Lean Manufacturing of the Midframe Process

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by

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Richard C. Grossman Jr.– rcgjr@wpi.edu

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Natalie Senenfelder – nms@wpi.edu

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Approved:

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Professor Yiming (Kevin) Rong

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Professor Sharon Johnson

imagination at work

Abstract

General Electric Engine Services in Winfield, Kansas is a repair and overhaul site for the CT7 and T700 engine models. This plant desired to reduce their TAT for their midframe process from 60 to 30 days. Lean Six Sigma principles were used in order to attain this goal.

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Professor Yiming (Kevin) Rong- Guidance and advice
Professor Sharon Johnson- Guidance and advice

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1. Introduction

General Electric Engine Services desires to reduce their TAT of their CT7/T700 midframe repair and overhaul process from 60 to 30 days. The use of lean six sigma tools is going to be used in order to attain a TAT of 30 days. The team used a four-step approach in this project:

1. Problem definition
2. Measure and Analyze
3. Improve
4. Control

First the team directly observed the midframe process in order to acquire a full understanding of the problem. The team gathered data on the current process to be able to identify bottlenecks in the process. This data allowed the team to develop a solution to reduce the TAT. The solution included the use of prioritized racking systems for parts, development of new tooling and the improvement of communication amongst all levels in the shop. Lastly, the team collected data on the new TAT. The team used graphs to compare the new data to the old data; therefore, the team could determine how much of an improvement was made.

2. Background

A good understanding of the company, process and Lean Six Sigma was needed before any changes could be made.

2.1 Company

General Electric Infrastructure Aviation is a worldwide division of GE. More commonly know as GE Aviation or GEAE. GEAE has many different tasks from new make production of 33 different engines to the full overhaul and repair of these same engines. These engines are for commercial, corporate, marine and military customers.

The Strother Field site in Arkansas City/Winfield Kansas is strictly an overhaul and repair site. At the Winfield plant there are only two different engine lines and their many different versions, the CT7 and the T700. The T700 is the military version of the CT7. These engines were first produced in 1978 and their ruggedness has been the key to their success. The commercial engines go on turbo-prop planes and helicopters. The T700 hundred engines are put into military helicopters like the Black Hawk and Apache. Three CT7-8 engines, the latest version of the CT7, are being used in new presidential helicopter. “The T700/CT7 engine family is the most widely used in its class--powering 21 types of rotary and fixed-wing aircraft for close to 130 customers in 55 countries.” (www.geae.com, 2007)

2.2 Process

Currently there are two different repair categories for commercial engines, the Engine Care Maintenance Program (ECMP) and non-ECMP clients. An ECMP allows for the use of rotatable hardware in the promise of a 32-day turn around time. Meaning the engine is disassembled, repaired and cleaned, assembled, tested and shipped within the 32 day time period. Non-ECMP customers are guaranteed their engine in 60 days but every part is the original part or a new part. With military customers there is a stockpile of engines at the site and then GE is contracted to ship them with a 60 day turn time. Each engine will have its original parts or new parts placed back onto it.

Currently the midframe repair sets the pace for the engines taking a total of 60 hours touch time and roughly 60 days to finish. As a result, there is approximately 1300 hours of queue time. Due to competition from other companies and the cost of keeping spare rotatable hardware in the shop there is a great need to reduce the queue time. The goal was to decrease the queue time; therefore, a midframe can be processed in 30 days. The ideal time is somewhere around 22 days leaving 10 days for disassembly, assembly and testing of an engine.

When a midframe is disassembled from an engine an "As Received" router, a Work Order (WO) or Shop Movement Order (SMO) is generated. This router will get the midframe cleaned and inspected in one of its 11 distinct steps. After inspection a new router is created, to get the midframe sent through the shop and have it's identified problems repaired. The most commonly used routers for these repairs have approximately 45 steps.

2.3 Literary Resources

The goal of lean manufacturing is to reduce the amount of waste that is generated. Lean manufacturing was founded on the idea of "kaizen" or rapid improvement processes. The Kaizen strategy is to incorporate shop floor workers and managers in the improvement of a process. Additionally, there needs to be communication amongst the shop floor workers and managers in order to effectively improve a process.

There are eight types of waste that are listed as follows; overproduction, transportation, motion, waiting, processing, inventory, defects and environmental waste. Listed below are numerous tools that are used in lean manufacturing.

- **5S:** “System to reduce waste and optimize productivity through maintaining an orderly workplace and using visual cues to achieve more consistent operational results.” (Lean Manufacturing and the Environment, Oct. 2003). The 5S’s are as follows:
  1. Simplify: Dispose of unnecessary things.
  2. Straighten: Organize items in the plant.
  3. Shine: Clean the work area.
  4. Stabilize: Maintain the first 3S’s. For example, create checklists.
  5. Sustain: Ensure that the first 4S’s are being carried out in the process.
- **Total Productive Maintenance (TPM):** To involve all job levels in the improvement and maintenance of production equipment. For example, the goal of TPM is to reduce the breakdown of equipment. The improvement and maintenance of production equipment reduces the amount of defects that occur.
- **Cellular Manufacturing:** Work areas and equipment are arranged in a product-aligned sequence. This provides a smooth flow of parts throughout the plant.
- **Jidoka:** When a defect occurs the machine should shut down and the workers should fix the defect right away. This is a concept used by Toyota.
- **Just in Time (JIT): “**Means making only what is needed, when it is needed, and in the amount needed." (Toyota).

3. Methodology

The goal of this project was to reduce the turn time from sixty days to thirty days for the GE T700/CT7 midframe repair process. GE Aviation defined many possible improvements that they wanted to be implemented. GE Aviation's main concern was reducing the queue time. The implementation of a continuous flow throughout the process, visual aids and the improvement of communication amongst workers were used in order to reduce the queue time.

The team decided to utilize the Lean Six Sigma approach in order to improve the engine turn time. The team found that the six-sigma approach is the most systematic and effective. The steps of the six-sigma approach are in the order as follows: define, measure, analyze, improve and control.

The first phase included defining what the client's specifications were. In addition, the define phase accounted for the defects that existed in the current process.

Secondly, the measure and analyze phase consisted of gathering data on the current process. Then creating graphs that consisted of the queue time and touch time to analyze the process. As a result, the team could visually see where changes needed to be made.

The third phase consisted of specifying what improvements were made.

Lastly, the team specified what lean tools were used to ensure that the new process did not fail.

4. Define

The team had to collect data in order to define what the client's specifications were. For example, the team collected data on the router sheets, shop movement order tracking schedule, shop layout and the data on the current process

4.1 Routing Sheets

The team referred to the routing sheets for each repair. A routing packet is used throughout the shop to track the sequences that were completed for the repair. The router description of the type of repair is included in each routing packet. Each routing packet includes the name of the person that issued the router and the date that it was issued. This particular General Electric Aviation engine facility repairs two engine models, the CT7 (commercial) and the T700 (military). Therefore, there is a different router for each model type and series.

A routing packet includes the sequence of steps for each repair. A sequence number is designated for each step in a particular routing packet. For example, sequence number 030 for a specific router might state that one must weld the B-sump leak. Furthermore, each router sheet has sequence numbers and the respective work center numbers. Each work center has a designated a number (i.e. the work center number for the machine shop is 8820).

The team referred to the routing packets in order to get a full overview of the operations that are carried out by each work center. Then the team spoke with the shop floor workers to inquire about their specific tasks for each repair. The shop floor workers physically repair the engines daily; therefore, they are the best resource for learning about the engine repair process. An engineer cannot make an improvement in the repair process if they do not have a full understanding of how an engine is physically repaired. Refer to Appendix A for the “CT7 Midframe As Received” router.

4.2 Shop Layout

The team referred to the shop layout in order to get a full overview of the shop floor. The shop layout includes where each work center is located and their designated machines. The team utilized the shop layout to see how far the part travels throughout the process.

4.3 Shop Movement Order Tracking Schedule

GE Aviation provided the team with the Shop Movement Order tracking schedule. This schedule indicates where each midframe is in the repair process throughout the shop. The roll date (date the midframe must be completed), the work order number and the start date for the turn around time are included in the schedule. A work order number is designated to each midframe that goes through the shop. In addition, the turn around time is the total amount of time that it takes for a midframe to be repaired. Refer to Appendix B for a copy of a midframe SMO tracking schedule. The light gray color on the SMO tracking schedule indicates the diffuser case moving throughout the process. The dark gray color indicates the midframe moving throughout the process.

The SMO tracking schedule was an excellent visual tool for being able to determine the amount of time it takes for a midframe to go through the shop. Additionally, the team used the tracking schedule in order to determine how the shop keeps track of the midframes.

4.4 Current Process

The team referred to one of the most common types of repairs that are completed at the repair shop. The current process for the “CT7 midframe as Received” repair is listed below.

1. Clean per process 131 and 6. Process 131 is a power washing process. This process uses an alkaline cleaner called Blue Gold that primarily removes oil residue. Process 6 is steam clean. The steam clean is used to remove the residual blue gold and excess oil residue that the blue gold did not remove.
2. Remove the strainer from the oil inlet tube.
3. Oven bake at 850-875 degrees Fahrenheit with 3 PSI of air being blown through the midframe tubes. This procedure is used to create combustion and burn any carbon material that is in the midframe.
4. Clean using process 4. Process 4 is an ultrasonic clean that uses an alkaline cleaner called Intex 8135. This cleaner is primarily used to remove particulates (i.e. carbon material).
5. Visual inspect the accelerator housing.
6. Disassemble the midframe if required.
7. Pressure Test EB Welds.
8. Remove the heat shield in order to identify the source of the leak.
9. Prepare to weld the B-sump leaks.
10. Clean the tube welds inside diameter “D” and the deswirler EB weld with a wire brush. The welds need to be cleaned before they are inspected. Therefore, when the welds are inspected one can more easily determine cracks and defects.

11. Fluorescent Penetration Inspection of: 1.tube welds, 2.aft flange, 3.forward flange, 4.outer casing, 5.tube weld joints, 6.EB weld joints, 7.B-sump weld repair and 8. B-sump inner webbing.
12. Visual inspect and issue a new shop manual operation based on the results.

A copy of this routing packet can be found in appendix A.

After investigating the current process the team was able to decipher where defects occur in the process.

The defects that the team found were:

- Parts were sitting for extended periods of time waiting to be worked on.
- There was a lack of communication amongst shop floor workers and managers.
- There was a lack of continuous flow throughout the shop.
- The time for the high volume flush clean process was inconsistent. The team spoke with many hourly workers and discovered that each worker has their own definition of what a clean filter is. The team needed to set a cleaning standard to solve this issue.
- There were large amounts of carbon deposits found in the midframe during the flow test. Therefore, the midframes failed the flow test. The ultrasonic clean process is used to remove the carbon deposits. There were carbon deposits present because the chemical (Intex 8135) in the ultrasonic clean tank was not replaced with new chemical.
- The Blue Gold tornado clean process was not operating at optimum performance. The Blue Gold tornado clean process is a rotating spray and

wash process. In addition, this cleaning process uses Blue Gold industrial cleaner, which is aqueous based. The shop did not monitor the pressures that the Blue Gold tornado was operating at. In order for this cleaning process to clean effectively one needs to monitor the operating pressures. In many circumstances when the pressure is increased the cleaning effectiveness increases.

5. Measure & Analyze

Additional data was needed in order to depict where the bottlenecks in the process were. The team created a process flow chart for each router. In addition, the team calculated the touch time and queue time for each sequence in the repair process. This data enabled the team to visually identify bottlenecks in each process.

5.1 Eliminating Steps

All the routers and the order of the steps were looked at to see if anything could be eliminated or moved. Eliminating steps would save both touch time and queue time. The diffuser case is assembled and disassembled multiple times creating extra work. Also the flow testing with calibration fluid would eliminate a clean process.

5.2 Touch Time Calculation

First the work orders of all the completed midframes from January 1st 2007 to June 1st 2007 were collected. The work orders were then used to gather information on these midframes. Every time someone is working on a part a barcode is scanned at the start and the completion of the job. This system keeps track of time utilized to work on the parts. This information was then used to calculate the touch times and queue times for all the steps on the routing sheets.

The team calculated the median values (P50) and the 90th percentile values (P90). Furthermore, the touch time values enabled the team to identify which sequences took the longest.

The touch times for the high volume flush clean process varied greatly. For example, the P50 was 0.4 hours and the P90 touch time was 1.54 hours. After further investigation the team concluded that clean room workers have their own cleanliness standard. For example, one worker might think that a sufficient amount of particulate matter was filtered out. .

5.3 Queue Time Calculation

The team calculated the median (P50) and the 90th percentile (P90) queue time for each sequence on each routing sheet. The queue time is the amount of time that a part has been waiting to be repaired. There is a table of some queue times pictured below.

Table 5.3. 1Queue Time

Work Area	Description	P50 (hours)	P90 (hours)
Rework	Visual Inspect IBP & B-Sump Seals	6.3	20.8
Machine Shop	Machine out IBP Seal	2.08	16.12
Plasma Spray	Plasma Spray	21.61	37.98
FPI	FPI Tubes	3.43	11.7

After calculating the queue time the team discovered that the queue time was the main bottleneck in the overall process. According to the table, the P50 for "Visually inspecting the IBP and B-Sump Seals" is 6.3 hours and the P90 is 20.8 hours.

5.3.1 Direct Investigation

After direct investigation of the process the team discovered that the queue time was high due to a lack of organization in the work areas.

5.3.1.1 Rework Area

The midframe rework area referred to a tracking sheet from the bottom up for a work order number in the area. Then the rework employees would search the shelf for the midframes. There have been numerous instances where the front midframe on the middle racks was worked on first because they were more accessible.

5.3.1.2 Machine Shop

The machine shop utilized a gravity rack and divided the repairs into three categories: seals, pre-machine and finish machine. Each week one shift would be held responsible for one of these categories. This system built in sixteen hours of queue time between shifts. In addition, this system also created problems when a midframe fell behind schedule. Therefore, another a shift was asked to cut something that was not their job.

5.3.1.3 Plasma Spray Operation Area

The plasma spray booth did not have an organized system for incoming parts or for prioritizing the parts. For example, the smaller parts were placed on a rack behind the operator's table. The larger parts were stacked on the floor; therefore, the midframe that arrived first was on the bottom and most likely worked on last.

5.3.1.4 Fluorescent Penetration Inspection (FPI) Area

In the FPI area all small incoming parts were placed on a rack while larger parts were set on the floor outside the dark room. The employees inspected the larger parts that were on the top first. As a result, the part that arrived first was inspected last.

5.4 Process Flow Charts

The team referred to each routing packet for each repair and created a process flow chart. Each sequence in the router was designated a box on the process flow chart. There is an arrow that leads from each sequence to the next. The work center for each sequence is included in each box as well. The team compared similar process flow charts on a single chart. The team used the color red on the process flow charts to note the differences between the charts that were compared. Refer to Appendix C to see a copy of the “CT7 Midframe As Received/T700 Midframe As Received” repair combined process flowchart. On this particular combined process flow chart each repair is designated a different colored arrow. For example, red arrows lead from each sequence in the “CT7 Midframe as Received” repair to the next. In addition, the team included the touch time, queue time and the number of steps between each work center on the combined process flow charts.

5.5 Calculation of the Time Traveled between Work Centers

The team calculated the number of steps from one work center to another. Each step was the equivalent of 3 feet. Then the team converted the number of steps into distance. The team used the average walking speed of a person and the distances to calculate the time traveled in hours and minutes. According to the “Time and Distance Traveled for the “As Received” router ” the travel between the rework area and the clean room is the most common. In addition, the distance between the rework area and the clean room is approximately 318 feet. Refer to Appendix D to see the time travel calculations for the “Time and Distance Traveled for the As Received router”.

6. Improve

The team implemented numerous improvements in this particular engine repair process. For example, the team designed new tooling for this process. The oil that was used during the flow test of the engine is the process of being replaced with calibration fluid. An organized racking system was installed in numerous work centers. There were also changes made to the routing sheets as well.

6.1 Tooling

6.1.2 Pre-Tooling

Currently the midframes are broken down on the "As Received" router and then move through the shop on two new and different routers, one for the diffuser case and one for the midframe. The diffuser case will be cleaned and then have Diameter X plasma sprayed. The diffuser case will then finish up in the Midframe Rework Area and wait for the arrival of the its midframe. When the midframe catches up to the diffuser case, there is a sequence on the router to have them reassembled. After reassembly the midframe is routed to the machine shop where Diameter H and Surface E have the diameter and TIR measured.

Figure 6.1.2.1 Midframe X, H, and E

The measurements are taken after the midframe has been chucked up on a lathe off Diameter X on the diffuser case (Refer to Figure 1 for location of the diameters and surface). The midframe is centered off one of the three rings in the BP Bore. If the diffuser case is not mounted to the midframe the B-sump which houses the BP Bore, it will be able to float around within the midframe making it impossible to center. The measurements of Diameter H and Surface E are recorded on the router and accepted or rejected depending on whether or not they are within the tolerance range. If the surface or diameter is out of range on the high end it will be machined down to be within the tolerance range. Most of the time at least one surface is undersized creating a need for it to be pre-machined and plasma sprayed.

After the pre-machining is finished the midframe is routed to the Midframe Rework Area to be disassembled. The reason for this is in the past there have been issues of engine failures traced back to the metal generation in the Number 4 Bearing inside the midframe. In appendix J the statistics of low hour engine failures over the past three years and causes can be seen. These engine failures are from Aluminum Oxide (grit) trapped in the midframe. The grit comes from grit blasting the surfaces before plasma spraying which is necessary for the bonding of the plasma.

After disassembly the midframe is routed to the plasma spray area where it is masked off for spraying the required surfaces. Next the surfaces are grit blasted at 60 PSI from a distance of about 6 inches. Once grit blasted that surface can not be touched because the oils from you skin will contaminate it, possibly causing the plasma spray not to stick. The midframe is then blown off and placed on top of a scrap diffuser case in the plasma spray booth. Once there is enough plasma on the midframe it is routed to the

Clean Room. There it is cleaned to remove any grit left inside and routed to the Midframe Rework Area where it reassembled to its diffuser case and routed to the machine shop.

In the machine shop the plasma is machined down to get Diameter H and/or Surface E inside the tolerance. Once inside tolerance the midframe is routed back to the Midframe Rework Area and will finish without being disassembled again bearing that nothing chips.

6.1.2 Reasoning For The Tooling

Years ago the midframe and diffuser case were plasma sprayed together. The midframe had a piece of tooling, which had 2 plates one on each side and then was masked off with tape. As volume increased through the shop so did issues with contamination of metal particles in the midframe. The metal particles were traced back to aluminum oxide grit trapped in the midframe and diffuser case. Eventually after many engines returning to the shop for failure causes traced back to Number 4 bearing from aluminum oxide grit. Every engine that is returned to the shop for an engine failure costs the company roughly $500,000 to repair it. GE was not only losing millions of dollars but the reputation of the company was also declining. Something had to be done to solve the problem quick. The solution was to break apart every midframe and diffuser case for the plasma spray operations and clean each part after plasma spray. This added more time but was less expensive than having engines come back.

The midframe and diffuser are bound together by 60 bolts, which are tightened to a certain torque in a certain order. Even with this method in place Surface E flexes every time the midframe and diffuser case is assembled. Because of this flex any time the midframe is disassembled and reassembled after Surface E has been accepted it needs to be rechecked and may require plasma spray again.

If the plasma chips on Surface E, Diameter H or X during machining or while the midframe is routed through the shop it has to be taken apart and the above process is repeated. Adding 5 extra steps along with touch time and queue time in each area. It takes roughly 30 minutes for disassembly and assembly of the midframe and diffuser case. If a midframe has thin D-tube walls many times it will require multiple plasma spray operations because it chips easily. Also with the overspray you cannot see the actual thickness of the plasma spray on the D-tube walls until it is benched off in the Midframe Rework Area after the midframe and diffuser case are separated.

Another reason for creating a way to plasma spray the midframe and diffuser case as one is on a Midframe Minor. If a midframe is on a “Minor SMO” it does not require it to be separated from the diffuser case. However at this point in time if Surface E and/or Diameter H or X is under tolerance it requires the surface to be plasma sprayed. This means the diffuser case and midframe need to be separated and when this happens it requires a full inspection. The midframe can no longer be considered a minor once it is separated and has to get the inspection and required repairs of a Major.

All the steps taken from when the midframe is assembled to the time it is in the Machine Shop being finished machined is wasted time. To eliminate this waste something had to be created to allow the midframe and diffuser case to be grit blasted and plasma sprayed together.

6.1.3 Creating The Tooling

The first step was to create a design and then talk with Production Control to get midframes that could be used for testing. The midframes that were used for the testing all happened to be military because testing would add roughly a day or two extra to the process. Five midframes were given for the first batch of testing. The original design was to replicate the current tooling for the diffuser case while adding a rod to go up through center of the B-sump. A cover for the B-sump was constructed from aluminum, similar to the cover wooden covers used while the midframe is being transported throughout the shop. A flat plate was made to sit down inside the midframe on top of the B-sump cover. This created a surface to be able to tape to while taping off the gap between the edges of the plate and the midframe. The rod going up through the B-sump was threaded on the end and a nut was screwed on to hold everything in place. This design was flawed and allowed grit to get into the midframe. Drawings of this can been viewed in appendix K.

After speaking with the plasma spray operators the troubled areas were found to be around the D-tubes where it is hard to get tape to stick and plugging the D-tubes with rolled up tape. To plug the D-tubes a mold was created to pour rubber plugs that could be placed in the D-tubes and cut off smooth to Surface E. These plugs were found to do a better job than tape because grit would not build up top of them or stick to them. To solve the problem around the sides of the D-tubes, a solid disc shaped piece of rubber was poured with slightly less hardener to allow it to flex. The idea was to lower seating of the current plate by cutting the B-sump cover into the center of it. Then place the rubber disc on top of it and place another aluminum plate to sit on top of the rubber. The idea was that when the nut was tightened down onto the rod the rubber would be compressed by the two plates. The compression would force the rubber to expand outward pressing the rubber up tight against the midframe sealing it off from the grit. This works in theory but not enough pressure could be created to make the rubber disc expand enough to seal off the midframe.

This led to the third modification in the tooling. A gasket was created, by making a metal piece with a downward bevel, to sit centered in the mold. This gasket was also poured in a midframe so it would fill in the area behind the D-tube walls. Since this rubber gasket was made, the upper plate used to force the rubber to the out had to be modified. The plate was made to be slightly larger than the metal piece in the mold with the same two different degrees of bevels cut into it. This way as the plate is forced down by the tightening of the nut it forces the rubber out creating a seal around the D-tubes and the wall of the midframe. This version of the tool was tested and it was found that the bottom plate for Diameter X allowed grit inside. Also if the plate was used for plasma spraying it would of been bonded to the midframe. This is because the current process for Diameter X uses two identical plates one for grit blasting and one for plasma spraying. The plasma plate is coated with stencil ink to keep the plasma from bonding to it. There was no possible way to use the original plate because it cannot be sprayed with stencil ink without getting it on the midframe. This is because the plate has a slight overhang on Diameter X and spraying the underside is impossible.

The next version of the tooling was designed to eliminate these problems. The bottom plate to cover Diameter X was made to house a rubber gasket. The rubber gasket is poured in a mold to be slightly thicker than the depth of Diameter X. This gasket sits in the bottom plate, which has been modified so that there is no overhang on Diameter X.

This way when the midframe and diffuser case are placed on the tooling they sit up a little higher until the top plates and gaskets are in place and the nut is tightened down. Once everything is tight the lower gasket has been crushed so that the lip of Diameter X is tight against the bottom plate. Last a piece of Lexan was cut so that it would fit over the tooling and cover the undesired areas from being sprayed with stencil ink. This version was tested with colored grit and found to be successful at keeping grit out of the midframe. The grit was dyed with a red food color to make it distinguishable between the grit used in different plasma spray operations. There was a slight problem when plasma spraying Diameter X though. The plasma built straight up and was hard to break off without chipping it below Diameter X. This was never a problem before because the over hang on the plate cause the plasma to step out and gave a surface to break the excess plasma spray on.

Knowing that the tooling worked keeping grit out the next step was to solve the problem of creating an area to break the plasma spray on. To solve this problem a cover was created that would sit on top of the diffuser case plate in the plasma spray booth. This cover would not be used during the grit blasting process and would get stencil inked before being place over the diffuser case plate. This cover is screwed on to keep from flying off during plasma spray and to make sure that it will only fit on one way. The cover creates an overhang like the plates currently in use and gives a surface to break the overspray on.

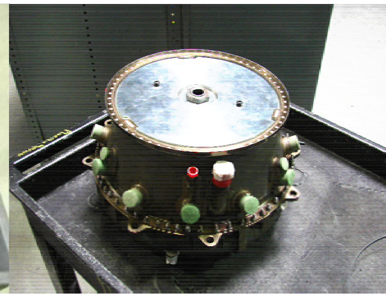


Figure 6.1.3.1 (Left) Tooling Pieces

Figure 6.1.3.2 (Center) Midframe with Tooling

Figure 6.1.3.3 (Right) Tooling

6.1.4 Improvements From The Tooling

The use of the tooling will eliminate four steps in the midframe processes. These four steps will save 5.6 hours of touch time per midframe. Over a one-year time period it will save 3,920 hours based on the processing of 700 midframes a year. This calculates out to annual saving $98, 784 based on the average pay of $25.20 an hour. Also it will eliminate the queue time at every step, which the P75 total is 6.19 hours.

6.2 Plasma Spray Gasket

After viewing the plasma spray operations it was evident that much of the operator’s time was spent on preparing the parts for grit blasting and plasma spraying. The operators also had plasma spray shots they dreaded because of the amount of prep work it entailed. With Surface E on the midframes there are 60 bolt holes, (As seen in Figure 7) which have to be plugged. To plug these holes operators would tape off the bottom of these holes and then roll up double-sided tape to the proper thickness. The tape roll would then be pushed into the holes and cut off flush at the top. (As seen in Figure 6) The rolling of the tape took time and if does not come out to the correct size then another roll would have to be made. The cutting of the tape was time consuming and if a dull blade is used, during the grit blasting process the taped will fold over onto the surface and leave a black residue. This residue has to be removed before the plasma spray operation and the only way to do that is with more grit blasting which will make it worse before it gets better.

A couple of different solutions were thought up for this process like using a rubber tubing which would only save the time of rolling the tape. Another suggestion from Aerospace International Materials (AIM) MRO was a tapered silicon plug, which they make, that could be pressed in and cut off. Once again this lead to buying other material and it still needed to be cut. The final solution was to create a rubber gasket that could be pressed up from the bottom and could be made in the shop. This gasket is a solid circle (As seen in Figure 5) that stretches over Surface E and then is pressed up from the bottom. Having been poured in a midframe, the gasket has the perfect height to plug the holes so no cutting is needed. The gasket fits tight but needs a few pieces of tape to hold it in place. This gasket saves .375 hours for every Surface E shot.

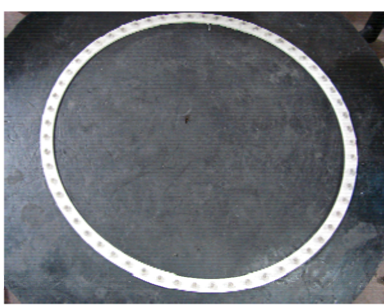
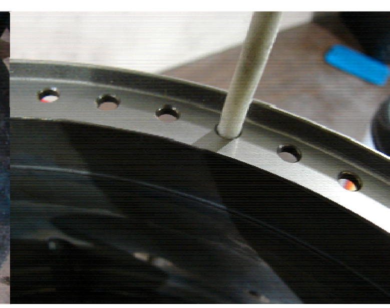
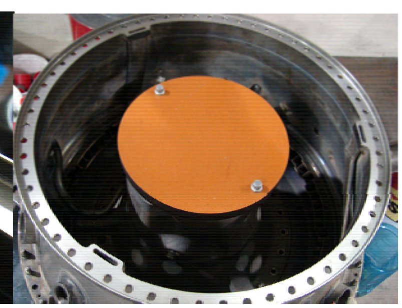




Figure 6.2.1 (Left) Rubber gasket for Surface E
Figure 6.2.2 (Center) Using tape to plug holes
Figure 6.2.3 (Right) The 60 bolt holes on Surface E

6.3 First in First Out System

During the week of the lean event the main focus was getting parts to flow through the shop properly. The main bottleneck of the process was the queue time. A system for proper flow would improve the queue times. A First In First Out (FIFO) system is proven to have the best results. In many areas there was no particular order to work parts or even a racking system. Racking systems were installed and running rules were placed into effect. Also after talking with Production Control the a goal of three engine tear downs and assemblies a day was desired, equating to at least three midframes a day being inducted into the system and three a day being finalized.

6.3.1 Midframe Rework Area

In the midframe rework area the only system in place was to look at a tracking sheet from the bottom up for a work order number in the area and then search a shelf, which held midframes two deep. Many times the front midframe on the middle racks were grabbed because they are the easiest to get to. Each midframe weighs 26 pounds and a midframe diffuser case assembly weighs 44 pounds so bending over to pick one up or reaching high for them is undesired. This system was removed and gravity racks were installed in the place of the shelf. Every midframe into the area is dropped off at a staging location and placed into the gravity rack every night by the 3rd shift work leader. The midframes are placed on the gravity rack in priority and work needing to be done. This way all the workers can pull from the front of the rack and follow the running rules: 1-Check oven bake process (oven holds three), 2-Complete any finals (to get flow tested since accessories only works first shift), 3- As Received (at least 1 per shift 3 shifts= 3 a day), 4- New Arrivals (ship in midframes), 5- All others, Always Pull From The Front.


Figure 6.3.1.1 (Left) Rework Area Before
Figure 6.3.1.2 (Right) Rework Area After

6.3.2 Machine Shop

The machine shop already had a gravity rack and split everything up into three categories seals, pre-machine, and finish machine. Each week one shift would be in charge of one of these categories. This system was the primary cause of the sixteen hours of queue time between shifts. In addition, this system also created problems when a midframe fell behind schedule. Therefore, another shift was asked to cut something that was not their job. Also machinists were not working to the end of their shift if they could not finish a job in time. This sometimes meant a machinist could be sitting idle for up to 2 hours. This system was changed to a FIFO system also where each midframe was arranged in order and numbered starting from one on up and the lowest number is to be worked on. Also all machinists were talked to and agreement to leave parts on the machine for the next shift to finish was reached. The running rules in the machine shop are: 1-Finish what is left on the machine, 2- Work parts needing rework, 3- Pull lowest number of the rack, 4- If no midframes ask for another task, 5- deliver midframes immediately to the proper work station, 6- Set up machine if more than 30 minutes remained before the end of the shift if less than 30 minutes carry out housekeeping activities in the area.

6.3.3 Plasma Spray

The plasma spray booth did not have a sufficient system for incoming parts or for prioritizing the parts. The smaller parts were placed on a rack that could not be seen from the operator's table and all the larger parts were stacked on the floor. As a result, the midframe that was there first is on the bottom and most likely worked last. The plasma spray operators ran parts in order off a list given to them by Production Control. The solution to this problem came from moving a large rack in the area next to the operator's table; therefore, all incoming parts could be loaded from the back side and the plasma sprayers can pull the parts off the other side. The rack was painted and labeled so each part received it's own area and worked as a first in first out system. The same thing happened for the smaller parts.

6.3.4 Weld/E.B. Weld

The Electron Beam Welder (E.B. Welder) was not much of an issue since parts move through the area relatively fast and only back up when the machines are down. All parts were set on two tables and usually the closest one was worked on first. A rack was placed in the area so the parts could be loaded onto it.

6.3.5 FPI

In the FPI area all small incoming parts are placed on a rack while larger parts are set on the floor outside the dark room. Just like in the plasma area the inspectors pull the large parts off the top instead of the bottom so the first part sits the longest. The inspectors here once again followed a sheet, which is given out daily by Production

Control telling them what to work on. To solve this problem a gravity rack is being built to have two slots. All small parts come in at once in batches and will be placed into boxes like the large parts sit in. This way every part will fit into the gravity rack and be worked on a first in first out system.

6.4 Floor Stock

Many times midframes sit idle because they are awaiting parts. The biggest problem is at quarter points because every division at the plant is trying to make their quarterly goal. The shops are trying to get there engine quotas filled and finance is controlling inventory so they don't over spend and make their goal. This sometimes creates huge backups in the shop because many time midframes will have to wait for parts until after the quarter. To solve this problem some of the lower cost parts were made available as floor stock. This will speed up the process because the parts will be ordered before midframes are in the shop.

For the parts to become floor stock a system storage system had to be put into place first. This system needed to include the fact that commercial and military parts need to be separated even though they are the same thing. This is for billing purposes the commercial customers do not want to be billed for the military parts and the same holds true for the military. A bin rack system was ordered that would hold colored bins on either side along with a label on the top to allow for visual differentiation of military and commercial parts.

Also by making items floor stock they no longer have to be ordered in a kit. Kits are much more expensive than ordering parts individually. This will create a saving for GE and it can be passed on to the customer.

6.5 Router Changes

Every part going through the shop receives at least one router. The midframes usually receive two routers. Some of the routers are old and have sequences that are being done on a different router or are no longer done. For instance the midframes are disassembled on the "As Received" router but yet it also says to disassemble on the major routers that it receives after the completion of the "As Received". Also the midframes are all being pressure tested and welded on the "As Received" router instead of on the majors. The "As received router was changed to reflect the this. Also in doing this the routers sequences numbers were changed so that sequence 0100 is the same on every router whether military or commercial, Plasma or W-seal, -5 or -9. This is still in progress but when complete will help because then the operators will know what work needs to be done just by reading the sequence number.

Another router change was putting the measurement of the Number 4 Bearing Seating Surface. This measurement can easily be done by when the midframe is in the machine shop and centered off the BP Bore. This adds very little time to the process and has great benefits. The check of this surface to see if it's within tolerance will identify a bad B-sump before the midframe goes through the whole repair process. Without this check a bad B-sump would be identified during the assembly process when Production Control is planning on having the engine shipped. This didn't happen often but will save large rework loop.

Lastly the machine shop operations were divided up so that every step could be bought off individually. The machinists wanted this change so that if they leave parts on the lathe they will not have to worry about the next person that finishes the job making a error that will come back to them. This is also still in progress.

6.6 Improvements Still In Progress

6.6.1 Fluid replacement for the Flow Test Procedure

Each engine is flow tested in order to ensure that the proper amount of oil will flow through the midframe to allow the engine to run properly. The team consulted employees from another GE Aviation facility and discovered that they are using calibration fluid instead of oil in their flow test procedure. If calibration fluid is used the midframe would not have to be cleaned after the flow test procedure due to the high evaporation rate of calibration fluid. The oil from the flow test procedure is removed by "process 7a", a spray wash with a degreaser cleaner to remove the oil. In addition, the clean "process 7a" uses a cleaner that is produced from crude oil and is highly toxic. Therefore, the elimination of the clean "process 7a" reduces the use of this toxic chemical. The disposal of toxic waste is costly; therefore, lean manufacturing should also focus on the reduction of toxic waste.

6.6.2 Automating High Volume Flush

One area where the parts tend to sit for an extended period of time is the High Volume Flush (HVF) tank. Every midframe must go through this process towards the end of the of its shop visit. Currently there is one machine with two slots dedicated to commercial midframes and another machine with three slots that are shared by midframes, front frames, inlet and mainframes. There is no way to predict how long a part will need to be flushed. Midframes sometimes only take hours in the HVF but can also take days even as long as a week. There are many different variables attributing to how long a midframe is flushed. Each midframe need to have two clean filters in a row to be considered clean. These filters are collected every hour by workers in the Clean

Room and laid on a table. There are roughly ten different people over three different shifts, which all have different opinions of what is considered dirty.

A way to eliminate this factor would be by installing a Laser Particle Counter or Particle Monitoring System upstream from the filter. One company Chemtrac offered both a Laser Particle Counter and Particle Monitoring System. This equipment could be attached to draw a small continuous sample upstream of the filter and measure the particulate in the solution and return it back to the tank. A Laser Particle Counter will not only tell the user how much particulate has passed through but will also give the size of each particle. It has the capabilities of measuring down to 2 microns while the Particle Monitoring System will detect anything that is 4 microns or large. Chemtrac said they could write a program so that after a certain period of time when no particles pass through the system would let the operator know the part is clean. Also this program could be arranged so that a single particle will not affect a clean reading 30 minutes from the end.

Chemtrac quoted prices on the high end of roughly $20,000 for a Particle Monitoring System that would have four sensors and all the accessories. For a single Laser Particle Counter with all accessories a quote of $8,000 each with discounts as more are purchased. To have a computer program written as talked about before that would add an extra $7,500 max. Chemtrac could not give a total cost estimate without seeing exactly what the system required. Chemtrac also allows the rental of equipment with the option to purchase.

6.6.3 Product Departure Report

In the Plasma Spray Area the commercial and military midframe are each sprayed with a different material on Surfaces F and B. The commercial midframe uses a softer material that is less likely to chip during machining operations. The softer material allows the same plasma spray to be re-sprayed on top of it while the harder material has to be machined down to parent material before it can be re-sprayed. Also the harder material cannot be cut it needs to be ground down which takes roughly four hours compared to the hours to cut F and B. Not to mention that every time a midframe is ground to parent material it loses some of that material eventually getting to a point where it will be under the minimum repairable dimension causing the midframe to be scraped.

For these reasons the Military representative was contacted to see if a change could be made from spraying the harder plasma to the softer plasma. It was explained how using the softer plasma is the best commercial practice and how it would benefit both the Military and GE. It would not only save time during machining but the possibility of the plasma chipping would be minimized.

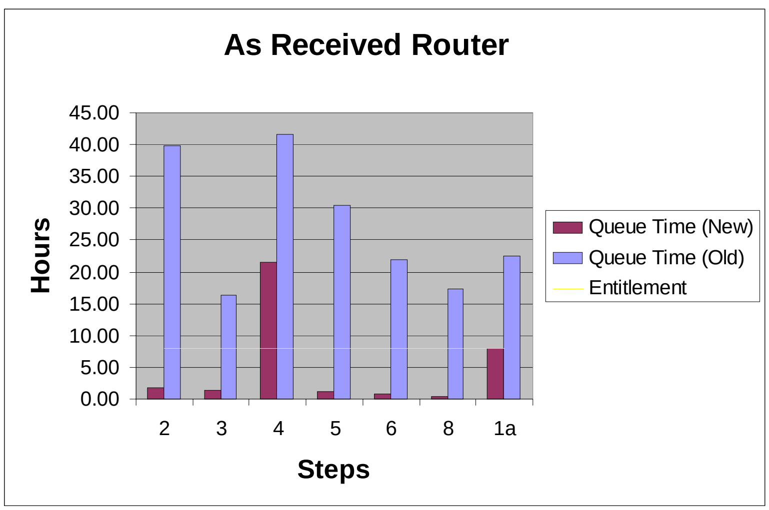
The Military representative was open to these changes and wanted a Product Departure Report (PDR) submitted so they could review the information before any changes were made.

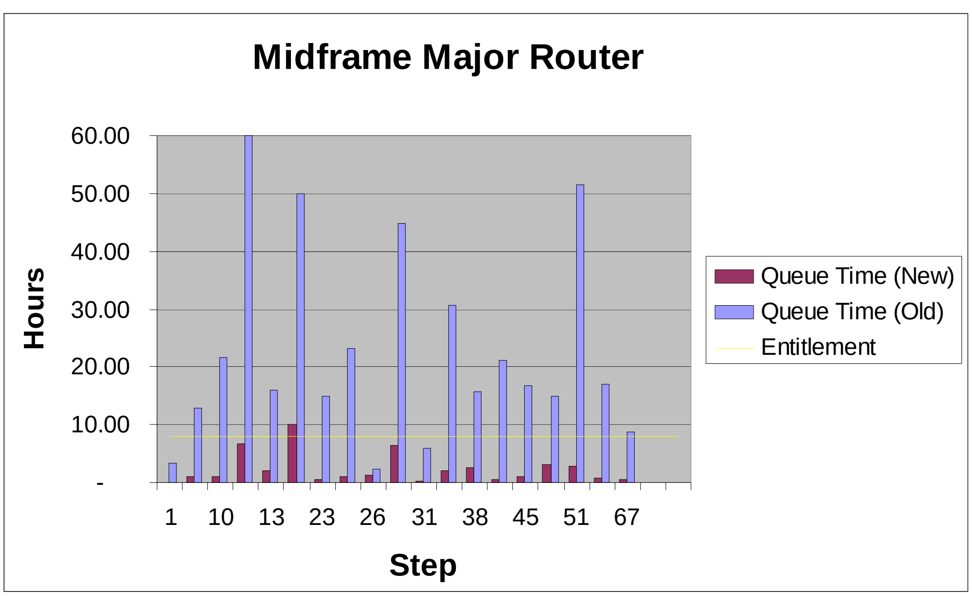
6.7 Analysis of Improvements

Data was once again pulled for completed midframes in the same fashion as before with the exception of the dates. Information on any completed midframe from August 6, 2007 to October 2, 2007 was pulled. These dates were picked because they were after improvements in the process were made. Therefore this data should reflect it the improvements. The new total touch and queue reduction is 23.15 days. It will take more time for all the midframes that were in the system when the changes occurred to exit and not skew the data.

A quick indication of the midframe process speeding up is by looking at the WIP. This is the number of midframe in process at any given time. On October 2, 2007 the WIP was down to 64 midframes from 87 back in June. This is a 26% percent reduction. Production Control has also noticed an increase in speed for the midframe throughout the shop along with the hourly workers in the midframe rework area.

Below are the graphs of two different routers showing the queue time reduction.





7. Control

The control process is the most crucial in lean manufacturing. There have been numerous cases where an effective process was implemented and failed due to lack of control of the process. Therefore, the team used many lean tools to ensure that the new processes did not fail. For example, the team used a control plan, documentation of procedures and the transfer of ownership.

7.1 Control Plan

The team put a control plan in place to sustain improvements. For instance, the lean team met once a week to talk about the progress of the changes. Each member of the lean team was held responsible for making sure that a certain improvement was made and controlled. Furthermore, each member needed to implement a certain improvement by a certain date.

7.2 Documentation of Procedures

The team documented new procedures in order to control the process. For instance, the team created running rules for the machine shop and the plasma spray area.

7.3 Transfer of Ownership

The team needed to ensure that the new changes were going to be controlled after they leave. As a result the team identified a process control for each new process and someone to finish out any unfinished work. In addition, the team set up an automated email that would be sent to each manager to ensure that the cleaning chemicals will be replaced on a scheduled basis.

7.3.1 Implementation of a Schedule for the replacement of Cleaners

After thorough investigation of the cleaning processes used at the plant the team discovered that many of the cleaning chemicals were not regularly replaced with new chemicals. Each cleaning chemical becomes inactive after a certain period of time; therefore, the cleaning chemicals should be replaced. For example, there were complaints from employees that the ultrasonic clean process was not effectively removing carbon particles. Furthermore, the accumulation of carbon particles caused the midframes to fail flow test on numerous occasions. The ultrasonic clean process was not effective because the chemical was not replaced regularly.

There were also complaints about the “high volume flush” clean process taking too long. The team concluded that the cleaning rate of the chemical was low because the chemical needed to be replaced.

The team met with managers to devise an automated email that would be sent on a scheduled basis to each manager. This automated email reminds the managers to ensure that the chemicals in the clean tanks are replaced. The managers need to report back to the Environmental Health and Safety (EHS) when they replace the chemicals.

8 Recommendations

8.1 Green Cleaner Recommendation

Many industrial cleaners contain a high percentage of volatile organic compounds (VOCs). VOC's are organic gases that are emitted into the air. They are the primary cause of ozone formation at the ground level (i.e. smog). Ozone formation at the ground level (smog) is formed from the reaction between VOCs and nitrogen oxides. Nitrogen oxides are primarily emitted from car exhausts, aircraft, trains and fossil fuel burning power plants. Too much ozone formation can negatively impact the environment and public health.

The disposal of toxic industrial cleaners is very costly. Therefore, the industrial sector should implement non-hazardous cleaners in their processes. There are two hazardous cleaning chemicals used at the GE Aviation facility in Winfield, Kansas: Stoddard PD 680 Type II (a degreaser) and Intex 8135 (an alkaline cleaner).

Stoddard PD 680 Type II

Stoddard PD 680 Type II (a Stoddard solvent) is used to remove oil produced from crude oil. Stoddard Solvent has about one hundred percent of VOC's. According to the MSDS for Stoddard solvent it has a health rating of two. Therefore, it is moderately hazardous to the public health. Inhalation of Stoddard solvent vapors irritates the respiratory tract. Chronic exposure negatively affects the central nervous system. According to the MSDS for Stoddard solvent it has a flammability rating of two. Therefore, it is moderately flammable. The flash point for Stoddard solvent is 100 degrees Fahrenheit.

Intex 8135

Intex 8135 is used at this facility to remove carbon deposits. According to the MSDS for Intex 8135 it contains 70-80% by weight of sodium carbonate. Sodium carbonate is used as a buffer in alkaline cleaners in order to stabilize alkalinity. High alkalinity is corrosive to aluminum, brass, bronze, steel and iron. High alkalinity can cause embrittlement in steel. According to the MSDS for sodium carbonate it is slightly affective to the public health (i.e. dermatitis and irritation to the eyes). However, if there is direct contact with sodium carbonate it can cause permanent damage (to the skin). Additionally, according to the MSDS for sodium carbonate it is toxic to certain aquatic life. Therefore, Intex 8135 is disposed as toxic waste.

Turco Cleaners

There are three Turco cleaners that are used in a three-step process to remove contaminants from the diffuser cases. Turco 4181 is an alkaline cleaner that is used to remove rust. Turco 4338C is an alkaline permanganate. This particular alkaline permanganate oxidizes the carbon on the diffuser case causing it to crack. As a result it is easier to remove the carbon. Lastly, Turco 4409 is a phosphoric acid that is used to remove the carbon.

According to the MSDS for Turco 4181 and Turco 4409 the Hazardous Material Identification System (HMIS) health rating is a three. The HMIS gives ratings from 0-4, four being a severe hazard. The HMIS health rating for Turco 4338 C is a three but is also noted as a chronic hazard. The HMIS reactivity rating for Turco 4338 C is a two because it may react with acids and organic material. The MSDS for each Turco product that is listed can be found in appendixes G and H. One believes that this GE facility should replace these Turco cleaning products with safer alternatives.

Toxic Waste Disposal Costs

The cost to dispose toxic waste can be very costly. Included below is a table of the disposal costs for the toxic waste for this particular GE facility.

Table 8.1. 2 2006 Waste Disposal Costs

Chemical	Amount (lbs)	# Of Drums	Disposal Cost for Toxic Waste (Per drum)	Cost per drum (Dollars)	Total Cost (Dollars)
Stoddard PD 680 Type II	1595	4	82.45	50.00	529.80
Turco 4181	2600	6.5	140.00	50.00	1235.00
Turco 4338C	400	1	150.00	50.00	200.00
Total Cost (Dollars): 1964.80					

Green Cleaner Recommendation

There are many effective cleaners that are non-hazardous. For example, Vertec BioGold is non-carcinogenic, non-hazardous to the environment, biodegradable and has a very high flash point. Vertec BioGold by Vertec BioSolvents is a combination of methyl soyate (soy ester) and ethyl lactate (derivative of corn). "This combination offers the ideal cleaning characteristics of soy methyl ester and the quick evaporation rate of ethyl lactate (The United Soybean Board)." This product has a high flashpoint of 150 degrees

Fahrenheit; therefore, Vertec BioGold is not extremely volatile. Vertec BioGold is not a Hazardous Air Pollutant. Most esters are known to have a strong aromatic content; however, the MSDS for this product states that it only has a slight odor.

The main concern is the removal of carbon and aluminum oxide deposits from the midframes. According to The Aqueous Cleaning Handbook by Alconox Inc. cleaners that are in the ph range of 2-5.5 effectively remove inorganic salts, water, and soluble metal complexes (i.e. aluminum oxide). According to the MSDS for Vertec Gold the pH of water dispersion is 4.6 with 10 solution. Therefore, this cleaner is highly effective at removing aluminum oxide. One spoke with an employee at Vertec BioSolvents, Inc. and he stated that this product is known to effectively remove carbon.

Vertec BioGold is a soy methyl ester blend and is a cost effective cleaning compound. Soybeans are plentiful and are grown throughout numerous U.S states. Additionally, soybeans are harvested during many times of the year. This year, the U.S will produce almost three billion bushels of soybeans that will generate about four and a half billion gallons of soybean oil, according to the United Soybean Board. Soy methyl esters do not generate hazardous waste. Therefore, one does not have to pay for the disposal of hazardous waste. Vertec BioGold is an exceptional alternative due to its low cost and cleaning effectiveness.

8.2 Recommendation from Team Member (Natalie)

One specific area that must be addressed in any company dealing with modification is the human resources aspect. Productivity needs to be at its peak to truly be successful at modifying any aspect of this division of GE in Kansas. We are speaking of reducing the TAT for the CT7/T700 midframe engine repair and overhauling its process. This will affect the men and women on the floor who actually are responsible for the manual labor discussed here. We are talking about removing their overtime to accomplish this task we have set before ourselves. The humans resources question would be; "How does one keep employee productivity high." The answer is that people need to give in order to receive. We need to present the workers with a trade off. They need to know their job security is not being compromised. If the employees know they have job security, they will perform and produce at a level that will coincide with meeting our changes as well. One trade off could be the availability of a 10-hour workday. To successfully meet our needs we need to express the need for team playing at this particular GE plant.

9. Conclusion

Only one midframe has gone completely through the shop since the week of the Lean Event when most of the changes were implemented. This midframe was completed in 42 days, an 18-day reduction from the original data. Data was also collected from other midframes that have finished after the lean event and on ones that have yet to finish but started after the lean event. This data shows a reduction of 22.6 days in the overall process. A great portion of this reduction comes from the reduction of Queue time in the Rework, Machine Shop and Plasma Spray areas. Another indication of an improvement in the midframe process is the reduction in WIP. The WIP has decreased from 87 to 64. Overall the project was a success even though we missed out target goal bye 25.66%.

Appendices

Appendix A: CT7 Midframe As Received Routing Packet

Below is an As Received router for a CT7 midframe. This router dictates where the midframe move through the shop and what work will be done to it.

T.O: GEK 9250,70-32-02
T.O: SEI 578/72-39-00

ROUTER# :CT7F-0900 REV#: 23 REV DATE: 02/22/2007 Pag
ROUTER DESC :MIDFRAME/DIFF. (AS REC'D) GE PROPRIETARY

IRAN______O/H______

ISSUED BY :MARK PROPPS
ISSUE DATE :9/20/2007 0
ENG TYPE :CT7-FAMILY TSN : CSN :
COMP. CODE :44A TSO :NA CSO :NA

PART QTY : 0
ENGINE S/N : XXXX
PART NUMBER :
PART S/N :

APPROVED BY:
REMARKS:

SEQ. BCD	SEQUENCE	DESCRIPTION	OPER	AREA	WC
	0005	CLEAN PER MI ENG-DI-096, PROC.#131 AND PROC.6	0002	81	821Z
	0010	REMOVE STRAINER FROM OIL INLET TUBE. ISSUE SMO CT7F-0919 FOR CL/INSP OF STRAINER	0001	51	8750
	0020	OVEN BAKE AT 850-875 DEG. F WITH AIRFLOW THROUGH OIL NOZZLES. VERIFY WITH C-LEAK TO ASSURE AIRFLOW AT 1 TO 3 PSIG.	0081	51	8750
	0030	CLEAN PER MI MEM-DI-115 PROC. 4	0002	51	8208
	0040	VISUAL INSPECT ACCELERATOR HOUSING. ENSURE ALL PLUGS AND CAPS ARE INSTALLED PRIOR TO TRANSPORTING MIDFRAME TO NEXT SEQUENCE.	0003	51	8750
	0050	DISASSEMBLY MIDFRAME IF REQUIRED DIFFUSER CASE BDC/PL__________ CENTRIFUGAL DIFFUSER BDC/PL__________	0001	51	8750
	0060	TEST A) EB WELD WATER TEST PER T.R. CT7P-604 ACCEPT ________ REJECT ________ B) PRESSURE TEST PER 72-39-00 TESTING 002 PARA 8 100 PSIG ACCEPT ______ REJECT ______ 200 PSIG ACCEPT ______ REJECT ______ 300 PSIG ACCEPT ______ REJECT ______ C) REMOVE HEAT SHIELD TO IDENTIFY SOURCE OF LEAK D) PREP TO WELD B-SUMP LEAKS	0030	51	8750
	0070	CLEAN TUBE WELDS INSIDE DIA. "D" AND DESWIRLER EB WELD WITH A WIRE BRUSH. ENSURE ALL PLUGS AND CAPS ARE INSTALLED PRIOR TO TRANSPORTING TO THE NEXT SEQUENCE.	0002	51	8750

T.O: GEK 9250,70-32-02
T.O: SEI 578/72-39-00

ROUTER# :CT7F-0900
ROUTER DESC :MIDFRAME/DIFF. (AS REC'D)

REV#: 23 REV DATE: 02/22/2007 Page
GE PROPRIETARY

ISSUED BY :MARK PROPPS
ISSUE DATE :9/20/2007 0
ENG TYPE :CT7-FAMILY
COMP. CODE :44A

TSN :
TSO :NA
CSN :
CSO :NA

PART QTY : 0
ENGINE S/N : XXXX
PART NUMBER :
PART S/N :

APPROVED BY:
REMARKS:

SEQ. BCD	SEQUENCE	DESCRIPTION	OPER	AREA	WC	(
	0080		0004	51	**8504**	XXXX
		FPI PER GEK 9250, 70-32-02				XXXX
		A) TUBE WELDS				XXXX
		B) AFT FLANGE				XXXX
		C) FWD FLANGE				XXXX
		D) OUTER CASING				XXXX
		E) TUBE WELD JOINTS				XXXX
		F) EB WELD JOINTS				XXXX
		G) B-SUMP WELD REPAIR				XXXX
		H) B-SUMP INNER WEBBING (ADJACENT TO CDP MOUNTING SURFACE)				XXXX
		ENSURE ALL PLUGS AND CAPS ARE INSTALLED PRIOR TO TRANSPORTING THE MIDFRAME TO THE NEXT SEQUENCE.				XXXX
	0090		0003	09	**8750**	XXXX
		VISUAL INSPECT PER SEI 578 AND ISSUE REAPIR SMO BASED ON RESULTS.				XXXX
		ENSURE ALL PLUGS AND CAPS ARE INSTALLED PRIOR TO TRANSPORTING MIDFRAME TO NEXT SEQUENCE.				
	9999		STR	STR	**STR**	XXXX
		* Assure all operations on this router are signed off, all reject stamps are dispositioned and required data is recorded.				XXXX
		* Visually inspect the hardware for obvious defects.				XXXX
		P/N: ______ Qty: ______ Proceed to Router Barcode #: ______				XXXX

Appendix B: SMO Tracking Schedule

Below is the midframe tracking schedule. This schedule give the work order numbers of the midframes and tell where the midfame is throughout the process. Every block is colored in after the task has been finished.

Last Updat ▾ Bobby

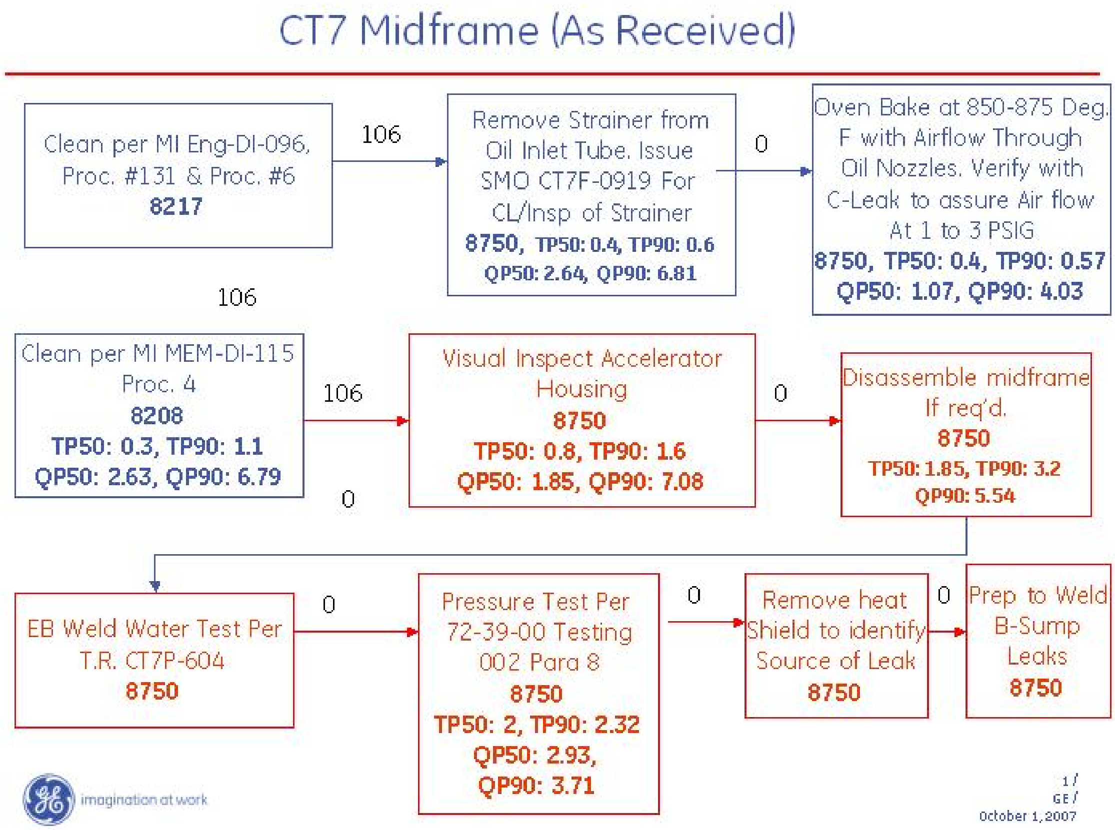
Date & Time 10/2-6:00am 64

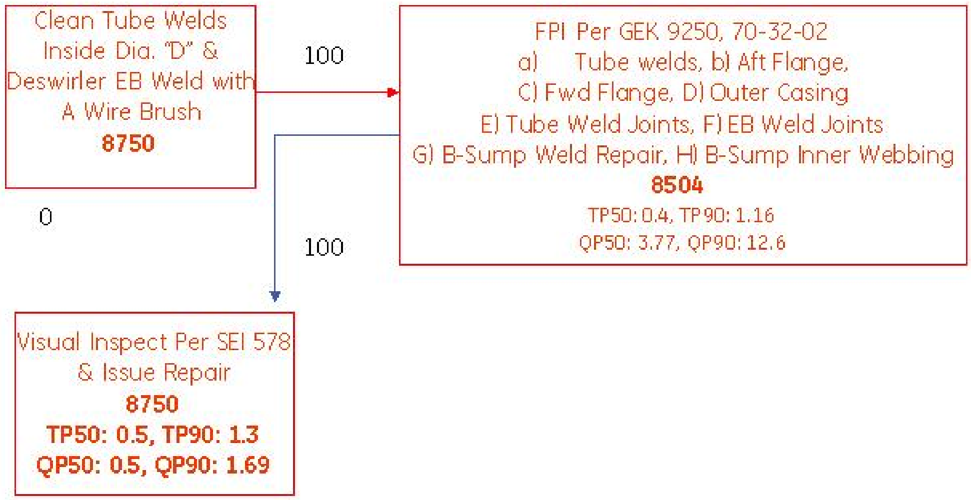
MIDFRAME SMO TRACKING FILE

Roll Date	Work Order	cnfg	BCD	TAT Start	Days Left to Ship	CL	RW	OB	CL	TST	FPI	INS	WD	FPI	INS	MS	RW	WD	FPI	RW	WD	INS	RW	EB	MS	PL	MS	RW	FPI	CL	INS	ASY	MS	DA	PL	CL	INS	ASY	MS	RW	CL	HV	FL	CL	F	TAT as of Now	
						DF	NEW												CS	W59476																						PL	CL	ASY	F		
10/15	281302		W68900	9/25			3,9-27	3,9-29		TST	FPI	INS	WD	FPI	INS	MS	RW	WD	FPI	RW	WD	INS	RW	EB	MS	PL	MS	RW	FPI	CL	INS	ASY	MS	DA	PL	CL	INS	ASY	MS	RW	CL	HV	FL	CL	F		10/2
				Rolling Oct 8 - Oct 12																																											10/2
10/12	412885		VY6492	5/24		DESWIRLER-IOU			W68135			RW	WD	TST	FPI	RW	WD	EB	FPI	MS	PL	MS			2,9-26	3,9-22	MS	RW	FPI	CL	INS	ASY	MS	DA	PL	CL	INS	ASY	MS	RW	CL	HV	FL	CL	F		10/2
10/11	412890		W58518	9/5																					3,9-24					3,9-2	INS	ASY	MS	DA	PL	CL	INS	ASY	MS	RW	CL	HV	FL	CL	F		10/2
						DF	NEW												CS	W57018																	3,9-24				RW	PL	CL	ASY	F		
10/10	411693		W61212	8/31		D&C COMPLETE																																	2,9-2	,9-30		HV	FL	CL	F		10/2
	161957	-2	W63548	8/30																							MS	RW	FPI	CL	INS	ASY	MS	DA	PL	CL	INS	ASY	MS	RW	CL	HV	FL	CL	F		10/2
10/10	411692		W60567	8/30																					2,9-25							ASY	MS	DA	PL	CL	INS	ASY	MS	RW	CL	HV	FL	CL	F		10/2
						DF	NEW												CS	W56894																		3,9-24				2,10-	CL	ASY	F		
	282116	1400	W58998	8/30						1,9-11									MCN # 27768 IN RW				RW	EB	MS	PL	MS	RW	FPI	CL	INS	ASY	MS	DA	PL	CL	INS	ASY	MS	RW	CL	HV	FL	CL	F		10/2
						DF	NEW												CS	W56193																									F		
	285064	2400	W45094	8/6		D&C COMPLETE																								3,9-10			3,10-	DA	PL	CL	INS	ASY	MS	RW	CL	HV	FL	CL	F		10/2
	281295	1400	W20044	7/25		D&C COMPLETE			MF SCR		IOU	3,9-1	WD	FPI	INS	MS	RW	WD	FPI	RW	WD	INS	RW	EB	MS	PL	MS	RW	FPI	CL	INS	ASY	MS	DA	PL	CL	INS	ASY	MS	RW	CL	HV	FL	CL	F		10/2
	281297	1400	W54708	8/29		D&C COMPLETE				S/N GEVEV5YE																													3,10-	RW	CL	HV	FL	CL	F		10/2
10/9	423717		W58806	8/29		D&C COMPLETE																						3,9-24																	F		10/2
	282112	1400	W55715	8/28		D&C COMPLETE																																		3,9-2	,9-2	HV	FL	CL	F		10/2
	196800		W58805	8/28		D&C COMPLETE																3,10-	3,10-	EB	MS	PL	MS	RW	FPI	CL	INS	ASY	MS	DA	PL	CL	INS	ASY	MS	RW	CL	HV	FL	CL	F		10/2
10/8	422817		W55077	8/27		D&C COMPLETE																																	2,10-	RW	CL	HV	FL	CL	F		10/2
	421761		W55076	8/27		D&C COMPLETE																					3,9-23						2,9-28									HV	FL	CL	F		
10/8	422816		W55078	8/24		D&C COMPLETE																														3,10-1			2,10-	RW	CL	HV	FL	CL	F		10/2
	285065	1400	W45747	8/9		D&C COMPLETE																																	2,9-2	,9-27		HV	FL	CL	F		10/2
				Rolling Oct 1 - Oct 5																																											10/2
10/5	422815		W55823	8/23		D&C COMPLETE																					3,9-25						2,10-	DA	PL	CL	INS	ASY	MS	RW	CL	HV	FL	CL	F		10/2

Appendix C: CT7/T700 As Received Process Flow Diagram

Below is process flow map comparing the CT7 and T700 As Received routers. It also shows the steps between each work station.




Clean Tube Welds Inside Dia. "D" & Deswirler EB Weld with A Wire Brush
8750
100
FPI Per GEK 9250, 70-32-02
a) Tube welds, b) Aft Flange,
C) Fwd Flange, D) Outer Casing
E) Tube Weld Joints, F) EB Weld Joints
G) B-Sump Weld Repair, H) B-Sump Inner Webbing
8504
TP50: 0.4, TP90: 1.16
QP50: 3.77, QP90: 12.6
0
100
Visual Inspect Per SEI 578 & Issue Repair
8750
TP50: 0.5, TP90: 1.3
QP50: 0.5, QP90: 1.69

Appendix D: Time and Distance Traveled "As Received"

Below is the calculation of the step, distance and time a part travels through a shop on an As Received router.

T700 Midframe As Received

Places	Steps	Distance (ft)	Time Traveled (h)	Time Traveled (min)
Rework to Clean	106	318	0.018531469	1.111888112
Clean to Rework	106	318	0.018531469	1.111888112
Rework to Oven	134	402	0.023426573	1.405594406
Oven to Clean	8	24	0.001398601	0.083916084
Clean to Rework	134	402	0.023426573	1.405594406
Rework to Rework	0	0	0	0
Rework to Rework	0	0	0	0
Rework to FPI	100	300	0.017482517	1.048951049
FPI to Rework	100	300	0.017482517	1.048951049
Total Steps	**688**	**2064**	**0.12027972**	**7.216783217**

Person 718 ***Hours per year*** ***48.11188811***

Appendix E: Time and Distance Traveled "CT7 Midframe Major"

Below is the calculation of the step, distance and time a part travels through a shop on a CT7 Major router.

CT7 Midframe Major

Places	Steps	Distance (ft)	Time Traveled (h)	Time Traveled (min)
Rework to Weld	89	267	0.015559441	0.933566434
Weld to Rework	89	267	0.015559441	0.933566434
Rework to Rework	0	0	0	0
Rework to FPI	100	300	0.017482517	1.048951049
FPI to Rework	100	300	0.017482517	1.048951049
Rework to Machine	42	126	0.007342657	0.440559441
Outside to Inside Machine	25	75	0.004370629	0.262237762
Machine to Rework	65.5	196.5	0.011451049	0.687062937
Rework to Rework	0	0	0	0
Rework to Weld	87.5	262.5	0.015297203	0.917832168
Weld to FPI	36	108	0.006293706	0.377622378
FPI to Rework	102	306	0.017832168	1.06993007
Rework to Weld	89	267	0.015559441	0.933566434
Weld to Rework	89	267	0.015559441	0.933566434
Rework to FPI	102	306	0.017832168	1.06993007
FPI to Rework	102	306	0.017832168	1.06993007
Weld to Rework	89	267	0.015559441	0.933566434
Rework to Rework	0	0	0	0
Rework to Rework	0	0	0	0
Rework to EB Weld	78	234	0.013636364	0.818181818
EB to Weld	10	30	0.001748252	0.104895105
Weld to EB	10	30	0.001748252	0.104895105
EB to Rework	78	234	0.013636364	0.818181818
FPI to EB	100	300	0.017482517	1.048951049
EB to Machine	62	186	0.010839161	0.65034965
Machine to Plasma	64.5	193.5	0.011276224	0.676573427
Plasma to Plasma	0	0	0	0
Plasma to Machine	64.5	193.5	0.011276224	0.676573427
Machine to Machine	0	0	0	0
Machine to Rework	67	201	0.011713287	0.702797203
Rework to Rework	0	0	0	0
Rework to Clean	115	345	0.020104895	1.206293706
Clean to Plasma	52.5	157.5	0.009178322	0.550699301
Plasma to Plasma	0	0	0	0
Plasma to Rework	70.5	211.5	0.012325175	0.73951049
Rework to Rework	0	0	0	0
Rework to Machine	67	201	0.011713287	0.702797203

Machine to Machine	0	0	0	0
Machine to Clean	74	222	0.012937063	0.776223776
Clean to HVF	7	21	0.001223776	0.073426573
HVF to Rework	108	324	0.018881119	1.132867133
Rework to Flow	114	342	0.01993007	1.195804196
Flow to Clean	67	201	0.011713287	0.702797203
Clean to Rework	115	345	0.020104895	1.206293706
Rework to Rework	0	0	0	0
Total	**2531**	**7593**	**0.442482517**	**26.54895105**
		Hours per year	***176.993007***	

Appendix F: Machine Shop Rules

Below is a copy of the rules that were placed into effect for the machine shop to help keep a continuous flow.

Machine Shop

Running Rules

1) Carry over work form one shift to the next to be completed by incoming shift before starting next job on rack.
2) Work reprocess parts before selection of days priorities.
3) Machinist to select from 'IN' rack lowest number available (1-15)
4) No Midframe- Ask Team Leader for a job
5) In absence of Team Leader ask Supervisor for next job.
6) Machinist to deliver finished work to the next area immediately on completion
7) In absence of any production work machinist to carry out housekeeping activities
8) Set up for next shift must be carried out up to half an hour before end of shift
9) Within half an hour of end of shift, machinist to carry out housekeeping of area in preparation for arrival of next shift

MCN Procedure

1) Enter MCN into computer which will automatically send request to engineering by email
2) Machinist to call support engineer if on site on extension number #### requesting immediate support. If no answer leave a message.
3) Where engineer is unavailable, machinist to take job down and place on designated MCN rack await engineering action
4) Machinist to abide by priority rules following placement of midframe on MCN rack

Appendix G: MSDS for Turco 4181

Below is the Material Safety Data Sheet (MSDS) for Turco 4181.

Material Safety Data Sheet

Material Name: TURCO® LIQUID ARR (T-4181L) **ID: 238229**

* * * Section 1 - Chemical Product and Company Identification * * *

Product Trade Name TURCO® LIQUID ARR (T-4181L)

Manufacturer Information

Henkel Technologies
Henkel Corporation
32100 Stephenson Highway
Madison Heights, MI 48071

Contact Phone: (248) 583-9300

Chemtrec Emergency # (800) 424-9300

* * * Section 2 - Composition / Information on Ingredients * * *

CAS #	Component	Percent
1310-73-2	Sodium hydroxide	10-30
527-07-1	Sodium gluconate	1-10
102-71-6	Triethanolamine	1-10

* * * Section 3 - Hazards Identification * * *

Emergency Overview:

DANGER! Contact with this material will cause burns to the skin, eyes and mucous membranes.

Eye Contact:

Contact with the eyes can cause severe burns and permanent eye damage.

Skin Contact:

Contact with the skin or mucous membranes will cause severe burns and possible ulceration.

Ingestion:

Ingestion may produce burns to the lips, oral cavity, upper airway, esophagus and possibly the digestive tract.

Inhalation:

Inhalation of mists of this product may cause severe irritation and burns to the respiratory tract.

Medical Conditions Aggravated by Exposure:

Pre-existing eye, skin and respiratory disorders.

* * * Section 4 - First Aid Measures * * *

Eye Contact:

In case of contact with the eyes, rinse immediately with plenty of water for 15 minutes, and seek immediate medical attention.

Skin Contact:

For skin contact, flush with large amounts of water. If irritation persists, get medical attention.

Ingestion:

If the material is swallowed, get immediate medical attention or advice -- Do not induce vomiting. Give one to two glasses of water or milk. Never give anything by mouth to a victim who is unconscious or is having convulsions.

Inhalation:

If mist or vapor of this product is inhaled, remove person immediately to fresh air. Seek medical attention if symptoms develop or persist.

* * * Section 5 - Fire Fighting Measures * * *

Flash Point:	None	**Method Used:**		**Flammability Classification:**	
Upper Flammable Limit (UFL):	NA	**Lower Flammable Limit (LFL):**	NA		

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Fire & Explosion Hazards:
This product is an aqueous mixture which will not burn. If evaporated to dryness, the solid residue may pose a moderate fire hazard.

Extinguishing Media:
Use methods for the surrounding fire.

Fire-Fighting Instructions:
Fire fighters should wear full-face, self contained breathing apparatus and impervious protective clothing. Fire fighters should avoid inhaling any combustion products.

* * * Section 6 - Accidental Release Measures * * *

Containment Procedures:
Stop the flow of material, if this is without risk. Dike the spilled material, where this is possible. Ventilate the contaminated area. Do not allow the spilled product to enter public drainage system or open water courses.

Clean-Up Procedures:
Collect spilled material with an inert absorbent such as sand or vermiculite. Place in properly labeled closed container. Dispose of collected material according to regulation.

* * * Section 7 - Handling and Storage * * *

Handling Procedures:
Do not get this material in your eyes, on your skin, or on your clothing. Use this product with adequate ventilation. Avoid breathing vapors or mists of this product. Wash thoroughly after handling.

Storage Procedures:
Keep the container tightly closed and in a cool, well-ventilated place.

* * * Section 8 - Exposure Controls / Personal Protection * * *

Component Exposure Limits

Sodium hydroxide (1310-73-2)
ACGIH: 2 mg/m3 Ceiling
OSHA: 2 mg/m3 TWA
NIOSH: 2 mg/m3 Ceiling

Triethanolamine (102-71-6)
ACGIH: 5 mg/m3 TWA

Engineering Controls:
Ventilation should effectively remove and prevent buildup of any vapor or mist generated from the handling of this product.

PERSONAL PROTECTIVE EQUIPMENT
As prescribed in the OSHA Standard for Personal Protective Equipment (29 CFR 1910.132), employers must perform a Hazard Assessment of all workplaces to determine the need for, and selection of, proper protective equipment for each task performed.

Eyes/Face Protective Equipment:
Wear chemical goggles.

Skin Protection:
Use impervious gloves. Use of impervious apron and boots are recommended.

Respiratory Protection:
If ventilation is not sufficient to effectively prevent buildup of aerosols or vapors, appropriate NIOSH/MSHA respiratory protection must be provided.

Work Practices:
Eyewash fountains and emergency showers are required.

* * * Section 9 - Physical & Chemical Properties * * *

Physical State:	Liquid	**Appearance:**	Cloudy, light tan liquid
Odor:		**Vapor Pressure:**	NE
Vapor Density:	NE	**Boiling Point:**	> 200 F
Melting Point:	NA	**Specific Gravity:**	1.24
pH:	> 12.0	**Viscosity:**	
VOC:	6.5% (calculated)	**Solubility Water:**	Soluble

* * * Section 10 - Chemical Stability & Reactivity Information * * *

Chemical Stability:

Stable under normal conditions.

Conditions to Avoid:

Avoid contact with acids.

Incompatibility:

Avoid contact with strong acids. Contains organic amine compounds. Nitrite based materials should not be added due to possible nitrosoamine formation.

Decomposition Products:

Upon decomposition, this product emits carbon monoxide, carbon dioxide and/or low molecular weight hydrocarbons.

Hazardous Polymerization:

Will not occur.

* * * Section 11 - Toxicological Information * * *

Acute Toxicity:

A: General Product Information

No information available for the product.

B: Component Analysis - LD50/LC50

Sodium hydroxide (1310-73-2)
Dermal LD50 Rabbit: 1350 mg/kg

Triethanolamine (102-71-6)
Oral LD50 Rat: 4190 mg/kg; Dermal LD50 Rabbit: >2000 mg/kg

Component Carcinogenicity

None of this product's components are listed by ACGIH, IARC, OSHA, NIOSH, or NTP.

Chronic Toxicity

No information available for the product.

Epidemiology:

No information available for the product.

Neurotoxicity:

No information available for the product.

Mutagenicity:

No information available for the product.

Teratogenicity:

No information available for the product.

* * * Section 12 - Ecological Information * * *

Ecotoxicity:

A: General Product Information

No information available for the product.

Appendix H: MSDS for Turco 4338C

Below is the Material Safety Data Sheet (MSDS) for Turco 4338C.

Material Safety Data Sheet

Material Name: TURCO® 4338 C **ID: 239311**

* * * Section 1 - Chemical Product and Company Identification * * *

Product Trade Name TURCO® 4338 C

Manufacturer Information

Henkel Surface Technologies
Henkel Corporation
32100 Stephenson Highway
Madison Heights, MI 48071

Contact Phone: (248) 583-9300

Chemtrec Emergency # (800) 424-9300

* * * Section 2 - Composition / Information on Ingredients * * *

CAS #	Component	Percent
1310-73-2	Sodium hydroxide	30-60
497-19-8	Sodium carbonate	30-60
7722-64-7	Potassium permanganate	10-30

Component Related Regulatory Information

This product may be regulated, have exposure limits or other information identified as the following: Manganese compounds, n.o.s., Permanganates, inorganic, n.o.s..

* * * Section 3 - Hazards Identification * * *

Emergency Overview:

DANGER -- CORROSIVE! OXIDIZER! Contact with other materials may cause a fire. Contact with this material will cause burns to the skin, eyes and mucous membranes. Avoid breathing dusts.

Eye Contact:

Contact with the eyes can cause severe burns and permanent eye damage.

Skin Contact:

Contact with the skin or mucous membranes will cause severe burns and possible ulceration.

Ingestion:

Not a likely route of entry. Ingestion may produce burns to the lips, oral cavity, upper airway, esophagus and possibly the digestive tract.

Inhalation:

Inhalation of dusts of this product may cause severe irritation and burns to the respiratory tract.

Medical Conditions Aggravated by Exposure:

Pre-existing eye, skin and respiratory disorders.

* * * Section 4 - First Aid Measures * * *

Eye Contact:

In case of contact with the eyes, rinse immediately with plenty of water for 15 minutes, and seek immediate medical attention.

Skin Contact:

For skin contact flush with large amounts of water while removing contaminated clothing. If irritation persists, repeat flushing and get medical attention. Discard any shoes or clothing items that cannot be decontaminated.

Ingestion:

If the material is swallowed, get immediate medical attention or advice -- Do not induce vomiting. Give one to two glasses of water or milk. Never give anything by mouth to a victim who is unconscious or is having convulsions.

Inhalation:

Move person to non-contaminated air. If not breathing, give artificial respiration, preferably mouth-to-mouth. If breathing is difficult, give oxygen. Seek medical attention.

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* * * Section 5 - Fire Fighting Measures * * *

Flash Point:	Not applicable	**Method Used:**	Not applicable	**Flammability Classification:**	Non-flammable
Upper Flammable Limit (UFL):	Not applicable	**Lower Flammable Limit (LFL):**	Not applicable		

Fire & Explosion Hazards:

May react with metals to form flammable hydrogen gas. Avoid direct contact of this product with water since this can cause a violent exothermic reaction. Oxidizing agent, may cause spontaneous ignition of combustible materials.

Extinguishing Media:

Use any media suitable for the surrounding fires.

Fire-Fighting Instructions:

Firefighters should wear full protective clothing including self contained breathing apparatus.

* * * Section 6 - Accidental Release Measures * * *

Containment Procedures:

Stop the flow of material, if this is without risk. Contain the discharged material. Block any potential routes to water systems. Isolate area. Keep unnecessary personnel away.

Clean-Up Procedures:

Avoid the generation of dusts during clean-up. Sweep up or gather material and place in appropriate container for disposal. Flush area with water to remove trace residue. Dispose of collected material according to regulation.

* * * Section 7 - Handling and Storage * * *

Handling Procedures:

Do not get this material in your eyes, on your skin, or on your clothing. Use this product with adequate ventilation. Do not breathe dust from this material. Wash thoroughly after handling. Do not reuse the empty container. NEVER ADD WATER TO PRODUCT. For dilutions, add product slowly to water while stirring. Use caution; heat may be generated.

Storage Procedures:

Keep the container tightly closed and in a cool, well-ventilated place.

* * * Section 8 - Exposure Controls / Personal Protection * * *

Exposure Guidelines:

A: General Product Information

Follow all applicable exposure limits.

B: Component Exposure Limits

Sodium hydroxide (1310-73-2)

ACGIH: 2 mg/m3 Ceiling
OSHA: 2 mg/m3 TWA
NIOSH: 2 mg/m3 Ceiling

Potassium permanganate (7722-64-7)

OSHA: 5 mg/m3 Ceiling (as Mn) (related to Manganese compounds)
NIOSH: 1 mg/m3 TWA (as Mn) (related to Manganese compounds)
3 mg/m3 STEL (as Mn) (related to Manganese compounds)

Engineering Controls:

Ventilation should effectively remove and prevent buildup of any dust generated from the handling of this product.

PERSONAL PROTECTIVE EQUIPMENT

As prescribed in the OSHA Standard for Personal Protective Equipment (29 CFR 1910.132), employers must perform a Hazard Assessment of all workplaces to determine the need for, and selection of, proper protective equipment for each task performed.

Eyes/Face Protective Equipment:

Wear chemical goggles.

Skin Protection:

Use impervious gloves. Use of impervious apron and boots are recommended.

Respiratory Protection:

If ventilation is not sufficient to effectively prevent buildup of dust, appropriate NIOSH/MSHA respiratory protection must be provided.

Work Practices:

Eyewash fountains and emergency showers are required.

* * * Section 9 - Physical & Chemical Properties * * *

Physical State:	Solid	**Appearance:**	Violet and white flakes
Odor:	Little or none	**Vapor Pressure:**	Not applicable
Vapor Density:	Not applicable	**Boiling Point:**	Not applicable
Melting Point:	Not applicable	**Specific Gravity:**	Not applicable
pH:	3.1 % in water 13.0	**Viscosity:**	
VOC:		**Solubility Water:**	Appreciable

* * * Section 10 - Chemical Stability & Reactivity Information * * *

Chemical Stability:

Stable under normal conditions.

Conditions to Avoid:

Avoid contact with acids. This product is an OXIDIZING AGENT - avoid contact with organic material.

Incompatibility:

This product reacts with acids. This product may react with aluminum, zinc, tin and their alloys to produce flammable hydrogen gas. Avoid contact with organic materials, oils, greases, and any oxidizable materials.

Decomposition Products:

None identified.

Hazardous Polymerization:

Will not occur.

* * * Section 11 - Toxicological Information * * *

Acute Toxicity:

A: General Product Information

Potassium permanganate is corrosive to the eyes, skin, mucous membranes and respiratory tract. Exposure can also lead to pulmonary edema, liver and kidney damage with delayed symptom onset. It has been estimated that the lethal dose of potassium permanganate is 10 grams for humans, with death possibly being delayed for up to one month. In rare instances, potassium permanganate has been shown to induce methemoglobin formation which can lead to hypoxia, headache, fatigue, and at very high levels coma and death. This compound has been shown to cause adverse effects to the nervous and reproductive systems.

B: Component Analysis - LD50/LC50

Sodium hydroxide (1310-73-2)
Dermal LD50 Rabbit: 1350 mg/kg

Sodium carbonate (497-19-8)

Appendix I: MSDS for Vertec BioGold

Below is the Material Safety Data Sheet (MSDS) for Vertec BioGold.

VertecBio

Vertec BioSolvents, Inc.
1441 Branding Lane, Suite 100
Downers Grove, IL 60515 USA
☎ 630.960.0600 • 630.960.0660 (fax)
vertecbio@aol.com (e-mail)

PRODUCT INFORMATION BULLETIN
VERTECBIO GOLD #1

Regulatory Agency Information
OSHA-DOT

PREPARATION/REVISION DATE
LMP 04/29/04

PRODUCT INFORMATION BULLETIN

MATERIAL SAFETY DATA SHEET

TRADE NAME: VERTECBIO GOLD #1 ETHYL LACTATE BLEND

SECTION 1

MANUFACTURER'S NAME VERTEC BIOSOLVENTS, INC.	**EMERGENCY TELEPHONE NO.** 800-424-9300 (CHEMTREC)
ADDRESS 1441 Branding Lane, Suite 100 Downers Grove, Illinois 60515 USA	
CHEMICAL NAME Ethyl Hydroxy Propionate / Fatty Acid Methyl Esters	**COMMON NAME** Ethyl Lactate / Methyl Soyate
DOT CLASSIFICATION Combustible Liquid	**FORMULA** Blend

CHEMICAL OR COMMON NAME	PERCENT	CAS NO.	APPLICABLE PEL-OSHA	EXPOSURE LIMITS TLV-ACGIH
Methyl Soyate	10-90	67784-80-9 & 67762-38-3	None established	None established
Ethyl Lactate	10-90	97-64-3	None established	None established

SECTION 2 HAZARDOUS INGREDIENTS

CHEMICAL OR COMMON NAME	PERCENT	CAS NO.	APPLICABLE PEL-OSHA	EXPOSURE LIMITS TLV-ACGIH
None				

CARCINOGENIC INGREDIENTS

CHEMICAL OR COMMON NAME	%	REFERENCE IARC	SOURCE NTP	OSHA	OTHER
None identified	-	-	-	-	-

SECTION 3 HEALTH HAZARD DATA

ACUTE HEALTH EFFECTS
- Eyes: Irritant.
- Skin Contact: Not an irritant.
- Ingestion: May cause irritation of the digestive tract.
- Inhalation: May cause irritation of mucous membranes.

CHRONIC HEALTH EFFECTS
None known, not listed as a carcinogen.

ROUTES OF ENTRY
Most common, skin and inhalation.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE
Mist may cause eye/respiratory irritation with coughing.

SECTION 4 FIRST AID MEASURES

EYES	Immediately flush with water for at least 15 minutes. See a medical doctor immediately.
SKIN	Wash affected area with soap and water.
INHALATION	Remove person to fresh air. If discomfort occurs and persists, obtain medical attention.
INGESTION	Induce vomiting. See a medical doctor immediately.

SECTION 5 FIRE FIGHTING MEASURES

EXTINGUISHING MEDIA	Water fog, carbon dioxide (co_2), dry chemical.
SPECIAL FIREFIGHTING PROCEDURES	Wear a self-contained breathing apparatus.
DEGREE OF FIRE AND EXPLOSION HAZARD	Moderate. Rags soaked with any solvent can present a fire hazard and should be stored in UL listed or Factory Mutual approved, covered containers. Improperly stored rags, under certain conditions can lead to spontaneous combustion. Not an explosion hazard.
HAZARDOUS DECOMPOSITION PROCEDURES	None required when completely combusted, decomposes to water and CO_2. However, during a fire, incomplete combustion can result in the production of CO.

SECTION 6 ACCIDENTAL RELEASE / SPILL MEASURES

PROCEDURE FOR RELEASE OR SPILL	Cover with large quantity of absorbent material (e.g. kitty litter) and collect in drums for disposal. Clean contaminated area with soap and water.

Has a pH of 4.6

SECTION 7 CHEMICAL AND PHYSICAL DATA

MELTING POINT (°C)	Not applicable	**SPECIFIC GRAVITY (H_2O=1)**	0.946	
BOILING POINT	292° F	**PERCENT VOLATILE BY VOLUME (%)**	55	
VAPOR PRESSURE (mmHg)	.9 @ 68°F	~~**EVAPORATION RATE**~~ **(butyl acetate=1)**	0.12	
VAPOR DENSITY (AIR=1)	4.1	**pH OF WATER DISPERSION**	4.6, 10% solution	
SOLUBILITY	50%, in water	~~**APPEARANCE AND**~~ **ODOR**	Clear colorless to light yellow liquid, with a mild odor.	
FLASH POINT (method used)	150° F, ASTM D93	**FLAMMABLE LIMITS**	**Lel**	**Uel**
		@ 212 F	No data	No data

EXTINGUISHING MEDIA
Water fog, foam, CO_2
SPECIAL FIRE FIGHTING PROCEDURES
None required
INCOMPATIBILITY (materials to avoid)
Strong oxidizing agents.
HAZARDOUS DECOMPOSITION PRODUCTS
Incomplete combustion can produce CO.

ODOR THRESHOLD	No data
BULK DENSITY (G/ML)	
VOC CONTENT	63.77% (604g/l)
PARTITION COEFFICIENT n-octanol/water)	No data
AUTOIGNITION TEMPERATURE	No data
EXPLOSIVE PROPERTIES	Not applicable
OXIDIZING PROPERTIES	Not applicable

SECTION 8 STABILITY AND REACTIVITY DATA

STABILITY	Stable
HAZARDOUS POLYMERIZATION	None known
CONDITIONS TO AVOID	None known
MATERIALS TO AVOID	Strong oxidizing agents.
CONTAMINANTS THAT CONTRIBUTE TO INSTABILITY	None known
INCOMPATIBILITY	None known
HAZARDOUS DECOMPOSITION PRODUCTS	None known
SENSITIVITY TO MECHANICAL IMPACT	None known
SENSITIVITY TO STATIC DISCHARGE	None known

SECTION 9 TOXICOLOGICAL INFORMATION

EYE CONTACT	Irritant
SKIN CONTACT	LD 50 (rat/24hrs.) >2000mg/kg
SKIN ABSORPTION	No data available
INHALATION	LC 50 (rat/4 hrs.) > 5400 mg/m^3
INGESTION	LD 50 > 4090 mg/kg (rat) (RTECS 1985-6)
ACUTE EFFECTS FROM OVEREXPOSURE	May cause irritation of the eyes.
CHRONIC EFFECTS FROM OVEREXPOSURE	None identified.
(effects considered include: *sensitivities, carcinogenicity, teratogenicity, mutagenicity, synergistic products, and any medical conditions generally recognized as being aggravated by exposure*)	

SECTION 10 ECOLOGICAL INFORMATION

ENVIRONMENTAL FATE	100% Biodegradable
ENVIRONMENTAL EFFECTS	No adverse effects known or suspected. Not listed toxic chemical under SARA Title III 302, 304 or 313.

SECTION 11 HANDLING AND STORAGE

HANDLING	Keep container tightly closed. Store in a cool, dry, well-ventilated, liquid storage area.
VENTILATION	Use adequate general or local exhaust ventilation to keep vapor and mist levels as low as possible.
STORAGE	Store in a cool dry area, away from oxidizers and acids.

SECTION 12 EXPOSURE CONTROL / PERSONAL PROTECTION

RECOMMENDED PERSONAL PROTECTIVE EQUIPMENT	
RESPIRATORY	None required where adequate ventilation conditions exist.
VENTILATION	
Local Exhaust	Recommended
Mechanical (general)	In most cases adequate ventilation can be achieved by use of an industrial floor or pedistal fan, combined with sizable inlet and outlet openings to the workspace, such as doors and/or windows.
EYE PROTECTION	Use chemical goggles.
GLOVES	Use impervious gloves to prevent skin contact.
SPECIAL CLOTHING AND EQUIPMENT	Aprons recommended. If clothing becomes contaminated, remove and launder before reuse.
OTHER PROTECTIVE EQUIPMENT	None identified.
FOOT PROTECTION	Industrial safety shoes are recommended in all industrial settings.
OTHER ENGINEERING CONTROLS	None identified.
WORK PRACTICES	Do not smoke in areas of storage or use. Avoid all contact with skin and eyes.
CONTROL MEASURES	Minimize eye and skin contact by using appropriate protective equipment. Use local or general room ventilation to control vapors or mist that may be generated into the work environment.

SECTION 13 SPECIAL PRECAUTIONS DATA

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING
Avoid all contact with eyes or skin. Wear the appropriate protective equipment. Protect containers from physical damage.

MAINTENANCE PERSONNEL
Wash down vessels. Check the oxygen and combustible vapor content of the vessel atmosphere. Use the appropriate protective equipment.

SECTION 14 DISPOSAL PROCEDURES

WASTE DISPOSAL METHOD	Take up with sand or other non-combustible absorbent material and place into container for later disposal. Flush area with water. Dispose in accordance with all applicable Federal, State, and local environmental regulations. Spent product may be offered for fuel blending incineration.

SECTION 15 TRANSPORT INFORMATION

DOT PROPER SHIPPING NAME	VertecBio Gold #1 (under 119 gallons)
IATA	Non-regulated
IMDG	Non-regulated
DOT CLASSIFICATION	Combustible liquid
DOT LABELS	None required, under 119 gallons.
DOT MARKING	Not applicable
DOT PLACARD	Bulk: Combustible liquid,1993
IDENTIFICATION NUMBER	NA 1993
PACKAGING GROUP	III
HAZARDOUS SUBSTANCE/RQ	None
49 STCC NUMBER	Not applicable
PRECAUTIONS TO BE TAKEN IN TRANSPORTATION	None needed
OTHER SHIPPING INFORMATION	None

SECTION 16 REGULATORY INFORMATION

OSHA EXPOSURE LIMITS SUBSTANCE(S)	Ethyl Lactate, Methyl Soyate
OSHA PEL-TWA	None established
STEL	None established
CEILING	None established
SKIN DESIGNATION	None established
ACGIH TLV-TWA	None established
STEL	None established
CEILING	None established
SKIN DESIGNATION	None established
TARGET ORGAN EFFECTS	Eye
CARCINOGENIC POTENTIAL	None
REGULATED BY OSHA	No
LISTED ON NTP REPORT	No
IARC GROUP 1, 2A, 2D	No
US EPA REQUIREMENTS RELEASE REPORTING CERCLA (40 CFR 302)	
LISTED SUBSTANCE(S)	Not listed
RQ	Not applicable
Category	Not applicable
RCRA waste number	Not applicable
UNLISTED SUBSTANCE(S)	Ethyl Lactate, Methyl Soyate
RQ	None
Characteristic	Not applicable
RCRA waste number	Not applicable
SARA TITLE III SEC 313 (40 CFR 372)	
LISTED TOXIC CHEMICAL	Not listed
INVENTORY REPORTING SARA TITLE III SEC 311/312 (40 CFR 370)	
Substance(s)	Not listed
Hazard category	Not applicable
Planning threshold	Not applicable
Emergency planning	Not applicable
SARA TITLE III SEC 302-303 (40 CFR 355)	
Listed substance(s)	Not listed
RQ	Not applicable
Planning threshold	Not applicable
US TSCA STATUS	Listed
CANADA INGREDIENT DISCLOSURE LIST SUBSTANCE(S)	
CONTROLLED PRODUCT	Not listed
HAZARD SYMBOLS	
CLASS AND DIVISION	
PRODUCT IDENTIFICATION NO.	
DOMESTIC SUBSTANCE LIST	Listed
CEPA PRIORITY LIST	Not listed

SECTION 16 REGULATORY INFORMATION *(CONTINUED)*	
CARCINOGENICITY	Not listed in either OSHA, ACGIH, NTP, or IARC
ACGIH APPENDIX A	Not listed
A1 - CONFIRMED HUMAN	Not listed
A1 - SUSPECTED HUMAN	Not listed
IARC GROUP 1 OR 2	No
LABEL LANGUAGE (US/CANADA) HEALTH	Not applicable
PHYSICAL HANDLING AND STORAGE	Keep container tightly closed. Store in a cool, dry, well-ventilated liquid storage area.
FIRST AID	In case of contact, immediately flush eyes with water for at least 15 minutes. If irritation persists, obtain medical attention. Flush skin with water.
STATE REGULATIONS	

SECTION 17 ADDITIONAL INFORMATION

OSHA permissible exposure limit or ACGIH threshold limit value has not been established.

SECTION 18 HMIS LABEL

HEALTH	FLAMMABILITY	REACTIVITY	PERSONAL PROTECTION
1	2	0	B

DEPARTMENT OF TRANSPORTATION

Hazardous Materials Regulations, 49 CFR

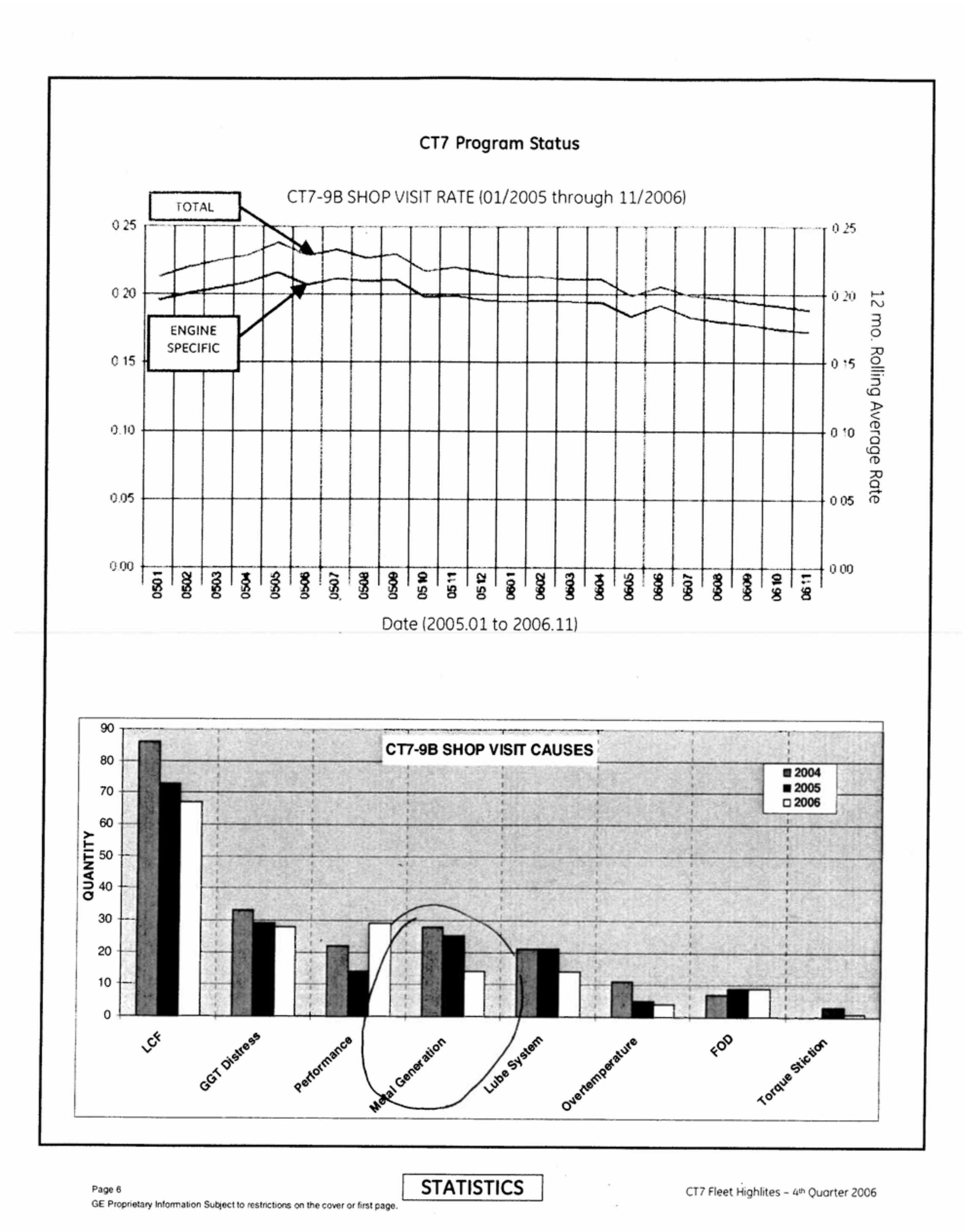
Non-hazardous

Proper Shipping Name:	**VertecBio Gold #1 (under 119 gallons)**
Hazard Class:	**Combustible liquid**
Packaging Group:	**III**
Reportable Quantity:	**None**
Label Required (Drums):	**None**
Placard Required (Bulk):	**Combustible liquid, 1993**
Max. Quantity Pass. Aircraft:	**60L/container**
Max. Quantity Cargo Aircraft:	**220L/container**
Stowage on Vessels:	**Above or Below Deck**

The information contained herein is, to the best of our knowledge and belief, accurate. However, since the conditions of handling and use are beyond our control, we make no guarantee of results, and assume no liability for damages incurred by use of this material. It is the responsibility of the user to comply with all applicable federal, state and local laws and regulations.

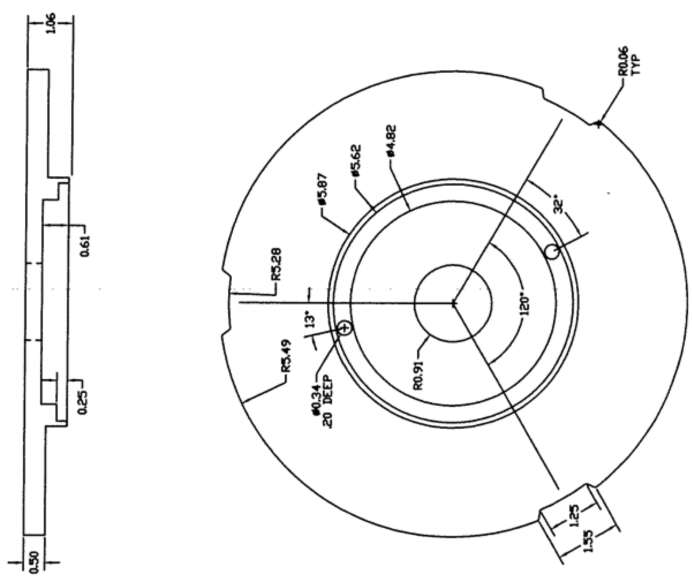
Appendix J: Reasons for Low Hour Visits

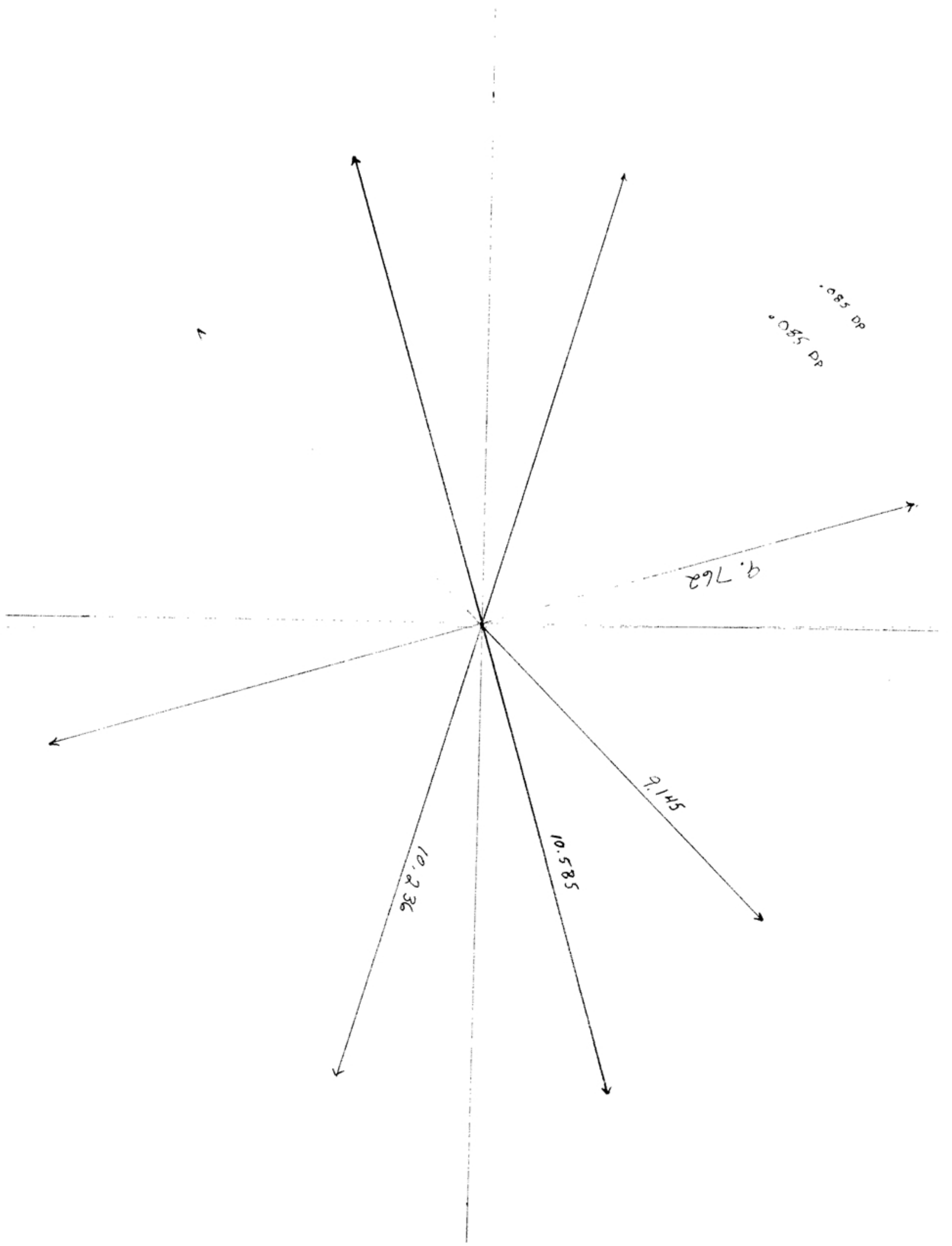
Below is a graph showing the decline of low hour engine visits. In the circled area, low hour visits caused by metal generation is shown.

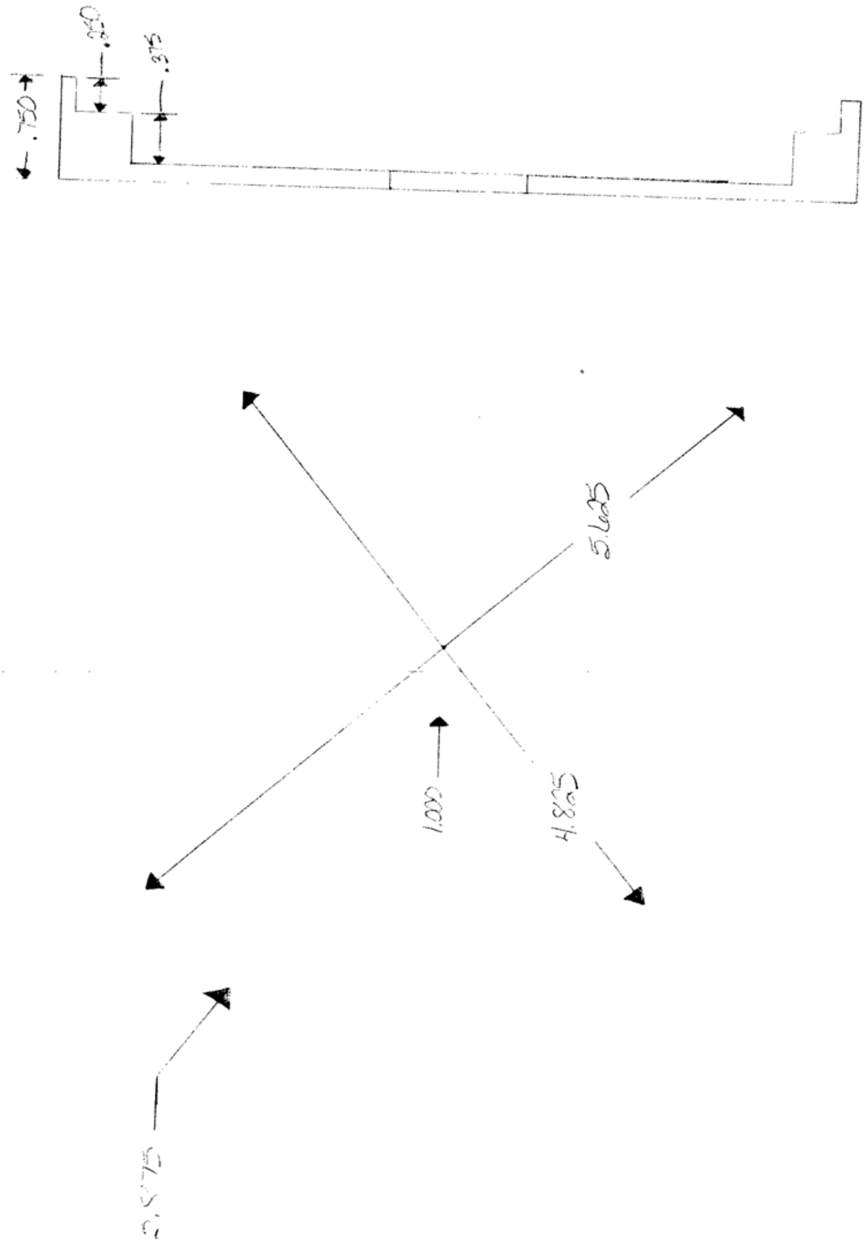


Appendix K: Tooling Drawings

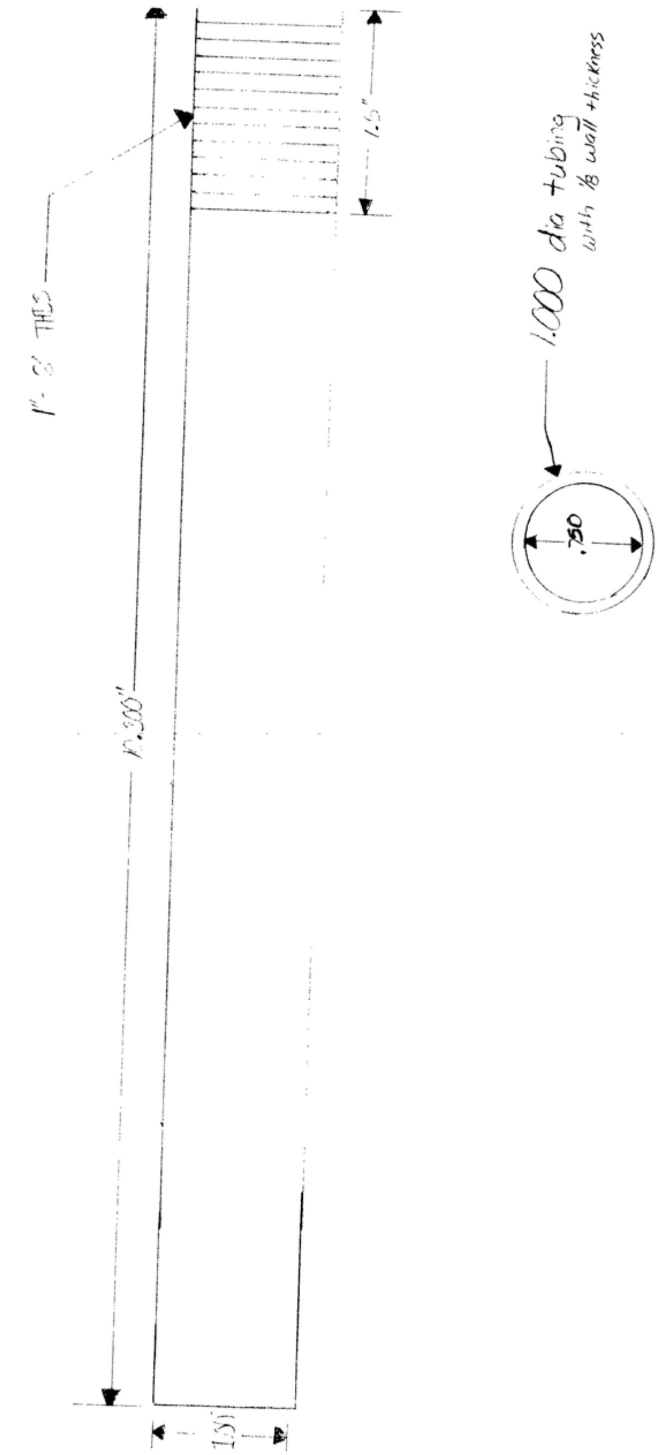
Below are some of the drawings made during the creation of the tooling.

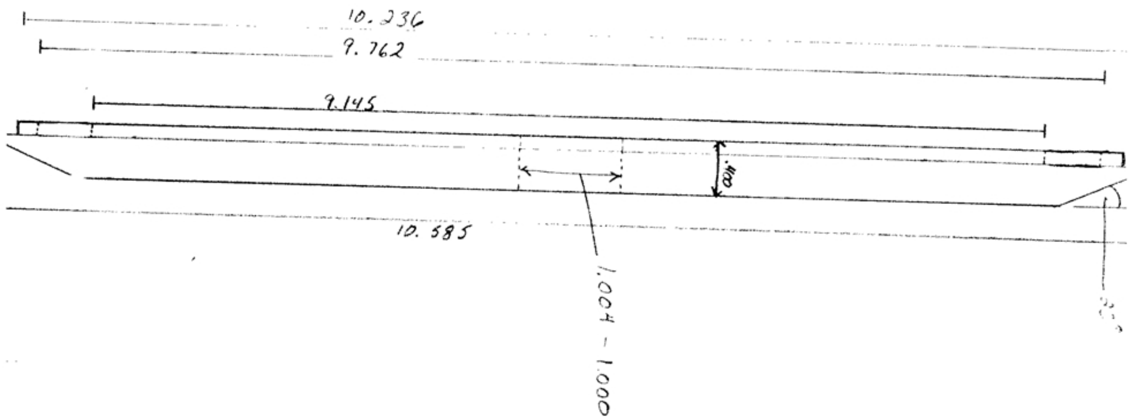



10.585
10.236
9.762



.750
.250
.375
5.625
1.000
4.825


17.300"
1.5"
.750
1.000 dia tubing
with 1/8 wall thickness


10.236
9.762
9.145
10.585
1.004 - 1.000

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