CHAPTER 4
RESULTS

In this section the results of the investigation into the manufacturing processes at CCH are presented.

4.1 Presentation of Results

A summary of the results is shown below. The full results can be viewed in Appendix A.

Stage	Availability	Performance	Quality	OEE
Cutting	0.88	0.65	0.991	**0.57**
Shearing	0.82	0.81	0.998	**0.67**
Forming	0.82	0.65	0.996	**0.53**
Welding	0.92	0.999	0.92	**0.85**
Galvanising	0.88	0.89	0.98	**0.77**
Average	0.86	0.80	0.98	**0.68**

Table 1: Summary of OEE Calculations for Steel Pole Manufacturing at CCH

Different research authors present different views with regards to acceptable values of OEE. Nakajima suggested the following ideal values that would confirm a world class manufacturer:

- Availability in excess of 90%
- Performance in excess of 95%
- Quality in excess of 99%
- These produce an overall OEE of approximately 85%

Kotze (1993) states a figure of over 50% as a more realistic figure whereas Ericsson (1997) states an acceptable OEE can be anywhere between 30% and 80%. An acceptable value obviously differs between industries and even between companies in the same industry due to differences in work practices. Obviously further analysis into the process stages is required. The process stages will be analysed in turn.

4.1.1 Stage 1: Cutting

OEE = 0.57

The first thing that must be noted about the cutting stage is that due to the short cycletime the machine does not have to operate at all possible times in order to cut the required quantity of sheet steel. The cutting process itself, which uses a guillotine action, takes only a second to complete and so the majority of the time is taken up by material handling and positioning of the material within the machine.

The company manufactures to order only and so each stage knows exactly what it must produce. This coupled with the large physical size of the products being manufactured means it is not necessary or practical to have a large quantity of work-in-progress because it would occupy a large area. Therefore, in the cutting stage there is no planned shift time and cutting will continue until all the required quantity for a particular batch has been processed. Planned shift time is therefore simply the total time from the machine being setup for the first batch until machine is cleaned at the end of the day's operation. The planned maintenance for the cutting machine is once every 500 operations and according to the maintenance records this is usually once a week on Saturday which is the maintenance department's usual day for its scheduled work. The machine is not very complicated and does not need advanced maintenance; just lubrication and adjustment of the cutting shears. The machine is also cleaned and simple lubrication is performed every day of operation. Over the month during which the data was collected there was a power supply problem in the building which houses the cutting, shearing, forming and welding stages which caused two power cuts. Only one power cut directly affected the cutting stage. The machine did however have a cutter jam which caused a delay of over an hour to fix. With regards to setup time the foreman explained that setting up the machine takes place before each new batch and being quite a simple procedure takes no more than 3-5 minutes per batch. Therefore, the setup time was assumed to be 5 minutes per batch.

Strictly speaking the cycle time for each unit would take just a second as the guillotine cuts the steel. In was therefore decided to measure cycletime from the moment a new sheet enters the machine until it exits the machine. The sheet steel is still slightly curved when it enters the cutting machine and passes through a set of levelling rollers before actually being positioned and cut. Defects in this stage can usually be re-cut and used although sometimes for a different batch size.

Cutting Availability

Availability losses are due to breakdowns, maintenance and setup times. The cutting machine is not a complex piece of machinery and so breakdowns are rare and when they do occur can be fixed easily. The machine does not require a lot of maintenance apart from routine lubrication and maintenance of the cutting mechanism. The setup time for each batch is only a matter of a few minutes. Therefore it is not surprising to find that the availability of the cutting process was 0.88 which is considered high.

Total Shift Time	Planned Downtime	Unplanned Downtime	Setup Time	Total Useful Time	Availability
2483	285	110	155	1933	0.88

Table 2: Cutting Availability Data

Cutting Performance

Although the cutting is performed by a machine the process does involve operators loading and unloading the sheets and also the sheets have to be passed through a set of rollers before being positioned and cut. The level of human involvement is high and so the variation of cycle times is also high. The ideal cycle time of 30 seconds is possible if all human operations are performed perfectly and no mistakes are made. Loading of the metal onto the machine and passing through the rollers can take different times for different sheets. The metal sheet must be positioned exactly to ensure the right length is cut and due to the size of the product this can be difficult. After cutting the metal must be extracted from the machine from the opposite end to which it entered. Therefore for this machine the actual cycle times rarely equal the ideal cycletime.

The team which operate the cutting machine are also responsible for material handling and this is the cause of the majority of the minor losses. The operators must locate the material themselves, prepare the rolled steel and also stack the cut metal before transporting it to the next stage. The performance was 0.65.

Total Useful Time	Output	Total Cycletime	Speed Loss	Minor Stoppages	Performance
1933	2520	1605	345	328	0.65

Table 3: Cutting Performance Data

Cutting Quality

The number of defects over the month was 22 out of a total output of 2520. Nearly all of the defects were re-used. The simple fact is that there is not much that can go wrong when cutting a piece of sheet steel using a specialised cutting machine. Therefore, the defect rate is low and quality was 0.99.

Output	Defects	Quality
2520	22	0.99

Table 4: Cutting Quality Data

4.1.2 Stage 2: Shearing

OEE = 0.67

The shearing stage is in many ways similar to the cutting stage which precedes it but there are some important differences. First of all similarly to the cutting stage it does not need to be operated at all possible times in order to fulfil the order quantities as the cycletime is short. There are two cuts required in this process and that necessitates turning the metal sheet over after the first side is sheared so that the opposite side can be cut. The actual cutting action does take longer than in the cutting stage though, but is controlled by the machine itself once the operator pushes the start button.

Planned shift time is measured the same way as for that cutting stage. It is the total time from when the operators setup the machine until the machine cleaned after the final batch of the day has been sheared. Planned maintenance is minimal and involves simple cleaning of the machine and lubrication after each day of operation combined with a longer check and maintenance performed once a week. Setup times were calculated in a similar fashion to the cutting stage but this time the set up time was assumed to be 10 minutes per batch. Measuring the cycle time as the total time the machine was shearing would have been pointless as the time is exactly the same for every unit produced. Therefore, the cycle time was measured as the time from when the operators pick up the new piece of sheet steel, through processing until the finished sheet was put down. The physical movement of the operators is minimal as unlike the cutting machine the material enters and exits the machine from the same direction.

Shearing Availability

Again the machine suffered few breakdowns during the month. The metal is clamped in place when being sheared and the clamp jammed several times during the month which needed the maintenance department to fix. This unplanned downtime of clamp jams, when added to the time wasted due to the power cut totalled just over two hours. Both planned maintenance and setup times are relatively short in this stage and so the overall availability was 0.82.

Total Shift Time	Planned Downtime	Unplanned Downtime	Setup Time	Total Useful Time	Availability
2893	405	130	310	2048	0.82

Table 5: Shearing Availability Data

Shearing Performance

It would seem that the performance of the shearing and cutting stages should be similar given that they are similar processes. However, the results suggest otherwise, with the performance of the shearing stage was 0.82 whilst the cutting stage was much lower at 0.65. One explanation for this is the performance of the shearing stage is less dependent on the human element than in the cutting stage. During the cutting stage operators are responsible for passing the steel through rollers before cutting. There is no preliminary rolling in the shearing machine. The relative movement of the material is also much less in shearing as the material enters and exits from the same side whereas during cutting the material passes along the length of the machine. The input material for shearing is also in a much more convenient form, the sheet steel being stacked on trolleys ready, which reduces minor stoppages of material handling.

Total Useful Time	Output	Total Cycletime	Speed Loss	Minor Stoppages	Performance
2048	2518	1843	181	205	0.81

Table 6: Shearing Performance Data

Shearing Quality

The defect rate of the shearing stage is extremely low, just 4 defects over the month. Once the sheet metal is clamped in position within the machine there is very little chance of any defective output. Therefore the quality rate was 0.99.

Output	Defects	Quality
2518	4	0.99

Table 7: Shearing Quality Data

4.1.3 Stage 3: Forming

OEE = 0.53

The third stage was the bottleneck of the overall process. The reason for this is the considerably long cycletime and the necessary die changes to produce the different pole cross sections. The forming stage has shift times that usually involve overtime to meet the required quantities. The machinery itself is not complex and requires the same basic maintenance as the cutting and shearing machines. Breakdowns are rare and easily fixed. However, the setup times are a source of considerable lost time due to the circular and polygonal poles requiring different dies. The cycletime in this stage was measured as the time for the machine to form each sheet into the pole shape. Due to this reason the minor losses were expected to be high compared to other stages. The cycletime is purely the time the machine operates and does not include any of the human operations. The ideal cycletime was given as 2.5 minutes but that figure is taken for forming of the pole with the smallest cross section.

Forming Availability

The dominant figure in the availability is the time to change the die. This event is normally scheduled to cause the minimal upheaval but occasionally the marketing department request an order be rushed for a customer and so the production department must make an unscheduled die-change. This occurred once during the month monitored and caused a major bottle neck with other stages starved of work-in-progress. One breakdown did occur due to hydraulic failure but the maintenance records show breakdowns to be rare due to the frequent maintenance checks. Even with the die-change problems the availability was 0.82 but this figure does not take into account the delays caused to other stages.

Total Shift Time	Planned Downtime	Unplanned Downtime	Setup Time	Total Useful Time	Availability
12210	660	320	1775	9455	0.82

Table 8: Forming Availability Data

Forming Performance

Speed losses are minimal because the machine works at a set rate and the operators just rotate the material in time with the machine. However, due to its definition in this stage, the measured cycletime does not take into account the material handling which is considerable because once in their new form, the poles are much more difficult to store than previously when they were sheets. Also, the nature of the process by which the action of the die forces the sheet into a cylindrical form results in the die being 'trapped' in the pole and so the pole must be slid lengthways off the die. This increases the minor losses considerably. Periodic lubrication of the die itself increases the lost time. The performance of the forming stage was 0.65.

Total Useful Time	Output	Total Cycletime	Speed Loss	Minor Stoppages	Performance
9455	2467	6477	310	2978	0.65

Table 9: Forming Performance Data

Forming Quality

As with the preceding stages the reliability of the output is high. Only 9 defective poles were produced. These were re-processed or passed through to the welding stage where any problems could be rectified. Quality was again 0.99.

Output	Defects	Quality
2467	9	0.99

Table 10: Forming Quality Data

4.1.4 Stage 4: Welding

This stage posed measurement problems and it was difficult to apply the definitions of the six major losses to the welding process. This was because the process is very labour intensive and no heavy machinery is used. On a normal day there would be 20-30 welders working. The ideal cycletime for one man welding one pole was irrelevant as the number of men changed daily and the output would be the total number of poled produced by all the welders combined. However, the foremen stated that for a standard 7.5 hour day the expected output was approximately 100. Therefore the ideal cycletime was set at 4.5 minutes so that in a 450 minute day, 100 would be produced. The MIG welding equipment used required no planned maintenance except for changing gas bottles and electrodes which would occur periodically as the men worked and so the planned maintenance was not applicable. The setup procedure for each pole was to simply set the pole in a jig and clamp it firmly. This time was measured for just one welding station per day.

Welding Availability

There was no planned maintenance and the setup time for each pole was minimal. These two pieces of information would already suggest that the availability would be a high value. The welding machines suffered little breakdown time and even if a machine did breakdown then a replacement MIG machine could easily be substituted. The section did suffer lost time due to the power cuts during the second week. There was also WIP shortages due to the die changes of the forming stage. Normally the welding stage had some buffer WIP that it could clear but due to the length of the stoppage due to the die-change, once the buffer WIP had been processed the welding stage was forced to shutdown. Overall the availability was 0.92 – a high value.

Total Shift Time	Planned Downtime	Unplanned Downtime	Setup Time	Total Useful Time	Availability
12330	0	885	84.3	11366	0.92

Table 11: Welding Availability Data

Welding Performance

As stated before the welding stage is the most labour intensive of all the processes and that makes it difficult to measure the losses which are needed to calculate OEE. During the welding stage there are no machines used and all work is performed by skilled welders. It was impossible to measure the exact time the welders were welding and not preparing or pausing. Therefore the cycletime was assumed to be the total time the welders worked on the poles during a day. The minor stoppages were assumed to be zero. Due to the number of welders changing daily the speed losses also varied considerably, registering both positive and negative values. Overall the sum of all speed losses came to just 3.5 minutes and since the minor stoppages were zero the performance of the welding stage was approximately 100%. Obviously the research methodology needs to be revised for this stage.

Total Useful Time	Output	Total Cycletime	Speed Loss	Minor Stoppages	Performance
11366	2525	11366	3.5	0	0.99

Table 12: Welding Performance Data

Welding Quality

The total for defective welding was taken from the inspection immediately after welding and the final inspection after galvanising. The total number of poles with defective welds was 192. This generated a quality rate of 0.92. All defective poles were reworked.

Output	Defects	Quality
2525	192	0.92

Table 13: Welding Quality Data

4.1.5 Stage 5: Galvanising

OEE = 0.77

Judging from the results and from inspection this stage is the best organised. The production department mentioned that considerable efforts were put into improving the galvanising stage as part of the ISO 9001:2000 achievement. The stage does not contain any machinery as such and therefore there is no scheduled maintenance. The dips do need refilling and checking to see if the contents have the correct chemical concentrations but this occurs at the start of each day or 'on-the-fly' and minor adjustments can made as the process continues. From the data it can be seen that this stage also suffers lost time due to the rolling effect of the die change in the forming stage which results in work-in-progress starvation.

Galvanising Availability

From the data it can easily be seen that there were no major breakdowns during the month. There was a stoppage due to a chemical spillage and also due to one of the cranes malfunctioning but these breakdowns were fixed in 45 minutes and 40 minutes respectively. The WIP starvation resulting from the die-change in the forming stage generated total lost time of 210 minutes. However, it should be noted that during this time the galvanising machines were used to process outside contracts and therefore was not completely wasted. This time, although spent processing outside orders, still qualifies as lost time with regards to the steel pole manufacturing process. The setup time for this process is 50 minutes a day during which the dips are checked and the zinc 'kettle' is heated to working temperature. As mentioned before there is no scheduled maintenance for this stage. The availability was 0.87, a high value. This can easily be demonstrated by watching the stage as an observer; the process never seems to stop during the working hours.

Total Shift Time	Planned Downtime	Unplanned Downtime	Setup Time	Total Useful Time	Availability
12390	0	295	1250	10835	0.88

Table 14: Galvanising Availability Data

Galvanising Performance

The process is very tightly controlled because the poles must be dipped into each treatment for a specified time. Therefore it is unsurprising to find the average speed loss each day was just 13.5 minutes. The minor stoppages total was just over 800 minutes. One cause of minor stoppages is the time taken to attach the poles into the jig. The overall performance was 0.89.

Total Useful Time	Output	Total Cycletime	Speed Loss	Minor Stoppages	Performance
10835	2491	9675	334	826	0.89

Table 15: Galvanising Performance Data

Galvanising Quality

The galvanising stage does produce a higher defect rate than the majority of the manufacturing process. The final rate was 0.98. The defects are easy to spot on inspection due to incomplete zinc covering. However, this incomplete covering could be caused by any one of the dips being performed incorrectly or the contents of any bath being slightly different to that required. All defective poles must be re-galvanised.

Output	Defects	Quality
2491	52	0.98

Table 16: Galvanising Quality Data

The data collected about the processes has now been presented and in next chapter the analysis of the data can begin, followed by the solutions to reduce the lost time.