MIT Leaders for Manufacturing Program

H. C. Starck, Inc.[1]

1. The Arrival

Tom Carroll was a Fellow in MIT's Leaders for Manufacturing Program. On June 1st, 1999, after completing a difficult academic year, Tom arrived at H.C. Starck, Inc. to start on his six-month internship. He knew that his work would involve reducing lead times, but did not know any specifics. His first meeting was with Lee Sallade, Director of Operations. Figure 1 presents an abbreviated organizational chart for H.C. Starck. Lee explained that the sales group was pressuring him to reduce lead times - defined here as the time from when the customer places the order, until the product is shipped. The general feeling was that this metric was running at eight to fourteen weeks, mostly due to the long manufacturing time, but there was no hard data. The sales department felt that if lead-time could be reduced to three weeks, they would have a substantial advantage in the marketplace, and would realize incremental sales volume. Lee agreed that lead-time was important, but cautioned about focusing solely on lead-time, and not overall cycle time, which is the length of time it takes material to physically flow through the manufacturing process:

> *We need to reduce cycle time as well as lead-time. Larry* [the company president] *got burned once on a lead-time reduction project. The distributors ended up taking all the benefit. You should talk to him about that.*

Lee explained that cycle time and inventory were important, but were difficult to influence since the company held such a high level of tantalum inventory:

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> *Making Ta ingot from scrap gives us a cost advantage compared to making it from good Ta powder. We have the technology to process and refine scrap that other companies do not. We buy scrap before we need it, because the supply is so erratic. We ran out once in 1996, and we don't want that to happen again. Sometimes we buy more than is needed, just to ensure an uninterrupted supply.*

Lee also stressed the idea of managing with data. He was concerned that many operational decisions were based on ‘industrial mythology’, and that rigorous data collection and analysis could help to break out of this mode of operation. Tom spent some more time discussing the operation with Lee, and left the meeting with a clear project goal: Reduce customer lead time to three weeks or less for all metallurgical products, without increasing inventory. While the goal was clear, the method was not. According to Lee: “We’re not really sure how to achieve this. That is why we hired a smart MIT student like you!” Tom had a lot of work to do, and was eager to apply his newly learned skills.

2. The Company

H.C. Starck, Inc. traces its roots back to 1940, when MIT graduate Richard Morse founded National Research Corporation (NRC) as a process-development company focused on exploiting vacuum technology. The company was originally located at 70 Memorial Drive in Cambridge (currently MIT building E51). Early processes developed at NRC include 'Minute Maid' frozen concentrated orange juice, and 'Holiday Brand' instant coffee. In the 1950’s, NRC applied its vacuum technology to the production of high-purity metals, and in 1959 entered the tantalum processing business. Morse left in 1960, and the company went through a series of ownership changes, starting with the acquisition by Norton in 1963. Norton divested its interest in NRC in 1976, with H.C. Starck AG (a German company specializing in refractory metals) acquiring 50%, and a venture capital group acquiring the other 50%. Bayer AG purchased the majority of H.C. Starck AG in 1986; Bayer Corp USA purchased the remaining 50% of H.C. Starck Inc. shortly thereafter. At this point, HCST was focused primarily on the reduction of tantalum, and production of tantalum powders. It wasn’t until HCST acquired the tantalum mill & wire products from Fansteel in 1989 that it entered the metallurgical products market in a large way. The H.C. Starck International Group also has Ta reduction and powder manufacturing operations in Japan, Thailand and Germany, but the Newton, MA location is the only plant with melting and mill capability.

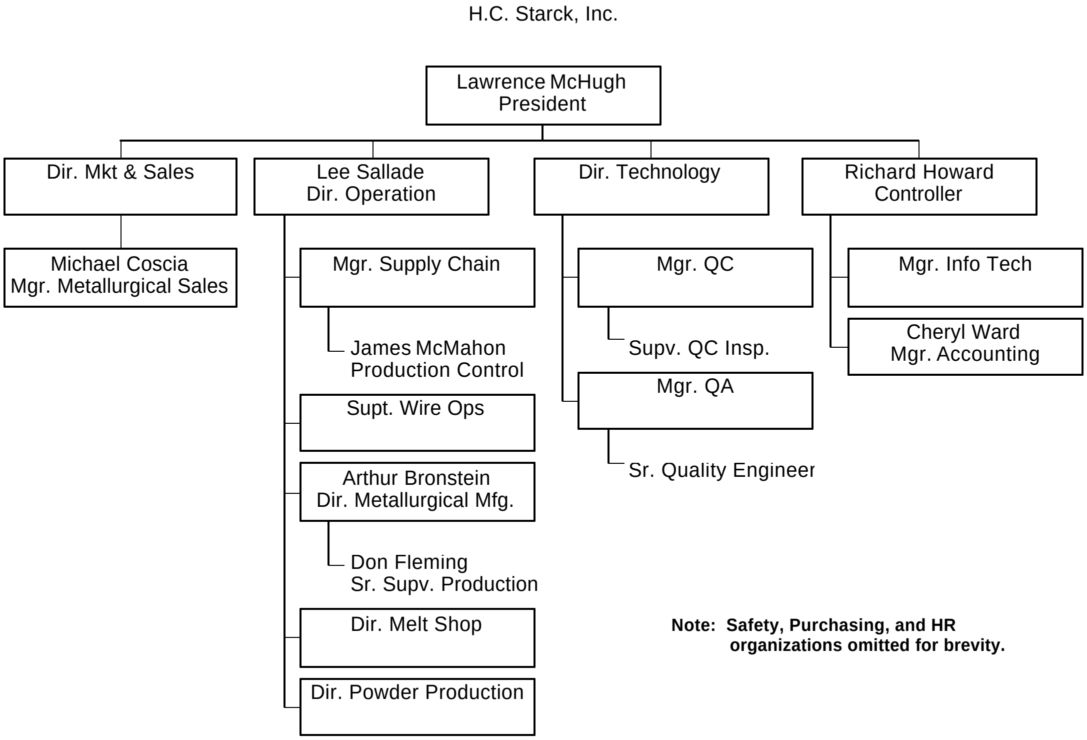


Figure 1: Abbreviated H.C. Starck Organizational Chart

3. Tantalum

Tantalum (Ta) was discovered in 1802 by Ekeberg, but many chemists thought niobium and tantalum were identical elements until Rowe in 1844, and Marignac, in 1866, showed that niobic and tantalic acids were two different acids. The first relatively pure ductile tantalum was produced by von Bolton in 1903. Tantalum ores are found in Australia, Brazil, Mozambique, Thailand, Portugal, Nigeria, Zaire, and Canada. Separation of tantalum from niobium requires several complicated steps. Several methods are used to commercially produce the element, including reduction of potassium fluorotantalate with sodium.

Tantalum is a gray, heavy, and very hard metal. Tantalum is almost completely immune to chemical attack at temperatures below 150C, and is attacked only by hydrofluoric acid, acidic solutions containing the fluoride ion, and free sulfur trioxide. Alkalis corrode it only very slowly. At high temperatures, tantalum becomes much more reactive. The element has a melting point (about 3000 C) exceeded only by tungsten and rhenium. Tantalum is used to make a variety of alloys with desirable properties such as high melting point, high strength, and good ductility. Tantalum is used to make electrolytic capacitors and vacuum furnace parts, which account for about 60% of its use. The metal is also widely used to fabricate chemical process equipment, nuclear reactors, and aircraft and missile parts. Tantalum is completely immune to body liquids and is a nonirritating material. It has, therefore, found wide use in making surgical appliances. Tantalum oxide is used to make special glass with high index of refraction for camera lenses. The metal has many other uses, with a total worldwide annual consumption of about 550 tons.

Tantalum is very expensive, as shown below in Figure 2. Compare this to $0.65/lb for Aluminum and $5/troy oz ($ 73/lb) for silver (WSJ 6/23/99). It is expensive stuff!

Form	Price per Pound
Tantalite ore (contained pentoxide basis)	$ 35 - 45
Capacitor-Grade Powder	$ 135 - 240
Capacitor Wire	$ 180 - 250
Sheet	$ 100 - 150

(Prices are from 1998 USGS data)

Figure 2: Tantalum Prices

4. H.C. Starck, Inc. in the Tantalum Supply Chain

Tantalum-containing tin slags and mined ore are processed and refined to the tantalum "double salt", K_2TaF_7 by H.C. Starck AG. This free-flowing white powder is shipped from Germany in pallet-sized containers to the four Ta powder production operations worldwide. The "double salt" is reacted with molten sodium and then cooled to form particles of elemental tantalum dispersed in a solid salt mass. The large mass is mechanically broken up, and the salts are leached out through several steps, leaving pure tantalum powder. Figure 3 diagrams a simplified version of the Ta supply chain. A large portion of the powder is further refined and graded, and sold for the production of sintered tantalum capacitors. Some of the powder is sintered into bars for the production of wire, also mostly for capacitors. Ta powder that is under or over the desired particle size is scrapped, and sent to the melt shop for recycling. Also, any scrap from the sintering or wire forming operations is collected and recycled.

The melt shop receives the above-mentioned scrap, as well as scrap from the metallurgical products divisions, scrap purchased on the open market, scrap generated by customers, and occasionally Ta ingots purchased from government reserves. (The U.S. and Russia have recently been reducing their strategic metal reserves, and periodically sell excess inventory at auction.) The scrap is processed and blended to achieve the desired chemistry, and is then melted into ingots in an electron-beam vacuum furnace. The 8-inch diameter round ingots are cold-forged to a four-inch thick 'sheet bar', which is the starting material for the Metallurgical Products division.

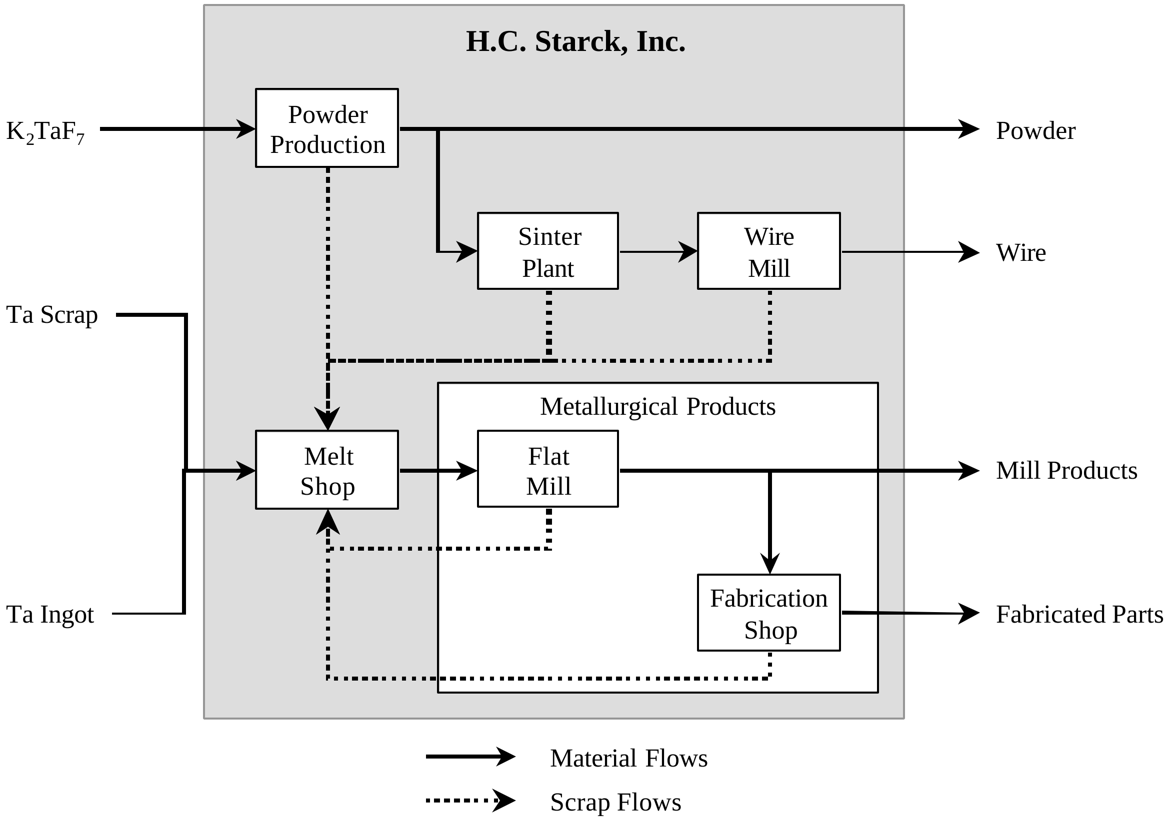


Figure 3: H.C. Starck, Inc. in the Tantalum Supply Chain

5. Metallurgical Products

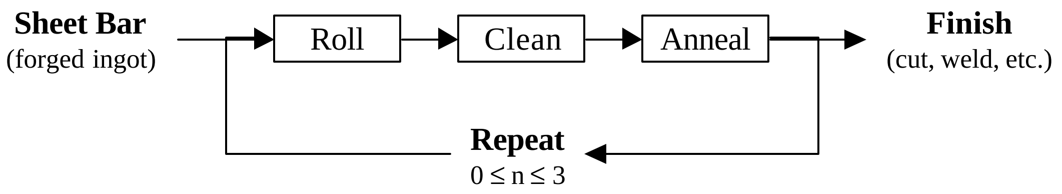
The metallurgical products (MP) division of HCST comprises two basic functional areas, rolling and fabrication. The rolling plant has three mills that reduce the incoming four inch thick ‘sheet bar’ to the final gauge thickness, and a variety of equipment to perform functions such as cleaning, cutting to size, and annealing. The rolling plant produces only flat shapes. The fabrication area includes a sheet-metal shop, a machine shop, and several tube-welding lines. The fabrication shop takes flat stock from the rolling plant, and produces more complex finished products.

All incoming 4” thick sheet bars first undergoes a ‘breakdown’ rolling process on the large mill. This mill can produce pieces up to thirty-six inches wide, and as thin as 0.015”. A twelve-inch wide foi-l mill can start with materials as thick as 0.030”, and is used for most production with a final gauge of 0.014” or less. There is also a sixteen-inch wide intermediate mill, but it is only used for very small custom jobs. Don Fleming, Sr. Supervisor of Production for the rolling plant, has been with the HCST for just over a year, but has extensive experience from another rolling plant. Don describes the process:

> *When we roll a bar down from 4 inches, it develops 'fishtailing' and edge cracks. We need to stop rolling and trim it all around when we get to 1/4" thick, to prevent these cracks from propagating. This typically results in a trim loss of 20%. If the final gauge is going to be thicker than 1/16", we'll also anneal at this point.*

As a metal is cold-rolled, it becomes work hardened. A piece of Tantalum that starts out soft and ductile can be reduced up to 95% in cross-sectional area, but will become hard and brittle beyond this amount of reduction. By annealing the metal at over 1000°C, the grain structure has a chance to recrystallize to a stress-free state. This restores the original softness and ductility, allowing the piece to be rolled further. Before annealing, the piece of metal must be chemically cleaned. The high annealing temperatures would allow any surface contaminants (notably carbon, oxygen, nitrogen, and hydrogen from the atmosphere and hydrocarbon lubricants) to diffuse interstitially into the metal, causing embrittlement. This cycle of roll-clean-anneal may be repeated several times, as described in Figure 4. Don continues his explanation:

> *If the final gauge will be less than 1/16", then it will get rolled down to 1/8" before we anneal it. We can roll sheet down to 0.015" on the large mill. Anything thinner than that goes to the foil mill. Even though we use the same mill, the rolling process is different depending on the gauge. 'Breakdown' is done on the large mill in a free-rolling mode, and brings it to as thin as 1/8". From 1/8" down is 'finish' rolling, which is done in tension. Also, we use a different set of work rolls for breakdown and finish - it takes a full shift to convert the large mill between the two processes.*



n	Final Gauge (inches)
0	0.250 – 3.99
1	0.060 – 0.249
2	0.015 – 0.059
3	0.000 – 0.014

Figure 4: Basic Production Process

During 'free rolling', the workpiece moves through the mill simply by the action of the working rolls. Since the piece is not connected to anything, its entire length can be rolled. In tension rolling, a titanium 'leader' is attached to each end of the workpiece with a spiral spring (much like the pages of a spiralbound notebook are attached together). The leader is coiled up on an arbor at each end of the mill. Tension applied to the workpiece helps to 'pull' it through the working rolls. Since the spring connection cannot go through the work rolls, there is a yield loss at each end of the piece. This yield, together with the typical side trim yields averages 10%.

This series of rolling operations is the start of every product in the portfolio. By arranging the products by final gauge, and then mapping the number of individual rolling steps and standard stopping points, a generic product hierarchy can be constructed as shown in Figure 5.

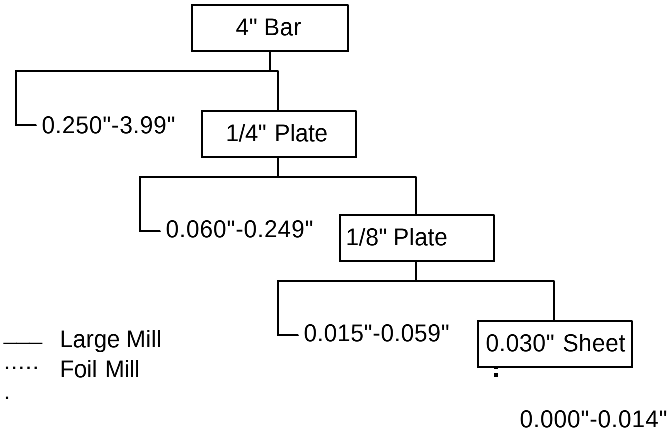


Figure 5: Generic Product Hierarchy

After discussing the process with Don, Tom met with Arthur Bronstein, Director of Metallurgical Products. Arthur helped to fill in some of the details of the operation:

> *The average piece of tantalum going through the large rolling mill for breakdown rolling is 570 pounds, and it takes 55 minutes to process it, including piece-to-piece set-up. For finish rolling, the average piece is 450 pounds, and it takes two hours to complete. The changeover between breakdown and finish takes a full eight-hour shift. The large mill is staffed with two operators both during rolling and changeover. The fully loaded wage rate is about $25/hour, and we typically run 5% to 10% overtime.*

Arthur also gave Tom a spreadsheet with the mill's production report for last year, and the current year-to-date, shown here in Figure 6. The large mill ran on a two-week cycle, with about one-week of breakdown followed by one week of finish rolling. This schedule was run 3 shifts per day (i.e., 24 hours), five days per week, with just four weeks per year shut down for holidays and maintenance. The large mill averaged 85% uptime over the course of the year. Arthur wondered if this were the optimal schedule, or if more frequent changeovers would be beneficial.

(pounds)	1998		1999	
	Breakdown	Finish	Breakdown	Finish
Jan	28,936	12,307	36,255	8,686
Feb	68,001	10,828	46,175	18,106
Mar	38,210	24,529	75,256	15,500
Apr	78,514	22,122	16,978	14,112
May	61,782	20,155	28,539	18,219
Jun	43,176	24,277	28,103	25,586
Jul	57,216	15,880		
Aug	7,838	9,296		
Sep	28,394	15,981		
Oct	44,151	11,383		
Nov	23,731	6,287		
Dec	46,591	9,792		
YTD	526,540	182,837	231,306	100,209

Figure 6: Large Mill Production Report

6. Scheduling

H.C. Starck had installed a new ERP system (SAP’s R/3) at the beginning of 1999, and was currently using the system to record all transactions. Production planning and scheduling, however, continued to be performed manually. Jim McMahon, Supervisor of Production Control and a 20-year HCST veteran, explains the raw material ordering method.

> *I get the sales forecast, and convert it into a production forecast. I set the ingot orders by month for a year at a time, and revise the orders a few times per year. Getting the ingots is the real chore - the melt shop only has so much capacity. Also, sales orders typically come in spikes, and are very unpredictable.*

In addition to the sales forecast variability, there was also some production variability. Jim estimated that the mill met its planned schedule about 90% of the time, and the melt shop about 80% of the time. Most of the schedule misses were due to equipment failures. In addition to raw material ordering, Jim also manually performed shop floor scheduling. The SAP scheduling utility was not used.

> *I just know what is going on - all the orders come through me. Paul* [Jim's assistant] *or I generate a production order as soon as we get a sales order. Then I stack them up on my desk, until it is time to release it to the floor. If it isn't due for another eight weeks, I*

> *might keep it here four weeks before releasing it, depending on the loading in the shop at the time. I've been here enough years that I just know how long things will take. I don't have faith in SAP because I don't think the recipes are right.*

In fact, the recipes were a problem. One indicator of the problem was standard cost. Standard costs were calculated from the recipes, and for some products these costs were lower than for the raw material used to make them – a logical impossibility. The engineering department was working to review and fix these problems, but it was a painstakingly slow process. A particularly problematic product to schedule was tubing. Tubing was produced by rolling flat sheet into a tube, and sealing the resulting seam by gas-tungsten arc welding. The plant could produce and inspect about 1,500 feet of tubing per day, working two shifts. Tube orders tended to be unpredictable and large – an order totaling 1,000 feet would be considered typical. Also, due to the extremely high material cost, nearly all orders were cut-to-length. In addition to the length, bending to a shape (for example, a u-bend for a heat exchanger application), or having caps welded on one end, further customized many orders. Jim explained the problem:

> *The big problem in tubing is the erratic schedule, big peaks and valleys. This has been helped somewhat by 'blanket orders', which allow us to do some smoothing.*

In a "blanket order", a customer would commit to buy a quantity of a certain product, say 5,000 feet of ¾" diameter x 0.015" wall thickness tubing, by the end of the year. Then the plant would build the 5,000-foot tube inventory at standard twenty-foot lengths. Randomly throughout the year, the customers would issue 'releases' against the blanket order. A typical release might ask for fifty tubes at 9-foot-9- inches each, to be shipped in six weeks. The tubes would be cut from stock, and shipped. In this example, the scrap rate works out well; 25 of the 20-foot standard sections could be cut to make the 50 tubes, with less than 3% scrap. Often times, however, the scrap rate was much worse. If the above example had been for slightly longer tubes, say 50 pieces at 10-foot-9-inches each, then 50 of the standard 20-foot pieces would be cut to fill the order, with 50 pieces at 9-foot-3-inches each left over. These were set aside in the hope that they would eventually be used on another order, leading to an accumulation of odd-sized pieces. Sections shorter than 2 feet were scrapped.

7. Sales and Marketing

Mike Coscia, Manager of Marketing and Sales, Metallurgical Products, discussed the sales incentives:

> *Our corporate profit sharing bonus is based on four goals: Sales volume, Return on Assets, Quality, and Safety. We've hit the maximum payout each of the last two years, and we're shooting to do it again this year. Reducing lead-time is a great thing to do, in*

> *that it may help us make more sales, and will improve ROA, but it doesn't directly affect our bonus.*

Still, he agreed that lead-time reduction was important:

> *Tantalum is 4x the price of Zirconium or Hasteloy. If the customers can't get the Tantalum in time, they might substitute one of the other alloys. If it works, they'll never switch back.*

Mike was skeptical about our ability to achieve the goal of 3-week lead-time.

> *I don't think we can get there. Our sales volumes are ten times what they were 15 years ago, but the process hasn't changed. Sometimes I think the best thing sales can do is not take an order. We've just started to load the forecast data into SAP. Production planning is still done manually. There seems to be an 'information black hole' - orders go to the mill, but the demand data doesn't seem to make it back upstream to the melt shop.*

There was a team started a few months ago to look at order processing, with the goal of getting all the paperwork from customer to production in less than two weeks, 80% of the time. Mike expressed frustration with the new SAP R/3 system:

> *I don't understand why it takes so long, especially now that we have SAP. Why is there a physical piece of paper that travels from Sales to Production? Why can't this be automated through SAP? I know SAP can do this, but there are a lot of complaints about the system, and fear of doing it wrong.*

As one way around the “information black hole”, Sales, Production Control, and Operations had recently instituted a ‘drumbeat’ meeting each morning at 8:00 am. This meeting focused on achieving on-time delivery, by each morning reviewing the status of all the shipments that were due in the next week. Any that were at risk of being late were expedited through the plant. The meeting did keep everyone up-to-date on order status, but an unintended effect was that most jobs were bypassed until they made it to the ‘drumbeat list’, then it was a race to get them completed on time.

8. Finance

Cheryl Ward was HCST’s Manager of Accounting, and had led the implementation of the financial module of SAP:

> *SAP has made a fundamental change in how we collect financial data. The manufacturing people used to give weekly time sheets and material tickets to accounting, who entered the data, and made sure that it all made sense. Now, the manufacturing people enter the data directly into SAP, as a real-time transaction. This is a big cultural change.*

It took a couple of months, but the operators on the manufacturing floor became proficient at making the transactions, with fairly high accuracy and reliability. While the transaction recording was going well, the behind-the-scenes calculations performed by SAP were not. One example of this involved the anneal oven. Each shop order was being charged for eight hours of oven time. Parts do take approximately eight hours to anneal, however many parts can be in the oven simultaneously. The system was not set up to account for this, leading to errors in both allocation of overhead (and therefore product costs), and also in the scheduling system (one of the reasons it was not used). From a financial standpoint, these errors led to large cost allocation variances that were adjusted at the end of the accounting period. Even six months into the implementation, the adjustments were sometimes as large as 100% of the actual values. Rick Howard, HCST's Controller, discussed inventory:

> *Inventory is very expensive - we seem to have years of inventory. Since scrap is such an important raw material for us, we consider it a strategic purchase - we buy it even when we don't really need it. Tantalum is a thinly traded market, so we take it when we can get it, if for nothing else than to keep it out of the hands of our competitors. Reducing inventory in the plant won't really save us money - it will just push the inventory back in the pipeline to scrap. Scrap is valued at $75 per pound, heavy gauge material (thicker than ¼ inch) at $100 per pound, and thinner gauges averages $125 per pound, so there is not a huge savings for holding material earlier in the pipeline. We're going to hold the inventory somewhere in the system; it might as well be at strategic points near the end.*

Rick pointed out that as a subsidiary of Bayer, HCST's cost of capital was a favorable 9%. Rick also expressed concern about a Chinese company that recently started selling Ta wire. While their quality was not very good, their sales price was roughly equal to HCST's production cost. Rick was worried that the Chinese would eventually improve their quality, and then might enter the mill products market.

9. The President

Tom also met with Larry McHugh, President of H.C. Starck, Inc. Larry described one of his experiences with cycle-time reduction at another company:

> *I'm not a big fan of lead time and service level projects. These will help your business when you are supplying end customers, but not when you are supplying intermediates, like we are. We already have a majority of the worldwide chemical process industry Ta market. Some of our customers whine about long deliveries, but most would not buy more even if we improved it. I think quicker deliveries might give us an advantage in some of the smaller segments, such as furnace parts and sputtering targets. Before I came to H.C. Starck, I ran operations at another company. We spent a pile of money implementing Goldratt's "The Goal" management method. We really took it to heart, and substantially reduced cycle times, but gained no benefit. Our product was sold through regional distributors - they ended up taking all the inventory savings. You could argue that with the improved performance, we could have recruited more distributors, but with the geographic exclusions, and with others being locked up by our competitors, there was really no way to change. So we spent a bunch of money, with nothing to show for it. I don't want that to happen here. The one area where this really may help is with inventory. If you can figure a way to cut our inventories, then that may really save some money.*

10. Lead Time and Inventory Data

By this time, Tom's head was spinning with conflicting opinions and advice from each of the different players. Everyone seemed to have an opinion, but few people had much supporting data. Tom decided it was time to collect some hard data on which to base his recommendation. While the SAP R/3 system was not being used for planning or scheduling, it was being used to record all the accounting transactions, including order creation and all material movements. Transactions were recorded in near real-time, usually within a few hours of when they physically occurred, and often within minutes. Even though some of the values calculated by recipes were unreliable, the data resulting from manually entered transactions were quite accurate. Figure 7 shows lead-time data from a customer perspective – how long does it take from order to delivery? (Initial compliance for using SAP to record transactions was poor, so data for January and February were ignored.) The data showed that the average lead-time was under seven weeks, not twelve, as was commonly quoted. Many of the longest orders were actually "blanket orders" with no releases against them yet.

At the start of the project, the generally accepted belief was that the customer lead-time was long due to the long manufacturing time. Figure 8 shows this manufacturing lead-time, counting the time from 'goods issue' to 'goods receipt'. 'Goods issue' is the transaction that occurs when the input material is physically issued to the shop floor, and 'goods receipt' is the transaction that is completed after all manufacturing and inspection steps are complete, and the material physically moves to the stockroom, to be shelved or packaged for shipment. This graph shows that on average, final items are manufactured in just over two weeks, with 75% complete in three weeks. How could it be that manufacturing averaged just over two weeks, but order-to-delivery averaged nearly seven weeks? What happened to the other five weeks? One possibility is that there was a shortage of material, with no raw-material inventories from which to produce.

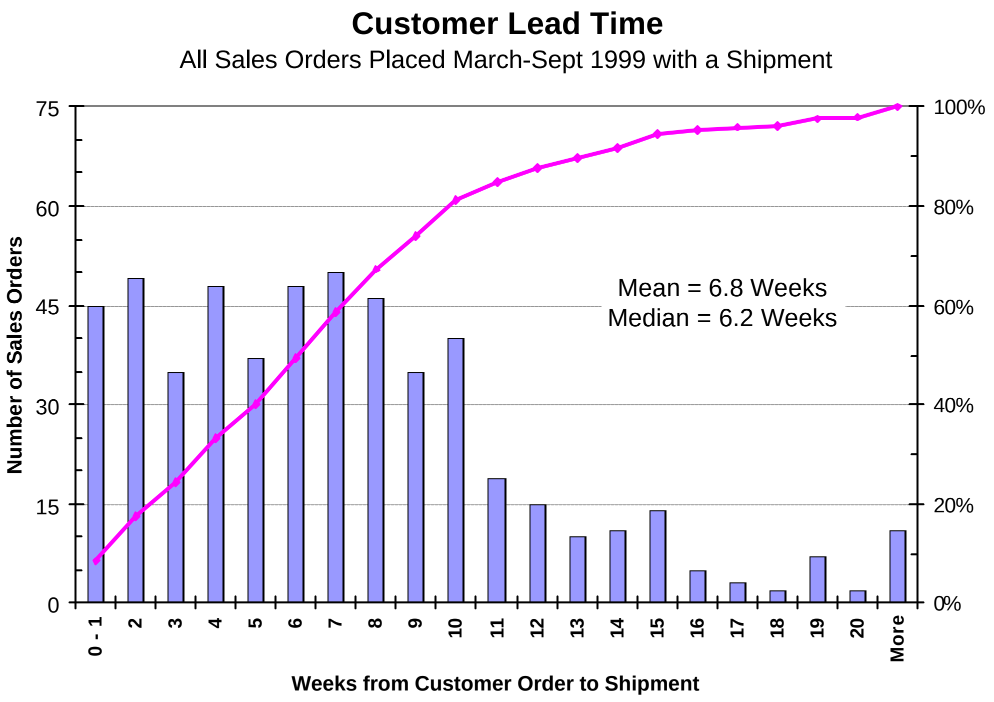


Figure 7: Customer Lead-Time

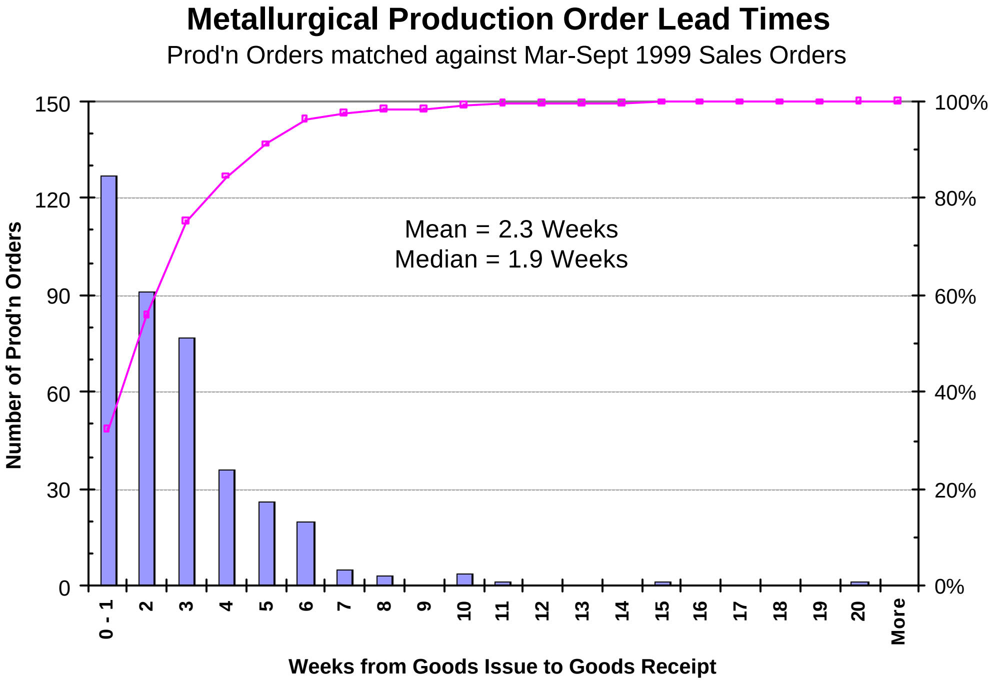
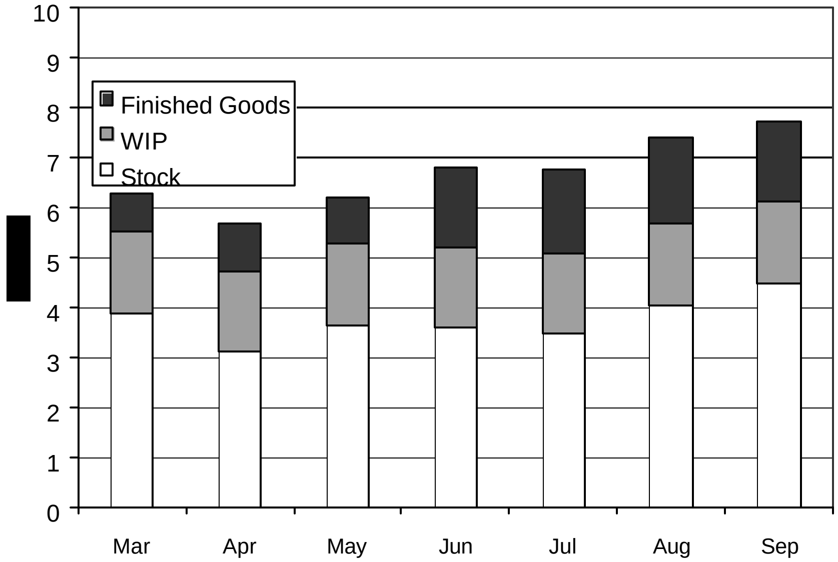


Figure 8: Manufacturing Lead-Time

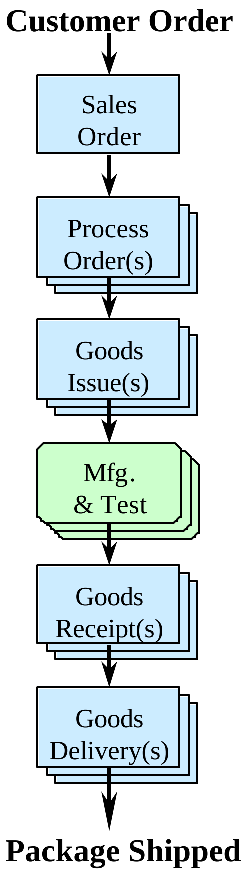


[redacted]

Finished Goods:	Material produced to a customer specification, and held in reserve for that particular customer.
WIP:	Material that is assigned to in-progress work orders.
Stock:	Any material in the stockroom that is neither Finished Goods nor Scrap. This could include both incoming sheet bar from the melt shop, intermediate and standard shapes, and small ‘left over’ pieces from customer orders.

Figure 9: Inventory Coverage

Figure 9 shows inventory levels. They appear to be more than adequate to ensure a high level of availability. If neither manufacturing time nor inventory levels were the cause of the long customer lead times, what could it be? Before Tom’s arrival, it was felt that a lot of time was wasted getting the customers’ orders to the shop floor. A group had been meeting for several weeks looking at the issue, and had started some process mapping. In theory, the information flow was controlled by SAP R/3 as shown in Figure 10. In reality, SAP was often ignored, and a manual paper-based process was used to transmit the order from Sales to Operations.



Customer order (CO) arrives by fax, mail, telephone, etc. *Sales* logs the receipt.

Step 1:
Sales creates a Sales Order (SO) in SAP. Includes material number, delivery dates, specific sizes, inspection needs, etc.

Step 2:
Production Control converts the SO to one or more Process Orders (PO). Prints a "job ticket" with the recipe for *Operations*.

Step 3:
Stockroom issues materials (GI) to the order.

Step 4:
The material is manufactured by *Operations*, and certifed by *Quality Control*, according to the recipe.

Step 6:
Stockroom receives (GR) finished goods into inventory, assembles paperwork, and delivers it all to *Shipping*.

Step 7:
Shipping packages the material and arranges for delivery. A Goods Delivery (GD) is performed that triggers the invoice.

Carrier (i.e., FedEx, UPS, etc.) takes package.

Figure 10: Order Flow Diagram

A custom ABAP (SAP's programming language) report had been created to look at the first two steps in the process, and procedures had been implemented that reduced the first step (create the SO) to one business day or less. The second step (create the PO) was still taking up to two weeks, and there was no real data for the rest. Tom had the report expanded to include the entire delivery process, and the data is shown in Figure 11. This data confirmed that manufacturing time (GI-GR) was only a small portion (about 25%) of the total lead-time. The time that finished material sat waiting to be shipped was also relatively small – most orders were shipped as soon as they were built. The problem lied in the SO to GI phase – all that time between when the sales department entered the order in to SAP, and when the plant actually started manufacturing. (The large increase in SO-PO in August can be attributed to the annual two-week plant shutdown.) This long lag time can be partially explained by the slow manual process of transmitting orders, and partially by the current production policy. The typical production routing used a make-to-order policy, with either 4" sheet bar or ¼" plate from a stock inventory as the initial input. Depending on the final gauge and form, the material will likely flow through multiple process orders before ending up as the final product.

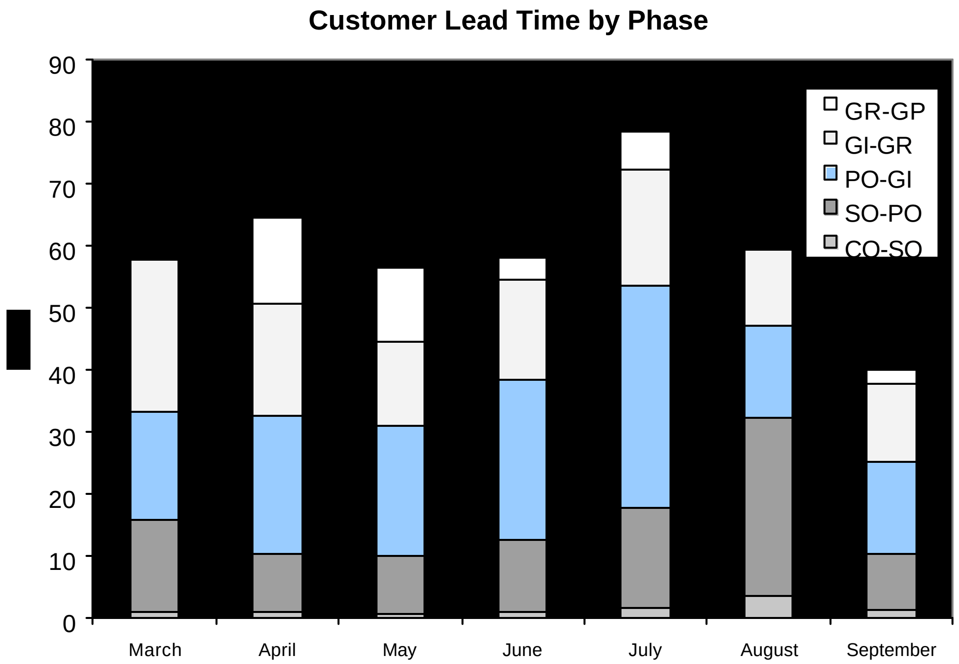


Figure 11: Customer Lead-Time - By Order Phase

Figure 12 illustrates a typical scenario – the customer has ordered 0.015” wall thickness tubing, and three separate production orders are generated. The first order is to “breakdown” a 4” thick sheet-bar to ¼” plate. The next order takes the ¼” plate, and rolls it in two steps to 0.015” sheet. The final order – for the product that the customer ordered – starts with the wide-format 0.015” sheet, slits it to the proper width for tubing, and rolls, forms and inspects the tubing. The problem with this scheme is that the final process order, the one that makes the product for the customer, cannot be started until the previous steps, that create the necessary intermediate material, are completed. Figure 8 measured only the manufacturing lead time for customer-ordered items, in this case, equivalent to the in-process time of production order #3, which produced the tubing from the 0.015” gauge sheet.

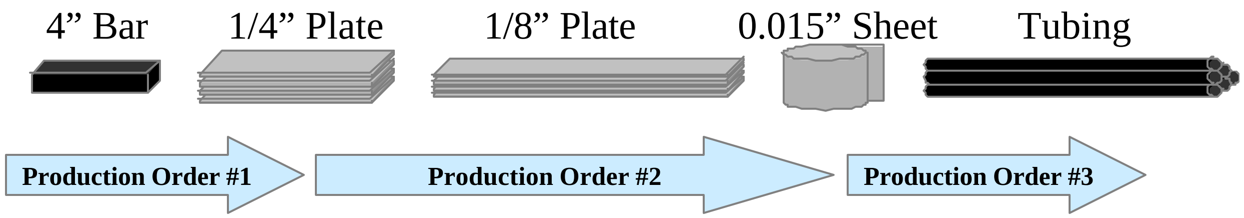


Figure 12: Multiple Process Orders

Compounding this are certain ordering and expediting schemes. As a way to cut customer lead-times, the sales department enters hard orders on probable sales, so that when the actual customer order arrives, the material is already partially through the manufacturing process. Sometimes this works well, but often it causes one of two problems. Since SAP requires that orders have a delivery date, sales makes up a date. If the date is too far into the future, the order may be ignored by Operations. If the date is too close, Operations may build and ship the material before the customer wants it, or completes the probable order, only to find that the customer modified their requirements for the firm order, and the material just made is obsolete. The daily 'drumbeat' meeting exacerbates these problems. At this meeting between Sales, Operations, Quality and Production Control, all orders due to ship in the next week are reviewed. Any orders found to be falling behind schedule are expedited. An effect of this is that until orders show up on the 'drumbeat' list, they are largely ignored. The resulting production policy effectively becomes "Expedite late orders".

11. Sales Data

The primary argument for maintaining a pure make-to-order job shop was that the Metallurgical Products division sold four different alloys, with a total of over six-hundred unique part numbers on the books. The extreme product diversity and unpredictable line-item demand seemed to preclude any make-to-stock possibility. A review of the sales data for the first nine months of the year, however, seemed to indicate that the product diversity was actually much less than originally thought. (For brevity, we will consider only two of the four alloys – these two were chosen as illustrations because they have very different demand profiles, and together they account for 80% of the total demand.) While each alloy has one- to two-hundred unique part numbers, Figures 13 and 14 show that less than half of these were sold over the course of nine months, and many of these only sold once or twice. Demand seems to be concentrated in just a few parts.

12. Case Wrap-Up

Having spent two months learning about the operation, building relationships, and trying to make small operational gains, Tom spent a few minutes reviewing the situation. The Metallurgical Products department at HCST was scheduled as a make-to-order job-shop, with customer lead-time performance averaging seven weeks. Order expediting is the rule rather than the exception, and in fact a daily meeting occurs to enable the expediting. The plant carries an average of six months inventory, yet few items are sold from stock, or even made in a single production step from stock. Nearly all work passes through some of the standard gauges of 4", ¼", 1/8", and 0.030", yet no standard stock is held at these sizes other than a small amount at ¼", and small left-over pieces at the other gauges. The Sales group was pressing hard to reduce customer lead-times to under three weeks. The goal seemed attainable since production orders averaged just over two weeks, but something needed to be done to speed the time between when an order was received, and operations began working on producing the final product. It seemed as though maintaining stocks of some of the standard intermediate sizes would help customer lead times, since end-items could be produced in a single production operation, but which items should be stocked, and at what levels? Also, not everyone in the organization was convinced that reduction of customer lead-time was a priority – some were more focused on inventory reduction, while others felt that inventory levels were not that important. Tom had four months left to come up with a plan and implement it – what was he going to do?

			1999 Invoiced Sales - Pounds per month								
Material	Gauge -	Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1001	0.005	Sheet - 1.0" x 23.75"	171	0	0	20	0	0	0	17	0
1002	0.010	Sheet	20	56	287	179	41	204	560	143	276
1003	0.005	Sheet	263	576	584	812	617	969	572	359	909
1004	0.015	Sheet	68	611	1,263	167	1,917	803	321	377	404
1005	1.000	Thermowell per Dwg #ABC12	0	0	0	0	0	0	5	0	2
1006	0.150	Sheet	101	0	0	0	0	0	0	0	0
1007	0.060	Plate	0	146	32	117	129	414	581	26	191
1008	0.040	Sheet	321	101	191	486	8	98	263	176	690
1009	0.030	Sheet	0	122	614	275	422	360	686	246	177
1010	0.020	Sheet	0	54	102	183	45	54	126	92	119
1011	0.002	Foil	618	1,079	1,215	1,188	1,020	290	1,590	849	1,017
1012	0.125	Plate	228	8	32	90	432	17	8	0	450
1013	0.150	Plate	1,100	0	0	0	0	35	0	0	0
1014	0.250	Plate	6	12	0	770	0	752	0	0	174
1015	0.375	Plate	0	0	0	0	0	0	375	0	0
1016	0.500	Tube - 0.50" OD	3	0	0	51	6	54	33	27	33
1017	0.750	Tube - 3/4"	0	0	0	8	12	558	0	0	12
1018	0.015	Tube - 1.0" OD	8	0	0	0	0	230	0	41	0
1019	0.020	Tube - 1.5" OD	0	0	0	0	0	0	0	11	0
1020	0.500	Tube - .50"OD	44	3	0	0	0	0	35	0	0
1021	0.020	Tube - 5/8"OD	0	6	0	0	0	8	0	0	0
1022	0.102	Sheet	0	27	33	0	0	0	0	0	0
1023	0.010	Sheet - 1.0" x 23.75"	0	99	14	18	0	0	0	0	0
1024	0.060	Plate - 7/8" x 39.125"	15	0	24	0	0	0	0	15	0
1025	1.125	Ring - 6.25"OD x4.5"ID	45	0	0	0	0	0	0	0	0
1026	1.000	Ring - 4.0"OD X 2.5"ID	12	0	0	0	0	0	0	0	0
1027	0.015	Sputter Target - 2.0" x 5.0"	0	105	0	0	0	0	0	0	0
1028	0.500	Ring - 10" OD x 8.5" ID	0	189	0	48	293	93	0	0	174
1029	0.500	Disk - 10" dia	275	0	353	0	581	0	530	414	1,017
1030	0.250	Plate - 5.25" x 10.25	0	0	0	57	0	18	0	17	0
1031	0.500	Disc - 6" Dia	0	0	0	15	0	0	0	0	0
1032	0.010	Tube - 2" OD	0	0	0	14	0	12	12	0	0
1033	0.8 mm	Disc - 314 mm Dia	0	0	0	0	20	0	0	0	0
1034	0.375	Disk - 9.625" dia	0	0	0	0	57	0	0	0	0
1035	0.015	Tube - 1.0" w/end cap	0	0	0	0	0	2	0	0	0
1036	0.125	Ring - 12-3/4"OD x 9-3/8"ID	0	0	0	0	23	0	0	0	0
1037	0.125	Plate - 3.5" x 13.2"	0	0	0	0	0	0	0	0	33

Figure 13: Invoiced Sales for Alloy #1

Material	Gauge -	Description	1999 Invoiced Sales - Pounds per Month Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
2001	0.045	Repair Disc 4" Dia	0	0	0	0	0	0	0	0	13
2002	0.045	Repair Disc 2 1/2" Dia	0	0	0	9	0	0	0	0	0
2003	0.045	Repair Disc 1" Dia	0	0	0	0	0	2	0	0	0
2004	0.045	Repair Disc .75" Dia	0	0	2	0	0	0	1	0	0
2005	0.015	Endcap to fit 1"OD	0	0	0	0	0	0	0	0	0
2006	0.045	3/4" Repair Disk	0	4	4	0	9	4	9	0	5
2007	0.045	1" Repair Disk	0	6	7	0	0	8	0	2	1
2008	0.045	1 1/2" Repair Disk	0	4	4	8	0	0	4	0	4
2009	0.045	2" Repair Disk	0	4	5	4	10	10	0	4	0
2010	0.045	2-1/2" Repair Disk	0	6	7	0	0	0	4	0	4
2011	0.045	3" Repair Disk	0	0	0	9	0	0	10	0	5
2012	0.045	4" Repair Disk	0	8	6	15	0	84	7	9	8
2013	0.045	5" Repair Disk	10	0	0	0	0	12	0	11	0
2014	0.045	6" Repair Disk	0	12	0	0	8	0	0	6	32
2015	0.045	3/4" Patch Kit	0	0	2	0	0	1	0	0	3
2016	0.045	1" Patch Kit	0	0	2	0	1	0	1	0	3
2017	0.045	1 1/2" Patch Kit	0	0	1	0	2	1	1	0	6
2018	0.045	2" Patch Kit	0	0	0	0	0	1	0	0	5
2019	0.045	2 1/2" Patch Kit	0	0	0	0	0	1	1	0	4
2020	0.045	3" Patch Kit	0	0	0	0	5	1	0	0	6
2021	0.045	4" Patch Kit	0	0	0	0	9	0	5	0	16
2022	0.045	6" Patch Kit	0	0	0	0	9	0	0	0	0
2023	0.045	5" Patch Kit	0	7	0	0	5	0	0	0	0
2024	0.005	Sheet - Annealed	0	6	0	0	6	0	0	0	0
2025	0.002	Foil Annealed	551	0	0	0	0	0	0	0	0
2026	0.010	Sheet Annealed	0	0	435	0	251	412	0	0	0
2027	0.060	Plate Annealed	0	0	277	323	60	0	504	12	205
2028	0.045	Sheet Unnannealed	67	0	0	0	0	0	0	0	0
2029	0.045	Sheet Annealed	137	122	430	18	37	16	0	368	5
2030	0.375	Plate Annealed	0	0	0	23	0	0	0	0	0
2031	0.020	Sheet Annealed	761	521	826	671	889	1,004	3,975	27	7
2032	0.025	Plate Annealed	0	69	24	0	0	0	0	0	0
2033	0.150	Plate Annealed	0	0	0	0	41	0	0	0	0
2034	0.125	Plate Annealed	0	35	78	63	34	0	0	208	0
2035	0.030	Sheet Annealed	1,638	116	1,138	634	524	579	1,672	703	517
2036	0.015	Sheet Annealed	108	0	13	56	0	27	0	0	1
2037	0.015	Welded Tube .50" OD	0	0	6	0	0	23	7	0	0
2038	0.025	Welded Tube 1.5" OD	0	0	0	0	0	2	0	0	0
2039	0.020	Welded Tube .50" OD	0	0	181	142	0	0	0	0	0
2040	0.025	Welded Tube .75" OD	296	936	2,989	1,366	2,468	989	657	528	1,392
2041	0.020	Welded Tube .75" OD	0	50	316	3	379	0	2,856	0	0
2042	0.025	Welded Tube .75" OD	0	0	0	0	0	32	0	0	5
2043	0.015	Welded Tube 1"-1.49OD	0	0	480	444	0	77	118	343	0
2044	0.020	Welded Tube 1.0" OD	0	0	0	32	241	108	4	0	0
2045	0.030	Welded Tube 1.0" OD	0	0	370	0	0	1	0	0	41
2046	0.015	Welded Tube 1.5" OD	0	0	0	0	40	0	133	0	0
2047	0.030	WELDED TUBE 1.5O" OD	0	255	100	0	0	0	0	0	0
2048	0.030	Custom Sheet Annealed	0	1	1	0	0	0	0	0	0
2049	0.020	Custom Sheet Annealed	0	0	0	0	0	35	0	0	0
2050	0.015	Welded Tube 1" OD With Cap	0	0	0	1,003	0	0	176	0	0
2051	0.022	Welded Tube 1.25" OD	0	0	0	1,014	0	0	0	0	0
2052	0.035	Tube 1.25" OD	0	0	302	0	0	0	0	0	0
2053	0.020	Disc 66mm OD	0	0	0	0	0	0	0	0	0
2054	0.118	Tube .815" od x 3mm wall	0	0	0	8	8	0	0	0	0
2055	0.118	Tube .614" od x 3mm wall	0	0	0	6	0	0	0	0	0

Figure 14: Invoiced Sales for Alloy #2