processes / outer first, inner second

	N	E	S	W		
FLANGE1 INNER	62	61	60	60		
FLANGE1 MIDDLE	25	25	26	25		
FLANGE1 OUTER	37	36	30	35		
O/D TOP	33	34	35	34	57	62
O/D MIDDLE	25	27	36	33	60	52
O/D BOTTOM	29	34	37	37	58	56
FLANGE2 OUTER	23	25	32	37		
FLANGE2 MIDDLE	20	25	23	23		
FLANGE2 INNER	59	63	61	54		
I/D BOTTOM	58		56			
I/D MIDDLE	60		52			
I/D TOP	57		62			

SC5 — Two processes / inner first, outer second

	N	E	S	W
FLANGE1 INNER	42	42	41	43
FLANGE1 MIDDLE	29	23	26	25
FLANGE1 OUTER	27	31	57	58
O/D TOP	47	44	54	56
O/D MIDDLE	32	26	26	52
O/D BOTTOM	56	56	56	54
FLANGE2 OUTER	56	52	51	43
FLANGE2 MIDDLE	25	24	24	24
FLANGE2 INNER	31	38	36	29
I/D BOTTOM	42		38	
I/D MIDDLE	38		33	
I/D TOP	43		42	
Pre-outer FLANGE1 INNER	60	50	56	60
Pre-outer FLANGE2 INNER	28	34	56	58

SC6 — Heat Wave Test
Two processes / inner first, outer second
Heat wavefront not allowed to reach opposite diameter

	N	E	S	W
FLANGE1 INNER	36	25	35	39
FLANGE1 MIDDLE	26	26	24	26
FLANGE1 OUTER	34	39	59	51
O/D TOP	57	57	58	59
O/D MIDDLE	59	30	30	50
O/D BOTTOM	58	55	52	60
FLANGE2 OUTER	59	39	34	29
FLANGE2 MIDDLE	26	27	25	26
FLANGE2 INNER	35	38	24	20

SC7 — Two process / inner first, outer second / inner surface cooled

	N	E	S	W
FLANGE1 INNER	42	45	42	46
FLANGE1 MIDDLE	25	25	24	25
FLANGE1 OUTER	33	36	54	52
O/D TOP	55	49	55	53
O/D MIDDLE	47	37	51	21
O/D BOTTOM	57	57	55	52
FLANGE2 OUTER	57	55	28	35
FLANGE2 MIDDLE	25	25	25	25
FLANGE2 INNER	41	37	37	42

Minutes of meeting 19/10/00

Present: Harvey, Ralph, Garth, Greg, and Mark

1. Tech NZ Reports

All are in except the final report, which is due after completion of the project.

2. Succession Planning

Meeting planned for 25 October, 9am.

3. Induction Automation

Going very well & on schedule.

4. Roller Heat Treatment

Results of the latest heating tests and a roller trials recommendation paper were distributed.

Garth brought up the issue of using a material that already has the requisite hardness. Greg indicated there would be problems with machining, material cost, etc.

The recommendation of trialing the Princess Leah coil for the 6/7.5K rollers and the cooled dual process for the 12/15K rollers was accepted.

Much discussion was had on the possibilities of various coil configurations, their difficulties and possible benefits. Harvey and Ralph decided to do some experimentation with constructing a small inner coil for the 6/7.5K roller at Massey. Harvey noted on his piece of paper the words "I told you so." !! ;-)

Press fitting the inner surfaces of the coils was considered but a hardened rolled inner would cause problems if the splits of both the roller inner and the bush met under load. The cost of a machined inner would be too high to be feasible.

5. Induction Automation Savings

The bill of materials - route sheet show a discrete saving of only 0.7% to 1.4% with automation on the manual labour costing per foot of chain. This figure is too low to say the least but as discussion of the issue showed, the discrete numbers in the spreadsheet do not reflect practical savings. The savings in relation to labour units are between 1/4 to 1/2 a labour unit per annum, which represents between $5000 and $10,000 in wages (minimum).

6. Next Meeting

The meeting is tentatively set at 9am, Wednesday 1 November 2000. Please contact me if the chosen date and/or time is unsuitable and I will organise a more mutually convenient time.

Mark

12/15K Roller Induction Heating Data (CURVED SURFACES HEATING)

SC2 — Single process / inner & outer coils in parallel

	N	E	S	W
FLANGE1 INNER	55	58	55	60
FLANGE1 MIDDLE	48	39	32	56
FLANGE1 OUTER	57	48	57	55
O/D TOP	55	55	59	58
O/D MIDDLE	41	25	35	41
O/D BOTTOM	46	41	52	47
FLANGE2 OUTER	53	48	52	58
FLANGE2 MIDDLE	30	33	30	42
FLANGE2 INNER	54	57	57	54

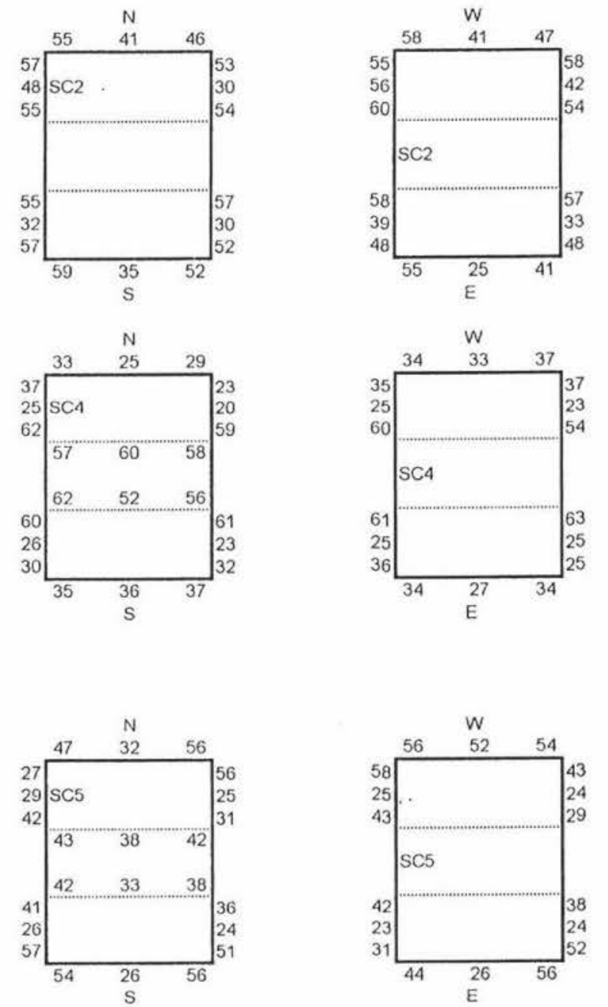
SC4 — Two processes / outer first, inner second

	N	E	S	W
FLANGE1 INNER	62	61	60	60
FLANGE1 MIDDLE	25	25	26	25
FLANGE1 OUTER	37	36	30	35
O/D TOP	33	34	35	34
O/D MIDDLE	25	27	36	33
O/D BOTTOM	29	34	37	37
FLANGE2 OUTER	23	25	32	37
FLANGE2 MIDDLE	20	25	23	23
FLANGE2 INNER	59	63	61	54
I/D BOTTOM	58		56	
I/D MIDDLE	60		52	
I/D TOP	57		62	

SC5 — Two processes / inner first, outer second

	N	E	S	W
FLANGE1 INNER	42	42	41	43
FLANGE1 MIDDLE	29	23	26	25
FLANGE1 OUTER	27	31	57	58
O/D TOP	47	44	54	56
O/D MIDDLE	32	26	26	52
O/D BOTTOM	56	56	56	54
FLANGE2 OUTER	56	52	51	43
FLANGE2 MIDDLE	25	24	24	24
FLANGE2 INNER	31	38	36	29
I/D BOTTOM	42		38	
I/D MIDDLE	38		33	
I/D TOP	43		42	
Pre-outer FLANGE1 INNER	60	50	56	60
Pre-outer FLANGE2 INNER	28	34	56	58

Roller Induction Heating Data

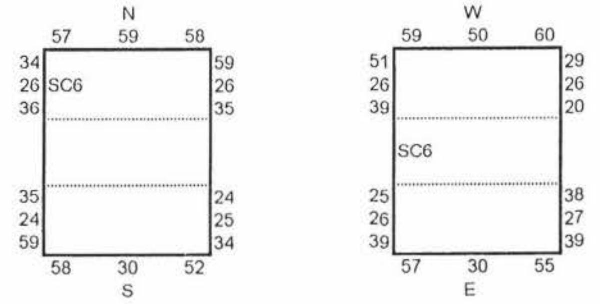


Roller Induction Heating Data

SC6

Heat Wave Test
Two processes / inner first, outer second
Heat wavefront not allowed to reach opposite diameter

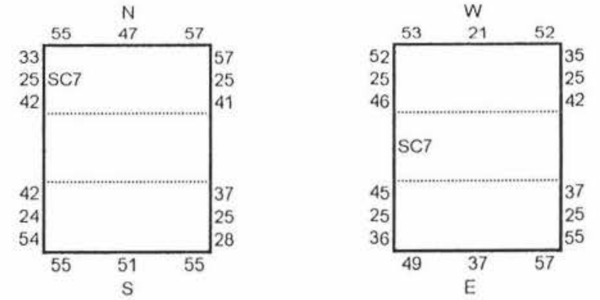
	N	E	S	W
FLANGE1 INNER	36	25	35	39
FLANGE1 MIDDLE	26	26	24	26
FLANGE1 OUTER	34	39	59	51
O/D TOP	57	57	58	59
O/D MIDDLE	59	30	30	50
O/D BOTTOM	58	55	52	60
FLANGE2 OUTER	59	39	34	29
FLANGE2 MIDDLE	26	27	25	26
FLANGE2 INNER	35	38	24	20



SC7

Two process / inner first, outer second / inner surface cooled

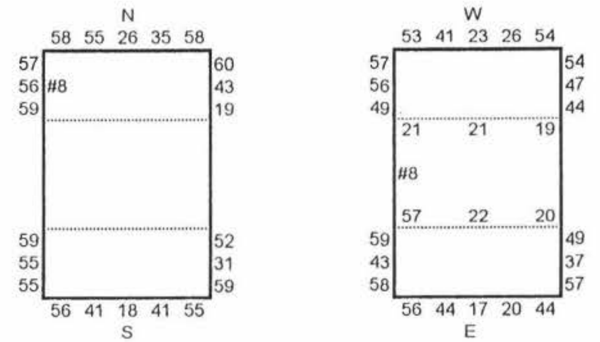
	N	E	S	W
FLANGE1 INNER	42	45	42	46
FLANGE1 MIDDLE	25	25	24	25
FLANGE1 OUTER	33	36	54	52
O/D TOP	55	49	55	53
O/D MIDDLE	47	37	51	21
O/D BOTTOM	57	57	55	52
FLANGE2 OUTER	57	55	28	35
FLANGE2 MIDDLE	25	25	25	25
FLANGE2 INNER	41	37	37	42

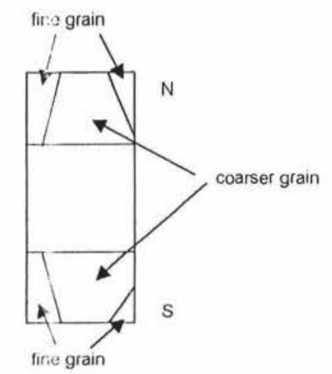


#8

12/15Kroller / Flange heat using 30/40/30 rule

	N	E	S	W
FLANGE1 INNER	59	59	59	49
FLANGE1 MIDDLE	56	43	55	56
FLANGE1 OUTER	57	58	55	57
O/D TOP	58	56	56	53
	55	44	41	41
O/D MIDDLE	26	17	18	23
	35	20	41	26
O/D BOTTOM	58	44	55	54
FLANGE2 OUTER	60	57	59	54
FLANGE2 MIDDLE	43	37	31	47
FLANGE2 INNER	19	49	52	44
I/D BOTTOM		20		19
I/D MIDDLE		22		21
I/D TOP		57		21



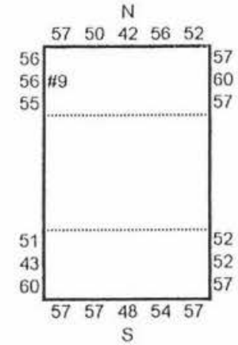


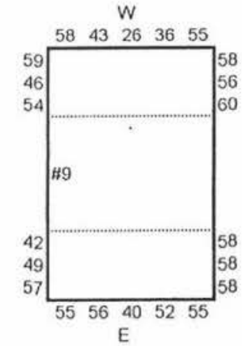
NB:

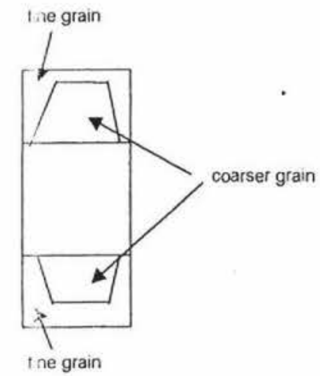
1. Two pancake coils / Approx 5 to 5.5 turns each / wound same direction
2. 65mm to 70mm diameter
3. Coils placed in volume centre between coils
4. P=12.5 / T=8 sec
5. HAMMER TEST: approx 6 blows with med ball pean - roller broke into two pieces

#9 12/15Kroller / Flange heat using 30/40/30 rule

	N	E	S	W
FLANGE1 INNER	55	42	51	54
FLANGE1 MIDDLE	56	49	43	46
FLANGE1 OUTER	56	57	60	59
O/D TOP	57	55	57	58
	50	56	57	43
O/D MIDDLE	42	40	48	26
	56	52	54	36
O/D BOTTOM	52	55	57	55
FLANGE2 OUTER	57	58	57	58
FLANGE2 MIDDLE	60	58	52	56
FLANGE2 INNER	57	58	52	60
I/D BOTTOM				
I/D MIDDLE				
I/D TOP				



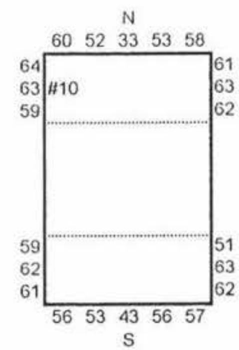


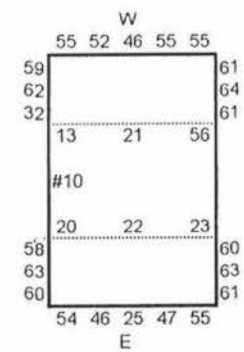


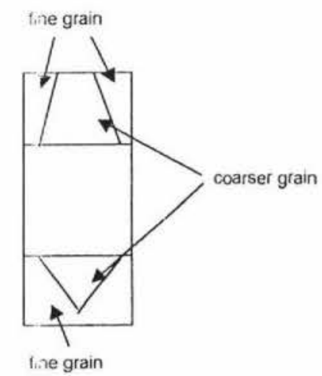
NB:
1. Two pancake coils / Approx 5 to 5.5 turns each / wound same direction
2. 65mm to 70mm diameter
3. Coils placed in volume centre between coils
4. P=12.5 / T=10 sec
5. HAMMER TEST: approx 3 blows with med ball pean - roller broke into two pieces

#10 6/7.5Kroller / Flange heat using 30/40/30 rule

	N	E	S	W
FLANGE1 INNER	59	58	59	32
FLANGE1 MIDDLE	63	63	62	62
FLANGE1 OUTER	64	60	61	59
O/D TOP	60	54	56	55
	52	46	53	52
O/D MIDDLE	33	25	43	46
	53	47	56	55
O/D BOTTOM	58	55	57	55
FLANGE2 OUTER	61	61	62	61
FLANGE2 MIDDLE	63	63	63	64
FLANGE2 INNER	62	60	51	61
I/D BOTTOM		23		56
I/D MIDDLE		22		21
I/D TOP		20		13



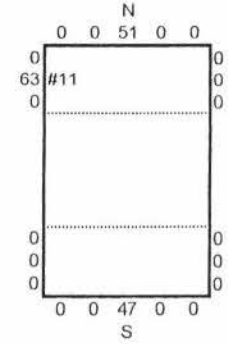


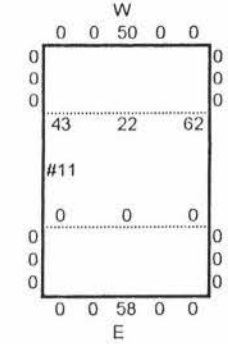


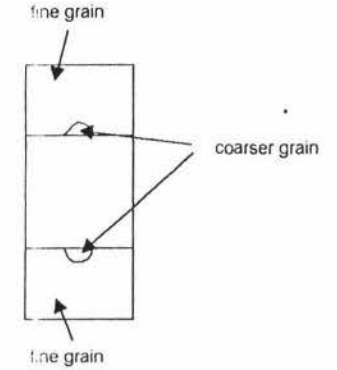
NB:
1. Two pancake coils / Approx 5 to 5.5 turns each / wound same direction
2. 65mm to 70mm diameter
3. Coils placed in volume centre between coils
4. P=13 / T=5 sec
5. HAMMER TEST: approx 2 blows with med ball pean - roller broke into 3 pieces / roller deformed oval before breaking

#11 6/7.5Kroller / Flange heat using 30/40/30 rule

	N	E	S	W
FLANGE1 INNER				
FLANGE1 MIDDLE	63			
FLANGE1 OUTER				
O/D TOP				
O/D MIDDLE	51	58	47	50
O/D BOTTOM				
FLANGE2 OUTER				
FLANGE2 MIDDLE				
FLANGE2 INNER				
I/D BOTTOM				62
I/D MIDDLE				22
I/D TOP				43





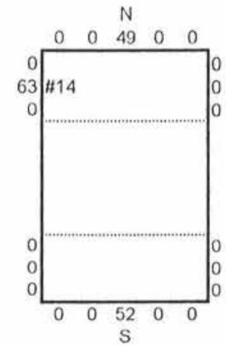


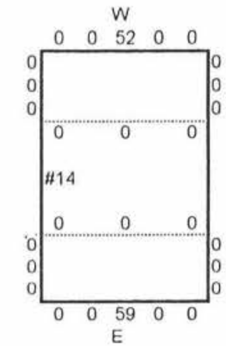
NB:

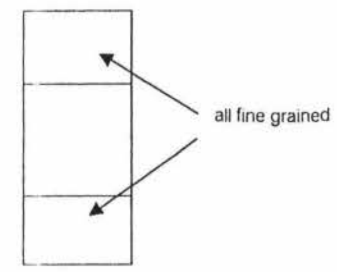
1. Two pancake coils / Approx 5 to 5.5 turns each / wound same direction
2. 65mm to 70mm diameter
3. Coils placed in volume centre between coils
4. P=13 / T=6 sec
5. HAMMER TEST: one blow with med ball pean - roller broke into 3 pieces / no deformation before breaking / roller TOO HARD

#14 6/7.5Kroller / Flange heat using 30/40/30 rule

	N	E	S	W
FLANGE1 INNER				
FLANGE1 MIDDLE	63			
FLANGE1 OUTER				
O/D TOP				
O/D MIDDLE	49	59	52	52
O/D BOTTOM				
FLANGE2 OUTER				
FLANGE2 MIDDLE				
FLANGE2 INNER				
I/D BOTTOM				
I/D MIDDLE				
I/D TOP				







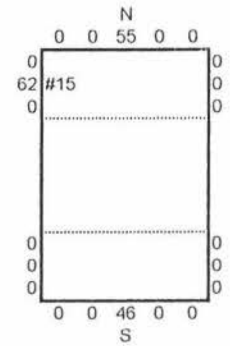
NB:

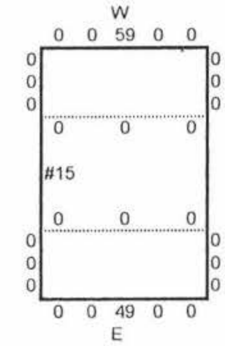
1. Two pancake coils / Approx 5 to 5.5 turns each / wound same direction
2. 65mm to 70mm diameter
3. Coils placed in volume centre between coils
4. P=14 / T=6 sec
5. HAMMER TEST: one blow with med ball pean - roller broke into 3 pieces / no deformation before breaking / roller TOO HARD

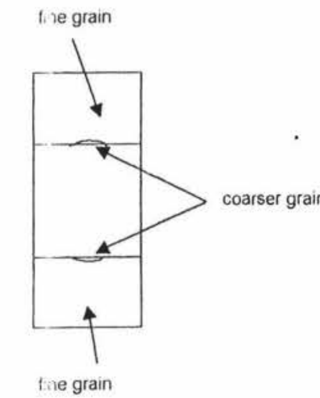
Roller Induction Heating Data

#15 6/7.5Kroller / Flange heat using 30/40/30 rule

	N	E	S	W
FLANGE1 INNER				
FLANGE1 MIDDLE	62			
FLANGE1 OUTER				
O/D TOP				
O/D MIDDLE	55	49	46	59
O/D BOTTOM				
FLANGE2 OUTER				
FLANGE2 MIDDLE				
FLANGE2 INNER				
I/D BOTTOM				
I/D MIDDLE				
I/D TOP				



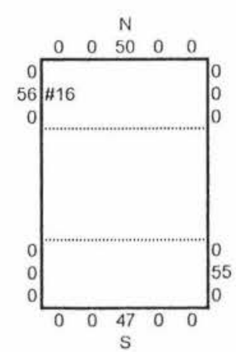


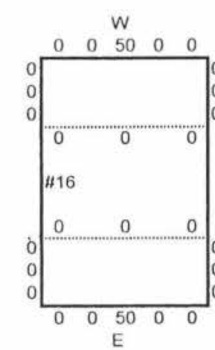


NB:
1. Two pancake coils / Approx 5 to 5.5 turns each / wound same direction
2. 65mm to 70mm diameter
3. Coils placed in volume centre between coils
4. P=14 / T=7 sec
5. HAMMER TEST: one light blow with med ball pean - roller broke into 4 pieces / no deformation before breaking / roller TOO HARD

#16 6/7.5Kroller / Through heat using oxy-acetylene

	N	E	S	W
FLANGE1 INNER				
FLANGE1 MIDDLE	56			
FLANGE1 OUTER				
O/D TOP				
O/D MIDDLE	50	50	47	50
O/D BOTTOM				
FLANGE2 OUTER				
FLANGE2 MIDDLE			55	
FLANGE2 INNER				
I/D BOTTOM				
I/D MIDDLE				
I/D TOP				





NB:
1. Through heated using oxy-actetylene torch
2. HAMMER TEST: one blow with med ball pean - roller broke into 2 pieces / no deformation before breaking / roller TOO HARD
3. Roller #17 same results

Minutes of meeting 02/11/00

Present: Harvey, Ralph, Garth, Greg, and Mark

1. Roller Induction Heat Treatment

6/7.5K Rollers

The Princess Leah coil (a standard helical coil with a gap in the middle of the windings) was totally ineffective. The coil produced two hot spots on the roller that were circumferentially opposite and on opposite sides of the roller. No amount of coil manipulation changed this.

A rectangularly wound helical coil (approx. 25mm x 75mm inside measurements x approx. 100mm long) was then made up. Ceramic blocks were placed in the bottom of the coil and fibreglass mat wound around the sides to prevent contact with the coil. The roller was then pulled through the coil. Results were very promising. A new smaller coil was made up and a ceramic channel was devised for rolling the roller through. Very good 30/40/30 flange heating results were obtained. Timing the roller in the coil is difficult due to the manual nature of the process.

The resulting hardened rollers (results under 'Roll Through Trial' in roller induction heating data spreadsheet) were mounted in an inner link and placed on a lathe running against rubber seals (roller wouldn't rotate against metal) at approximately 90rpm for 9hr 20min, resulting in about 50,000 revolutions. The rollers showed no signs of wear but this is not surprising, as the loading on them was insufficient for a fair comparison to actual.

Greg suggested testing these rollers in a local cement factory. About 20 feet of chain would be given and installed in this high wear environment. All agreed with this proposal.

Mark noted that before these rollers are placed in a commercial test they had to be consistently produced. Due to the variability of the present manual system, a mechanical system would be required. **NB: At time of writing a simple pneumatic system had been devised and purchased.**

12/15K Rollers

Rollers 18 & 19 show best results using a double process [inner 1st, outer 2nd + inner cooled] (see roller induction heating data spreadsheet). It is anticipated that results would be even better if a heat sink was designed for the bottom of the roller. It is being made up now by PML. The heat treatment of this size of roller in the induction heater has been deemed a success and the rollers are of a sufficient quality to use commercially. Mark indicated he would like to see a wear test done on the flanges before in-situ tests and final acceptance.

Testing in situ of this size roller is to be investigated by Garth and Greg. Mark is to set up a flange wear test in-house.

24/30K Rollers

Mark is to trial induction heat these rollers in the same manner as the 12/15K rollers.
NB: At time of writing this trial had failed to produce acceptable results. The current induction heater has insufficient power for this size of roller.

2. Roller Heat Treatment Savings

The spreadsheet was discussed. Assuming worst case scenario's (ie: slowest rate) inhouse induction heat treatment could save between 32% (6/7.5K rollers) and 60% (12/15K rollers).

3. Succession Planning

Planning list was handed out and discussed briefly. Next (final?) meeting tentatively 17 November.

4. Factory Automation Savings

Spreadsheet issued and discussed. Ralph noted that the discrete savings figures are somewhat irrelevant as it is the overall effect in dollar savings and hence extra possible sales that is the important issue and actually the real measurement of whether automation is worth while. Greg estimated that for a 20% to 30% reduction in costs it would be feasible to almost double the sales of stock chain (in particular 6/7.5K chain).

5. Pin Induction Automation

This project is going well although is a bit behind. At the moment it is waiting on electrical and pneumatic wiring (Carl) and the micro programming (Mark). Garth suggested that once it is operational there should be some publicity.

6. TBG

Garth and Ralph need to meet to get ideas and possibilities down on paper. A meeting with Lins Kerr of Technology NZ would also be in order.

Ralph indicated several options are available. There is the TBG (which is restrictive in terms of its requirements - 20% cash injection / 30% in-kind / 50% TBG / 3rd party involved [university] / must have technological development) and also the Small Business Growth scheme (more open - not as stringent requirements).

7. Next Meeting

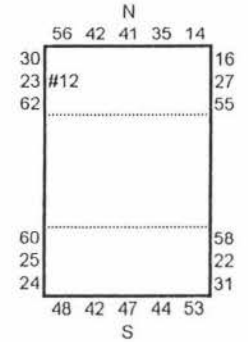
The meeting is tentatively set at ***9:30am, Wednesday 17 November 2000***. Please contact me if the chosen date and/or time is unsuitable and I will organise a more mutually convenient time.

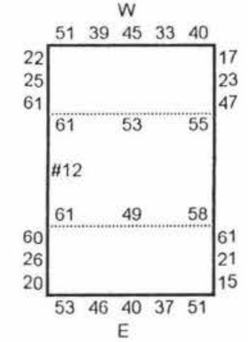
Mark

#12 — 12/15K roller / double process - inner first, outer second + inner cooled

	N	E	S	W
FLANGE1 INNER	62	60	60	61
FLANGE1 MIDDLE	23	26	25	25
FLANGE1 OUTER	30	20	24	22
O/D TOP	56	53	48	51
	42	46	42	39
O/D MIDDLE	41	40	47	45
	35	37	44	33
O/D BOTTOM	14	51	53	40
FLANGE2 OUTER	16	15	31	17
FLANGE2 MIDDLE	27	21	22	23
FLANGE2 INNER	55	61	58	47
I/D BOTTOM		58		55
I/D MIDDLE		49		53
I/D TOP		61		61

NB:
1. Outer is old square copper tubing & coil has had a hard life (very imperfect)
2. Inner P=16.5, T=11s / Outer P=11, T=7s

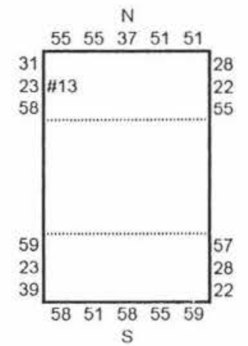


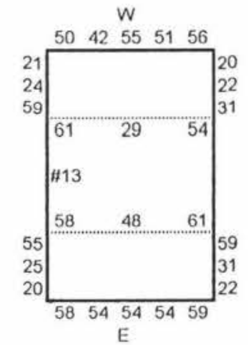


#13 — 12/15K roller / double process - inner first, outer second + inner cooled

	N	E	S	W
FLANGE1 INNER	58	55	59	59
FLANGE1 MIDDLE	23	25	23	24
FLANGE1 OUTER	31	20	39	21
O/D TOP	55	58	58	50
	55	54	51	42
O/D MIDDLE	37	54	58	55
	51	54	55	51
O/D BOTTOM	51	59	59	56
FLANGE2 OUTER	28	22	22	20
FLANGE2 MIDDLE	22	31	28	22
FLANGE2 INNER	55	59	57	31
I/D BOTTOM		61		54
I/D MIDDLE		48		29
I/D TOP		58		61

NB:
1. Outer is old square copper tubing & coil has had a hard life (very imperfect)
2. Inner P=16.5, T=11s / Outer P=11, T=11s



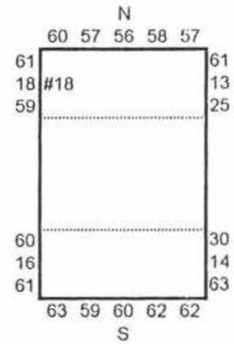


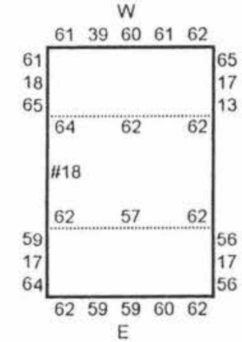
Roller Induction Heating Data

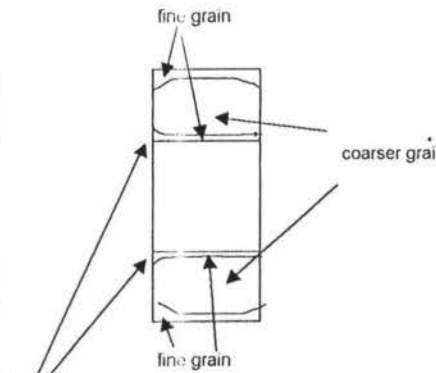
#18 12/15K roller / double process - inner first, outer second + inner cooled

	N	E	S	W
FLANGE1 INNER	59	59	60	65
FLANGE1 MIDDLE	18	17	16	18
FLANGE1 OUTER	61	64	61	61
O/D TOP	60	62	63	61
	57	59	59	39
O/D MIDDLE	56	59	60	60
	58	60	62	61
O/D BOTTOM	57	62	62	62
FLANGE2 OUTER	61	56	63	65
FLANGE2 MIDDLE	13	17	14	17
FLANGE2 INNER	25	56	30	13
I/D BOTTOM		62		62
I/D MIDDLE		57		62
I/D TOP		62		64

NB:
1. New outer coil 4.5 windings
2. Inner P=16.5, T=11s / Outer P=10.5, T=10s





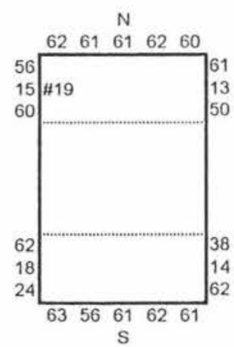


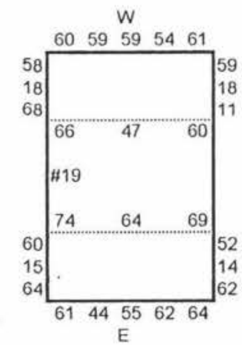
NB:
1. Note inner diameter hardness is altered by contact with copper cooling head
2. HRc tests applied outside of the inner chamfer. Hardness goes to chamfer therefore tests not picking up hard surface on flange 2 inner points.

#19 12/15K roller / double process - inner first, outer second + inner cooled

	N	E	S	W
FLANGE1 INNER	60	60	62	68
FLANGE1 MIDDLE	15	15	18	18
FLANGE1 OUTER	56	64	24	58
O/D TOP	62	61	63	60
	61	44	56	59
O/D MIDDLE	61	55	61	59
	62	62	62	54
O/D BOTTOM	60	64	61	61
FLANGE2 OUTER	61	62	62	59
FLANGE2 MIDDLE	13	14	14	18
FLANGE2 INNER	50	52	38	11
I/D BOTTOM		69		60
I/D MIDDLE		64		47
I/D TOP		74		66

NB:
1. New outer coil 4.5 windings
2. Inner P=16.5, T=11s / Outer P=10.5, T=12s

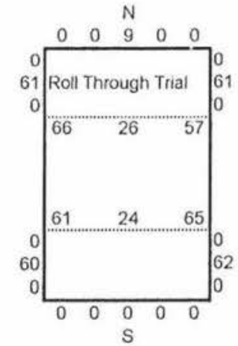


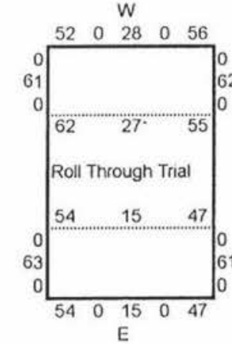


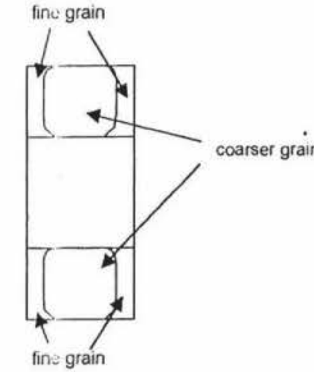
Roll Through Trial 6/7.5K roller / single process flange heat

	N	E	S	W
FLANGE1 INNER				
FLANGE1 MIDDLE	61	63	60	61
FLANGE1 OUTER				
O/D TOP		54		52
O/D MIDDLE	9	15		28
O/D BOTTOM		47		56
FLANGE2 OUTER				
FLANGE2 MIDDLE	61	61	62	62
FLANGE2 INNER				
I/D BOTTOM	57	47	65	55
I/D MIDDLE	26	15	24	27
I/D TOP	66	54	61	62

Roller Induction Heating Data







NB:

1. Horizontal (slightly sloped) rectangular coil fitted with ceramic channel. Roller rolled down channel
2. P=15.5, T approx 3 to 4 seconds
3. Multiple tests done with very similar results.
4. Time in coil hard to gauge manually.
5. Manual production with this method would be nearly impossible as consistency would be unachievable.

Roller	**Mass (kg)**
12/15K102	**0.2**

External Cost of Gas Carburising

HTAuck	$ 1.10	$ 5.50	/kg
Freight	$ 0.06	$ 0.30	/kg
Total	$ 1.16	per roller	

Internal Cost of Induction Heat Treatment

rollers/hr	kg/hr	$cost/hr	$cost/kg	$cost/roller	% savings on external heat treatment	
120	24	$ 28.00	$ 1.17	$ 0.23	80%	30 secs/roller
100	20	$ 28.00	$ 1.40	$ 0.28	76%	36 secs/roller
80	16	$ 28.00	$ 1.75	$ 0.35	70%	45 secs/roller
60	12	$ 28.00	$ 2.33	$ 0.47	60%	60 secs/roller

1. Two processes: 1/ inside diameter, 2/ outside diameter+ cooling inner.
2. Assume each process takes equal time of 15 seconds - therefore 30 sec/roller
3. Therefore 120 rollers per hour
4. Assume running costs: $ 28.00 /hr
5. Includes overheads
6. TOTALLY manual operation

Roller	**Mass (kg)**
6/7.5K102	**0.059**

External Cost of Gas Carburising

HTAuck	$ 0.32	$ 5.50	/kg
Freight	$ 0.02	$ 0.30	/kg
Total	$ 0.34	per roller	

Internal Cost of Induction Heat Treatment

rollers/hr	kg/hr	$cost/hr	$cost/kg	$cost/roller	% savings on external heat treatment	
240	14.16	$ 28.00	$ 1.98	$ 0.12	66%	15 secs/roller
200	11.8	$ 28.00	$ 2.37	$ 0.14	59%	18 secs/roller
160	9.44	$ 28.00	$ 2.97	$ 0.18	49%	22.5 secs/roller
120	7.08	$ 28.00	$ 3.95	$ 0.23	32%	30 secs/roller

1. Single process: rolling through heating tunnel.
2. Assume process takes time of 15 seconds/roller
3. Therefore 240 rollers per hour
4. Assume running costs: $ 28.00 /hr
5. Includes overheads
6. Totally manual operation - although the process of rolling the component through the coil manually would be a hit and miss affair.

automation savings

Chain	Cost per Foot (manual)	Cost per Foot (induction automated)	Percentage savings per Foot after induction automation	Cost per Foot (logo stamp automated)	Percentage savings per Foot after logo stamp automation	Cost per Foot (12/15K bush roller automated)	Percentage savings per Foot after 12/15K bush roller automation	Cost per Foot (75T Press ALL blanking ops automated)	Percentage savings per Foot after 75T Press automation	Cost per Foot (150T Press ALL blanking ops automated)	Percentage savings per Foot after 150T Press automation	Cost per Foot with Automatic Inner Link Assembly	Percentage Savings per Foot with Inner Link Assembly automation
7.5K3.0	$ 12.95	$ 12.76	1.44%	$ 12.64	2.41%			$ 11.95	7.70%			$ 12.48	3.60%
7.5K4.0	$ 10.02	$ 9.88	1.40%	$ 9.79	2.33%			$ 9.27	7.46%			$ 9.67	3.49%
7.5K6.0	$ 6.94	$ 6.85	1.34%	$ 6.79	2.24%			$ 6.45	7.18%			$ 6.71	3.36%
6K3.0	$ 14.99	$ 14.80	1.25%	$ 14.68	2.08%			$ 13.99	6.65%			$ 14.52	3.11%
6K4.0	$ 11.55	$ 11.41	1.21%	$ 11.32	2.02%			$ 10.80	6.47%			$ 11.20	3.03%
6K6.0	$ 7.96	$ 7.87	1.17%	$ 7.81	1.96%			$ 7.47	6.26%			$ 7.73	2.93%
15K4.0	$ 17.99	$ 17.82	0.91%	$ 17.68	1.69%	$ 17.51	2.64%	$ 17.85	0.78%	$ 16.68	7.27%	$ 17.57	2.33%
15K6.0	$ 12.54	$ 12.43	0.87%	$ 12.34	1.61%	$ 12.23	2.53%	$ 12.45	0.74%	$ 11.67	6.95%	$ 12.26	2.23%
12K4.0	$ 19.10	$ 18.96	0.73%	$ 18.80	1.59%	$ 18.62	2.49%	$ 18.96	0.73%	$ 17.79	6.85%	$ 18.68	2.20%
12K6.0	$ 13.28	$ 13.19	0.70%	$ 13.08	1.52%	$ 12.97	2.39%	$ 13.19	0.70%	$ 12.41	6.56%	$ 13.00	2.11%
Estimated Automation Cap Ex		$ 10,000.00		$5000 - $8,000 PLUS repair & reassembly 30tPres		$5000 - $8,000 PLUS redesign of mechanism		$30,000 - $50,000+ NOT including new automation ready tooling. May be less expensive to automate segments of assembly.		$30,000 - $50,000+		$30,000 - $50,0000	
Average of Percentage Savings			1.10%		1.95%		2.51%		4.47%		6.91%		2.84%
Weighted Average Across Total Footage			1.22%		2.09%		0.54%		5.73%		1.49%		3.09%
Potential Labour Savings per Year			$5,000 - $10,000		$5,000 - $10,000		$3,000 -$4,000						$10,000 - $15,000

NB:

1. Manual production costs $28.00/hr
2. Setup left in costing & unchanged at $28.00/hr
3. Automated production costs $0/hr
4. Remember - production rates have overheads built in!
5. Total listed weighted percentage savings: 14.17%
6. Savings are based on specified automation individually - on a progressive basis, the savings would become less upon successful introduction of the previous automation option.
7. Labour savings based on $20,000 pa wage.

Stock Chain Details

Chain	1999 Value @ Cost	1999 (ft)	% of Production		%Total production stock chain
7.5K3.0	$ 18,079.33	1396	19.4%		
7.5K4.0	$ 12,256.66	1223	17.0%		
7.5K6.0	$ 5,881.31	847	11.8%	6/7.5K	79%
6K3.0	$ 6,071.28	405	5.6%		
6K4.0	$ 13,977.67	1210	16.8%		
6K6.0	$ 4,642.84	583	8.1%		
15K4.0	$ 10,181.66	566	7.9%		
15K6.0	$ 3,612.10	288	4.0%	12/15K	21%
12K4.0	$ 11,039.16	578	8.0%		
12K6.0	$ 1,328.21	100	1.4%		
Totals	$ 87,070.20	7196			

Southchain Conveying Systems Ltd. Succession Planning List		
Admin Type Issues		
Priority	Responsibility	Description
		Future directions of Mark (suggestions and contacts for work post-project).
		Start liasing with Ralph relatively soon on developing a strategy & focusing on a specific project for TBG (technology for business growth) funding.
HIGH		Pins supplied to the induction heater automation MUST be swarth and tit free. Failure to ensure this will result in machine breakages, blown coils, etc.
Production Issues		
Priority	Responsibility	Description
HIGH		Purchase hardness tester.
HIGH		Reassemble the 30T press.
HIGH		Automate the existing logo stamp tool.
		New press tooling progressively (minimum 1 per year) brought in for the higher production chains + include logo stamp in all new tools.
HIGH		Triple the number of bolt boxes and carts.
HIGH		Use shelving (like transmission chain shelf) for dynamic job storage using bolt boxes. This could also be used for standard stock storage, making inventory control (kan ban) and stock takes easier and more efficient.
		Obtain short-stroke presses and/or maintain both the 75T & 150T long-stroke presses.
		Proper seating for the assembly stations.
		Southchain workshop tools and shadow board.
		Get rid of transmission chain from Southchain's responsibility. It is not their core business.
HIGH		Contact Australian conveyor chain manufacturers for cooperative benchmarking.
		Mori Seiki online to the OWL software.
		Do cost benefit analysis on the purchase of a gas carburising unit for Southchain. Also for the purchase of a larger kilowatt power scanning induction heater.
		Start a QA system of testing (hardness, tensile, pitch tolerances, etc) on all chains that leave the factory.
		Start following a standard so you can stipulate this to clients.
HIGH		Start stocking assembled standard pitch/strength chains for better customer service.
MED		Redesign 12/15K bush roller into one operation and automate
		Computer for Greg

Roller Induction Heat Treatment Options as at 18/11/00

At this stage I believe we have very few roller induction treatment options left open to us.

1. 30/40/30 Flange Method

The 30/40/30 trials were unsuccessful due to the heating patterns in both the 12/15K and the 6/7.5K rollers (figure 1). With the current pancake coils, flange heat treatment does not give an evenly treated, composite roller. The important inner diameter surface does not get anywhere near acceptable levels of hardness. We do not know whether this is due to lack of magnetic coupling on the inner surface or due to poor cooling rates on the inner diameter surface.

Here we have two options left to pursue. Option 1 is one which neither Greg nor I wish to continue with. We both believe the 30/40/30 rule in the 12/15K roller is unacceptable even with a perfect composite 30/40/30 roller. Too much untreated material is left on the most important (curved inner and outer diameters) surfaces. Therefore I don't think this method of treating the 12/15K rollers should be pursued any further.

Option 2: With the 6/7.5K rollers we have little choice as to the manner of induction heat treatment. Due to the small inner diameter surface treatment on the curved surfaces is not possible. That leaves us with the 30/40/30 flange method. Assuming a good result can be achieved this alternative is acceptable. So if we wish to improve the heating pattern, I will have to attempt a radically different coil configuration (the Princess Leah configuration - figure 2). Hopefully this will produce acceptable results.

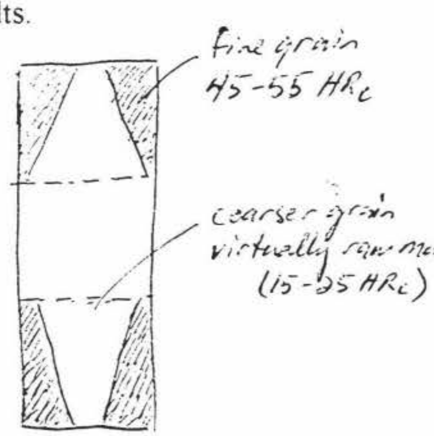
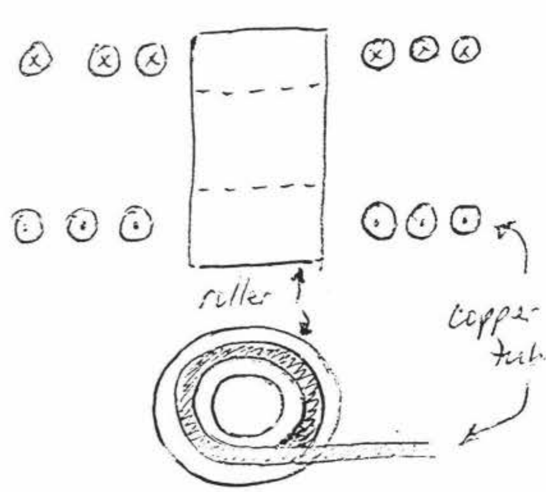


Figure 1

Figure 2



2. Curved surface treatments

Induction treating the 12/15K rollers can be done by focusing on the curved surfaces for heat treatment. Again two options are left to use to investigate.

Option 1: Single process treatment using the inner and outer coils in parallel. This configuration has produced moderate results to date but more investigation needs to be done (more coils built and tested). Regardless of the results obtained this method would be very difficult to implement in a manufacturing process. As such, I feel we should drop this line of investigation.

Option 2: Two process treatment / inner first, outer second whilst cooling inner. This method needs to be investigated properly to establish whether proper cooling on the inner diameter would prevent its annealment. From results to date I feel this can be done effectively and relatively easily in a production situation (figure 3). This method would give us to all intents and purposes a 30/40/30 rule but taking the most important surfaces into account.

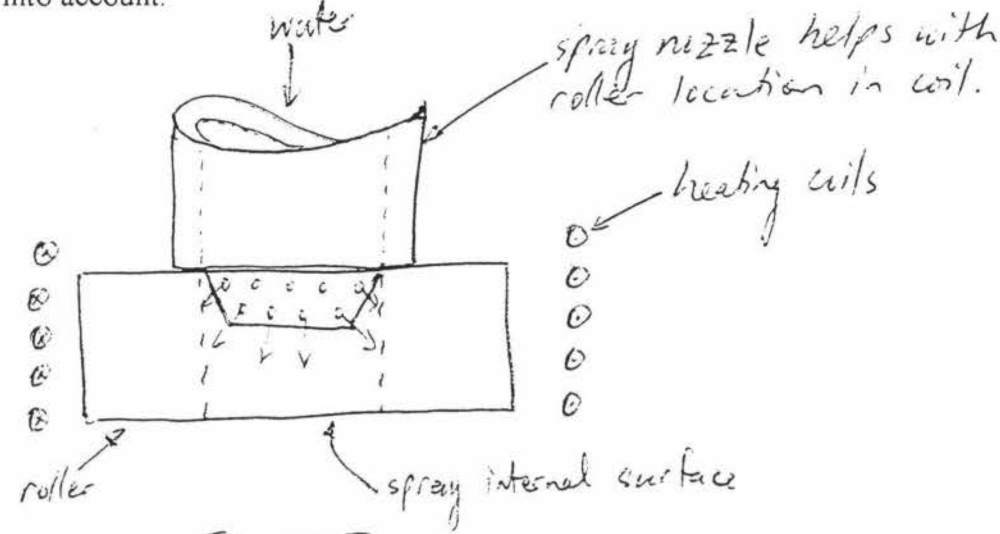


Figure 3

Summary:

1. Trial Princess Leah coils on 6/7.5K rollers attempting to get a 30/40/30 heat treatment pattern on the flanges.
2. Trial a two-stage treatment including cooling during the second stage on 12/15K rollers to achieve a 30/40/30 heat treatment pattern on the curved surfaces.

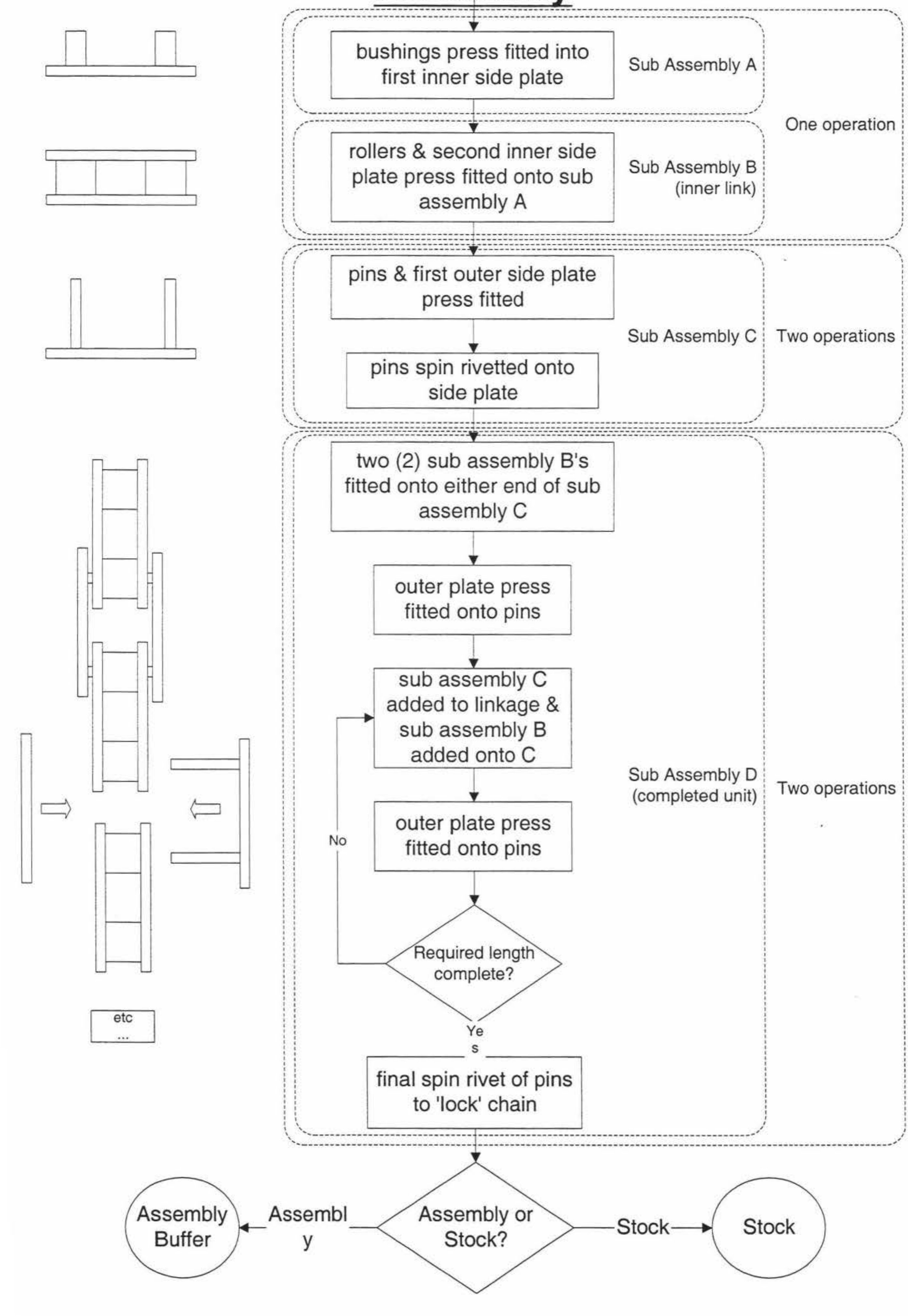
M

Mark

Appendix C

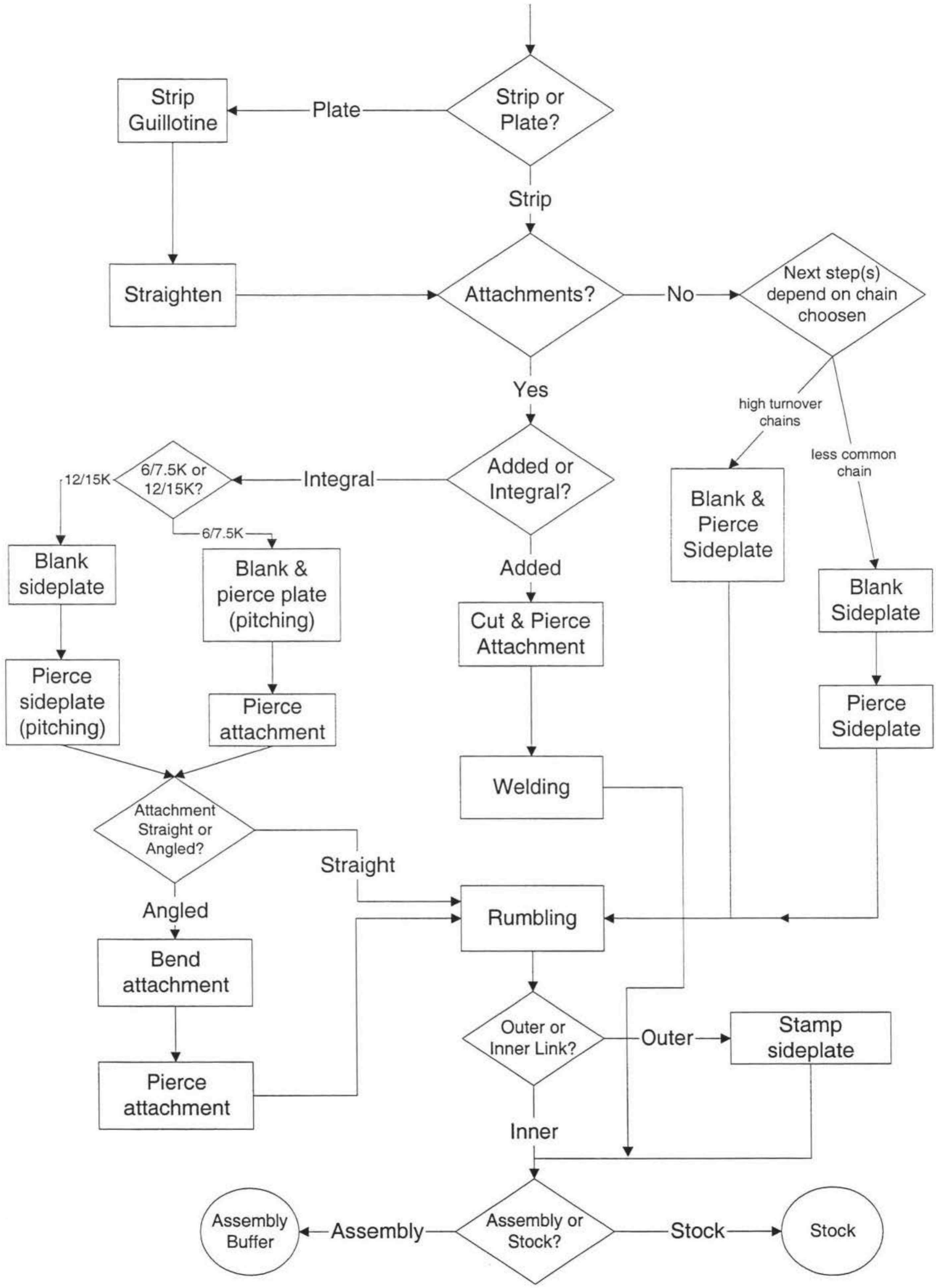
Southchain Conveying Systems Ltd
Author: M Caukill
27/01/2000

Chain Assembly



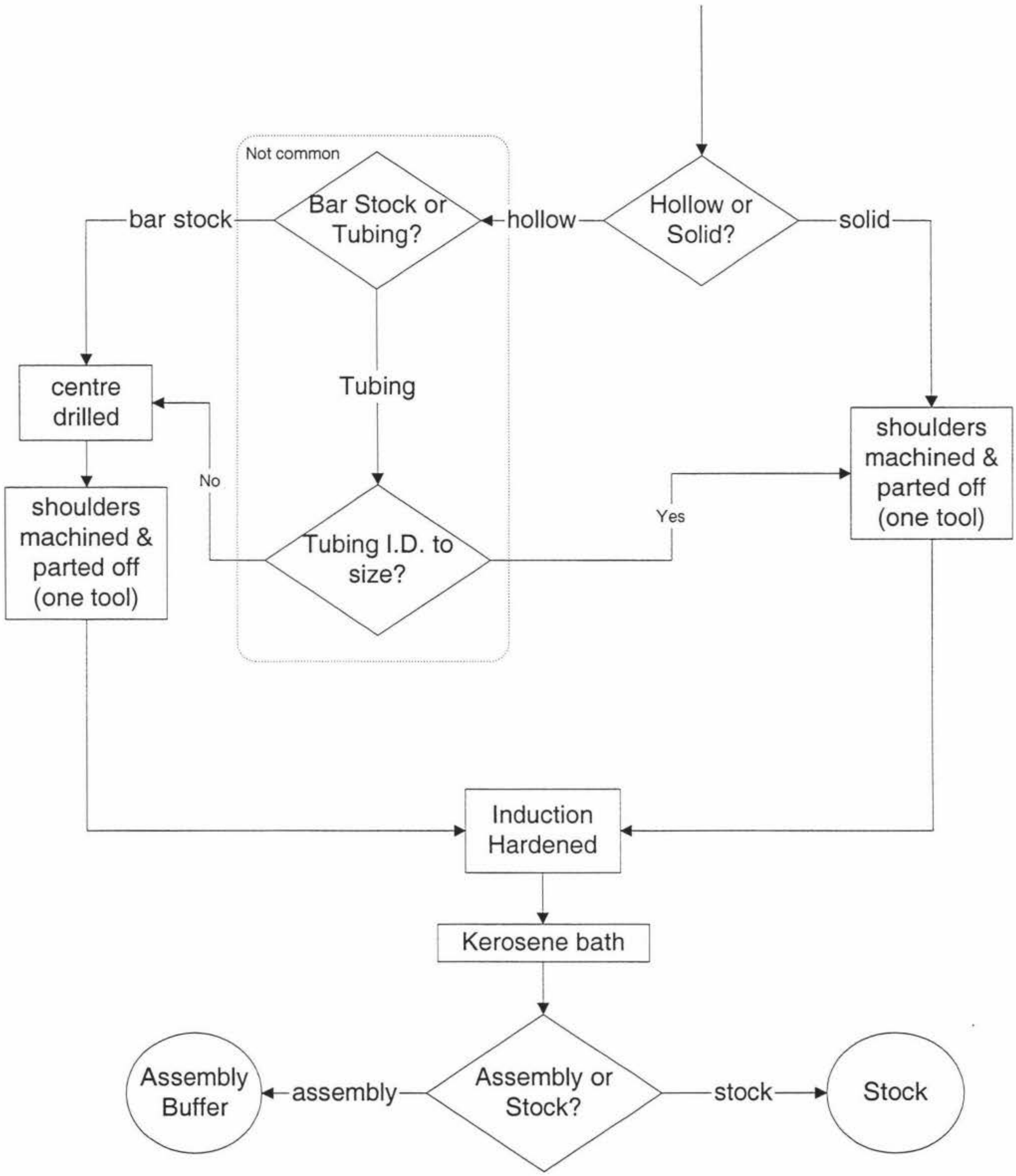
Southchain Conveying Systems Ltd
Author: M Caukill
27/01/2000

Side Plates



Pins

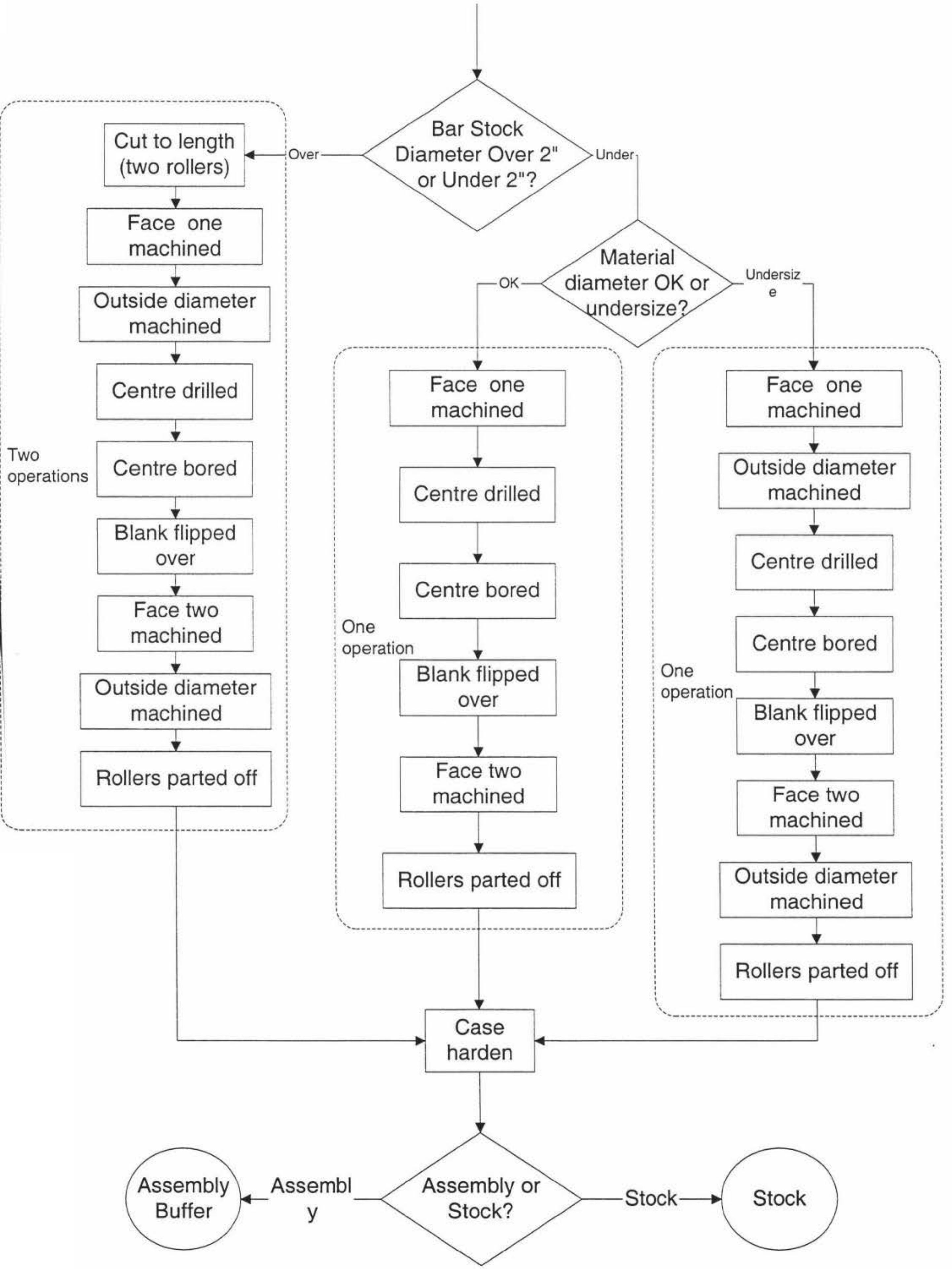
Southchain Conveying Systems Ltd
Author: M Caukill
27/01/2000



NB: When the shoulder of the pins is machined, the end of pin1 and the start of pin2 is done as one operation.

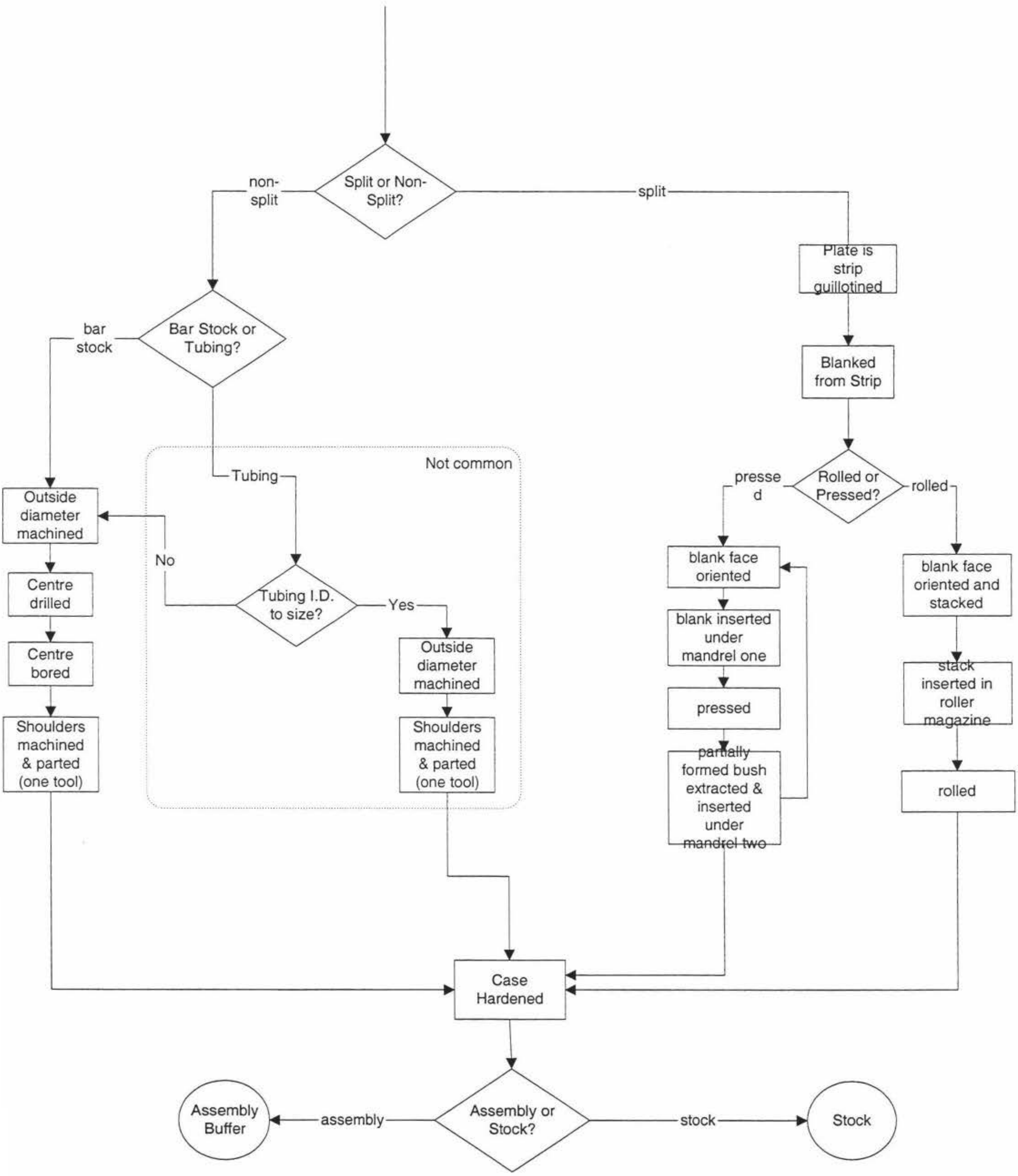
Rollers

Southchain Conveying Systems Ltd
Author: M Caukill
27/01/2000



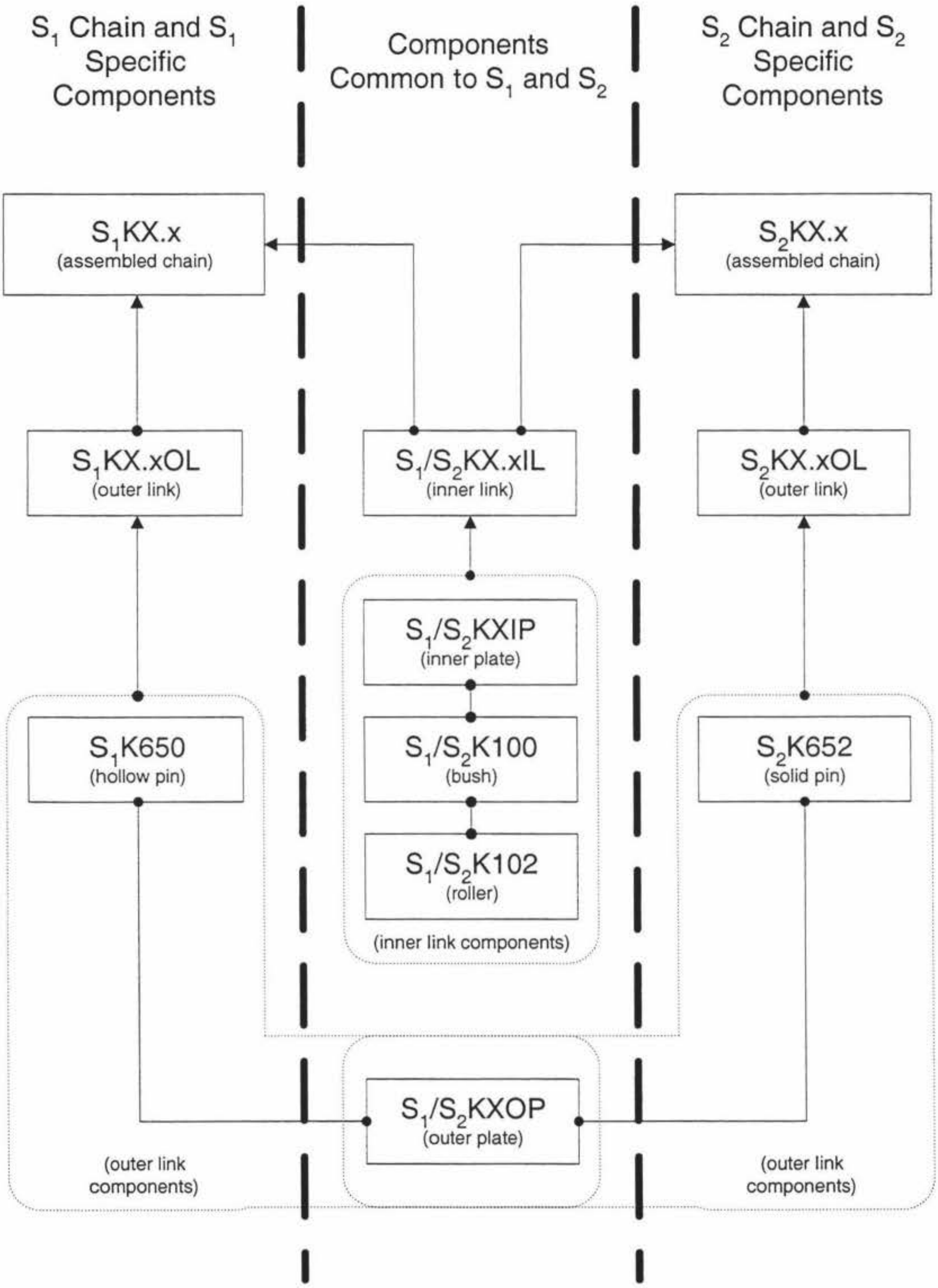
Bushes

Southchain Conveying Systems Ltd
Author: M Caukill
27/01/2000



Southchain Conveying Systems
Ltd
Author: M Caukill
23/04/2000

Nonspecific Chain Component Diagram



Legend:
S_1 = Chain Strength 1 (eg: 12K)
S_2 = Chain Strength 2 (eg: 15K)
K = Thousand Pounds
X or X.x = Pitch Length (eg: 6 or 6.0 inches)

Appendix D

Chain	Sub-assembly	SA-Qty	Components	C-Qty	Materials	No. Components per basic Raw Material Unit	Mat'l Unit Cost	Material Cost Rollup	Labour Cost Rollup	Subtotals	Sub Assembly Rollup	Chain Rollup	Cost per Foot	Cost per Metre
6K2.0							n/a	$ 1.06	$ 0.36	$ 0.36		$ 7.23	$ 21.70	$ 71.19
	6/7.5K2.0IL	1					n/a	$ 0.66	$ 0.24	$ 0.24	$ 3.61			
			6/7.5K2IP	2	MTF025004	64	$ 0.12	$ 0.23	$ 0.45	$ 0.68				
			6/7.5K100	2	MSP0016	1500	$ 0.04	$ 0.07	$ 0.63	$ 0.70				
			6/7.5K102	2	BFC1250	205	$ 0.18	$ 0.35	$ 1.63	$ 1.98				
	6K2.0OL	1					n/a	$ 0.40	$ 0.33	$ 0.33	$ 3.26			
			6/7.5K2OP	2	MTF025004	64	$ 0.12	$ 0.23	$ 0.66	$ 0.89				
			6K650	2	014MT	85	$ 0.08	$ 0.17	$ 1.88	$ 2.04				
6K2.5							n/a	$ 1.13	$ 0.36	$ 0.36		$ 7.30	$ 17.52	$ 57.48
	6/7.5K2.5IL	1					n/a	$ 0.69	$ 0.24	$ 0.24	$ 3.64			
			6/7.5K2.5IP	2	MTF025004	56	$ 0.13	$ 0.27	$ 0.45	$ 0.71				
			6/7.5K100	2	MSP0016	1500	$ 0.04	$ 0.07	$ 0.63	$ 0.70				
			6/7.5K102	2	BFC1250	205	$ 0.18	$ 0.35	$ 1.63	$ 1.98				
	6K2.5OL	1					n/a	$ 0.44	$ 0.33	$ 0.33	$ 3.30			
			6/7.5K2.5OP	2	MTF025004	56	$ 0.13	$ 0.27	$ 0.66	$ 0.93				
			6K650	2	014MT	85	$ 0.08	$ 0.17	$ 1.88	$ 2.04				
6K3.0							n/a	$ 1.32	$ 0.36	$ 0.36		$ 7.50	$ 14.99	$ 49.18
	6/7.5K3.0IL	1					n/a	$ 0.79	$ 0.24	$ 0.24	$ 3.74			
			6/7.5K3IP	2	MTF025004	41	$ 0.18	$ 0.37	$ 0.45	$ 0.81				
			6/7.5K100	2	MSP0016	1500	$ 0.04	$ 0.07	$ 0.63	$ 0.70				
			6/7.5K102	2	BFC1250	205	$ 0.18	$ 0.35	$ 1.63	$ 1.98				
	6K3.0OL	1					n/a	$ 0.53	$ 0.33	$ 0.33	$ 3.39			
			6/7.5K3OP	2	MTF025004	41	$ 0.18	$ 0.37	$ 0.66	$ 1.02				
			6K650	2	014MT	85	$ 0.08	$ 0.17	$ 1.88	$ 2.04				
6K4.0							n/a	$ 1.53	$ 0.36	$ 0.36		$ 7.70	$ 11.55	$ 37.90
	6/7.5K4.0IL	1					n/a	$ 0.89	$ 0.24	$ 0.24	$ 3.84			
			6/7.5K4IP	2	MTF025004	32	$ 0.23	$ 0.47	$ 0.45	$ 0.92				
			6/7.5K100	2	MSP0016	1500	$ 0.04	$ 0.07	$ 0.63	$ 0.70				
			6/7.5K102	2	BFC1250	205	$ 0.18	$ 0.35	$ 1.63	$ 1.98				
	6K4.0OL	1					n/a	$ 0.64	$ 0.33	$ 0.33	$ 3.50			
			6/7.5K4OP	2	MTF025004	32	$ 0.23	$ 0.47	$ 0.66	$ 1.13				
			6K650	2	014MT	85	$ 0.08	$ 0.17	$ 1.88	$ 2.04				

Chain	Sub-assembly	SA-Qty	Components	C-Qty	Materials	No. Components per basic Raw Material Unit	Mat'l Unit Cost	Material Cost Rollup	Labour Cost Rollup	Subtotals	Sub Assembly Rollup	Chain Rollup	Cost per Foot	Cost per Metre
6K5.0							n/a	$ 1.66	$ 0.36	$ 0.36		$ 7.84	$ 9.40	$ 30.85
	6/7.5K5.0IL	1					n/a	$ 0.96	$ 0.24	$ 0.24	$ 3.91			
			6/7.5K5IP	2	MTF025004	28	$ 0.27	$ 0.54	$ 0.45	$ 0.98				
			6/7.5K100	2	MSP0016	1500	$ 0.04	$ 0.07	$ 0.63	$ 0.70				
			6/7.5K102	2	BFC1250	205	$ 0.18	$ 0.35	$ 1.63	$ 1.98				
	6K5.0OL	1					n/a	$ 0.70	$ 0.33	$ 0.33	$ 3.56			
			6/7.5K5OP	2	MTF025004	28	$ 0.27	$ 0.54	$ 0.66	$ 1.19				
			6K650	2	014MT	85	$ 0.08	$ 0.17	$ 1.88	$ 2.04				
6K6.0							n/a	$ 1.79	$ 0.36	$ 0.36		$ 7.96	$ 7.96	$ 26.13
	6/7.5K6.0IL	1					n/a	$ 1.02	$ 0.24	$ 0.24	$ 3.97			
			6/7.5K6IP	2	MTF025004	25	$ 0.30	$ 0.60	$ 0.45	$ 1.05				
			6/7.5K100	2	MSP0016	1500	$ 0.04	$ 0.07	$ 0.63	$ 0.70				
			6/7.5K102	2	BFC1250	205	$ 0.18	$ 0.35	$ 1.63	$ 1.98				
	6K6.0OL	1					n/a	$ 0.77	$ 0.33	$ 0.33	$ 3.63			
			6/7.5K6OP	2	MTF025004	25	$ 0.30	$ 0.60	$ 0.66	$ 1.26				
			6K650	2	014MT	85	$ 0.08	$ 0.17	$ 1.88	$ 2.04				

Chain	Sub-assembly	SA-Qty	Components	C-Qty	Materials	No. Components per basic Raw Material Unit	Mat'l Unit Cost	Material Cost Rollup	Labour Cost Rollup	Subtotals	Sub Assembly Rollup	Chain Rollup	Cost per Foot	Cost per Metre
7.5K2.0							n/a	$ 1.06	$ 0.36	$ 0.36		$ 6.21	$ 18.64	$ 61.15
	6/7.5K2.0IL	1					n/a	$ 0.66	$ 0.24	$ 0.24	$ 3.61			
			6/7.5K2IP	2	MTF025004	64	$ 0.12	$ 0.23	$ 0.45	$ 0.68				
			6/7.5K100	2	MSP0016	1500	$ 0.04	$ 0.07	$ 0.63	$ 0.70				
			6/7.5K102	2	BFC1250	205	$ 0.18	$ 0.35	$ 1.63	$ 1.98				
	7.5K2.0OL	1					n/a	$ 0.40	$ 0.33	$ 0.33	$ 2.24			
			6/7.5K2OP	2	MTF025004	64	$ 0.12	$ 0.23	$ 0.66	$ 0.89				
			7.5K652	2	014MT	85	$ 0.08	$ 0.17	$ 0.86	$ 1.02				
7.5K2.5							n/a	$ 1.13	$ 0.36	$ 0.36		$ 6.28	$ 15.07	$ 49.44
	6/7.5K2.5IL	1					n/a	$ 0.69	$ 0.24	$ 0.24	$ 3.64			
			6/7.5K2.5IP	2	MTF025004	56	$ 0.13	$ 0.27	$ 0.45	$ 0.71				
			6/7.5K100	2	MSP0016	1500	$ 0.04	$ 0.07	$ 0.63	$ 0.70				
			6/7.5K102	2	BFC1250	205	$ 0.18	$ 0.35	$ 1.63	$ 1.98				
	7.5K2.5OL	1					n/a	$ 0.44	$ 0.33	$ 0.33	$ 2.28			
			6/7.5K2.5OP	2	MTF025004	56	$ 0.13	$ 0.27	$ 0.66	$ 0.93				
			7.5K652	2	014MT	85	$ 0.08	$ 0.17	$ 0.86	$ 1.02				
7.5K3.0							n/a	$ 1.32	$ 0.36	$ 0.36		$ 6.48	$ 12.95	$ 42.49
	6/7.5K3.0IL	1					n/a	$ 0.79	$ 0.24	$ 0.24	$ 3.74			
			6/7.5K3IP	2	MTF025004	41	$ 0.18	$ 0.37	$ 0.45	$ 0.81				
			6/7.5K100	2	MSP0016	1500	$ 0.04	$ 0.07	$ 0.63	$ 0.70				
			6/7.5K102	2	BFC1250	205	$ 0.18	$ 0.35	$ 1.63	$ 1.98				
	7.5K3.0OL	1					n/a	$ 0.53	$ 0.33	$ 0.33	$ 2.37			
			6/7.5K3OP	2	MTF025004	41	$ 0.18	$ 0.37	$ 0.66	$ 1.02				
			7.5K652	2	014MT	85	$ 0.08	$ 0.17	$ 0.86	$ 1.02				
7.5K4.0							n/a	$ 1.53	$ 0.36	$ 0.36		$ 6.68	$ 10.02	$ 32.88
	6/7.5K4.0IL	1					n/a	$ 0.89	$ 0.24	$ 0.24	$ 3.84			
			6/7.5K4IP	2	MTF025004	32	$ 0.23	$ 0.47	$ 0.45	$ 0.92				
			6/7.5K100	2	MSP0016	1500	$ 0.04	$ 0.07	$ 0.63	$ 0.70				
			6/7.5K102	2	BFC1250	205	$ 0.18	$ 0.35	$ 1.63	$ 1.98				
	7.5K4.0OL	1					n/a	$ 0.64	$ 0.33	$ 0.33	$ 2.48			
			6/7.5K4OP	2	MTF025004	32	$ 0.23	$ 0.47	$ 0.66	$ 1.13				
			7.5K652	2	014MT	85	$ 0.08	$ 0.17	$ 0.86	$ 1.02				

Chain	Sub-assembly	SA-Qty	Components	C-Qty	Materials	No. Components per basic Raw Material Unit	Mat'l Unit Cost	Material Cost Rollup	Labour Cost Rollup	Subtotals	Sub Assembly Rollup	Chain Rollup	Cost per Foot	Cost per Metre
7.5K5.0							n/a	$ 1.66	$ 0.36	$ 0.36		$ 6.82	$ 8.18	$ 26.83
	6/7.5K5.0IL	1					n/a	$ 0.96	$ 0.24	$ 0.24	$ 3.91			
			6/7.5K5IP	2	MTF025004	28	$ 0.27	$ 0.54	$ 0.45	$ 0.98				
			6/7.5K100	2	MSP0016	1500	$ 0.04	$ 0.07	$ 0.63	$ 0.70				
			6/7.5K102	2	BFC1250	205	$ 0.18	$ 0.35	$ 1.63	$ 1.98				
	7.5K5.0OL	1					n/a	$ 0.70	$ 0.33	$ 0.33	$ 2.54			
			6/7.5K5OP	2	MTF025004	28	$ 0.27	$ 0.54	$ 0.66	$ 1.19				
			7.5K652	2	014MT	85	$ 0.08	$ 0.17	$ 0.86	$ 1.02				
7.5K6.0							n/a	$ 1.79	$ 0.36	$ 0.36		$ 6.94	$ 6.94	$ 22.78
	6/7.5K6.0IL	1					n/a	$ 1.02	$ 0.24	$ 0.24	$ 3.97			
			6/7.5K6IP	2	MTF025004	25	$ 0.30	$ 0.60	$ 0.45	$ 1.05				
			6/7.5K100	2	MSP0016	1500	$ 0.04	$ 0.07	$ 0.63	$ 0.70				
			6/7.5K102	2	BFC1250	205	$ 0.18	$ 0.35	$ 1.63	$ 1.98				
	7.5K6.0OL	1					n/a	$ 0.77	$ 0.33	$ 0.33	$ 2.61			
			6/7.5K6OP	2	MTF025004	25	$ 0.30	$ 0.60	$ 0.66	$ 1.26				
			7.5K652	2	014MT	85	$ 0.08	$ 0.17	$ 0.86	$ 1.02				

Chain	Sub-assembly	SA-Qty	Components	C-Qty	Materials	No. Components per basic Raw Material Unit	Mat'l Unit Cost	Material Cost Rollup	Labour Cost Rollup	Subtotals	Sub Assembly Rollup	Chain Rollup	Cost per Foot	Cost per Metre
12K3.0							n/a	$ 3.09	$ 0.41	$ 0.41		$ 12.01	$ 24.03	$ 78.83
	12/15K3.0IL	1					n/a	$ 1.88	$ 0.29	$ 0.29	$ 7.34			
			12/15K3IP	2	MTF040005	41	$ 0.38	$ 0.77	$ 0.79	$ 1.56				
			12/15K100	2	MSP002	1125	$ 0.06	$ 0.12	$ 1.01	$ 1.13				
			12/15K102	2	BFC1875	166	$ 0.50	$ 1.00	$ 3.36	$ 4.36				
	12K3.0OL	1					n/a	$ 1.21	$ 0.41	$ 0.41	$ 4.27			
			12/15K3OP	2	MTF040005	41	$ 0.38	$ 0.77	$ 1.05	$ 1.82				
			12K650	2	750MT	112	$ 0.22	$ 0.45	$ 1.59	$ 2.04				
12K4.0							n/a	$ 3.81	$ 0.41	$ 0.41		$ 12.73	$ 19.10	$ 62.66
	12/15K4.0IL	1					n/a	$ 2.09	$ 0.29	$ 0.29	$ 7.55			
			12/15K4IP	2	MTF040005	32	$ 0.49	$ 0.98	$ 0.79	$ 1.77				
			12/15K100	2	MSP002	1125	$ 0.06	$ 0.12	$ 1.01	$ 1.13				
			12/15K102	2	BFC1875	166	$ 0.50	$ 1.00	$ 3.36	$ 4.36				
	12K4.0OL	1					n/a	$ 1.72	$ 0.41	$ 0.41	$ 4.77			
			12/15K4OP	2	MTF040005	32	$ 0.49	$ 0.98	$ 1.05	$ 2.03				
			12K650	2	750MT	68	$ 0.37	$ 0.74	$ 1.59	$ 2.33				
12K6.0							n/a	$ 4.36	$ 0.41	$ 0.41		$ 13.28	$ 13.28	$ 43.58
	12/15K6.0IL	1					n/a	$ 2.37	$ 0.29	$ 0.29	$ 7.83			
			12/15K6IP	2	MTF040005	25	$ 0.63	$ 1.26	$ 0.79	$ 2.05				
			12/15K100	2	MSP002	1125	$ 0.06	$ 0.12	$ 1.01	$ 1.13				
			12/15K102	2	BFC1875	166	$ 0.50	$ 1.00	$ 3.36	$ 4.36				
	12K6.0OL	1					n/a	$ 1.99	$ 0.41	$ 0.41	$ 5.04			
			12/15K6OP	2	MTF040005	25	$ 0.63	$ 1.26	$ 1.05	$ 2.31				
			12K650	2	750MT	68	$ 0.37	$ 0.74	$ 1.59	$ 2.33				

Chain	Sub-assembly	SA-Qty	Components	C-Qty	Materials	No. Components per basic Raw Material Unit	Mat'l Unit Cost	Material Cost Rollup	Labour Cost Rollup	Subtotals	Sub Assembly Rollup	Chain Rollup	Cost per Foot	Cost per Metre
15K3.0							n/a	$ 3.09	$ 0.41	$ 0.41		$ 11.25	$ 22.50	$ 73.82
	12/15K3.0IL	1					n/a	$ 1.88	$ 0.29	$ 0.29	$ 7.34			
			12/15K3IP	2	MTF040005	41	$ 0.38	$ 0.77	$ 0.79	$ 1.56				
			12/15K100	2	MSP002	1125	$ 0.06	$ 0.12	$ 1.01	$ 1.13				
			12/15K102	2	BFC1875	166	$ 0.50	$ 1.00	$ 3.36	$ 4.36				
	15K3.0OL	1					n/a	$ 1.21	$ 0.39	$ 0.39	$ 3.50			
			12/15K3OP	2	MTF040005	41	$ 0.38	$ 0.77	$ 1.05	$ 1.82				
			15K652	2	750MT	112	$ 0.22	$ 0.45	$ 0.85	$ 1.30				
15K4.0							n/a	$ 3.81	$ 0.41	$ 0.41		$ 11.99	$ 17.99	$ 59.02
	12/15K4.0IL	1					n/a	$ 2.09	$ 0.29	$ 0.29	$ 7.55			
			12/15K4IP	2	MTF040005	32	$ 0.49	$ 0.98	$ 0.79	$ 1.77				
			12/15K100	2	MSP002	1125	$ 0.06	$ 0.12	$ 1.01	$ 1.13				
			12/15K102	2	BFC1875	166	$ 0.50	$ 1.00	$ 3.36	$ 4.36				
	15K4.0OL	1					n/a	$ 1.72	$ 0.41	$ 0.41	$ 4.03			
			12/15K4OP	2	MTF040005	32	$ 0.49	$ 0.98	$ 1.05	$ 2.03				
			15K652	2	750MT	68	$ 0.37	$ 0.74	$ 0.85	$ 1.59				
15K6.0							n/a	$ 4.36	$ 0.41	$ 0.41		$ 12.54	$ 12.54	$ 41.15
	12/15K6.0IL	1					n/a	$ 2.37	$ 0.29	$ 0.29	$ 7.83			
			12/15K6IP	2	MTF040005	25	$ 0.63	$ 1.26	$ 0.79	$ 2.05				
			12/15K100	2	MSP002	1125	$ 0.06	$ 0.12	$ 1.01	$ 1.13				
			12/15K102	2	BFC1875	166	$ 0.50	$ 1.00	$ 3.36	$ 4.36				
	15K6.0OL	1					n/a	$ 1.99	$ 0.41	$ 0.41	$ 4.30			
			12/15K6OP	2	MTF040005	25	$ 0.63	$ 1.26	$ 1.05	$ 2.31				
			15K652	2	750MT	68	$ 0.37	$ 0.74	$ 0.85	$ 1.59				

Chain	Sub-assembly	SA-Qty	Components	C-Qty	Materials	No. Components per basic Raw Material Unit	Mat'l Unit Cost	Material Cost Rollup	Labour Cost Rollup	Subtotals	Sub Assembly Rollup	Chain Rollup	Cost per Foot	Cost per Metre
24K6.0							n/a	$ 7.07	$ 0.49	$ 0.49		$ 23.74	$ 23.74	$ 77.87
	24/30K6.0IL	1					n/a	$ 4.61	$ 0.34	$ 0.34	$ 17.56			
			24/30K6IP	2	ABC	25	$ 0.64	$ 1.28	$ 0.79	$ 2.07				
			24/30K100	2	KLM	80	$ 1.13	$ 2.25	$ 3.00	$ 5.25				
			24/30K102	2	GHJ	166	$ 0.54	$ 1.08	$ 8.80	$ 9.89				
	24K6.0OL	1					n/a	$ 2.46	$ 0.49	$ 0.49	$ 5.69			
			24/30K6OP	2	ABC	25	$ 0.64	$ 1.28	$ 1.05	$ 2.33				
			24K650	2	DEF	68	$ 0.59	$ 1.18	$ 1.69	$ 2.87				
24K8.0							n/a	$ 8.78	$ 0.49	$ 0.49		$ 25.44	$ 19.08	$ 62.60
	24/30K8.0IL	1					n/a	$ 5.47	$ 0.34	$ 0.34	$ 18.41			
			24/30K6IP	2	ABC	15	$ 1.07	$ 2.13	$ 0.79	$ 2.93				
			24/30K100	2	KLM	80	$ 1.13	$ 2.25	$ 3.00	$ 5.25				
			24/30K102	2	GHJ	166	$ 0.54	$ 1.08	$ 8.80	$ 9.89				
	24K8.0OL	1					n/a	$ 3.31	$ 0.49	$ 0.49	$ 6.54			
			24/30K6OP	2	ABC	15	$ 1.07	$ 2.13	$ 1.05	$ 3.18				
			24K650	2	DEF	68	$ 0.59	$ 1.18	$ 1.69	$ 2.87				

Chain	Sub-assembly	SA-Qty	Components	C-Qty	Materials	No. Components per basic Raw Material Unit	Mat'l Unit Cost	Material Cost Rollup	Labour Cost Rollup	Subtotals	Sub Assembly Rollup	Chain Rollup	Cost per Foot	Cost per Metre
30K6.0							n/a	$ 7.07	$ 0.49	$ 0.49		$ 23.11	$ 23.11	$ 75.81
	24/30K6.0IL	1					n/a	$ 4.61	$ 0.34	$ 0.34	$ 17.56			
			24/30K6IP	2	ABC	25	$ 0.64	$ 1.28	$ 0.79	$ 2.07				
			24/30K100	2	KLM	80	$ 1.13	$ 2.25	$ 3.00	$ 5.25				
			24/30K102	2	GHJ	166	$ 0.54	$ 1.08	$ 8.80	$ 9.89				
	30K6.0OL	1					n/a	$ 2.46	$ 0.49	$ 0.49	$ 5.06			
			24/30K6OP	2	ABC	25	$ 0.64	$ 1.28	$ 1.05	$ 2.33				
			30K652	2	DEF	68	$ 0.59	$ 1.18	$ 1.06	$ 2.24				
30K8.0							n/a	$ 8.78	$ 0.49	$ 0.49		$ 24.81	$ 18.61	$ 61.05
	24/30K8.0IL	1					n/a	$ 5.47	$ 0.34	$ 0.34	$ 18.41			
			24/30K6IP	2	ABC	15	$ 1.07	$ 2.13	$ 0.79	$ 2.93				
			24/30K100	2	KLM	80	$ 1.13	$ 2.25	$ 3.00	$ 5.25				
			24/30K102	2	GHJ	166	$ 0.54	$ 1.08	$ 8.80	$ 9.89				
	30K8.0OL	1					n/a	$ 3.31	$ 0.49	$ 0.49	$ 5.91			
			24/30K6OP	2	ABC	15	$ 1.07	$ 2.13	$ 1.05	$ 3.18				
			30K652	2	DEF	68	$ 0.59	$ 1.18	$ 1.06	$ 2.24				

Part Number	Std Batch Qty	Op. #	Description	Work Centre / Machine / Operator	Batch Setup Time (hours)	Batch Setup Cost	INTERNAL Unit prodn time (min) OR EXTERNAL Unit measurement (kg,m,hr)	Batch Processing Cost	Std Batch Cost	Std Unit Labour Cost	Tool No.
6/7.5K100	1000	10	strip guillotined	Etech-guillotine	x	$ -	0.002	$ 72.00	$ 72.00		
split bush		20	blanked	75tPress	2	$ 56.00	0.1	$ 46.67	$ 102.67		
		30	rolled	BushRoll	0.25	$ 7.00	0.1	$ 46.67	$ 53.67		
		40	case hardened	HTAuck	x	$ -	0.015	$ 82.50	$ 82.50		
		50	freight to Auckland	Freight	x	$ -	0.015	$ 5.70	$ 5.70		
Totals					2.25	$ 63.00	0.232	$ 253.53	$ 316.53	$ 0.32	
6/7.5K102	1000	10	machined	Mori	1	$ 34.00	0.767	$ 434.63	$ 468.63		
roller		20	case hardened	HTAuck	x	$ -	0.059	$ 324.50	$ 324.50		
		30	freight to Auckland	Freight	x	$ -	0.059	$ 22.42	$ 22.42		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					1	$ 34.00	0.885	$ 781.55	$ 815.55	$ 0.82	
6K650	1000	10	machined	Mori	1	$ 34.00	1.5	$ 850.00	$ 884.00		
hollow pin		20	induction hardened	Induction	0.25	$ 7.00	0.1	$ 46.67	$ 53.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					1.25	$ 41.00	1.6	$ 896.67	$ 937.67	$ 0.94	
7.5K652	1000	10	machined	Mori	1	$ 34.00	0.6	$ 340.00	$ 374.00		
solid pin		20	induction hardened	Induction	0.25	$ 7.00	0.1	$ 46.67	$ 53.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					1.25	$ 41.00	0.7	$ 386.67	$ 427.67	$ 0.43	
6/7.5K3IP	1000	10	blanked & pierced	75tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					4	$ 112.00	0.277	$ 111.27	$ 223.27	$ 0.22	
6/7.5K3OP	1000	10	blanked & pierced	75tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	stamped	75tPress	1	$ 28.00	0.167	$ 77.93	$ 105.93		
		30	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					5	$ 140.00	0.444	$ 189.20	$ 329.20	$ 0.33	

Part Number	Std Batch Qty	Op. #	Description	Work Centre / Machine / Operator	Batch Setup Time (hours)	Batch Setup Cost	INTERNAL Unit prodn time (min) OR EXTERNAL Unit measurement (kg,m,hr)	Batch Processing Cost	Std Batch Cost	Std Unit Labour Cost	Tool No.
6/7.5K3.0IL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20				$ -		$ -	$ -		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.25	$ 7.00	0.5	$ 233.33	$ 240.33	$ 0.24	
7.5K3.0OL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.167	$ 77.93	$ 84.93		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.667	$ 311.27	$ 325.27	$ 0.33	
7.5K3.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.75	$ 350.00	$ 364.00	$ 0.36	
12/15K100 split bush	1000	10	strip guillotined	Etech-guillotine	x	$ -	0.002	$ 72.00	$ 72.00		
		20	blanked	75tPress	2	$ 56.00	0.1	$ 46.67	$ 102.67		
		30	rolled	75tPress	1	$ 28.00	0.25	$ 116.67	$ 144.67		
		40	case hardened	HTAuck	x	$ -	0.032	$ 176.00	$ 176.00		
		50	freight to Auckland	Freight	x	$ -	0.032	$ 12.16	$ 12.16		
Totals					3	$ 84.00	0.416	$ 423.49	$ 507.49	$ 0.51	
12/15K102 roller	1000	10	machined	Mori	1	$ 34.00	0.833	$ 472.03	$ 506.03		
		20	case hardened	HTAuck	x	$ -	0.2	$ 1,100.00	$ 1,100.00		
		30	freight to Auckland	Freight	x	$ -	0.2	$ 76.00	$ 76.00		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					1	$ 34.00	1.233	$ 1,648.03	$ 1,682.03	$ 1.68	
12K650 hollow pin	1000	10	machined	Mori	1	$ 34.00	1.25	$ 708.33	$ 742.33		
		20	induction hardened	Induction	0.25	$ 7.00	0.1	$ 46.67	$ 53.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					1.25	$ 41.00	1.35	$ 755.00	$ 796.00	$ 0.80	

Part Number	Std Batch Qty	Op. #	Description	Work Centre / Machine / Operator	Batch Setup Time (hours)	Batch Setup Cost	INTERNAL Unit prodn time (min) OR EXTERNAL Unit measurement (kg,m,hr)	Batch Processing Cost	Std Batch Cost	Std Unit Labour Cost	Tool No.
15K652	1000	10	machined	Mori	1	$ 34.00	0.583	$ 330.37	$ 364.37		
solid pin		20	induction hardened	Induction	0.25	$ 7.00	0.117	$ 54.60	$ 61.60		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					1.25	$ 41.00	0.7	$ 384.97	$ 425.97	$ 0.43	
12/15K3IP	1000	10	pierced	150tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	blanked	150tPress	2	$ 56.00	0.25	$ 116.67	$ 172.67		
		30	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					6	$ 168.00	0.527	$ 227.93	$ 395.93	$ 0.40	
12/15K3OP	1000	10	pierced	150tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	blanked	150tPress	2	$ 56.00	0.25	$ 116.67	$ 172.67		
		30	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		40	stamped	75tPress	1	$ 28.00	0.217	$ 101.27	$ 129.27		
		50				$ -		$ -	$ -		
Totals					7	$ 196.00	0.744	$ 329.20	$ 525.20	$ 0.53	
12/15K3.0IL	1000	10	assembled	RedRam	0.25	$ 7.00	0.6	$ 280.00	$ 287.00		
		20				$ -		$ -	$ -		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.25	$ 7.00	0.6	$ 280.00	$ 287.00	$ 0.29	
15K3.0OL	1000	10	assembled	GreyRam	0.25	$ 7.00	0.6	$ 280.00	$ 287.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.2	$ 93.33	$ 100.33		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.8	$ 373.33	$ 387.33	$ 0.39	
15K3.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.6	$ 280.00	$ 287.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.85	$ 396.67	$ 410.67	$ 0.41	

Part Number	Std Batch Qty	Op. #	Description	Work Centre / Machine / Operator	Batch Setup Time (hours)	Batch Setup Cost	INTERNAL Unit prodn time (min) OR EXTERNAL Unit measurement (kg,m,hr)	Batch Processing Cost	Std Batch Cost	Std Unit Labour Cost	Tool No.
6/7.5K2IP	1000	10	blanked & pierced	75tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					4	$ 112.00	0.277	$ 111.27	$ 223.27	$ 0.22	
6/7.5K2OP	1000	10	blanked & pierced	75tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	stamped	75tPress	1	$ 28.00	0.167	$ 77.93	$ 105.93		
		30	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					5	$ 140.00	0.444	$ 189.20	$ 329.20	$ 0.33	
6/7.5K2.0IL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20				$ -		$ -	$ -		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.25	$ 7.00	0.5	$ 233.33	$ 240.33	$ 0.24	
6K2.0OL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.167	$ 77.93	$ 84.93		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.667	$ 311.27	$ 325.27	$ 0.33	
6K2.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.75	$ 350.00	$ 364.00	$ 0.36	
7.5K2.0OL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.167	$ 77.93	$ 84.93		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.667	$ 311.27	$ 325.27	$ 0.33	

Part Number	Std Batch Qty	Op. #	Description	Work Centre / Machine / Operator	Batch Setup Time (hours)	Batch Setup Cost	INTERNAL Unit prodn time (min) OR EXTERNAL Unit measurement (kg,m,hr)	Batch Processing Cost	Std Batch Cost	Std Unit Labour Cost	Tool No.
7.5K2.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.75	$ 350.00	$ 364.00	$ 0.36	
6/7.5K2.5IP	1000	10	blanked & pierced	75tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					4	$ 112.00	0.277	$ 111.27	$ 223.27	$ 0.22	
6/7.5K2.5OP	1000	10	blanked & pierced	75tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	stamped	75tPress	1	$ 28.00	0.167	$ 77.93	$ 105.93		
		30	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					5	$ 140.00	0.444	$ 189.20	$ 329.20	$ 0.33	
6/7.5K2.5IL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20				$ -		$ -	$ -		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.25	$ 7.00	0.5	$ 233.33	$ 240.33	$ 0.24	
6K2.5OL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.167	$ 77.93	$ 84.93		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.667	$ 311.27	$ 325.27	$ 0.33	
6K2.5	1000	10	assembled	GreyRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.75	$ 350.00	$ 364.00	$ 0.36	

Part Number	Std Batch Qty	Op. #	Description	Work Centre / Machine / Operator	Batch Setup Time (hours)	Batch Setup Cost	INTERNAL Unit prodn time (min) OR EXTERNAL Unit measurement (kg,m,hr)	Batch Processing Cost	Std Batch Cost	Std Unit Labour Cost	Tool No.
7.5K2.5OL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.167	$ 77.93	$ 84.93		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.667	$ 311.27	$ 325.27	$ 0.33	
7.5K2.5	1000	10	assembled	GreyRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.75	$ 350.00	$ 364.00	$ 0.36	
6K3.0OL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.167	$ 77.93	$ 84.93		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.667	$ 311.27	$ 325.27	$ 0.33	
6K3.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.75	$ 350.00	$ 364.00	$ 0.36	
6/7.5K4IP	1000	10	blanked & pierced	75tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					4	$ 112.00	0.277	$ 111.27	$ 223.27	$ 0.22	
6/7.5K4OP	1000	10	blanked & pierced	75tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	stamped	75tPress	1	$ 28.00	0.167	$ 77.93	$ 105.93		
		30	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					5	$ 140.00	0.444	$ 189.20	$ 329.20	$ 0.33	

Part Number	Std Batch Qty	Op. #	Description	Work Centre / Machine / Operator	Batch Setup Time (hours)	Batch Setup Cost	INTERNAL Unit prodn time (min) OR EXTERNAL Unit measurement (kg,m,hr)	Batch Processing Cost	Std Batch Cost	Std Unit Labour Cost	Tool No.
6/7.5K4.0IL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20				$ -		$ -	$ -		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.25	$ 7.00	0.5	$ 233.33	$ 240.33	$ 0.24	
6K4.0OL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.167	$ 77.93	$ 84.93		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.667	$ 311.27	$ 325.27	$ 0.33	
6K4.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.75	$ 350.00	$ 364.00	$ 0.36	
7.5K4.0OL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.167	$ 77.93	$ 84.93		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.667	$ 311.27	$ 325.27	$ 0.33	
7.5K4.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.75	$ 350.00	$ 364.00	$ 0.36	
6/7.5K5IP	1000	10	blanked & pierced	75tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					4	$ 112.00	0.277	$ 111.27	$ 223.27	$ 0.22	

Part Number	Std Batch Qty	Op. #	Description	Work Centre / Machine / Operator	Batch Setup Time (hours)	Batch Setup Cost	INTERNAL Unit prodn time (min) OR EXTERNAL Unit measurement (kg,m,hr)	Batch Processing Cost	Std Batch Cost	Std Unit Labour Cost	Tool No.
6/7.5K5OP	1000	10	blanked & pierced	75tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	stamped	75tPress	1	$ 28.00	0.167	$ 77.93	$ 105.93		
		30	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					5	$ 140.00	0.444	$ 189.20	$ 329.20	$ 0.33	
6/7.5K5.0IL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20				$ -		$ -	$ -		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.25	$ 7.00	0.5	$ 233.33	$ 240.33	$ 0.24	
6K5.0OL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.167	$ 77.93	$ 84.93		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.667	$ 311.27	$ 325.27	$ 0.33	
6K5.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.75	$ 350.00	$ 364.00	$ 0.36	
7.5K5.0OL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.167	$ 77.93	$ 84.93		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.667	$ 311.27	$ 325.27	$ 0.33	
7.5K5.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.75	$ 350.00	$ 364.00	$ 0.36	

Part Number	Std Batch Qty	Op. #	Description	Work Centre / Machine / Operator	Batch Setup Time (hours)	Batch Setup Cost	INTERNAL Unit prodn time (min) OR EXTERNAL Unit measurement (kg,m,hr)	Batch Processing Cost	Std Batch Cost	Std Unit Labour Cost	Tool No.
6/7.5K6IP	1000	10	blanked & pierced	75tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					4	$ 112.00	0.277	$ 111.27	$ 223.27	$ 0.22	
6/7.5K6OP	1000	10	blanked & pierced	75tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	stamped	75tPress	1	$ 28.00	0.167	$ 77.93	$ 105.93		
		30	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					5	$ 140.00	0.444	$ 189.20	$ 329.20	$ 0.33	
6/7.5K6.0IL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20				$ -		$ -	$ -		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.25	$ 7.00	0.5	$ 233.33	$ 240.33	$ 0.24	
6K6.0OL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.167	$ 77.93	$ 84.93		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.667	$ 311.27	$ 325.27	$ 0.33	
6K6.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.75	$ 350.00	$ 364.00	$ 0.36	
7.5K6.0OL	1000	10	assembled	RedRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.167	$ 77.93	$ 84.93		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.667	$ 311.27	$ 325.27	$ 0.33	

Part Number	Std Batch Qty	Op. #	Description	Work Centre / Machine / Operator	Batch Setup Time (hours)	Batch Setup Cost	INTERNAL Unit prodn time (min) OR EXTERNAL Unit measurement (kg,m,hr)	Batch Processing Cost	Std Batch Cost	Std Unit Labour Cost	Tool No.
7.5K6.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.5	$ 233.33	$ 240.33		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.75	$ 350.00	$ 364.00	$ 0.36	
12K3.0OL	1000	10	assembled	GreyRam	0.25	$ 7.00	0.6	$ 280.00	$ 287.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.85	$ 396.67	$ 410.67	$ 0.41	
12K3.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.6	$ 280.00	$ 287.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.85	$ 396.67	$ 410.67	$ 0.41	
12/15K4IP	1000	10	pierced	150tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	blanked	150tPress	2	$ 56.00	0.25	$ 116.67	$ 172.67		
		30	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					6	$ 168.00	0.527	$ 227.93	$ 395.93	$ 0.40	
12/15K4OP	1000	10	pierced	150tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	blanked	150tPress	2	$ 56.00	0.25	$ 116.67	$ 172.67		
		30	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		40	stamped	75tPress	1	$ 28.00	0.217	$ 101.27	$ 129.27		
		50				$ -		$ -	$ -		
Totals					7	$ 196.00	0.744	$ 329.20	$ 525.20	$ 0.53	
12/15K4.0IL	1000	10	assembled	RedRam	0.25	$ 7.00	0.6	$ 280.00	$ 287.00		
		20				$ -		$ -	$ -		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.25	$ 7.00	0.6	$ 280.00	$ 287.00	$ 0.29	

Part Number	Std Batch Qty	Op. #	Description	Work Centre / Machine / Operator	Batch Setup Time (hours)	Batch Setup Cost	INTERNAL Unit prodn time (min) OR EXTERNAL Unit measurement (kg,m,hr)	Batch Processing Cost	Std Batch Cost	Std Unit Labour Cost	Tool No.
12K4.0OL	1000	10	assembled	GreyRam	0.25	$ 7.00	0.6	$ 280.00	$ 287.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.85	$ 396.67	$ 410.67	$ 0.41	
12K4.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.6	$ 280.00	$ 287.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.85	$ 396.67	$ 410.67	$ 0.41	
15K4.0OL	1000	10	assembled	GreyRam	0.25	$ 7.00	0.6	$ 280.00	$ 287.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.85	$ 396.67	$ 410.67	$ 0.41	
15K4.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.6	$ 280.00	$ 287.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.85	$ 396.67	$ 410.67	$ 0.41	
12/15K6IP	1000	10	pierced	150tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	blanked	150tPress	2	$ 56.00	0.25	$ 116.67	$ 172.67		
		30	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					6	$ 168.00	0.527	$ 227.93	$ 395.93	$ 0.40	
12/15K6OP	1000	10	pierced	150tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	blanked	150tPress	2	$ 56.00	0.25	$ 116.67	$ 172.67		
		30	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		40	stamped	75tPress	1	$ 28.00	0.217	$ 101.27	$ 129.27		
		50				$ -		$ -	$ -		
Totals					7	$ 196.00	0.744	$ 329.20	$ 525.20	$ 0.53	

Part Number	Std Batch Qty	Op. #	Description	Work Centre / Machine / Operator	Batch Setup Time (hours)	Batch Setup Cost	INTERNAL Unit prodn time (min) OR EXTERNAL Unit measurement (kg,m,hr)	Batch Processing Cost	Std Batch Cost	Std Unit Labour Cost	Tool No.
12/15K6.0IL	1000	10	assembled	RedRam	0.25	$ 7.00	0.6	$ 280.00	$ 287.00		
		20				$ -		$ -	$ -		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.25	$ 7.00	0.6	$ 280.00	$ 287.00	$ 0.29	
12K6.0OL	1000	10	assembled	GreyRam	0.25	$ 7.00	0.6	$ 280.00	$ 287.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.85	$ 396.67	$ 410.67	$ 0.41	
12K6.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.6	$ 280.00	$ 287.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.85	$ 396.67	$ 410.67	$ 0.41	
15K6.0OL	1000	10	assembled	GreyRam	0.25	$ 7.00	0.6	$ 280.00	$ 287.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.85	$ 396.67	$ 410.67	$ 0.41	
15K6.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.6	$ 280.00	$ 287.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.25	$ 116.67	$ 123.67		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	0.85	$ 396.67	$ 410.67	$ 0.41	
24/30K100	1000	10	machined	Mori	1	$ 34.00	1.583	$ 897.03	$ 931.03		
		20	case hardened	HTAuck	x	$ -	0.097	$ 533.50	$ 533.50		
		30	freight to Auckland	Freight	x	$ -	0.097	$ 36.86	$ 36.86		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					1	$ 34.00	1.777	$ 1,467.39	$ 1,501.39	$ 1.50	

Part Number	Std Batch Qty	Op. #	Description	Work Centre / Machine / Operator	Batch Setup Time (hours)	Batch Setup Cost	INTERNAL Unit prodn time (min) OR EXTERNAL Unit measurement (kg,m,hr)	Batch Processing Cost	Std Batch Cost	Std Unit Labour Cost	Tool No.
24/30K102	1000	10	machined	4Stn	1	$ 34.00	2.5	$ 1,416.67	$ 1,450.67		
		20	case hardened	HTAuck	x	$ -	0.502	$ 2,761.00	$ 2,761.00		
		30	freight to Auckland	Freight	x	$ -	0.502	$ 190.76	$ 190.76		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					1	$ 34.00	3.504	$ 4,368.43	$ 4,402.43	$ 4.40	
24K650	1000	10	machined	Mori	1	$ 34.00	1.283	$ 727.03	$ 761.03		
		20	induction hardened	Induction	0.25	$ 7.00	0.167	$ 77.93	$ 84.93		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					1.25	$ 41.00	1.45	$ 804.97	$ 845.97	$ 0.85	
30K652	1000	10	machined	Mori	1	$ 34.00	0.7	$ 396.67	$ 430.67		
		20	induction hardened	Induction	0.25	$ 7.00	0.2	$ 93.33	$ 100.33		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					1.25	$ 41.00	0.9	$ 490.00	$ 531.00	$ 0.53	
24/30K6IP	1000	10	pierced	150tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	blanked	150tPress	2	$ 56.00	0.25	$ 116.67	$ 172.67		
		30	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					6	$ 168.00	0.527	$ 227.93	$ 395.93	$ 0.40	
24/30K6OP	1000	10	pierced	150tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	blanked	150tPress	2	$ 56.00	0.25	$ 116.67	$ 172.67		
		30	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		40	stamped	75tPress	1	$ 28.00	0.217	$ 101.27	$ 129.27		
		50				$ -		$ -	$ -		
Totals					7	$ 196.00	0.744	$ 329.20	$ 525.20	$ 0.53	
24/30K6.0IL	1000	10	assembled	RedRam	0.25	$ 7.00	0.72	$ 336.00	$ 343.00		
		20				$ -		$ -	$ -		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.25	$ 7.00	0.72	$ 336.00	$ 343.00	$ 0.34	

Part Number	Std Batch Qty	Op. #	Description	Work Centre / Machine / Operator	Batch Setup Time (hours)	Batch Setup Cost	INTERNAL Unit prodn time (min) <u>OR</u> EXTERNAL Unit measurement (kg,m,hr)	Batch Processing Cost	Std Batch Cost	Std Unit Labour Cost	Tool No.
24K6.0OL	1000	10	assembled	GreyRam	0.25	$ 7.00	0.72	$ 336.00	$ 343.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.3	$ 140.00	$ 147.00		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	1.02	$ 476.00	$ 490.00	$ 0.49	
24K6.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.72	$ 336.00	$ 343.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.3	$ 140.00	$ 147.00		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	1.02	$ 476.00	$ 490.00	$ 0.49	
30K6.0OL	1000	10	assembled	GreyRam	0.25	$ 7.00	0.72	$ 336.00	$ 343.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.3	$ 140.00	$ 147.00		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	1.02	$ 476.00	$ 490.00	$ 0.49	
30K6.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.72	$ 336.00	$ 343.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.3	$ 140.00	$ 147.00		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	1.02	$ 476.00	$ 490.00	$ 0.49	
24/30K8IP	1000	10	pierced	150tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	blanked	150tPress	2	$ 56.00	0.25	$ 116.67	$ 172.67		
		30	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					6	$ 168.00	0.527	$ 227.93	$ 395.93	$ 0.40	
24/30K8OP	1000	10	pierced	150tPress	3	$ 84.00	0.217	$ 101.27	$ 185.27		
		20	blanked	150tPress	2	$ 56.00	0.25	$ 116.67	$ 172.67		
		30	rumbled	RumblerLg	1	$ 28.00	0.06	$ 10.00	$ 38.00		
		40	stamped	75tPress	1	$ 28.00	0.217	$ 101.27	$ 129.27		
		50				$ -		$ -	$ -		
Totals					7	$ 196.00	0.744	$ 329.20	$ 525.20	$ 0.53	

Part Number	Std Batch Qty	Op. #	Description	Work Centre / Machine / Operator	Batch Setup Time (hours)	Batch Setup Cost	INTERNAL Unit prodn time (min) OR EXTERNAL Unit measurement (kg,m,hr)	Batch Processing Cost	Std Batch Cost	Std Unit Labour Cost	Tool No.
24/30K8.0IL	1000	10	assembled	RedRam	0.25	$ 7.00	0.72	$ 336.00	$ 343.00		
		20				$ -		$ -	$ -		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.25	$ 7.00	0.72	$ 336.00	$ 343.00	$ 0.34	
24K8.0OL	1000	10	assembled	GreyRam	0.25	$ 7.00	0.72	$ 336.00	$ 343.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.3	$ 140.00	$ 147.00		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	1.02	$ 476.00	$ 490.00	$ 0.49	
24K8.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.72	$ 336.00	$ 343.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.3	$ 140.00	$ 147.00		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	1.02	$ 476.00	$ 490.00	$ 0.49	
30K8.0OL	1000	10	assembled	GreyRam	0.25	$ 7.00	0.72	$ 336.00	$ 343.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.3	$ 140.00	$ 147.00		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	1.02	$ 476.00	$ 490.00	$ 0.49	
30K8.0	1000	10	assembled	GreyRam	0.25	$ 7.00	0.72	$ 336.00	$ 343.00		
		20	riveted	SpinRiveter	0.25	$ 7.00	0.3	$ 140.00	$ 147.00		
		30				$ -		$ -	$ -		
		40				$ -		$ -	$ -		
		50				$ -		$ -	$ -		
Totals					0.5	$ 14.00	1.02	$ 476.00	$ 490.00	$ 0.49	

Labour Unit Costings Lookup

Part Number	Labour Unit Costing	
12/15K100	$	0.51
12/15K102	$	1.68
12/15K3.0IL	$	0.29
12/15K3IP	$	0.40
12/15K3OP	$	0.53
12/15K4.0IL	$	0.29
12/15K4IP	$	0.40
12/15K4OP	$	0.53
12/15K6.0IL	$	0.29
12/15K6IP	$	0.40
12/15K6OP	$	0.53
12K3.0	$	0.41
12K3.0OL	$	0.41
12K4.0	$	0.41
12K4.0OL	$	0.41
12K6.0	$	0.41
12K6.0OL	$	0.41
12K650	$	0.80
15K3.0	$	0.41
15K3.0OL	$	0.39
15K4.0	$	0.41
15K4.0OL	$	0.41
15K6.0	$	0.41
15K6.0OL	$	0.41
15K652	$	0.43
24/30K100	$	1.50
24/30K102	$	4.40
24/30K6.0IL	$	0.34
24/30K6IP	$	0.40
24/30K6OP	$	0.53
24/30K8.0IL	$	0.34
24/30K8IP	$	0.40
24/30K8OP	$	0.53
24K6.0	$	0.49
24K6.0OL	$	0.49
24K650	$	0.85
24K8.0	$	0.49
24K8.0OL	$	0.49
30K6.0	$	0.49
30K6.0OL	$	0.49
30K652	$	0.53
30K8.0	$	0.49
30K8.0OL	$	0.49
6/7.5K100	$	0.32
6/7.5K102	$	0.82
6/7.5K2.0IL	$	0.24
6/7.5K2.5IL	$	0.24
6/7.5K2.5IP	$	0.22
6/7.5K2.5OP	$	0.33
6/7.5K2IP	$	0.22
6/7.5K2OP	$	0.33
6/7.5K3.0IL	$	0.24
6/7.5K3IP	$	0.22
6/7.5K3OP	$	0.33
6/7.5K4.0IL	$	0.24

Labour Unit Costings Lookup

Part Number	Labour Unit Costing	
6/7.5K4IP	$	0.22
6/7.5K4OP	$	0.33
6/7.5K5.0IL	$	0.24
6/7.5K5IP	$	0.22
6/7.5K5OP	$	0.33
6/7.5K6.0IL	$	0.24
6/7.5K6IP	$	0.22
6/7.5K6OP	$	0.33
6K2.0	$	0.36
6K2.0OL	$	0.33
6K2.5	$	0.36
6K2.5OL	$	0.33
6K3.0	$	0.36
6K3.0OL	$	0.33
6K4.0	$	0.36
6K4.0OL	$	0.33
6K5.0	$	0.36
6K5.0OL	$	0.33
6K6.0	$	0.36
6K6.0OL	$	0.33
6K650	$	0.94
7.5K2.0	$	0.36
7.5K2.0OL	$	0.33
7.5K2.5	$	0.36
7.5K2.5OL	$	0.33
7.5K3.0	$	0.36
7.5K3.0OL	$	0.33
7.5K4.0	$	0.36
7.5K4.0OL	$	0.33
7.5K5.0	$	0.36
7.5K5.0OL	$	0.33
7.5K6.0	$	0.36
7.5K6.0OL	$	0.33
7.5K652	$	0.43

Work Centre Costings Lookup

Work Centre / Machine / Operator	Setup Costs (/hr)	Production Costs (/hour)
150tPress	$ 28.00	$ 28.00
75tPress	$ 28.00	$ 28.00
AirRam	$ 28.00	$ 28.00
BushRoll	$ 28.00	$ 28.00
GreyRam	$ 28.00	$ 28.00
Howa	$ 34.00	$ 34.00
Induction	$ 28.00	$ 28.00
Mori	$ 34.00	$ 34.00
RedRam	$ 28.00	$ 28.00
RumblerLg	$ 28.00	$ 10.00
RumblerSm	$ 28.00	$ 10.00
SpinRiveter	$ 28.00	$ 28.00
4Stn	$ 34.00	$ 34.00

External Sub-Contractor work centre / operation	Costings charge rate / unit	Charge Description
Electrozinc	1.1	$/kg
Etech-guillotine	36	$/hr
Etech-laser	45	$/m
Freight	0.38	$/kg
HTAuck	5.5	$/kg

Material	Cost per Raw Material Unit (bar stock, sheet, etc)	Unit Descriptor	Description
014MT	$ 7.18	3.6m length	14mm dia 1040 bar
750MT	$ 25.00	6m length	3/4" dia K1040 bar
ABC	$ 16.00		24/30K plate material
BFC1250	$ 35.88	3.68m length	6/7.5K roller material
BFC1875	$ 82.80	3.68m length	1 7/8" dia bright free cutting mild steel
DEF	$ 40.00		24/30K pin material
GHJ	$ 90.00		24/30K roller material
KLM	$ 90.00		24/30K bush material
MSP0016	$ 53.00	1.6mm X 2.4m X 1.2m Sheet	1020 panel steel (6/7.5K)
MSP002	$ 65.00	2mm x 2.4m X 1.2m Sheet	1020 panel steel (12/15K)
MTF025004	$ 7.50	5.8 m length	EN8 flat Square Edge 1" x 5/32" (6/7.5K)
MTF040005	$ 15.70	5.7m length	40 x 5 EN8 Flat Square Edge (12/15K)

seconds	minutes	seconds	minutes	seconds	minutes	seconds	minutes	seconds	minutes
4	0.067	28	0.467	52	0.867	76	1.267	100	1.667
5	0.083	29	0.483	53	0.883	77	1.283	101	1.683
6	0.1	30	0.5	54	0.9	78	1.3	102	1.7
7	0.117	31	0.517	55	0.917	79	1.317	103	1.717
8	0.133	32	0.533	56	0.933	80	1.333	104	1.733
9	0.15	33	0.55	57	0.95	81	1.35	105	1.75
10	0.167	34	0.567	58	0.967	82	1.367	106	1.767
11	0.183	35	0.583	59	0.983	83	1.383	107	1.783
12	0.2	36	0.6	60	1	84	1.4	108	1.8
13	0.217	37	0.617	61	1.017	85	1.417	109	1.817
14	0.233	38	0.633	62	1.033	86	1.433	110	1.833
15	0.25	39	0.65	63	1.05	87	1.45	111	1.85
16	0.267	40	0.667	64	1.067	88	1.467	112	1.867
17	0.283	41	0.683	65	1.083	89	1.483	113	1.883
18	0.3	42	0.7	66	1.1	90	1.5	114	1.9
19	0.317	43	0.717	67	1.117	91	1.517	115	1.917
20	0.333	44	0.733	68	1.133	92	1.533	116	1.933
21	0.35	45	0.75	69	1.15	93	1.55	117	1.95
22	0.367	46	0.767	70	1.167	94	1.567	118	1.967
23	0.383	47	0.783	71	1.183	95	1.583	119	1.983
24	0.4	48	0.8	72	1.2	96	1.6	120	2
25	0.417	49	0.817	73	1.217	97	1.617	121	2.017
26	0.433	50	0.833	74	1.233	98	1.633	122	2.033
27	0.45	51	0.85	75	1.25	99	1.65	123	2.05

Appendix E

Chain	Cost per Foot (manual)	Cost per Foot (induction automated)	Percentage savings per Foot after induction automation	Cost per Foot (logo stamp automated)	Percentage savings per Foot after logo stamp automation	Cost per Foot (12/15K bush roller automated)	Percentage savings per Foot after 12/15K bush roller automation	Cost per Foot (75T Press ALL blanking ops automated)	Percentage savings per Foot after 75T Press automation	Cost per Foot (150T Press ALL blanking ops automated)	Percentage savings per Foot after 150T Press automation	Cost per Foot with Automatic Inner Link Assembly	Percentage Savings per Foot with Inner Link Assembly automation	Cost per Foot with Inhouse Roller Induction Heat Treatment	Percentage Savings per Foot with Inhouse Roller Induction Heat Treatment
7.5K3.0	$ 12.95	$ 12.76	1.44%	$ 12.64	2.41%			$ 11.95	7.70%			$ 12.48	3.60%	$ 11.80	8.91%
7.5K4.0	$ 10.02	$ 9.88	1.40%	$ 9.79	2.33%			$ 9.27	7.46%			$ 9.67	3.49%	$ 9.16	8.64%
7.5K6.0	$ 6.94	$ 6.85	1.34%	$ 6.79	2.24%			$ 6.45	7.18%			$ 6.71	3.36%	$ 6.37	8.31%
6K3.0	$ 14.99	$ 14.80	1.25%	$ 14.68	2.08%			$ 13.99	6.65%			$ 14.52	3.11%	$ 13.84	7.70%
6K4.0	$ 11.55	$ 11.41	1.21%	$ 11.32	2.02%			$ 10.80	6.47%			$ 11.20	3.03%	$ 10.69	7.49%
6K6.0	$ 7.96	$ 7.87	1.17%	$ 7.81	1.96%			$ 7.47	6.26%			$ 7.73	2.93%	$ 7.39	7.25%
15K4.0	$ 17.99	$ 17.82	0.91%	$ 17.68	1.69%	$ 17.51	2.64%	$ 17.85	0.78%	$ 16.68	7.27%	$ 17.57	2.33%	$ 14.87	17.33%
15K6.0	$ 12.54	$ 12.43	0.87%	$ 12.34	1.61%	$ 12.23	2.53%	$ 12.45	0.74%	$ 11.67	6.95%	$ 12.26	2.23%	$ 10.46	16.57%
12K4.0	$ 19.10	$ 18.96	0.73%	$ 18.80	1.59%	$ 18.62	2.49%	$ 18.96	0.73%	$ 17.79	6.85%	$ 18.68	2.20%	$ 15.98	16.33%
12K6.0	$ 13.28	$ 13.19	0.70%	$ 13.08	1.52%	$ 12.97	2.39%	$ 13.19	0.70%	$ 12.41	6.56%	$ 13.00	2.11%	$ 11.20	15.65%
Estimated Automation Cap Ex		$ 10,000.00		$5000 - $8,000 PLUS repair & reassembly 30tPres		$5000 - $8,000 PLUS redesign of mechanism		$30,000 - $50,000+ NOT including new automation ready tooling. May be less expensive to automate segments of assembly.		$30,000 - $50,000+		$30,000 - $50,0000			
Average of Percentage Savings			1.10%		1.95%		2.51%		4.47%		6.91%		2.84%		11.42%
Weighted Average Across Total Footage			1.22%		2.09%		0.54%		5.73%		1.49%		3.09%		10.01%
Potential Labour Savings per Year			$5,000 - $10,000		$5,000 - $10,000		$3,000 -$4,000						$10,000 - $15,000	Efficient 12/15K manual setup: $2,000 / full automation $5,000 - $10,000 Semi-automatic 6/7.5K setup: $1,500 / full automation $3,000	

NB:
1. Manual production costs $28.00/hr
2. Setup left in costing & unchanged at $28.00/hr
3. Automated productign costs $0/hr
4. Remember - production rates have overheads built in!
5. Total listed weighted percentage savings: 24.18% NB: Percentage savings without press automation: 16.95%
6. Savings are based on specified automation individually - on a progressive basis, the savings would become less upon successful introduction of the previous automation option.
7. Labour savings based on $20,000 pa wage.
8. 12/15K rollers @ $1.40/kg (100/hr) & 6/7.5K @ $1.98/kg (240/hr)

	1999 Value @ Cost	1999 (ft)	% of Production		
Stock Chain De	$ 18,079.33	1396	19.4%		
Chain	$ 12,256.66	1223	17.0%		%Total production stock chain
7.5K3.0	$ 5,881.31	847	11.8%	6/7.5K	79%
7.5K4.0	$ 6,071.28	405	5.6%		
7.5K6.0	$ 13,977.67	1210	16.8%		
6K3.0	$ 4,642.84	583	8.1%		
6K4.0	$ 10,181.66	566	7.9%		
6K6.0	$ 3,612.10	288	4.0%	12/15K	21%
15K4.0	$ 11,039.16	578	8.0%		
15K6.0	$ 1,328.21	100	1.4%		
12K4.0	$ 87,070.20	7196			
12K6.0					
Totals					

Appendix I

Roller A

Approx Depth of Cut	thickness (mm)	depth (mm)	North	East	South	West	raw material
0	17.3	0	54	56	57	58	16
2	15.3	2	53	56	56	56	16
4	12.79	4.51	46	48	42	45	16
6	10.68	6.62	44	43	41	42	16
8	8.65	8.65	41	42	39	40	16
	6.65	10.65					16
	4.65	12.65					16
	2.65	14.65					16
	0	17.3	57	56	59	60	16
		outer diameter	54	53	35	43	

Roller B

Approx Depth of Cut	thickness (mm)	depth (mm)	North	East	South	West	raw material
0	17.3	0	49	61	58	61	15
2	15.3	2	55	57	57	59	15
4	13.42	3.88	53	57	50	48	15
6	11.29	6.01	49	51	45	42	15
8	9.28	8.02	42	44	41	41	15
	7.28	10.02					15
	5.28	12.02					15
	3.28	14.02					15
	0	17.3	61	62	62	62	15
		outer diameter	58	51	48	57	

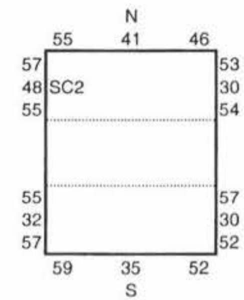
Roller C

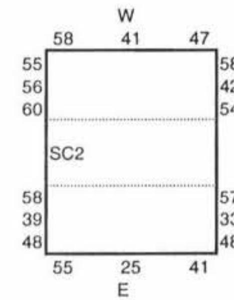
Approx Depth of Cut	thickness (mm)	depth (mm)	North	East	South	West	raw material
0	17.3	0	55	54	49	55	15
2	15.3	2	57	55	56	52	15
4	13.65	3.65	49	48	45	48	15
6	11.62	5.68	45	40	38	42	15
8	9.62	7.68	39	37	38	41	15
	7.62	9.68					15
	5.62	11.68					15
	3.62	13.68					15
	0	17.3	53	52	56	60	15
		outer diameter	57	52	45	48	

12/15K Roller Induction Heating Data (CURVED SURFACES HEATING)

SC2 Single process / inner & outer coils in parallel

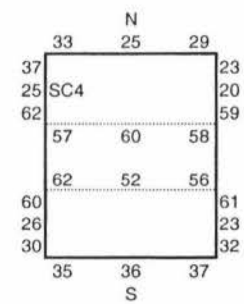
	N	E	S	W
FLANGE1 INNER	55	58	55	60
FLANGE1 MIDDLE	48	39	32	56
FLANGE1 OUTER	57	48	57	55
O/D TOP	55	55	59	58
O/D MIDDLE	41	25	35	41
O/D BOTTOM	46	41	52	47
FLANGE2 OUTER	53	48	52	58
FLANGE2 MIDDLE	30	33	30	42
FLANGE2 INNER	54	57	57	54

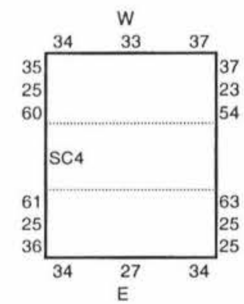




SC4 Two processes / outer first, inner second

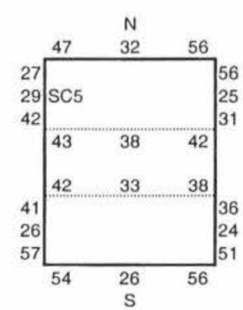
	N	E	S	W
FLANGE1 INNER	62	61	60	60
FLANGE1 MIDDLE	25	25	26	25
FLANGE1 OUTER	37	36	30	35
O/D TOP	33	34	35	34
O/D MIDDLE	25	27	36	33
O/D BOTTOM	29	34	37	37
FLANGE2 OUTER	23	25	32	37
FLANGE2 MIDDLE	20	25	23	23
FLANGE2 INNER	59	63	61	54
I/D BOTTOM	58		56	
I/D MIDDLE	60		52	
I/D TOP	57		62	

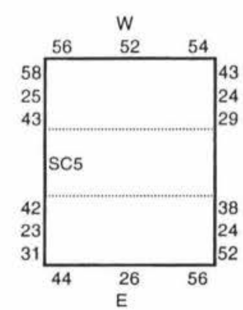




SC5 Two processes / inner first, outer second

	N	E	S	W
FLANGE1 INNER	42	42	41	43
FLANGE1 MIDDLE	29	23	26	25
FLANGE1 OUTER	27	31	57	58
O/D TOP	47	44	54	56
O/D MIDDLE	32	26	26	52
O/D BOTTOM	56	56	56	54
FLANGE2 OUTER	56	52	51	43
FLANGE2 MIDDLE	25	24	24	24
FLANGE2 INNER	31	38	36	29
I/D BOTTOM	42		38	
I/D MIDDLE	38		33	
I/D TOP	43		42	
Pre-outer FLANGE1 INNER	60	50	56	60
Pre-outer FLANGE2 INNER	28	34	56	58

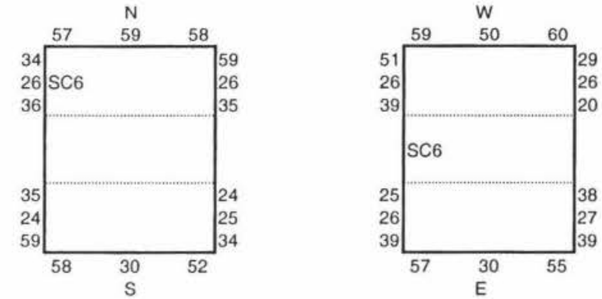




SC6

Heat Wave Test
Two processes / inner first, outer second
Heat wavefront not allowed to reach opposite diameter

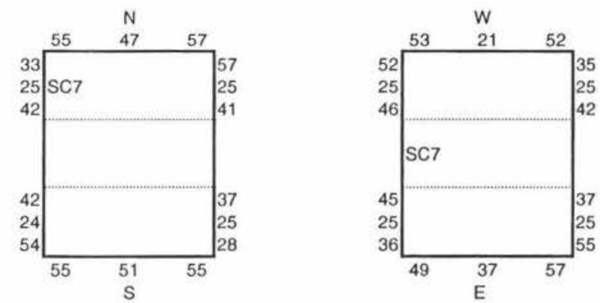
	N	E	S	W
FLANGE1 INNER	36	25	35	39
FLANGE1 MIDDLE	26	26	24	26
FLANGE1 OUTER	34	39	59	51
O/D TOP	57	57	58	59
O/D MIDDLE	59	30	30	50
O/D BOTTOM	58	55	52	60
FLANGE2 OUTER	59	39	34	29
FLANGE2 MIDDLE	26	27	25	26
FLANGE2 INNER	35	38	24	20



SC7

Two process / inner first, outer second / inner surface cooled

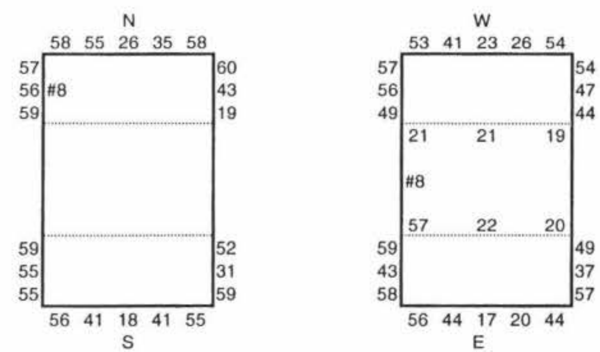
	N	E	S	W
FLANGE1 INNER	42	45	42	46
FLANGE1 MIDDLE	25	25	24	25
FLANGE1 OUTER	33	36	54	52
O/D TOP	55	49	55	53
O/D MIDDLE	47	37	51	21
O/D BOTTOM	57	57	55	52
FLANGE2 OUTER	57	55	28	35
FLANGE2 MIDDLE	25	25	25	25
FLANGE2 INNER	41	37	37	42

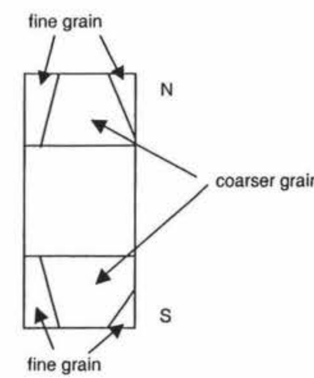


#8

12/15Kroller / Flange heat using 30/40/30 rule

	N	E	S	W
FLANGE1 INNER	59	59	59	49
FLANGE1 MIDDLE	56	43	55	56
FLANGE1 OUTER	57	58	55	57
O/D TOP	58	56	56	53
	55	44	41	41
O/D MIDDLE	26	17	18	23
	35	20	41	26
O/D BOTTOM	58	44	55	54
FLANGE2 OUTER	60	57	59	54
FLANGE2 MIDDLE	43	37	31	47
FLANGE2 INNER	19	49	52	44
I/D BOTTOM		20		19
I/D MIDDLE		22		21
I/D TOP		57		21





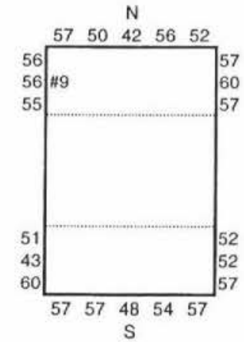
NB:

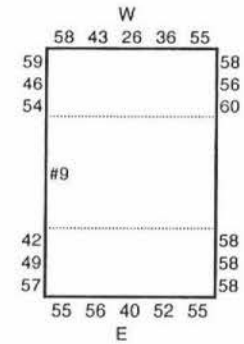
1. Two pancake coils / Approx 5 to 5.5 turns each / wound same direction
2. 65mm to 70mm diameter
3. Coils placed in volume centre between coils
4. P=12.5 / T=8 sec

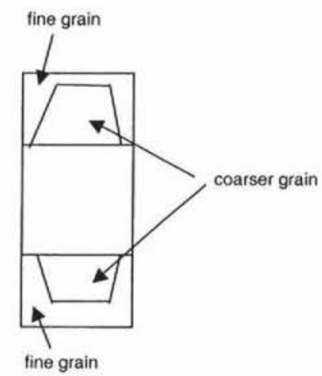
Roller Induction Heating Data

#9 12/15Kroller / Flange heat using 30/40/30 rule

	N	E	S	W
FLANGE1 INNER	55	42	51	54
FLANGE1 MIDDLE	56	49	43	46
FLANGE1 OUTER	56	57	60	59
O/D TOP	57	55	57	58
	50	56	57	43
O/D MIDDLE	42	40	48	26
	56	52	54	36
O/D BOTTOM	52	55	57	55
FLANGE2 OUTER	57	58	57	58
FLANGE2 MIDDLE	60	58	52	56
FLANGE2 INNER	57	58	52	60
I/D BOTTOM				
I/D MIDDLE				
I/D TOP				



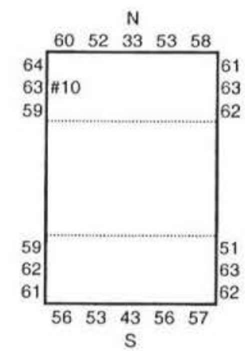


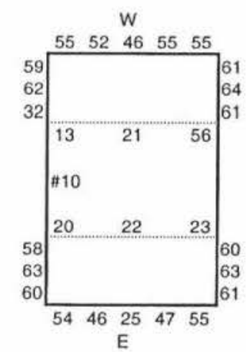


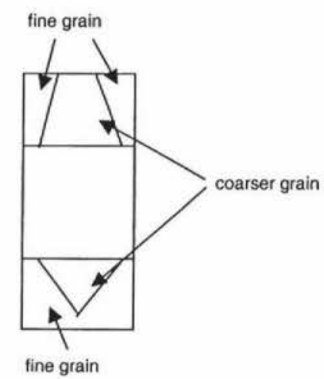
NB:
1. Two pancake coils / Approx 5 to 5.5 turns each / wound same direction
2. 65mm to 70mm diameter
3. Coils placed in volume centre between coils
4. P=12.5 / T=10 sec
5. HAMMER TEST: approx 3 blows with med ball pean - roller broke into two pieces

#10 6/7.5Kroller / Flange heat using 30/40/30 rule

	N	E	S	W
FLANGE1 INNER	59	58	59	32
FLANGE1 MIDDLE	63	63	62	62
FLANGE1 OUTER	64	60	61	59
O/D TOP	60	54	56	55
	52	46	53	52
O/D MIDDLE	33	25	43	46
	53	47	56	55
O/D BOTTOM	58	55	57	55
FLANGE2 OUTER	61	61	62	61
FLANGE2 MIDDLE	63	63	63	64
FLANGE2 INNER	62	60	51	61
I/D BOTTOM		23		56
I/D MIDDLE		22		21
I/D TOP		20		13





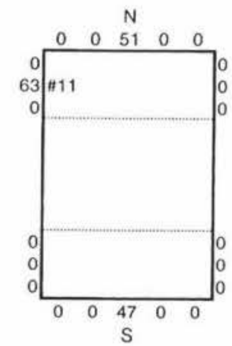


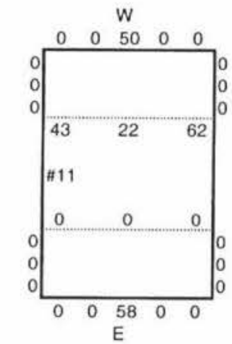
NB:
1. Two pancake coils / Approx 5 to 5.5 turns each / wound same direction
2. 65mm to 70mm diameter
3. Coils placed in volume centre between coils
4. P=13 / T=5 sec
5. HAMMER TEST: approx 2 blows with med ball pean - roller broke into 3 pieces / roller deformed oval before breaking

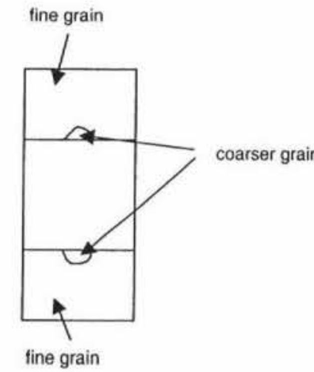
Roller Induction Heating Data

#11 6/7.5Kroller / Flange heat using 30/40/30 rule

	N	E	S	W
FLANGE1 INNER				
FLANGE1 MIDDLE	63			
FLANGE1 OUTER				
O/D TOP				
O/D MIDDLE	51	58	47	50
O/D BOTTOM				
FLANGE2 OUTER				
FLANGE2 MIDDLE				
FLANGE2 INNER				
I/D BOTTOM				62
I/D MIDDLE				22
I/D TOP				43



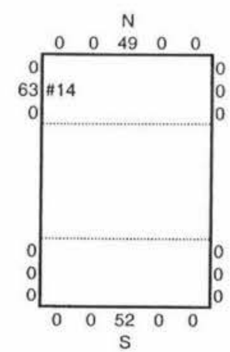


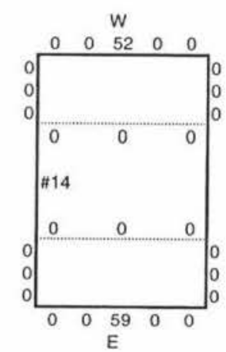


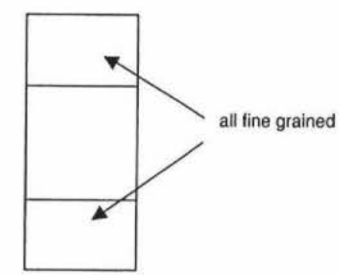
NB:
1. Two pancake coils / Approx 5 to 5.5 turns each / wound same direction
2. 65mm to 70mm diameter
3. Coils placed in volume centre between coils
4. P=13 / T=6 sec
5. HAMMER TEST: one blow with med ball pean - roller broke into 3 pieces / no deformation before breaking / roller TOO HARD

#14 6/7.5Kroller / Flange heat using 30/40/30 rule

	N	E	S	W
FLANGE1 INNER				
FLANGE1 MIDDLE	63			
FLANGE1 OUTER				
O/D TOP				
O/D MIDDLE	49	59	52	52
O/D BOTTOM				
FLANGE2 OUTER				
FLANGE2 MIDDLE				
FLANGE2 INNER				
I/D BOTTOM				
I/D MIDDLE				
I/D TOP				



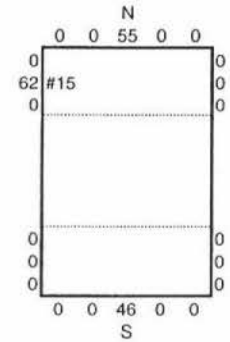


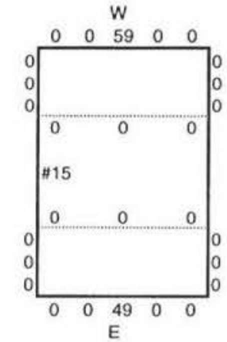


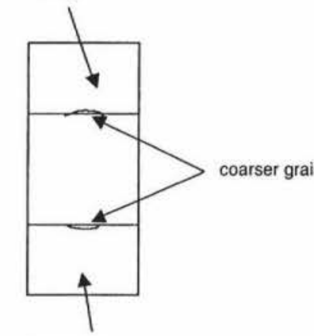
NB:
1. Two pancake coils / Approx 5 to 5.5 turns each / wound same direction
2. 65mm to 70mm diameter
3. Coils placed in volume centre between coils
4. P=14 / T=6 sec
5. HAMMER TEST: one blow with med ball pean - roller broke into 3 pieces / no deformation before breaking / roller TOO HARD

#15 6/7.5Kroller / Flange heat using 30/40/30 rule

	N	E	S	W
FLANGE1 INNER				
FLANGE1 MIDDLE	62			
FLANGE1 OUTER				
O/D TOP				
O/D MIDDLE	55	49	46	59
O/D BOTTOM				
FLANGE2 OUTER				
FLANGE2 MIDDLE				
FLANGE2 INNER				
I/D BOTTOM				
I/D MIDDLE				
I/D TOP				



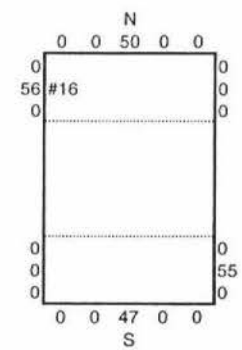


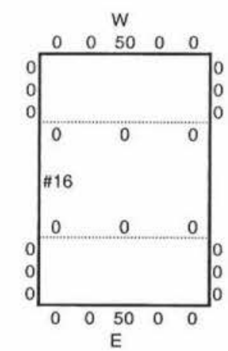


NB:
1. Two pancake coils / Approx 5 to 5.5 turns each / wound same direction
2. 65mm to 70mm diameter
3. Coils placed in volume centre between coils
4. P=14 / T=7 sec
5. HAMMER TEST: one light blow with med ball pean - roller broke into 4 pieces / no deformation before breaking / roller TOO HARD

#16 6/7.5Kroller / Through heat using oxy-acetylene

	N	E	S	W
FLANGE1 INNER				
FLANGE1 MIDDLE	56			
FLANGE1 OUTER				
O/D TOP				
O/D MIDDLE	50	50	47	50
O/D BOTTOM				
FLANGE2 OUTER				
FLANGE2 MIDDLE			55	
FLANGE2 INNER				
I/D BOTTOM				
I/D MIDDLE				
I/D TOP				

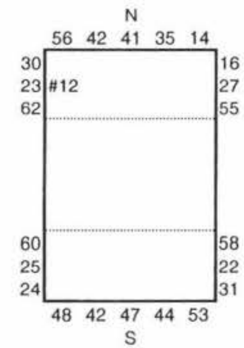


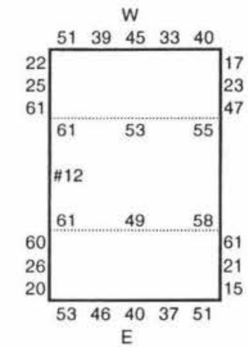


NB:
1. Through heated using oxy-acetylene torch
2. HAMMER TEST: one blow with med ball pean - roller broke into 2 pieces / no deformation before breaking / roller TOO HARD
3. Roller #17 same results

#12 12/15K roller / double process - inner first, outer second + inner cooled

	N	E	S	W
FLANGE1 INNER	62	60	60	61
FLANGE1 MIDDLE	23	26	25	25
FLANGE1 OUTER	30	20	24	22
O/D TOP	56	53	48	51
	42	46	42	39
O/D MIDDLE	41	40	47	45
	35	37	44	33
O/D BOTTOM	14	51	53	40
FLANGE2 OUTER	16	15	31	17
FLANGE2 MIDDLE	27	21	22	23
FLANGE2 INNER	55	61	58	47
I/D BOTTOM		58		55
I/D MIDDLE		49		53
I/D TOP		61		61

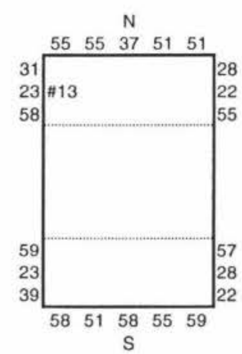


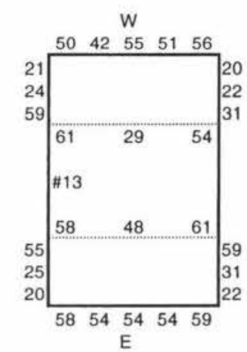


NB:
1. Outer is old square copper tubing & coil has had a hard life (very imperfect)
2. Inner P=16.5, T=11s / Outer P=11, T=7s

#13 12/15K roller / double process - inner first, outer second + inner cooled

	N	E	S	W
FLANGE1 INNER	58	55	59	59
FLANGE1 MIDDLE	23	25	23	24
FLANGE1 OUTER	31	20	39	21
O/D TOP	55	58	58	50
	55	54	51	42
O/D MIDDLE	37	54	58	55
	51	54	55	51
O/D BOTTOM	51	59	59	56
FLANGE2 OUTER	28	22	22	20
FLANGE2 MIDDLE	22	31	28	22
FLANGE2 INNER	55	59	57	31
I/D BOTTOM		61		54
I/D MIDDLE		48		29
I/D TOP		58		61





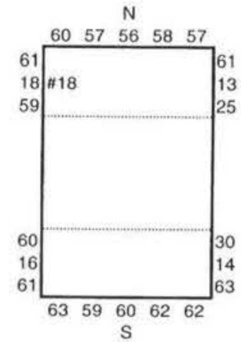
NB:
1. Outer is old square copper tubing & coil has had a hard life (very imperfect)
2. Inner P=16.5, T=11s / Outer P=11, T=11s

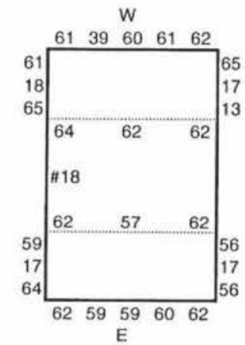
Roller Induction Heating Data

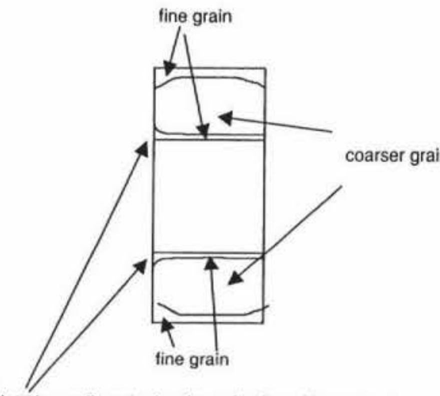
#18 — 12/15K roller / double process - inner first, outer second + inner cooled

	N	E	S	W
FLANGE1 INNER	59	59	60	65
FLANGE1 MIDDLE	18	17	16	18
FLANGE1 OUTER	61	64	61	61
O/D TOP	60	62	63	61
	57	59	59	39
O/D MIDDLE	56	59	60	60
	58	60	62	61
O/D BOTTOM	57	62	62	62
FLANGE2 OUTER	61	56	63	65
FLANGE2 MIDDLE	13	17	14	17
FLANGE2 INNER	25	56	30	13
I/D BOTTOM		62		62
I/D MIDDLE		57		62
I/D TOP		62		64

NB:
1. New outer coil 4.5 windings
2. Inner P=16.5, T=11s / Outer P=10.5, T=10s





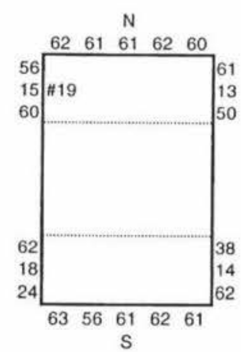


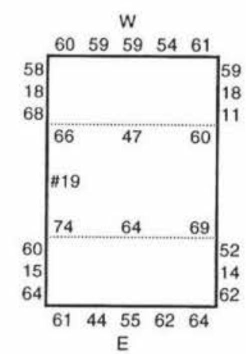
NB:
1. Note inner diameter hardness is altered by contact with copper cooling head
2. HRc tests applied outside of the inner chamfer. Hardness goes to chamfer therefore tests not picking up hard surface on flange 2 inner points.

#19 — 12/15K roller / double process - inner first, outer second + inner cooled

	N	E	S	W
FLANGE1 INNER	60	60	62	68
FLANGE1 MIDDLE	15	15	18	18
FLANGE1 OUTER	56	64	24	58
O/D TOP	62	61	63	60
	61	44	56	59
O/D MIDDLE	61	55	61	59
	62	62	62	54
O/D BOTTOM	60	64	61	61
FLANGE2 OUTER	61	62	62	59
FLANGE2 MIDDLE	13	14	14	18
FLANGE2 INNER	50	52	38	11
I/D BOTTOM		69		60
I/D MIDDLE		64		47
I/D TOP		74		66

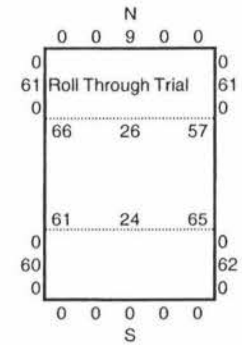
NB:
1. New outer coil 4.5 windings
2. Inner P=16.5, T=11s / Outer P=10.5, T=12s

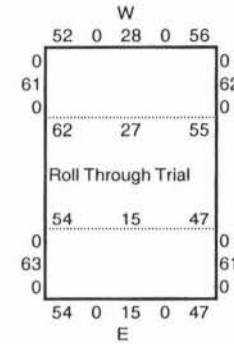


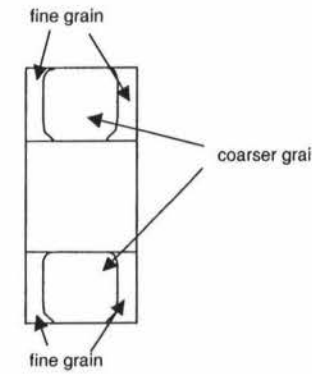


Roll Through Trial 6/7.5K roller / single process flange heat

	N	E	S	W
FLANGE1 INNER				
FLANGE1 MIDDLE	61	63	60	61
FLANGE1 OUTER				
O/D TOP		54		52
O/D MIDDLE	9	15		28
O/D BOTTOM		47		56
FLANGE2 OUTER				
FLANGE2 MIDDLE	61	61	62	62
FLANGE2 INNER				
I/D BOTTOM	57	47	65	55
I/D MIDDLE	26	15	24	27
I/D TOP	66	54	61	62







NB:

1. Horizontal (slightly sloped) rectangular coil fitted with ceramic channel. Roller rolled down channel
2. P=15.5, T approx 3 to 4 seconds
3. Multiple tests done with very similar results.
4. Time in coil hard to gauge manually.
5. Manual production with this method would be nearly impossible as consistency would be unachievable.

Appendix J

Roller	**Mass (kg)**
12/15K102	**0.2**

External Cost of Gas Carburising

HTAuck	$ 1.10	$ 5.50	/kg
Freight	$ 0.06	$ 0.30	/kg
Total	$ 1.16	per roller	

Internal Cost of Induction Heat Treatment

rollers/hr	kg/hr	$cost/hr	$cost/kg	$cost/roller	% savings on external heat treatment	
120	24	$ 28.00	$ 1.17	$ 0.23	80%	30 secs/roller
100	20	$ 28.00	$ 1.40	$ 0.28	76%	36 secs/roller
80	16	$ 28.00	$ 1.75	$ 0.35	70%	45 secs/roller
60	12	$ 28.00	$ 2.33	$ 0.47	60%	60 secs/roller

1. Two processes: 1/ inside diameter, 2/ outside diameter+ cooling inner.
2. Assume each process takes equal time of 15 seconds - therefore 30 sec/roller
3. Therefore 120 rollers per hour
4. Assume running costs: $ 28.00 /hr
5. Includes overheads
6. TOTALLY manual operation

Roller	**Mass (kg)**
6/7.5K102	**0.059**

External Cost of Gas Carburising

HTAuck	$ 0.32	$ 5.50	/kg
Freight	$ 0.02	$ 0.30	/kg
Total	$ 0.34	per roller	

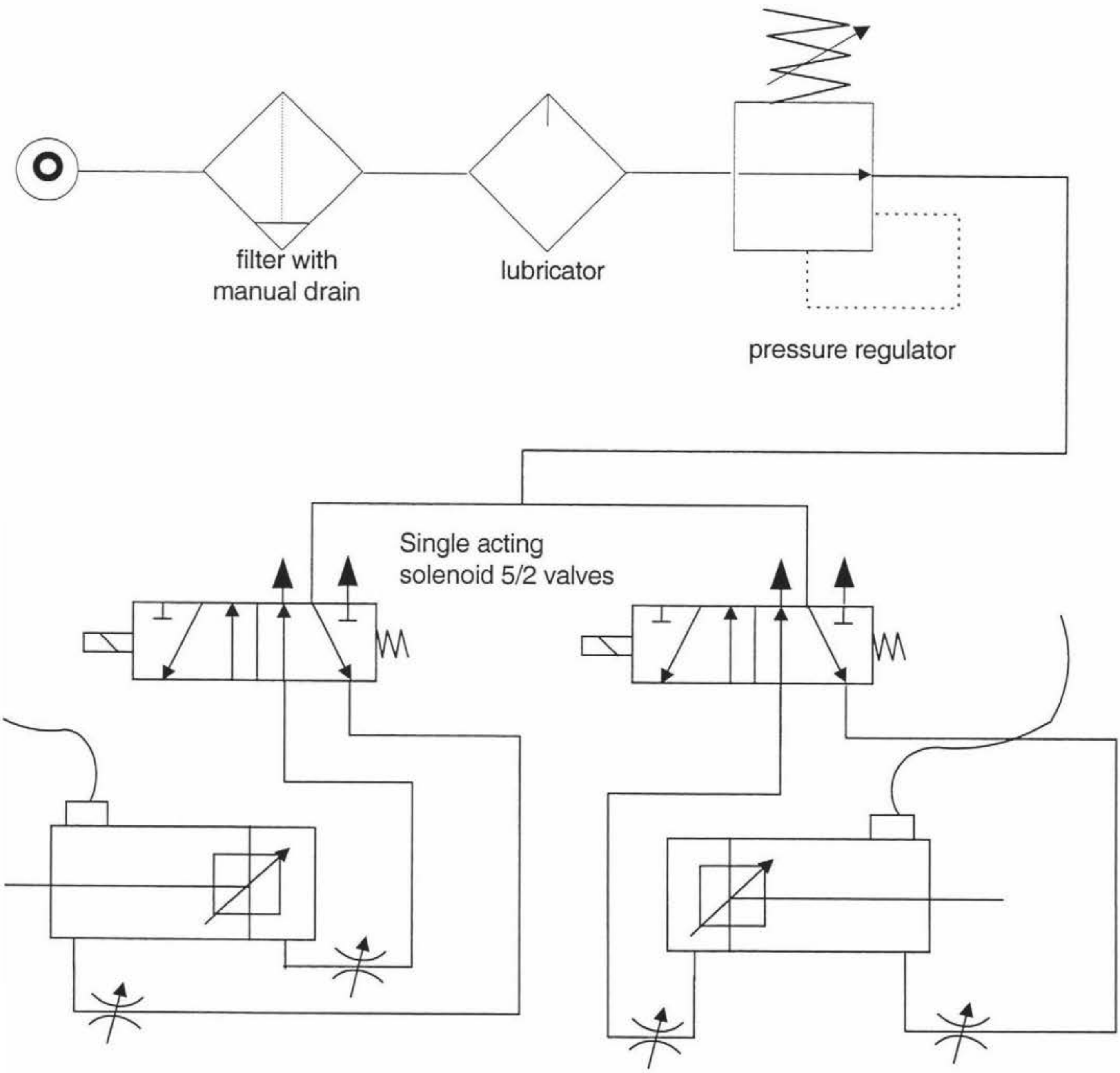
Internal Cost of Induction Heat Treatment

rollers/hr	kg/hr	$cost/hr	$cost/kg	$cost/roller	% savings on external heat treatment	
240	14.16	$ 28.00	$ 1.98	$ 0.12	66%	15 secs/roller
200	11.8	$ 28.00	$ 2.37	$ 0.14	59%	18 secs/roller
180	10.62	$ 28.00	$ 2.64	$ 0.16	55%	20 secs/roller
120	7.08	$ 28.00	$ 3.95	$ 0.23	32%	30 secs/roller

1. Single process: rolling through heating tunnel.
2. Assume process takes time of 15 seconds/roller
3. Therefore 240 rollers per hour
4. Assume running costs: $ 28.00 /hr
5. Includes overheads
6. Totally manual operation - although the process of rolling the component through the coil manually would be a hit and miss affair.

Appendix K

Induction Heater Automation
Pneumatics diagram
Southchain Conveying Systems Ltd.
Author: Mark Caukill 05/09/00



- double acting cylinders each with reed switches on extended position. Air cushioning for cylinder 2 (hopper) and rubber cushioning on cylinder 1 (rotary feeder).

-cylinder 1 (rotary feed) has 200mm stroke. Not much force is necessary so chosen on size: 25mm bore / 12mm rod size (approx)
-cylinder 2 (hopper) has 550mm stroke. Using a factor of 3 the force required is 120kg. Have chosen 63mm bor / 20mm rod size (approx)

Appendix L

INSTITUTION OF PRODUCTION ENGINEERS

FEEDING DEVICES FOR AUTOMATED ASSEMBLING

SIDE BLADE HOPPER FEEDER

Suitability

Spheres, discs, plain or headed pins, screws and bolts can be handled satisfactorily by this Hopper Feeder.

General Description

This type of Hopper Feeder is basically similar to the centreboard type described in Data Sheet No. 680008, but the blade is arranged to oscillate or reciprocate vertically in close proximity to a vertical wall forming one side of the Hopper. The opposite side of the Hopper slopes towards the blade.

If the blade oscillates it is pivoted at a point below the feed chute. The top of the blade is shaped to suit the type of component either by grooving for endwise delivery of such components as plain pins or discs or for clearing the shanks of headed components, or by having a bevelled edge for delivering spheres or pins laterally into the feed chute, which latter may be grooved to clear the shanks of headed components. With the bevelled edge type of blade, a conveyor is often used for cylindrical components instead of a feed chute.

For endwise delivery the top edge of the blade must slope downwards towards the feed chute when in the stroke up position and should then be at a sufficient angle to cause the components to slide or roll towards the feed chute.

For lateral delivery, the bevelled top edge may either slope at the same angle as the feed chute, or may be horizontal.

In either case, the top of the blade must be high enough in the stroke up position to clear the bulk in the hopper, and at the stroke down position, the blade should be level with or slightly below the bottom of the hopper.

Bulk Separating Action

As the blade passes upwards through the bulk, it tends to raise a number of components which are retained by the shape of the top edge. Components not sufficiently orientated to the blade and any remaining on it at the commencement of the down stroke are returned to the bulk.

The number of components separated per cycle depends upon:-

(1) Component size in relation to length of blade
(2) Stability of components when moving towards the feed chute.

Orientation Action

The orientating action is possible with many of the shapes which can be handled but some may have to be supplemented by a secondary device. The action which takes place is provided by the shape of the top edge of the blade, the sliding or rolling action, and the gate formed by the entrance to the feed chute in the case of endwise delivery.

The blade should not be thick enough to support wrongly orientated components.

;680002

opper

The hopper is a fixed container open at the top and provided with a machined surface on he vertical wall, below which the bottom is slotted to provide clearance for the blade. The lot must be a close fit if small components are to be handled. The opposite side of the opper slopes downwards towards the slot to cause the components to move towards the blade. he floor should be horizontal for oscillating blades or for reciprocating blades having a orizontal top edge. For reciprocating blades having a sloping top edge, the floor should be loped at the same angle so that the blade is level with or slightly below it in the stroke own position.

ignificant Features

Several components tend to be separated from the bulk at each cycle, but due to their ingle-file formation the number discharged per cycle is limited by the time available for iem to pass into the feed chute. It is therefore preferable that the blade is given a dwell eriod in the stroke up position.

To prevent jamming and consequent damage to components, the bottom edge of the blade must ot be allowed to rise above the slot in the hopper floor, and with pivoted blades, the front all of the hopper, or a guide, must be curved to fit close to the radius of the front edge f the blade. The blade pivot should be located outside the hopper, as shown in the llustration.

If the hopper and blade are properly proportioned the whole of the bulk can be discharged. th blades having bevelled top edges, it is possible to feed a range of sizes of such mponents as plain pins without recourse to change parts.

This hopper feeder is quiet in operation.

It is sometimes necessary to provide an auxilliary device to clear mis-orientated mponents from the entry to the gate.

High rates of feed can be achieved, particularly with lateral delivery in combination th a feed conveyor.

pical Equipment Dimensions and Speeds

Length of top edge of blade 38 mm. to 600 mm.; should usually be at least twice component ngth, and this should be increased for high rates of feed.

Blade speed up to 50 strokes per/minute.

pical Component Dimensions and Rates of Feed

Length/diameter ratio must exceed 2:1

ample:	Typical range –	minimum diameter 6 mm.
		maximum diameter 38 mm.
		minimum length 12 mm.
		maximum length 450 mm.
mple 2:		Plain pin 2.25 mm. diameter × 20 mm. long fed at 180 per minute using 150 mm. blade length.
mple 3:		Balance staff with pointed ends 1.5 mm. diameter × 15 mm. long fed at 60 per minute using 25 mm. blade length to restrict delivery to one component per stroke.

Tendency to Damage Components

As bulk is stationary and return drop of rejected components is low, this feeder causes little damage to components if designed correctly (see Hopper and Significant Features).

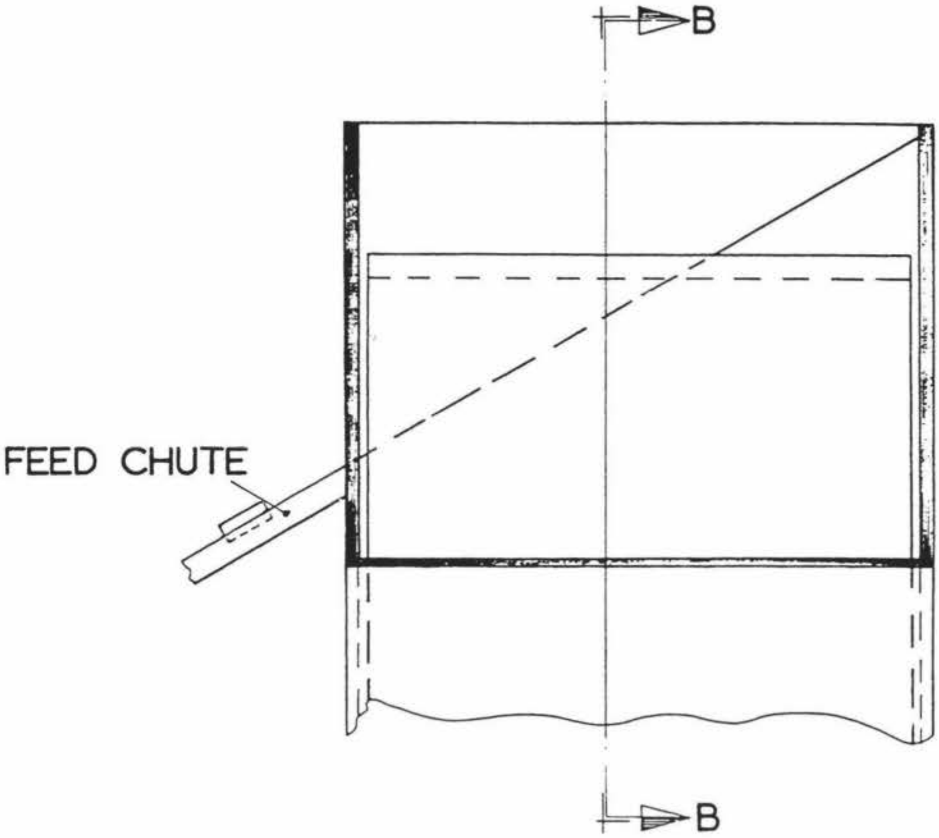
Drive

By fluid power or electric motor with reduction gear driving eccentric or preferably, cam with dwell period and linkage to blade.

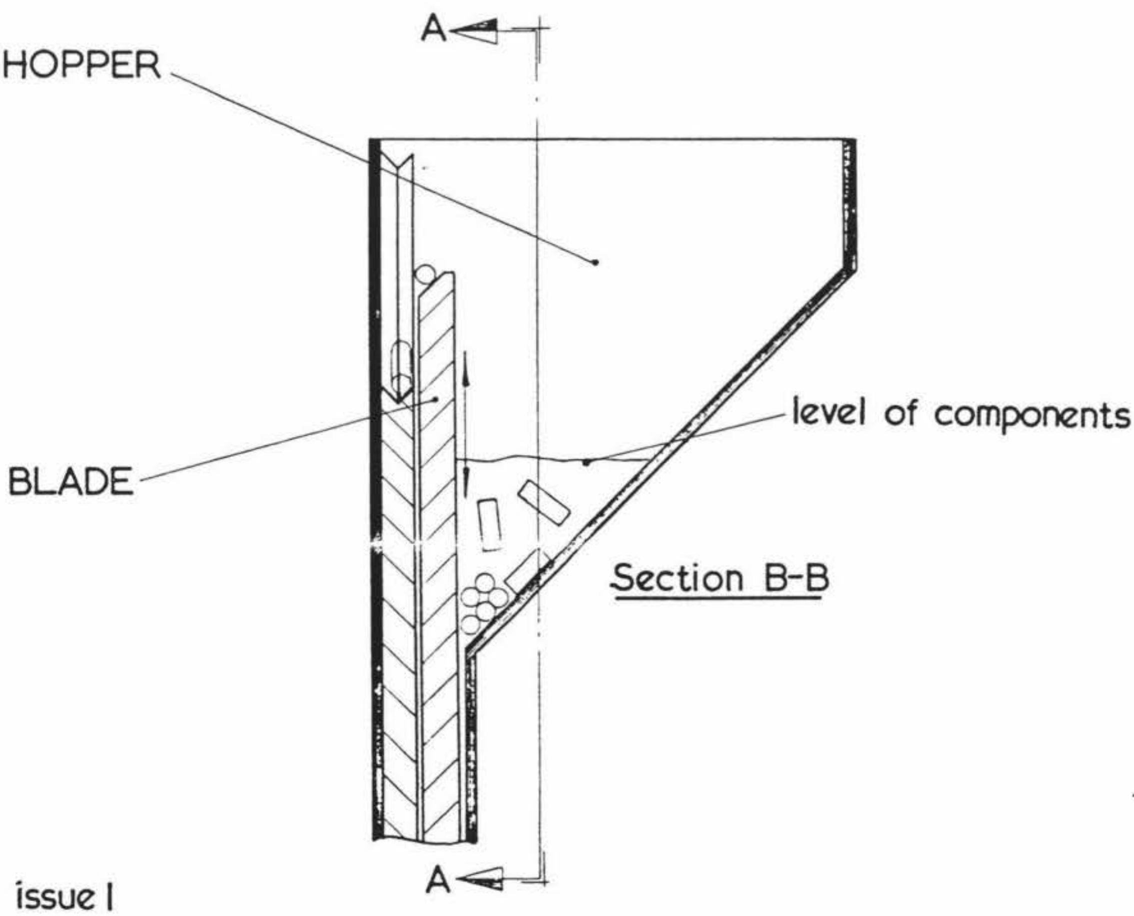
June 1968

SIDE BLADE HOPPER FEEDER

P
D 680002



Section A-A



Section B-B

issue 1

Appendix M

SPLat

Simply Programmed Logic
automation tools

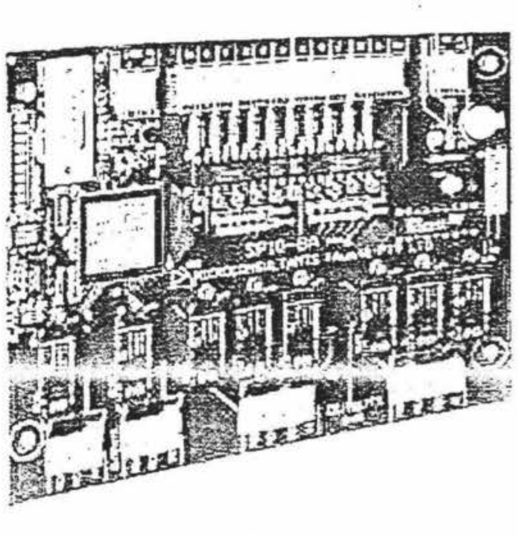
Instant Electronic Controls

SP10-8A fully isolated microPLC

The SP10-8A controller lets you make rugged, reliable industrial controls simply and at minimal cost. The SP10-8A is easily applied to tasks that require timing, sequencing, interlocks and switching. Convenient for quickly solving everyday tasks where timers and relays have traditionally been used, our powerful state-sequential programming method also lets you implement sophisticated control schemes which were difficult to achieve with older programming methods. SPLat makes it simple!

- ☐ **Control of small machines**
- ☐ **Multiple timer relay replacement**
- ☐ **Electronic cams**
- ☐ **Sequencers**
- ☐ **Shift registers**
- ☐ **Interlocks**
- ☐ **Batch counting**

NO PREVIOUS PROGRAMMING EXPERIENCE REQUIRED!



Pictured: SP10-8ANC

Ready to use electronics

Ten isolated inputs

Eight 5A relay outputs

Reprogrammable 100's of times

Easy to learn; results in hours

Acclaimed support software

SPLat makes it simple!

Microconsultants
(Aust) Pty Ltd A.C.N.052-484-689

We're making it .....
.... in Australia *

The SPLat System

Nothing could be quicker, easier or simpler

The SPLat hardware and software system now makes the design of machine controls simpler and more efficient than you ever believed possibl

Your programming is done entirely within user friendly SPLat/PC. This unique Windows software allows you to explore the easy to learn SPLa instructions via its gently staged tutorials, interactive keypad and informative on-screen displays. The in-built SP10-8A simulator behaves just li the actual module, and gives a realistic on-screen representation of inputs and outputs.

You write your program using the inbuilt text editor, and test sections of code totally within the PC using the on-screen simulator. Extensive debugging features, including single stepping and breakpoints, make the process highly interactive and productive.

When your program is working within the PC, you connect to the SP10-8A hardware module. Still running in the PC, your program will now access the real inputs and outputs. At this stage you also have full display of input states and manual control of output relays. This gives you an invaluable tool for testing your external sensors and actuators. Change an input (say a limit switch) and the on-screen switch will reflect the change. Click a LED on-screen and the corresponding relay will respond. Imagine that for testing your wiring!

Finally, when you are satisfied with your program, SPLat/PC transfers it to the SP10-8A module where it is stored in compact form for fast, efficient stand-alone operation. You can now unplug the connection to your PC and the SP10-8A is ready to function completely independently o the PC. As soon as power is applied, the SP10-8A starts its job. Its that simple!

SP10-8A

Programmable controller module

The SP10-8A is a complete programmable controller ready to wire into your industrial application. Only high quality components and materials are used throughout, and every module is rigorously tested prior to shipment.

- 10 isolated bidirectional (NPN or PNP) digital inputs
- 8 5A relay outputs, 2 with change-over contacts
- High quality terminal blocks (Optionally pluggable type)
- LED indicators on all inputs and outputs
- 8 timers, can be increased in software
- 64 data memories
- Re-programmable 100's of times
- 9 pin connector for connection to PC
- Runs off 24V dc unregulated power supply
- Optional DIN rail mounting

Technical Specifications:

Supply voltage	22-32VDC
Max Supply current (all inputs & outputs on)	300mA
Input voltage range (Ensure On state)	±12V to ±35V
Input voltage range (Ensure Off state)	0V to ±2V
Input current vs voltage (in mA)	$(V_{in}-1.4)/1.8$
Relay current, max, resistive load	5A
Relay voltage, max, resistive load	240V
Switched power, resistive load	2,500VA
Input isolation (wrt supply pins)	4kV rms
Output isolation (wrt supply pins)	4kV rms
Program memory	1999 bytes (~1200 instructions)
Data memory	64 bytes
Timers 100mS to 54.6 (15 bits)	4
Timers 10mS to 327 seconds (15 bits)	4
Dimensions (in mm) .. DIN module	142L x 119W x 55H
Dimensions (in mm) .. bare board	137L x 114W x 30H

Ordering information

SP10-8ANC	Bare board with standard terminal blocks
SP10-8A	Board in DIN rail mountable base with standard terminal blocks
UCC925	Universal cable kit for connecting to COM port with 9 way or 25 way connector (standard PC accessory parts)

This specification is subject to change without notice

SPLat/PC

The program that puts *you* in charge

SPLat/PC is the key to the speed and ease with which you can make live, working electronic controls with the SP10-8A. This widely acclaimed Windows based software package contains all the tools and instructional material you need to make your project a success. Features include:

- Structured tutorial lessons which start from absolute basics and go through to powerful, professional, programming techniques, all in easy stages
- In depth technical information on using inputs and outputs
- Real world examples on how to use various external devices such as lamps, keypads, switches and relays with confidence
- Interesting programming examples you can try for yourself, to get you up to speed quickly
- Powerful on screen representation of the SP10-8A for fast learning and easy program development

SPLat/PC ensures that your development will be easy and successful, due to the interactive, graded method of going from a program under development in your PC to a final, standalone program in the SP10-8A in small, easily controlled steps:

- Use on-screen keypad to explore SPLat commands
- Write your program using the inbuilt editor
- Emulate the SP10-8A on your computer screen
- Operate the SP10-8A as a slave to your PC
- Transfer program to the SP10-8A and run it stand-alone

The SPLat system can be used with any PC running Windows 3.1, Windows 95 or later. It requires 2MB hard disk space and one free serial (COM) port. You will also need a standard serial cable with a 9 pin plug for the SP10-8A.

This data sheet is not exhaustive. The SPLat/PC program contains full technical documentation on all SPLat hardware products, including connecti diagrams, advice on connecting external devices and safety precautions.

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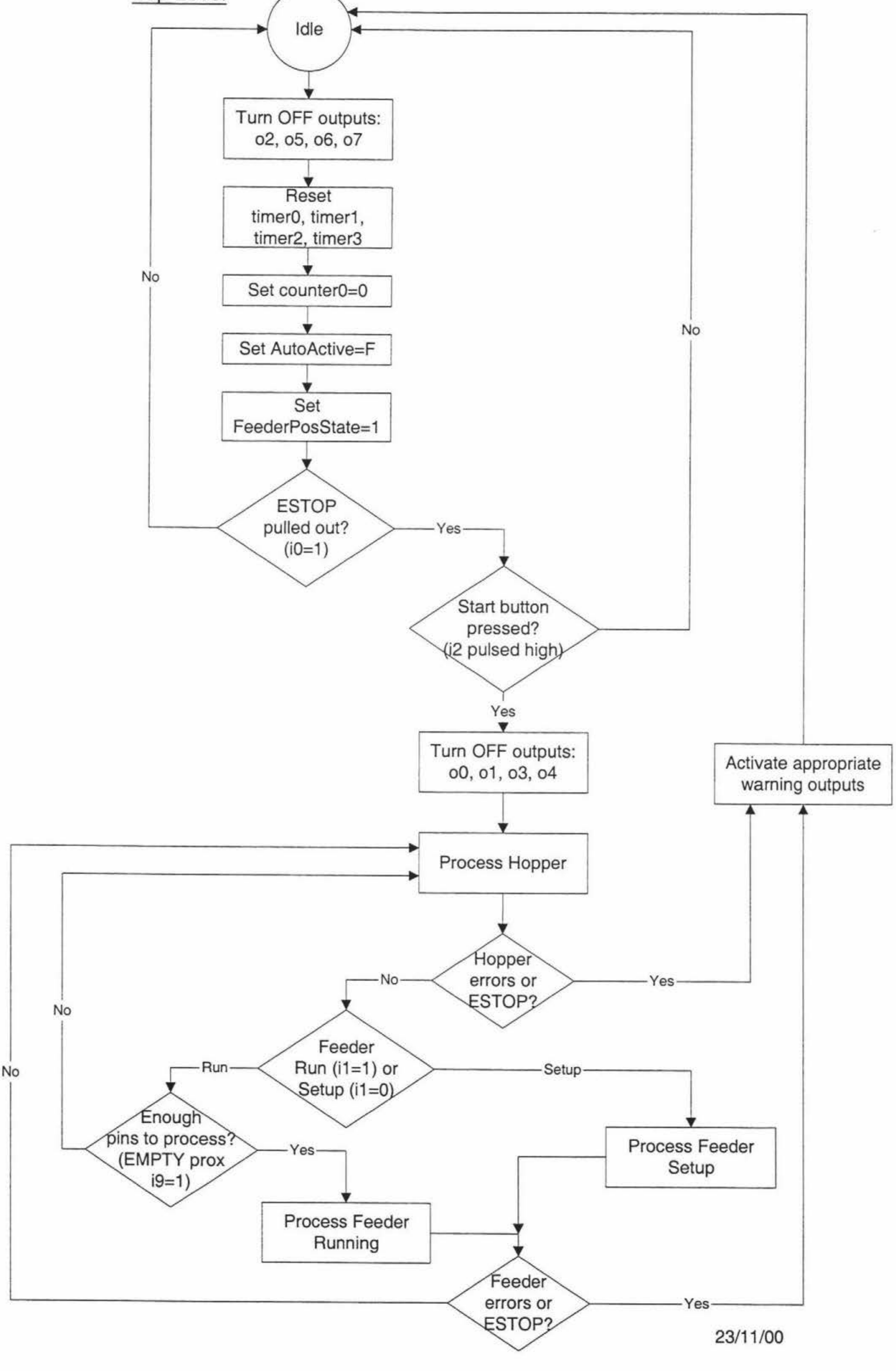
Appendix N

Top Level

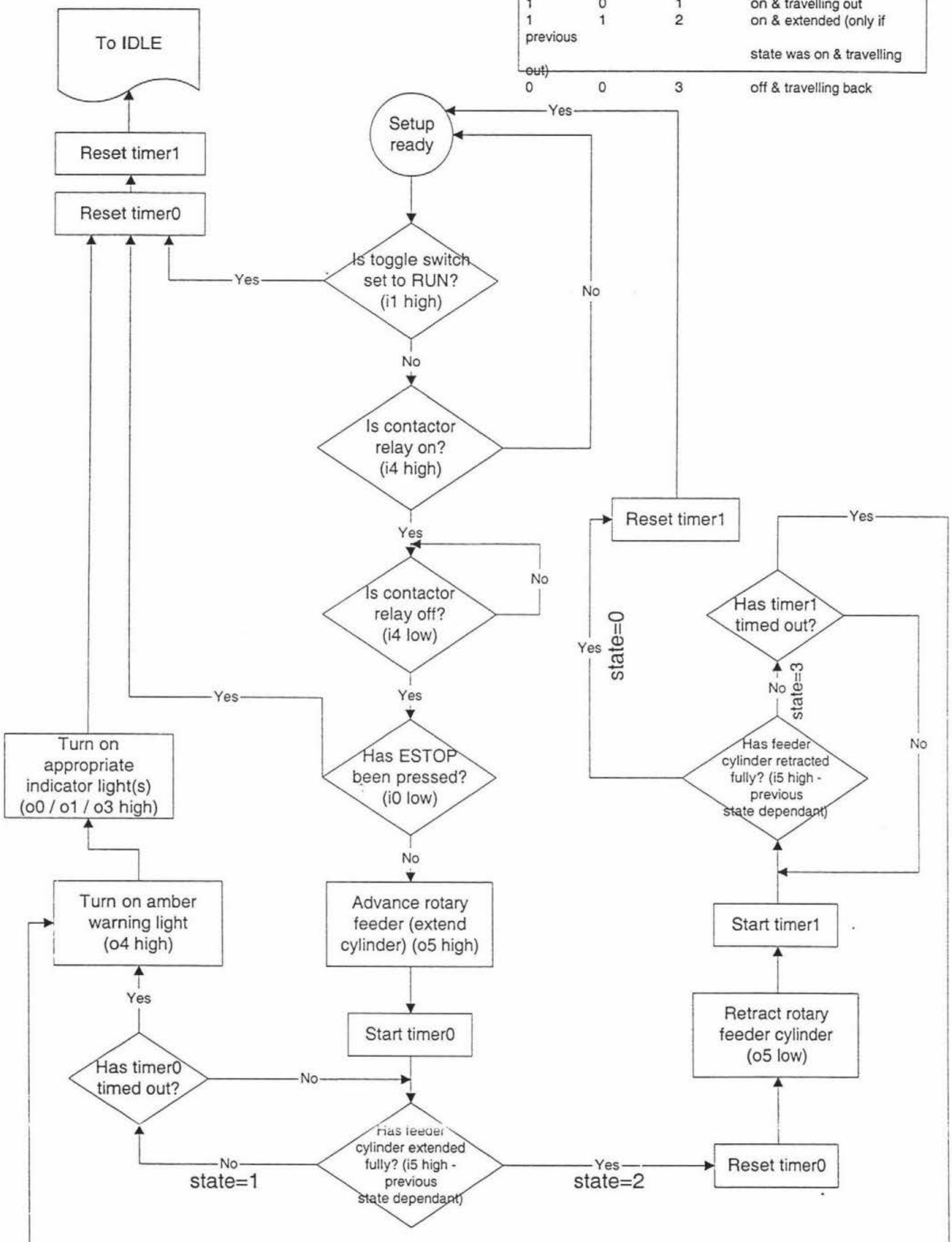


23/11/00

Feeder Setup

var=FeederPosState

o5	i5	state#	description
0	1	0	off & home (only if previous state was off & travelling back)
1	0	1	on & travelling out
1	1	2	on & extended (only if previous state was on & travelling out)
0	0	3	off & travelling back



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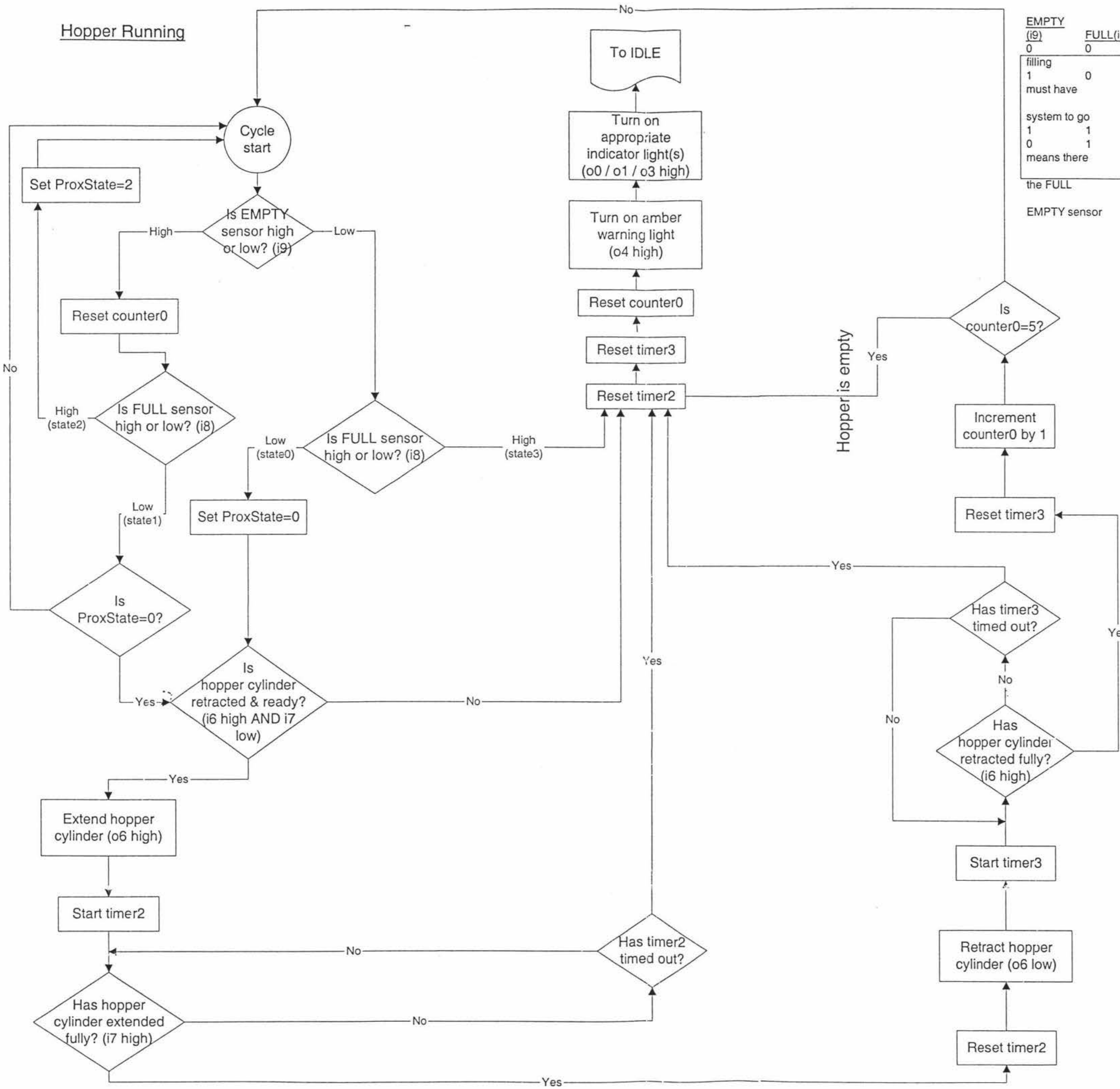
Hopper Running



EMPTY (i9)	FULL(i8)	var=ProxState state#	action	description
0	0	0	go	Chute is empty & needs filling
1	0	1	go conditional on prev state=0	Chute is partially empty - must have been empty previously for system to go
1	1	2	stop	Chute is full - stop blade
0	1	3	error	This should never occurr - means there is a jam in the chute below the FULL sensor & above the EMPTY sensor

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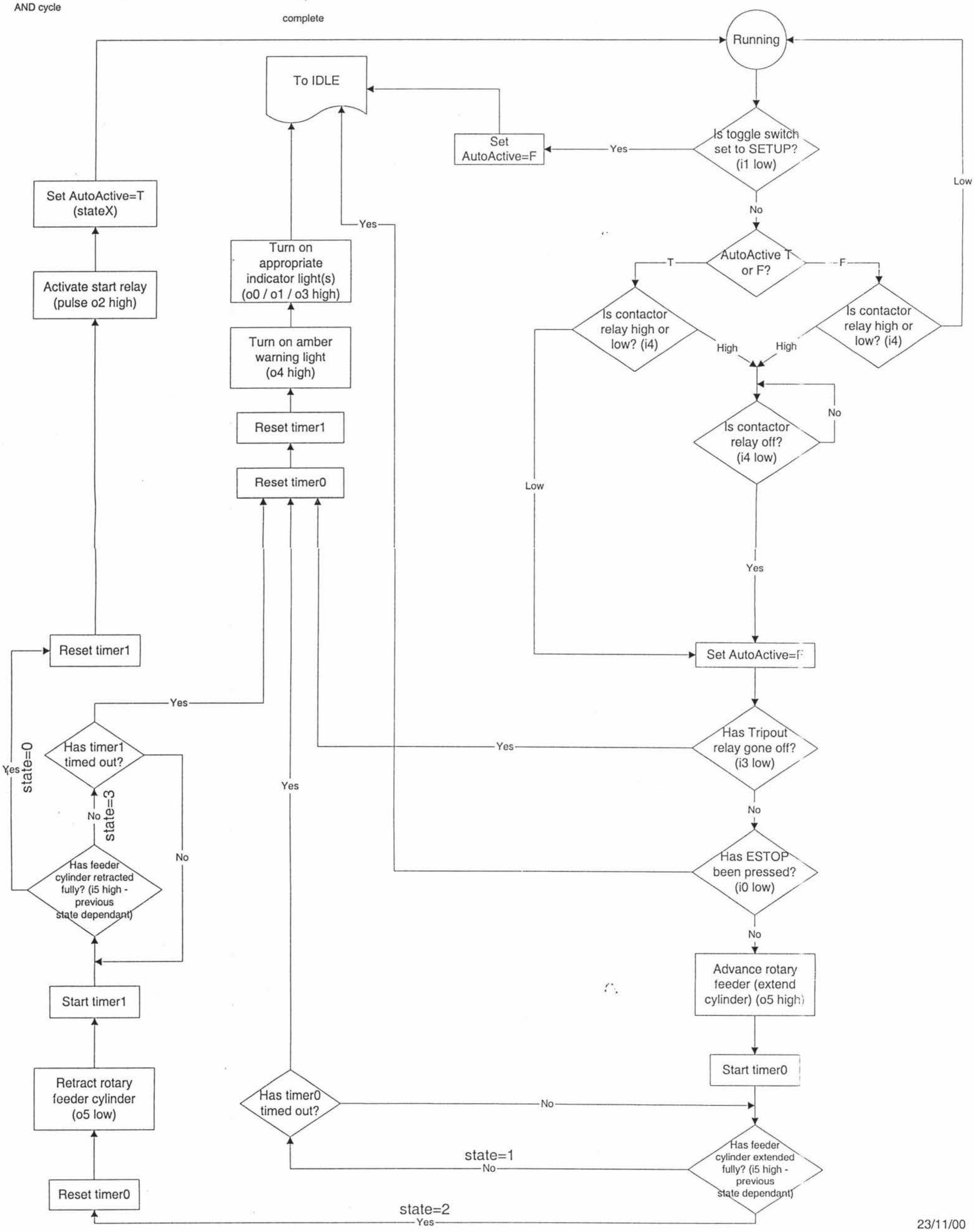
Feeder Running

var=AutoState

AutoActive	Contactor Relay (i4)	state#	description
F	0	0	Heater not yet AutoActivated AND not yet manually activated
F	1	1	Heater not yet AutoActivated AND has been manually activated
T	1	2	Heater AutoActivated AND is cycling
T	0	3	Heater AutoActivated AND cycle complete

var=FeederPosState

o5	i5	state#	description
0	1	0	off & home (only if previous state was off & travelling back)
1	0	1	on & travelling out
1	1	2	on & extended (only if previous state was on & travelling out)
0	0	3	off & travelling back



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Appendix O

	iESTOP	iRunOrSet	iStartButton	iTripout	iContactor	iRotaryReeds	iHopperDownReed	iHopperUpReed	iChuteFullProx	iChuteEmptyProx	oWarn1	oWarn2	oStart	oWarn3	oWarnAmber	oRotarySolenoid	oHopperSolenoid	AVAILABLE	
	i0	i1	i2	i3	i4	i5	i6	i7	i8	i9	o0	o1	o2	o3	o4	o5	o6	o7	Details
1	0	X	0	1	0	1	X	0	X	X	X	X	0	X	X	0	0	-	idle pre-ESTOP reset (pulled out)
2	1	X	0	1	0	1	X	0	X	X	X	X	0	X	X	0	0	-	idle post-ESTOP reset
3	1	X	1	1	0	1	X	0	X	X	0	0	0	0	0	0	0	-	idle post-start button pressed
4	1	X	0	1	X	X	1	0	0	0	0	0	X	0	0	X	1	-	empty chute, set ProxState=0, hopper cylinder retracted & ready, hopper solenoid energised
5							0	0	0	0							1	-	blade part way up
6							x	0	0	0	1	0		0	1		1	-	timer2 (extend) runs out - back to idle pre-start button
7							x	1	0	0							0	-	hopper cylinder extended, hopper solenoid de-energiesed
8							0	0	0	0							0	-	hopper solenoid de-energised causes both hopper reeds to go low
9							0	x	0	0	1	0		1	1		0	-	timer3 (retract) runs out - back to idle pre-start button
10							x	x	0	0	1	1		0	1		x	-	counter0=5 - hopper empty, back to idle pre start button
11							x	x	1	0	1	1		1	1		x	-	chute problem / blockage, back to idle
12							1	0	0	1							x	-	chute partially full and ProxState=0, hopper cylinder retracted & ready, hopper solenoid energised (ie: continue filling chute)
13							0	0	0	1							1	-	blade part way up
14							x	0	0	1	1	0		0	1		1	-	timer2 (extend) runs out - back to idle pre-start button
15							x	1	0	1							0	-	hopper cylinder extended, hopper solenoid de-energiesed
16							0	0	0	1							0	-	hopper solenoid de-energised causes both hopper reeds to go low
17							0	x	0	1	1	0		1	1		0	-	timer3 (retract) runs out - back to idle pre-start button
18							x	x	1	1							0	-	chute full, no processing until ProxState=0 (ie: EMPTY prox goes low again)
19							x	x	0	1							0	-	chute partially full but ProxState=2 so no processing
20																		-	
21																		-	
22																		-	
23																		-	
24																		-	
25																		-	
26																		-	
27																		-	
28																		-	
29																		-	
30																		-	
31																		-	
32																		-	

Appendix P

SP108 Micro Controller I/O Map

number	name	from/to	description
i0	iESTOP	ESTOP	1. physically isolates all micro outputs 2. 'stops' micro 3. interrupts heater cycle (as existing RED stop button on front of heater)
i1	iRunOrSet	toggle switch - run & setup	two position toggle switch - in HIGH position causes mirco to start processing pins automatically once GREEN go button is pushed, in LOW position causes mirco to watch heating cycle and upon cycle completion advance rotary feeder once and wait
i2	iStartButton	start button	turns micro 'on' to allow interaction between heater and micro - without this button being pushed the heater is totally manual.
i3	iTripout	tripout relay	relay connected to the tripout circuit in the induction heater - if the heater trips out for whatever reason the micro will 'know' about it and stop
i4	iContactor	contactor #2 relay	relay connected to the second contactor coil inside the induction heater - indicates heating cycle is complete as it is de-energised when contactor relay is de-energised
i5	iRotaryReeds	reed switches - rotary feeder	reed switches on rotary feeder cylinder: 1 located at home position & 1 located at end of travel NB: Must watch previous state of rotary feeder output (o5) to know what position this cylinder is in
i6	iHopperDownReed	reed switch -hopper blade retracted	reed switch on rotary feeder cylinder - located at start of travel indicating solenoid valve can be energised
i7	iHopperUpReed	reed switch - hopper blade extended	reed switch on hopper blade cylinder - located at end of travel indicating solenoid valve can be de-energised
i8	iChuteFullProx	proximity sensor - chute full	proximity sensor next to hopper, at top of feed chute - indicates chute is full and hopper blade should stop
i9	iChuteEmptyProx	proximity sensor - chute empty	proximity sensor above rotary feeder, at bottom of feed chute - indicates chute is empty and hopper blade should start
o0	oWarn1	1st warning indicator light	indicates specific problem area either singularly or in combination
o1	oWarn2	2nd warning indicator light	indicates specific problem area either singularly or in combination
o2	oStart	start relay	activates induction heater cycle - mimics existing GREEN go button on front of heater
o3	oWarn3	3rd warning indicator light	indicates specific problem area either singularly or in combination
o4	oWarnAmber	warning light	activates flashing amber light to indicate system needs attention (hopper empty, tripout, etc)
o5	oRotarySolenoid	solenoid valve - rotary feeder	activates single acting solenoid valve on rotary feeder - energised for cylinder extension, de-energised for cylinder return
o6	oHopperSolenoid	solenoid valve - hopper	activates single acting solenoid valve on hopper feeder blade - energised for cylinder extension, de-energised for cylinder return
o7	AVAILABLE	AVAILABLE	AVAILABLE

Appendix Q

```
;30/01/2001 11:08:25

;Added in V4
;      - feed_rv1.spt saved as this version of CTRL series
;      - sub_errors pasted in from ctrlv03
;      - sub-hopper and subhopper-subroutines pasted in from ctrlv03
;      - sub_idle pasted in from ctrlv03 & fleshed out
;      - subsub_tripout added in sub_feeder_run
;Added in V5
;      - subsub_prox will only run when feedstate=0
;      - subsub_prox partial full - all actions deleted
;      - subsub_T3 & subsub_T4 added as separate subroutines (taken out of
subsub_blade)
;Added in V6
;      - blade counter moved from watching hopper to feeder (count 8
positions)
;      - C0Value changed to 8
;      - subsub_toggle taken out of run&setup routines (now sub_toggle) and
put directly into main
;      - sub_toggle now resets vars
;Added in V7
;      - rework of MAIN code


      goto Initialise

;====================================================
;==== Main Program ====
;====================================================

¶MAIN
      recall            GenErr
      gosubifnz   SUB_ERRORS

      gosub       SUB_IDLE

POSTIDLE
      recall            GenErr
      gosubifz    SUB_HOPPER
;**
      input       iRunOrSet   ;checks toggle switch (i1) for: setup (low) or
run (high)
      push                    ;make a copy to Y, oldtogrun now in Z
      store       TogRun            ;store value of i1 in togrun - pops stack
      goifnz            FeedRun
;**

;     recall            GenErr
;     recall            FeedState
;     or
;     gosubifz    SUB_TOGGLE  ;checks state of run/setup toggle switch
;
;     recall            TogChng
;     goifnz            MAIN

      recall            GenErr
      recall            TogRun                        ;set in subsub_toggle /
high=run, low=setup
      or                            ;if either are true, will not run
sub_feeder_setup
      gosubifz    SUB_FEEDER_SETUP
```

```
	recall		Stopper				;set in subsub_estop /
high=estop, low=not estop
	goifnz		MAIN

FeedRun
	recall		GenErr
	recall		TogRun				;set in subsub_toggle /
high=run, low=setup
	not				;inverts so high -> low, low -> high
	or				;now if either high wont go into
subfeederrun
	gosubifz	SUB_FEEDER_RUN

	recall		Stopper				;set in subsub_estop /
high=estop, low=not estop
	recall		Tripper				;set in subsub_tripout/
high=tripped, low=not tripped
	or
	goifnz		MAIN

	recall		GenErr
	goifnz		MAIN

	goto POSTIDLE
;========================== end of main program ====

;====================================================
; ==== SUBROUTINES ====
;====================================================

; ==== subroutine ====
;watches and waits for ESTOP and Start button
SUB_IDLE
	off	2		;turn off all non-error outputs
	off	5
	off	6
	off	7
	waiton		iESTOP			;halts program execution until
estop is pulled out
	gosub SUBSUB_RESETMEM		;reset all non-error memory vars to 0
	waiton		iStart			;halts program execution until
start button pressed
	off	0		;turn off all error outputs
	off	1
	off	3
	off	4
	gosub SUBSUB_RESETERRMEM	;reset all error memory vars to 0

	setmem		SysReset,255		;so will drop into idle 1st prog
cycle after power up
	RETURN				;only (unless errors)

; ==== subroutine ====
SUB_TOGGLE
;	recall		TogRun		;puts togrun state in X
;	push			;make a copy to Y
;	store		OldTogRun	;store togrun state in oldtogrun state-pops
stack
;	input		iRunOrSet	;checks toggle switch (i1) for: setup (low) or
run (high)
```

```
;	push			;make a copy to Y, oldtogrun now in Z
;	store	TogRun		;store value of i1 in togrun - pops stack
;				;at this stage togrun in X, oldtogrun in Y
;
;	compare			;Compare X & Y, puts answer into X and
pops stack
;	branch
;	target		TRState0	;X = Y =>X=0 /X=togrun=Y=oldtogrun=0 OR 1
(state=0)
;				;high - was high prev, OR low - was low prev,
also happens on initial prog run
;	target		TRState1	;X > Y =>X=1 /X=togrun=1,Y=oldtogrun=0
(state=1)
;				;high (run) - was low (setup) previously
;	target		TRState2	;X < Y =>X=2 /X=togrun=0,Y=oldtogrun=1
(state=3)
;				;low (setup) - was high (run) previously

;no change in toggle
;TRState0
;	setmem		TogChng,0
;	RETURN

;toggle just set to run (from setup)
;TRState1
;	setmem		TogChng,255
;	setmem		TogRun,255	;sets run var to T
;	RETURN

;toggle just set to setup (from run)
;TRState2
;	setmem		TogChng,255
;	setmem		TogRun,0	;sets run var to F
;	setmem		Green4Go,0	;nullifies green4go var: green4go=F
;	setmem		AutoActive,0	;nullifies autoactive var:
autoactive=F
	RETURN

; ==== subroutine ====
SUB_HOPPER
	recall		BladeState	;set in subsub_blade for upping &
downing
	recall		GenErr		;if bladestate is anything
but z dont run subsubrnr
	or
	gosubifz	SUBSUB_RNR	;checks if blade is retracted & ready

	recall		BladeState
	recall		FeedState
	or
	recall		GenErr
	or
	gosubifz	SUBSUB_PROX	;looks at prox sensors determining go or
no go

	recall		StopBlade	;set in subsub_prox to halt blade
when full, etc
	recall		GenErr		;stopblade is not an error
	or
	gosubifz	SUBSUB_BLADE	;makes blade reciprocate
```

```
      recall            timer3start       ;1st prog cycle & when retracting
t3 will be z so dont test
      gosubifnz   SUBSUB_T3

      recall            timer4start       ;1st prog cycle & when extending t4
will be z so dont test
      gosubifnz   SUBSUB_T4

      RETURN

; ==== subroutine ====
SUB_FEEDER_SETUP
      recall            GenErr                  ;if gen err or feedstate z
then check contact relay
      recall            FeedState         ;feedstate z when rotary feeder cyl
retracted
      or
      gosubifz    SUBSUB_CONTACTRELAY     ;is it on or is it off - huh huh?

      recall            AdvanceFeed       ;set T in ss_contactrelay, F at end
ss_rotate
      gosubifnz   SUBSUB_ESTOP            ;if advance feed=T, heater has
finished cycle/stopped
                                    ;so check if estop has been pressed
      recall            Stopper
      retifnz

      recall            GenErr                  ;skip feed pin as gen err
might be extend/retract err
      recall            AdvanceFeed       ;if advance feed=T
      not
      or
      gosubifz    SUBSUB_ROTATE           ;make feeder advance!!

      recall            timer1start       ;1st prog cycle & when retracting
t1 will be z so dont test
      gosubifnz   SUBSUB_T1

      recall            timer2start       ;1st prog cycle & when extending t2
will be z so dont test
      gosubifnz   SUBSUB_T2

      RETURN

; ==== subroutine ====
SUB_FEEDER_RUN
      recall            GenErr                  ;if gen err or feedstate z
then check contact relay
      recall            FeedState         ;feedstate z when rotary feeder cyl
retracted
      or
      gosubifz    SUBSUB_CONTACTRELAY     ;is it on or is it off - huh huh?

      recall            AdvanceFeed       ;set T in ss_contactrelay, F at end
ss_rotate
      gosubifnz   SUBSUB_ESTOP            ;if advance feed=T, heater has
finished cycle/stopped
                                    ;so check if estop has been pressed
      recall            Stopper
      retifnz
```

```
      recall            AdvanceFeed
      gosubifnz   SUBSUB_TRIPOUT

      recall            Tripper
      retifnz

      recall            GenErr                  ;skip feed pin as gen err
might be extend/retract err
      recall            AdvanceFeed       ;if advance feed=T
      not
      or
      gosubifz    SUBSUB_ROTATE           ;make feeder advance!!

      recall            CountSw                 ;if count switch is T
      not
      recall            FeedState         ;if feedstate = zero AND
      or
      recall            ProxState         ;if proxstate = zero
      or
      recall            GenErr
      or
      gosubifz    SUBSUB_COUNTER          ;run counter (counts eight ie:
hopper empty)

      recall      ProxState               ;if proxstate other than = 0
      goifz NoCountReset                  ;resets counter0 to c0value
      loadx       C0Value                 ;when chute stays empty never gets
reset
      store       Counter0
NoCountReset

      recall            timer1start       ;1st prog cycle & when retracting
t1 will be z so dont test
      gosubifnz   SUBSUB_T1

      recall            timer2start       ;1st prog cycle & when extending t2
will be z so dont test
      gosubifnz   SUBSUB_T2

      recall            GenErr
      recall            FeedState
      or                          ;green4go set high in subsub_contactrelay
      recall            Green4Go          ;indicates heat cycle has been
manually activated
      not                         ;in the 1st instance & auto activate can
take over
      or
      recall            AutoActive        ;set high in subsub_autoactivate,
low in subsub_contactrelay
      or
      gosubifz    SUBSUB_AUTOACTIVATE

      RETURN

; ==== subroutine ====
SUB_ERRORS
      on          4           ;turn on the rotating amber warning light

      recall            HopExtendErr
      goifz       EndErr1
      on          0
```

```
      gosub         SUBSUB_ROTATE
      RETURN
EndErr1

      recall              HopRetractErr
      goifz         EndErr2
      on            0
      on            3
      gosub         SUBSUB_ROTATE
      RETURN
EndErr2

      recall              RetnRdyErr
      goifz         EndErr3
      on            1
      RETURN
EndErr3

      recall              HopEmptyErr
      goifz         EndErr4
      on            0
      on            1
      RETURN
EndErr4

      recall              ChuteProbErr
      goifz         EndErr5
      on            0
      on            1
      on            3
      gosub         SUBSUB_ROTATE
      RETURN
EndErr5

      recall              FeedRetractErr
      goifz         EndErr6
      on            1
      on            3
      RETURN
EndErr6

      recall              FeedExtendErr
      goifz         EndErr7
      on            3
      RETURN
EndErr7                                ;getting to this point
                                  ;effectively means no err lights on except
      RETURN                           ;amber warning which is the TRIPOUT relay
gone

;=====================================================
;===================== start of sub-subroutines ====

; ==== subhopper-subroutine ====
;this sub deals with checking that the hopper cylinder is in the correct
position (ie: down)
;before allowing any processing to take place

SUBSUB_RNR
      input iHopperDownReed   ;into X
      input iHopperUpReed     ;into X, 6 now in Y
```

```
      AND                ;logical AND comparison - if both true (nz), X is
true - pops stack
      goifnz      RnRErr             ;if X is true go to label
      input iHopperDownReed   ;into X
      input iHopperUpReed     ;into X, 6 now in Y
      CompareR           ;Compare X & Y, puts into R and DOESN'T pop stack
      BranchR
      Target      RnRErr             ;X = Y /R=0
      Target      RnRErr             ;X > Y /R=1
      Target      HopCylAllsFine     ;X < Y /R=2

RnRErr
      setmem      RetnRdyErr,99      ;sets RetnRdyErr mem location to 99
      setmem      GenErr,99   ;ditto GenErr

HopCylAllsFine
      pop                ;these pops clean out stack so it is clean for any
further ops
      pop
      RETURN

; ==== subhopper-subroutine ====
SUBSUB_PROX
      input iChuteFullProx    ;puts value of i8 to X & pushes stack
      push
      store FullProxState     ;stores current value of i8 to mem - pops stack
      input iChuteEmptyProx   ;puts value of i9 to X & pushes stack
      push
      store EmptyProxState    ;stores current value of i9 to mem - pops stack
                         ;at this stage iChuteFullProx is in Y,
iChuteEmptyProx is in X
      AND                ;logical AND comparison - if both true (nz), X is
true - pops stack
      goifnz      ChuteFull   ;if X is true go to ChuteFull (state=2)

      ;otherwise carry on as we still need to compare them
      recall             FullProxState           ;fullproxstate to X
      recall             EmptyProxState          ;emptyproxstate to X,
fullproxstate now in Y
      compare                               ;Compare X & Y, puts answer into R
and DOESN'T pop stack
      branch
      target             ChuteEmpty        ;X = Y /X=0
/X=EmptyProxState=Y=FullProxState=0 (state=0)
      target             ChutePartial            ;X > Y /X=1
/X=EmptyProxState=1,Y=FullProxState=0 (state=1)
      target             ChuteError        ;X < Y /X=2
/X=EmptyProxState=0,Y=FullProxState=1 (state=3)

;In State0 both prox sensors are low (chute is empty) therefore go (action
hopper cylinder)
ChuteEmpty
      setmem             ProxState,0
      setmem             StopBlade,0
      RETURN

;In State1 chute is partially empty (empty prox high & full prox low)was
proxstate=1
ChutePartial
      RETURN
```

```
;In State3 empty prox is low, full prox is high - this is an ERROR state
ChuteError
      setmem            ProxState,3
      setmem            ChuteProbErr,99
      setmem            GenErr,99
      RETURN


;In State2 both prox sensors are high (chute full) therefore stop blade via
StopBlade
ChuteFull
      setmem            ProxState,2
      setmem            StopBlade,99
      RETURN

; ==== subhopper-subroutine ====
;makes the hopper blade go up and down!! Oh - and checks for errors too using
timers!
SUBSUB_BLADE
      recall      BladeState
      branch
      target      BState0
      target      BState1
      target      BState2
      target      BState3
      target      BState4

;state will not change if ctrl not allowed into state (ie: not retracted) -
if allowed into
;state (retracted/down) - turn hopper solenoid on, set state# to resulting
state & start timer3
BState0
      input       iHopperDownReed           ;test i6
      goifnz            HopperReady         ;goto label if reed high (hopper is
ready)
      setmem            timer4start,255           ;otherwise set the timer
start var
      RETURN
HopperReady
      on          oHopperSolenoid           ;turn on o6
      loadx       1                   ;update bladestate # with resulting state
      store       BladeState
      settimer    3,60                ;set timer3 to 6s & start
      setmem            timer3start,255           ;timer3 start var=T
      RETURN

;going up- leave hopper solenoid on, set state# to resulting state
BState1
      loadx       2                   ;update bladestate # with resulting state
      store       BladeState          ;bladestate=2 not used
      RETURN

;extended/up position - if reed (i7) not high return
;ie:state will not change if ctrl not allowed into state
;if allowed into state - turn hopper solenoid off, set state# to resulting
state, & start timer4
BState2
      input       iHopperUpReed             ;test i7
      retifz                                ;return if i7 is not high
      off         oHopperSolenoid           ;turn off o6
      loadx       3                   ;update bladestate # with resulting state
```

```
      store         BladeState
      settimer      4,600               ;set timer4 to 6s (10ms timer!) & start
      setmem              timer4start,255         ;timer4 start var=T
      setmem              timer3start,0           ;no point in checking t3
(extend timer) if retracted!
      RETURN

;coming down - leave solenoid off, set state# to resulting state
BState3
      loadx         4                   ;update bladestate # with resulting state
      store         BladeState          ;bladestate=4 not used
      RETURN

;retracted/down position - if reed (i6) not yet high return
BState4
      input         iHopperDownReed           ;test i6
      retifz                                  ;return if i6 not high
      loadx         0                   ;update bladestate # with resulting state
      store         BladeState
      setmem              timer4start,0           ;no point in checking t4
(retract timer) if extended!
      RETURN

; ==== subhopper-subroutine ====
SUBSUB_T3
      test          3                   ;Check timer3
      goifnz              T3nz                ;goto label if timer not run out
      setmem              HopExtendErr,99         ;sets hopper extend error mem
location to 99
      setmem              GenErr,99
      recall              GenErr
      retifnz
T3nz
      RETURN

; ==== subhopper-subroutine ====
SUBSUB_T4
      test          4                   ;Check timer4
      goifnz              T4nz                ;goto label if timer not run out
      setmem              HopRetractErr,99  ;set hopper retract error mem
location to 99
      setmem              GenErr,99           ;set general error to 99
      recall              GenErr
      retifnz
T4nz
      RETURN

;===================== end of subhopper-subroutines ====

; ==== subfeeder-subroutine ====
SUBSUB_CONTACTRELAY
      recall              ContRelay   ;puts contactrelay state in X
      push                      ;make a copy to Y
      store         OldContRelay        ;store contactrelay state in
oldcontactrelay state-pops stack
      input         iContactor  ;state of iContactor (i4) now in X,
oldcontrelay in Y
      push                      ;make a copy to Y, oldcontrelay now in Z
      store         ContRelay   ;store value of i4 in contrelay - pops stack
                                ;at this stage contrelay in X, oldcontrelay in
Y
```

```
      compare                          ;Compare X & Y, puts answer into X and
pops stack
      branch
      target           CRState0    ;X = Y /X=0 /X=contrelay=Y=oldcontrelay=0
OR 1 (state=0)
                              ;off - was off prev, or on - was on prev, also
happens on initial prog run
      target           CRState1    ;X > Y /X=1
/X=contrelay=1,Y=oldcontrelay=0 (state=1)
                              ;on - was off previously
      target           CRState2    ;X < Y /X=2
/X=contrelay=0,Y=oldcontrelay=1 (state=3)
                              ;off - was on previously

;off & waiting state OR on & waiting state
CRState0
      RETURN

;just on state
CRState1
      off         oStart              ;start relay (o2) off now contact relay
(i4) is high
      RETURN

;just off state can...
CRState2
      setmem           AdvanceFeed,255   ;advance feeder &
      setmem           Green4Go,255      ;indicate heat cycle has been
manually activated in the
                              ;  first instance & auto activate can take over
      setmem           AutoActive,0      ;autoactive=F
      RETURN

; ==== subfeeder-subroutine ====
SUBSUB_ESTOP
      input       iESTOP              ;(i0)
      goifnz           NoProblemo  ;if i0 high (estop not pressed) no probs
otherwise
      setmem           Stopper,255 ;set stopper var =T (meaning estop
pressed)
      RETURN
NoProblemo
      setmem           Stopper,0   ;set stopper var=F (no problemo!!)
      RETURN

; ==== subfeeder-subroutine ====
SUBSUB_TRIPOUT
      input       iTripout    ;(i3)
      goifnz           NoTrip              ;if i3 high (trip rly not
triggered) no probs otherwise
      setmem           Tripper,255 ;set tripper var =T (meaning trip rly
triggered)
NoTrip
      setmem           Tripper,0
      RETURN

; ==== subfeeder-subroutine ====
;makes the feeder rotate!!
;NB: iFeederExtendReed & iFeederRetractReed are same input (i5) due to
shortage of avail inputs
```

```
SUBSUB_ROTATE
      recall      FeedState
      branch
      target      FState0
      target      FState1
      target      FState2
      target      FState3
      target      FState4

;state will not change if ctrl not allowed into state (ie: not retracted) -
if allowed into
;state (retracted) - turn feeder solenoid on, set state# to resulting state &
start timer1
FState0
      input       iFeederRetractReed      ;test i5
      goifnz            FeederReady       ;goto label if reed high (feeder is
ready)
      setmem            timer2start,255         ;otherwise set the timer
start var
      RETURN
FeederReady
      on          oRFeederSolenoid  ;turn on o5
      loadx       1                 ;update feedstate # with resulting state
      store       FeedState
      settimer    1,25              ;set timer1 to 2.5s & start
      setmem            timer1start,255         ;timer1 start var
      RETURN

;going out- leave feeder solenoid on, set state# to resulting state
FState1
      input       iFeederExtendReed ;test i5
      retifnz                             ;return if i5 is high
      loadx       2                 ;update feedstate # with resulting state
      store       FeedState
      RETURN

;extended position - if reed (i5) not high return
;ie:state will not change if ctrl not allowed into state
;if allowed into state - turn hopper solenoid off, set state# to resulting
state, & start timer2
FState2
      input       iFeederExtendReed ;test i5
      retifz                              ;return if i5 is not high
      off         oRFeederSolenoid  ;turn off o5
      loadx       3                 ;update feedstate # with resulting state
      store       FeedState
      settimer    2,25              ;set timer2 to 2.5s & start
      setmem            timer2start,255         ;timer2 start var=T
      setmem            timer1start,0           ;no point in checking t1
(extend timer) if retracted!
      RETURN

;coming back - leave solenoid off, set state# to resulting state
FState3
      input       iFeederRetractReed      ;test i5
      retifnz                             ;return if i5 is high
      loadx       4                 ;update feedstate # with resulting state
      store       FeedState
      RETURN
```

```
;retracted position - if reed (i5) not yet high return
FState4
      input       iFeederRetractReed        ;test i5
      retifz                                ;return if i5 not high
      loadx       0                   ;update feedstate # with resulting state
      store       FeedState
      setmem            timer2start,0            ;no point in checking t2
(retract timer) if extended!
      setmem            AdvanceFeed,0
;     setmem            CountSw,255         ;allows counting of rfeeder strokes
      RETURN

; ==== subfeeder-subroutine ====
;counts blade strokes for gauging empty hopper
SUBSUB_COUNTER
      recall      Counter0
      decx
      push
      store Counter0
      goifnz      C0nz
      loadx 99
      push
      store HopEmptyErr
      store GenErr
      RETURN
C0nz
      loadx 0
      store CountSw
      RETURN

; ==== subfeeder-subroutine ====
SUBSUB_T1
      test        1                   ;Check timer1
      goifnz            T1nz                ;goto label if timer not run out
      setmem            FeedExtendErr,99  ;sets feeder extend error mem
location to 99
      setmem            GenErr,99
      recall            GenErr
      retifnz
T1nz
      RETURN

; ==== subfeeder-subroutine ====
SUBSUB_T2
      test        2                   ;Check timer2
      goifnz            T2nz                ;goto label if timer not run out
      setmem            FeedRetractErr,99 ;set feeder retract error mem
location to 99
      setmem            GenErr,99           ;set general error to 99
      recall            GenErr
      retifnz
T2nz
      RETURN

; ==== subfeeder_run-subroutine ====
SUBSUB_AUTOACTIVATE
      on          oStart                    ;turn on start relay (o2)
      setmem            AutoActive,255            ;autoactive=T meaning micro
just activated heat cycle
      RETURN
```

```
; ==== subidle-subroutine ====
SUBSUB_RESETMEM

;IDLE vars

;TOGGLE vars
      setmem          TogRun,0
      setmem          OldTogRun,0
      setmem          TogChng,0

;HOPPER vars
      setmem          ProxState,0
      setmem          EmptyProxState,0
      setmem          FullProxState,0
      setmem          Counter0,C0Value  ;counter0 reset original value
(C0Value)
      setmem          StopBlade,0
      setmem          BladeState,0
      setmem          timer3start,0
      setmem          timer4start,0

;FEEDER vars
      setmem          ContRelay,0
      setmem          OldContRelay,0
      setmem          AdvanceFeed,0
      setmem          Stopper,0
      setmem          FeedState,0
      setmem          timer1start,0
      setmem          timer2start,0
      setmem          AutoActive,0
      setmem          Green4Go,0
      setmem          Tripper,0
      setmem          CountSw,0
      RETURN

; ==== subidle-subroutine ====
SUBSUB_RESETERRMEM

      setmem          GenErr,0

;HOPPER err vars
      setmem          ChuteProbErr,0
      setmem          RetnRdyErr,0
      setmem          HopExtendErr,0
      setmem          HopRetractErr,0
      setmem          HopEmptyErr,0

;FEEDER err vars
      setmem          FeedRetractErr,0
      setmem          FeedExtendErr,0

      RETURN

;=====================================================

Initialise

;all outputs off for programming purposes
      off 0
      off 1
      off 2
```

```
	off 3
	off 4
	off 5
	off 6
	off 7

;===================================================
;==== Setup Resource Equates ====
;===================================================

;==== ;input equates ====
iESTOP			iequ	0
iRunOrSet		iequ	1
iStart			iequ	2
iTripout		iequ	3
iContactor		iequ	4
iFeederRetractReed	equ	5
iFeederExtendReed equ	5
iRFeederReeds		iequ	5	;not used in prog - just for simulation
purposes
iHopperDownReed		iequ	6
iHopperUpReed		iequ	7
iChuteFullProx		iequ	8
iChuteEmptyProx		iequ	9

;==== output equates ====
oWarn1			oequ	0
oWarn2			oequ	1
oStart			oequ	2
oWarn3			oequ	3
oWarnAmber		oequ	4
oRFeederSolenoid	oequ	5
oHopperSolenoid		oequ	6
AVAILABLE		oequ	7

;==== memory equates ====

;IDLE equates
SysReset		mequ	3

;TOGGLE equates
TogRun			mequ	5
OldTogRun		mequ	6

;HOPPER equates
ProxState		mequ	9
EmptyProxState		mequ	10
FullProxState		mequ	11
StopBlade		mequ	12
BladeState		mequ	13
timer3start		mequ	14
timer4start		mequ	15

ChuteProbErr		mequ	19
RetnRdyErr		mequ	20
HopExtendErr		mequ	21
HopRetractErr		mequ	22
HopEmptyErr		mequ	23

;FEEDER equates
ContRelay		mequ	28
```

```
OldContRelay                    mequ   29
AdvanceFeed             mequ    30
Stopper                         mequ   31
FeedState               mequ    32
timer1start             mequ    33
timer2start             mequ    34
AutoActive              mequ    35
Green4Go                mequ    36
Counter0                mequ    37
CountSw                         mequ   38
TogChng                         mequ   39

FeedRetractErr                  mequ   40
FeedExtendErr                   mequ   41
Tripper                         mequ   42

;miscellaneous equates
GenErr                          mequ   46
C0Value                         equ    8

      goto MAIN
```

Appendix R

Southchain Conveying Systems Ltd. Succession Planning List		
Admin Type Issues		
Priority	Responsibility	Description
		Future directions of Mark (suggestions and contacts for work post-project).
		Start liasing with Ralph relatively soon on developing a strategy & focusing on a specific project for TBG (technology for business growth) funding.
HIGH		Pins supplied to the induction heater automation MUST be swarth and tit free. Failure to ensure this will result in machine breakages, blown coils, etc.
Production Issues		
Priority	Responsibility	Description
HIGH		Purchase hardness tester.
HIGH		Reassemble the 30T press.
HIGH		Automate the existing logo stamp tool.
		New press tooling progressively (minimum 1 per year) brought in for the higher production chains + include logo stamp in all new tools.
HIGH		Triple the number of bolt boxes and carts.
HIGH		Use shelving (like transmission chain shelf) for dynamic job storage using bolt boxes. This could also be used for standard stock storage, making inventory control (kan ban) and stock takes easier and more efficient.
		Obtain short-stroke presses and/or maintain both the 75T & 150T long-stroke presses.
		Proper seating for the assembly stations.
		Southchain workshop tools and shadow board.
		Get rid of transmission chain from Southchain's responsibility. It is not their core business.
HIGH		Contact Australian conveyor chain manufacturers for cooperative benchmarking.
		Mori Seiki online to the OWL software.
		Do cost benefit analysis on the purchase of a gas carburising unit for Southchain. Also for the purchase of a larger kilowatt power scanning induction heater.
		Start a QA system of testing (hardness, tensile, pitch tolerances, etc) on all chains that leave the factory.
		Start following a standard so you can stipulate this to clients.
HIGH		Start stocking assembled standard pitch/strength chains for better customer service.
MED		Redesign 12/15K bush roller into one operation and automate
		Computer for Greg