
Thermodynamics Demonstration Unit 1B
Power Generating Turbojet Engine

# HARDWARE REVIEW # 1

EGR 486C-01

Erich Gemballa: Manager; Print and Power Lead
Gavin Geiger: Treasurer; Casing Lead
Hamad Almutairi: Secretary; Heat Exchanger Lead
Abdullah Abdulghafour: Editor; Pressure Lead

Client: David Willy

Professor: Dr. Sarah Oman
Teaching Assistant: Amy Swartz

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# 1.0 Introduction

The purpose of this report is to illustrate the progress the team has completed for the summer semester of Capstone. A parametric CAD model has been completed and is in the process of iterations for the Turbine & Compressor stages. The compressor stage operates with decreasing area and increasing the area to maximize the heat transfer in the heat exchanger. Following the heat exchanger, the turbine section is designed to steal as much kinetic energy possible from the working fluid (air) to convert into rotational energy. In between each turbine section is a stator blade with the purpose of redirecting the air flow to flow more efficiently through the turbine section.

The casing was CAD designed and will be 3D printed in order to be adjusted accordingly to the blade designs. The casing will have a decreasing cross sectional area with a step design around the compressor blades to help compress the air. According to the current design, there will be an open section in the casing around the heat exchanger to prevent melting and deformations in the plastic. The casing will continue around the turbine section and will have an increasing cross sectional area. The two seperate sections of the casing will be anchored together with metal bolts to maintain structural integrity of the system.

The shaft is designed to extend passed the end of the casing and into a brushless DC generator in order to produce electricity. The purpose of the generator is to convert the rotational energy of the shaft into usable electrical energy. The generator will be connected to a LED light strip to demonstrate the physical process of work output. This project will demonstrate each individual stage of a Brayton cycle to a thermodynamic class.

# 2.0 Meeting Minutes of Hardware Review # 1

During every meeting, notes are taken by Erich and later transposed by Hamad into meeting minutes. The process of two team members going through the notes, allows communication to not be hindered. The meeting of June 19, 2018 was a hardware review staff meeting to discuss the overall completion of the project. Having not met the 50% requirement for the hardware review #1, meant an increase in work tasks to all members to guarantee completion of project.

# MEETING AGENDA

**Thermodynamics Demo Unit 1B**
**Topic: Hardware Review #1**

**Wednesday, June 19, 2018**
**~11:00 - 11:15 am**

Meeting called by: Dr. Sara Oman

**Attendees:**
**Erich Gemballa**
**Gavin Geiger**
**Hamad Almutairi**
**Abdullah Abdulghafour**

| | | |
|---|---|---|
| **Purpose of Meeting** | To discuss the progress of the project. Must be able to demonstrate project completion of 50% | EGR 220 |
| **Meeting Summary** | **Topic**<br>Estimated completion: 40%<br>Methods for printing prototypes -<br>1/4th or 1/8th of blade<br>Research SICCS building 3D printers<br>Acetone bath in RapidLab?<br>Address issues of blade thickness and print resolution<br>Material Casing-<br>Locate business that can assist in manufacturing<br>Resources in town & alternatives to manufacturing<br>Ball Bearings -<br>Inquire about Fastenal office in town regarding radial ball bearings<br>Automotive shops for radial ball bearings | |
| **Weekly Agenda** | **Next Week Agenda:**<br>Arrange meeting with professor Willy for heating and pressure operations<br>Complete casing research and design finalized<br>Print out prototypes and iterate accordingly | |

Figure 1: Hardware Review # 1 Meeting Minutes

## 3.0 Tasks and Future Planning

Following the hardware review staff meeting, it was determined that the team is not currently at 50% project completion. The work breakdown structure was altered to illustrate the tasks assigned to each team member, their current progress, and the final steps to conclude their responsible sub tasks. Tasks in progress must be completed by Thursday June 28, 2018. Currently the team is 35% completed by having the turbine and compressor staging printing in progress. By the end of June 28, the team will be at a project completion of 62%. All tasks, responsibilities, and due dates are all shown in the Work Breakdown Structure (WBS) in the appendix.

Table 1: Tasks with Future Planning

| Tasks for Team Members | Task Completed | Tasks in Progress | Tasks to Complete |
|---|---|---|---|
| 3D Print (Erich) | Ball Bearing Casing Designed CAD | Printing (3) Turbine Staging | Print Stator Sections including Ball Bearing Casing |
| | CAD update | Printing (6) Compressor Staging | Print Structural Support for Compressor Section |
| | Keyed Shaft purchased | | |
| Casing (Gavin) | Case Shape designed | Business research for how to manufacture casing | Purchase Cart |
| | Material Selected | | Manufacture Case |
| Heating System (Hamad) | Heat Band purchased | Purchase Thermal Fuse | Wire and Display Housing |
| | | Connect Thermal Fuse to heat band | Temperature Control |
| | | Design how to plug heat band into wall safely | Sensors & Data acquisition |
| Pressure System (Abdullah) | Pressure Transducer purchased | p-V & T-s diagram for power output ranging from 50 - 100 Watt | UI Selection for display and operation |
| | | Instructions and complete understanding for how to operate pressure transducer | Sensors & Data acquisition |
| Work Output System (Erich) | LED strip purchased | Purchase brushless DC motor | LED Display |
| | | Connection design from shaft to motor | Sensors & Data acquisition |

# 4.0 Work Breakdown Structure (WBS)

Working within a timeframe of ten weeks requires a schedule that allows for flexibility while focusing on the most efficient path of completion. The WBS that has been developed for the summer semester shows how tasks are related to each other, allowing for the planning that works best to make the project run with the least amount of errors and waste. Currently the team is 35% complete, the WBS shows the projected dates for 62% project completion. A working WBS is located in the appendix of the report.

# 5.0 Updated CAD

An updated CAD model of the project has been developed, as shown in figure X. The updated model includes the heating band as well as the heat sink that will be utilized to maximize heat transfer to the fluid into the turbine staging. Currently, the first iteration of the turbine staging has been printed as shown in Figure X. CAD drawings have been provided for every compressor and turbine staging in the appendix. To follow regulation and operations for the Rapid Lab located at the Northern Arizona University campus, all iterations for printing must include a drawing package along with updated drawings illustrating edits. Drawings have been labeled with the system SX.X to allow for quick inspection of which iteration and design is applied to the specific staging.

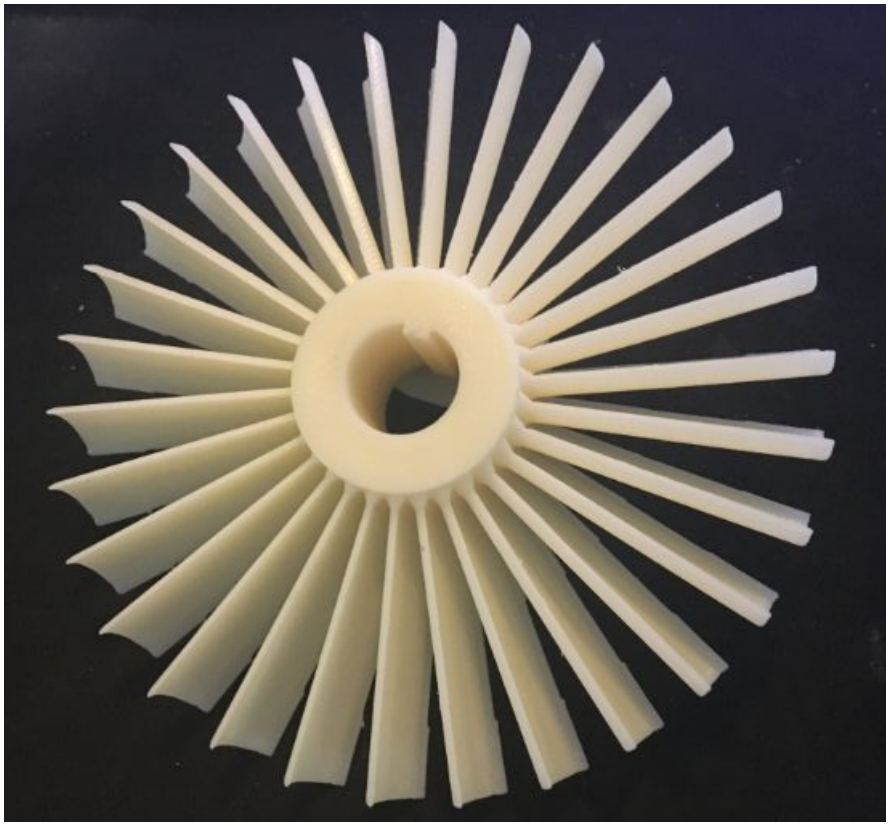

Figure 2: Turbine S1.0 Print Prototype

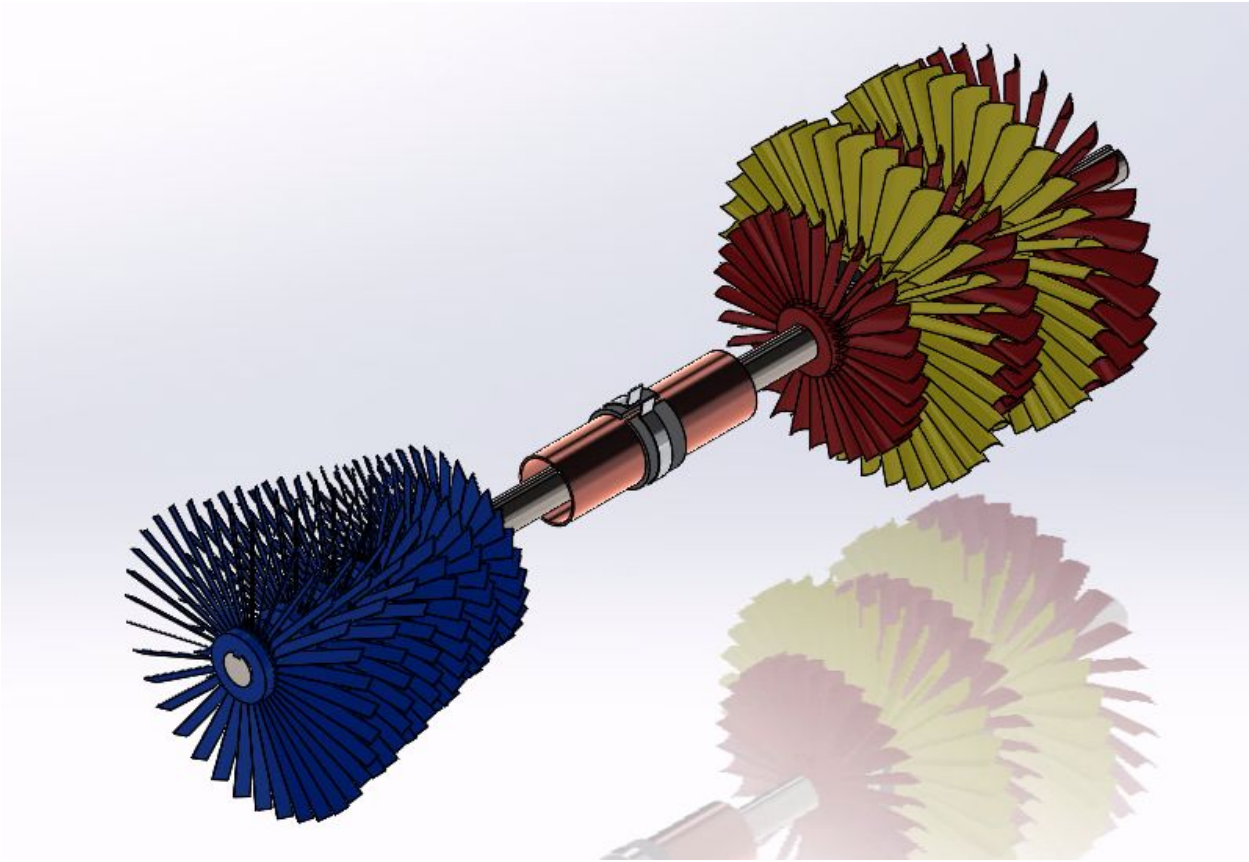

Figure 3: Isometric view of power generating brayton cycle

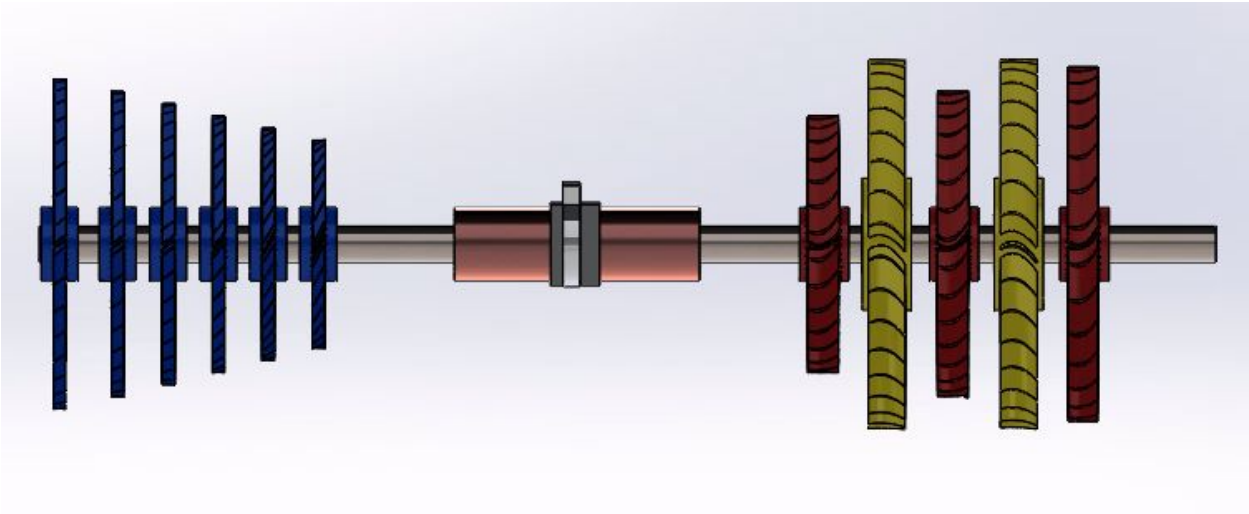

Figure 4: Side view of power generating brayton cycle

Stator staging have been designed for connection with the keyed shaft, as well as bonded with a radial ball bearing. The complete stator staging is incomplete as of now, it is missing the outer casing that allows interlocking of the stators containing the turbine staging.

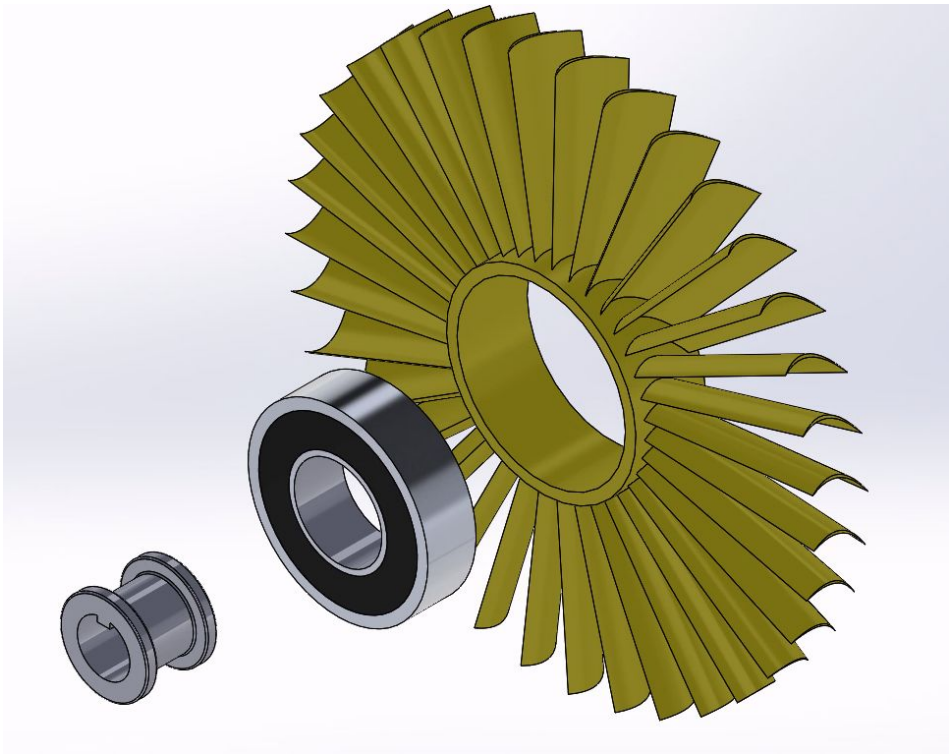

Figure 5: Ball Bearing casing with radial ball bearing and stator staging

Design will continue for the compressor and turbine stages throughout the duration of the project. To minimize waste, proper inspections of printed prototypes are underway to reflect an educated estimate towards a more efficient design.

# 6.0 Budget

A working budget has been created to manage purchases as well as determine a bill of materials. The working bill of materials contains all blue forms, as well as info regarding the actual cost amount. Both the working bill of materials and current budget have been cross referenced to ensure no errors.

| To Buy | | | | | $331.02 | | $82.76 | | |
|---|---|---|---|---|---|---|---|---|---|
| Description | Part | Part # | Quantity | Location | Cost | Purchased (Y/N) | Actual Cost (with tax) | Blue Form | INFO |
| Shaft | 3/4" - 24" Shaft K | 1570K63 | 1 | https://www.mcm | $47.40 | Y | $41.68 | | 12" is $25.38, 24" is $47.40 |
| Shaft | | 1497K31 | | https://www.mcmaster.com/#1497K31 | | | | | DECIDING TO PURCHASE |
| LED Strip | 1ft RGB LED | | 1 | https://www.solid | $14.00 | Y | | | |
| Air Compressor | PowerSmart 4 ga | PS60 | 1 | https://www.ama | $74.67 | N | | | |
| Generator | | | | | | | | | |
| Ball Bearings | 1.25" Ball Bearing | | 4 | https://www.grair | $14.15 | | | | |
| Heating Band | Tempco Heating | NHL00100 | | https://www.grair | $28.50 | Y | $41.08 | | |
| Heating band | | | | https://www.grair | $32.30 | N | | | UPDATED DIAMETER 1-1/2" |
| Thermal Switch | | | | | | | | | |
| Pressure acquistition | | | | | | | | | |
| Acryllic | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| Printed Parts | | | | | | | | | |
| | Turbine 1 | | 1 | Rapid Lab | $10.00 | | $0.00 | | |
| | Turbine 2 | | 1 | Rapid Lab | $10.00 | | $0.00 | | |
| | Turbine 3 | | 1 | Rapid Lab | $10.00 | | $0.00 | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | Compressor 1 | | 1 | Rapid Lab | $10.00 | | $0.00 | | |
| | Compressor 2 | | 1 | Rapid Lab | $10.00 | | $0.00 | | |
| | Compressor 3 | | 1 | Rapid Lab | $10.00 | | $0.00 | | |
| | Compressor 4 | | 1 | Rapid Lab | $10.00 | | $0.00 | | |
| | Compressor 5 | | 1 | Rapid Lab | $10.00 | | $0.00 | | |
| | Compressor 6 | | 1 | Rapid Lab | $10.00 | | $0.00 | | |
| | | | | | | | | | |
| | Stator 1 | | 1 | Rapid Lab | $10.00 | | $0.00 | | |
| | Stator 2 | | 1 | Rapid Lab | $10.00 | | $0.00 | | |
| | Stator 3 | | 1 | Rapid Lab | $10.00 | | $0.00 | | |
| | | | | | | | | | |
| | | | | | | | | | |

Figure 6: Working bill of materials

| Material | Cost per Unit | Estimated Amount | Manufacturer/Vendor | Part Number | Cost Before Tax | Actual cost w/ tax | Purchased |
|---|---|---|---|---|---|---|---|
| LED Light Strip | $14.00 | 1 | SolidApollo.com | SA-LS-RGB-5050-180-24V-1F | $14.00 | $15.00 | Yes |
| LED Wiring | $1 | 2 | Superbrightleds.com | 24AWG | $2.00 | | No |
| Air Compressor w/ 6 Gal Tank | $89 | 1 | CPOoutlets.com | PCBRC2002R | $89.00 | | No |
| PVC Pressure Regulator | $5 | 2 | Apollo/Home Depot | THDCOM103 | $10.00 | | No |
| DC Generator | $20 | 1 | Pacific Sky Power/Amazon.com | B01KMZQT1Q | $20.00 | | No |
| Band Heater | $28.50 | 1 | TEMPCO/grainger.com | NHL00100 | $28.50 | $41.08 | Yes |
| Tubing and Connections | $20 | 1 | Home Depot | 530048 | $20.00 | | No |
| 3/4" Aluminum Shaft | $47.50 | 1 | McMaster-Carr.com | 1497K31 | $47.50 | $41.68 | Yes |
| J Type Thermocouples | $4 | 2 | NAU | 1980-024 | Provided | | Provided |
| Pressure Gauges | $7.50 | 2 | PneumaticPlus.com | PSB15-160 | $15.00 | | No |
| Pressure Transducer | $49.00 | 2 | Tranducers Direct | TDH30BG025003B004 | $98.00 | $100.00 | Yes |
| Ball Bearings | $4 | 3 | VXB/VXB.com | 608ZZ VXB | $12.00 | | No |
| 3D Prints | $10 | 12 | Rapid Lab/Cline Library | | $120.00 | $0.00 | Continuous |
| | | | | **Estimated Total:** | $476.00 | $197.76 | |

Figure 7: Current Budget

The figure above shows the team's current budget of materials. There are two estimate totals, one is the online price of the materials before tax and shipping is applied and the other is the total cost of the material after tax and shipping is added in. Additionally, a purchased column is shown to show if the team has purchased the item or not.

# 7.0 Conclusion

Progress for the project has been slow for the start of the summer semester. As purchases begin to accumulate and printing is underway, percent completion will drastically increase in the following week. To minimize errors for the project, parametric designs for CAD have been implemented for the quick alterations required in the design process. Although the team is currently behind for the 50% completion mark for Hardware Review #1, all the tasks required for 62% are currently underway and will be completed by June 28, 2018.

# 8.0 Appendix

## 8.1 Turbine Staging S1.0 Drawings

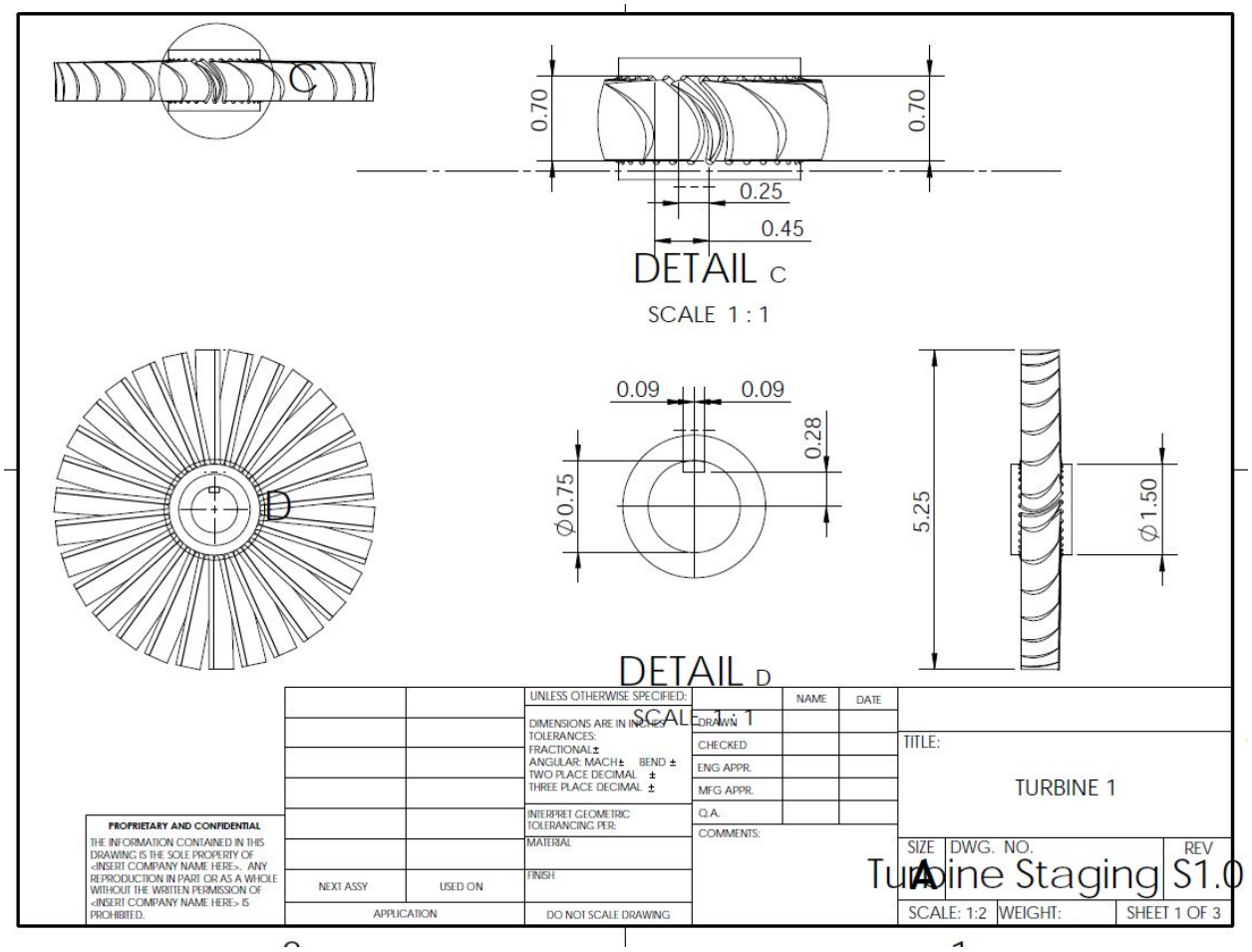


Figure 7: Turbine 1 S1.0

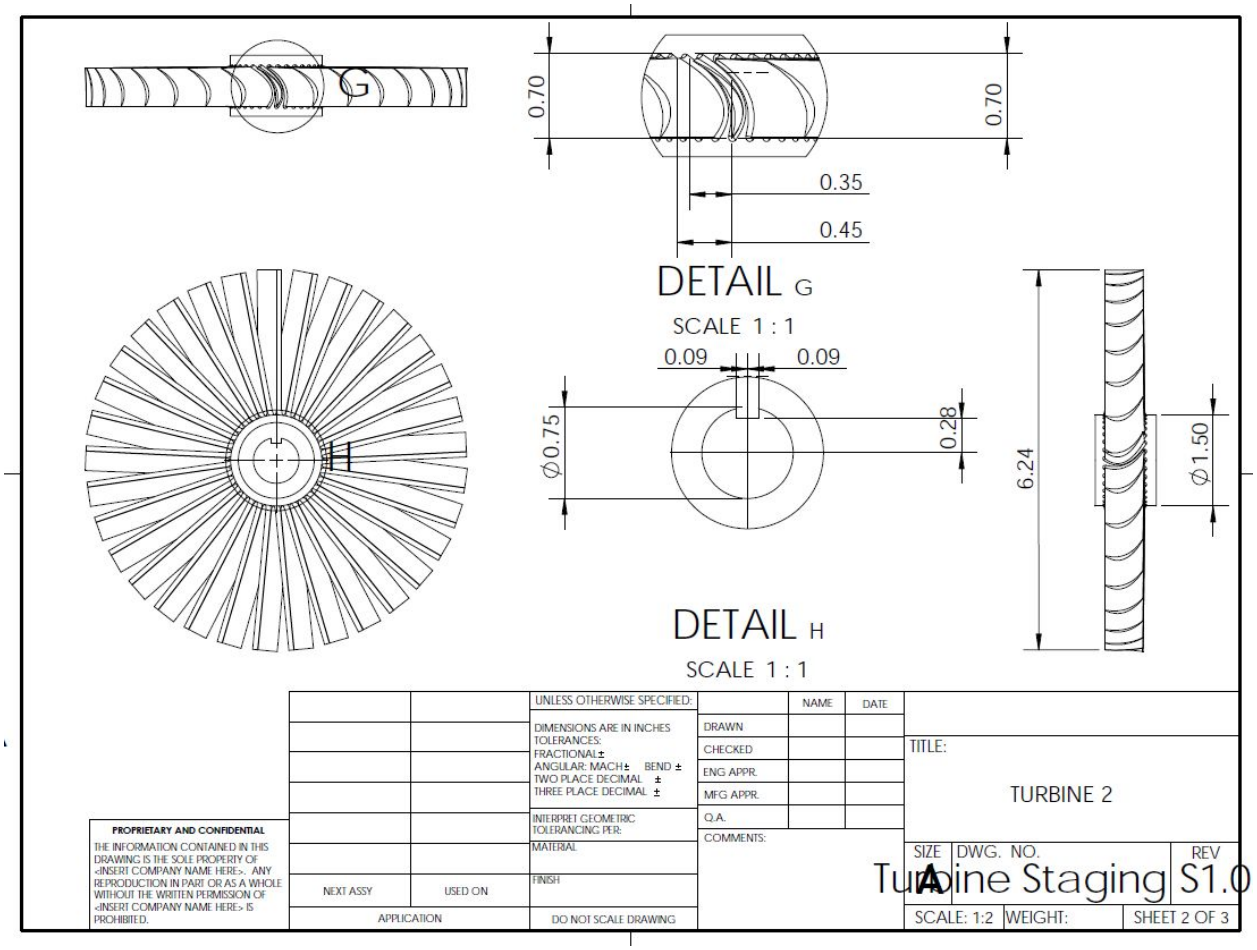


Figure 8: Turbine 2 S1.0

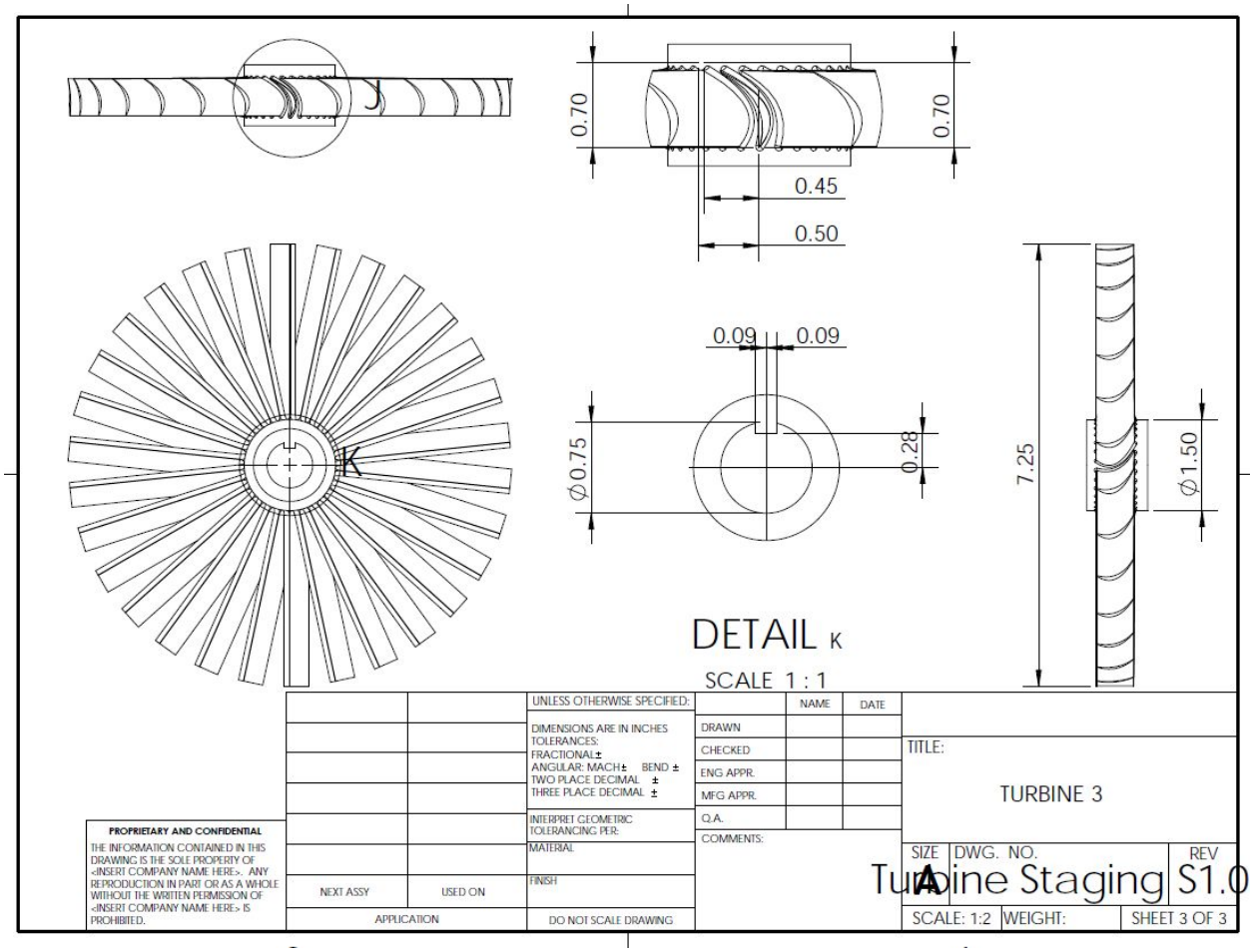


Figure 9: Turbine 3 S1.0

## 8.2 Compressor Staging S1.0 Drawings

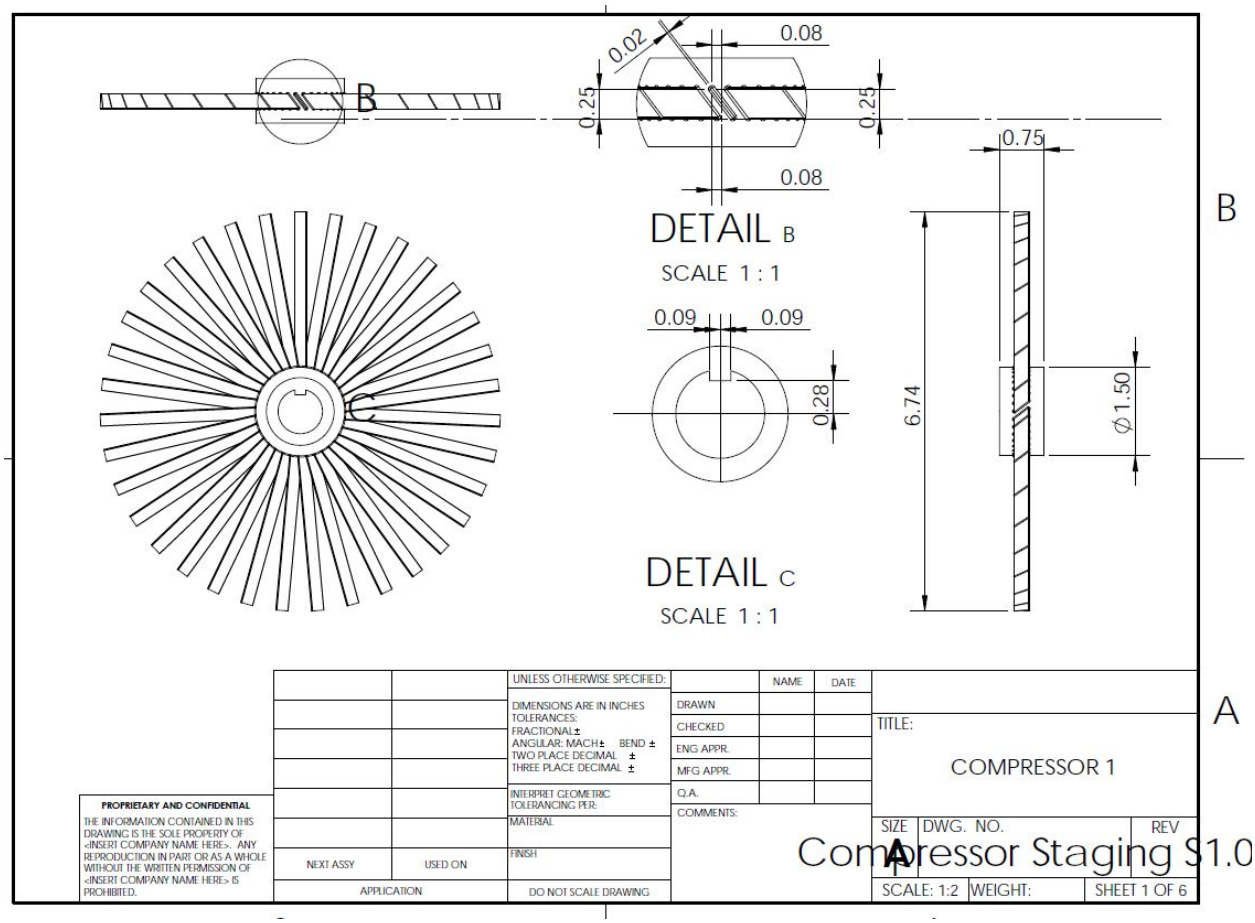


Figure 10: Compressor 1 S1.0

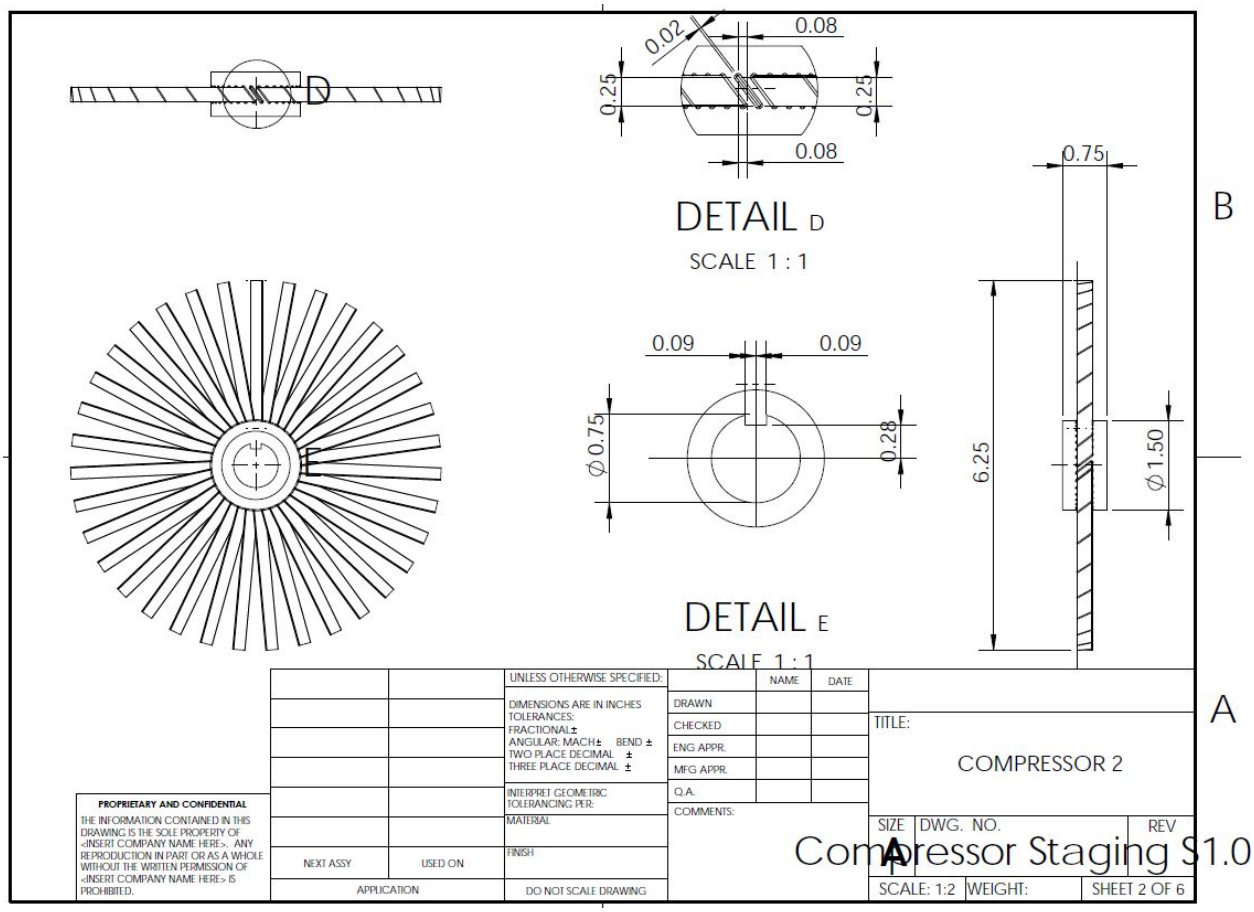


Figure 11: Compressor 2 S1.0

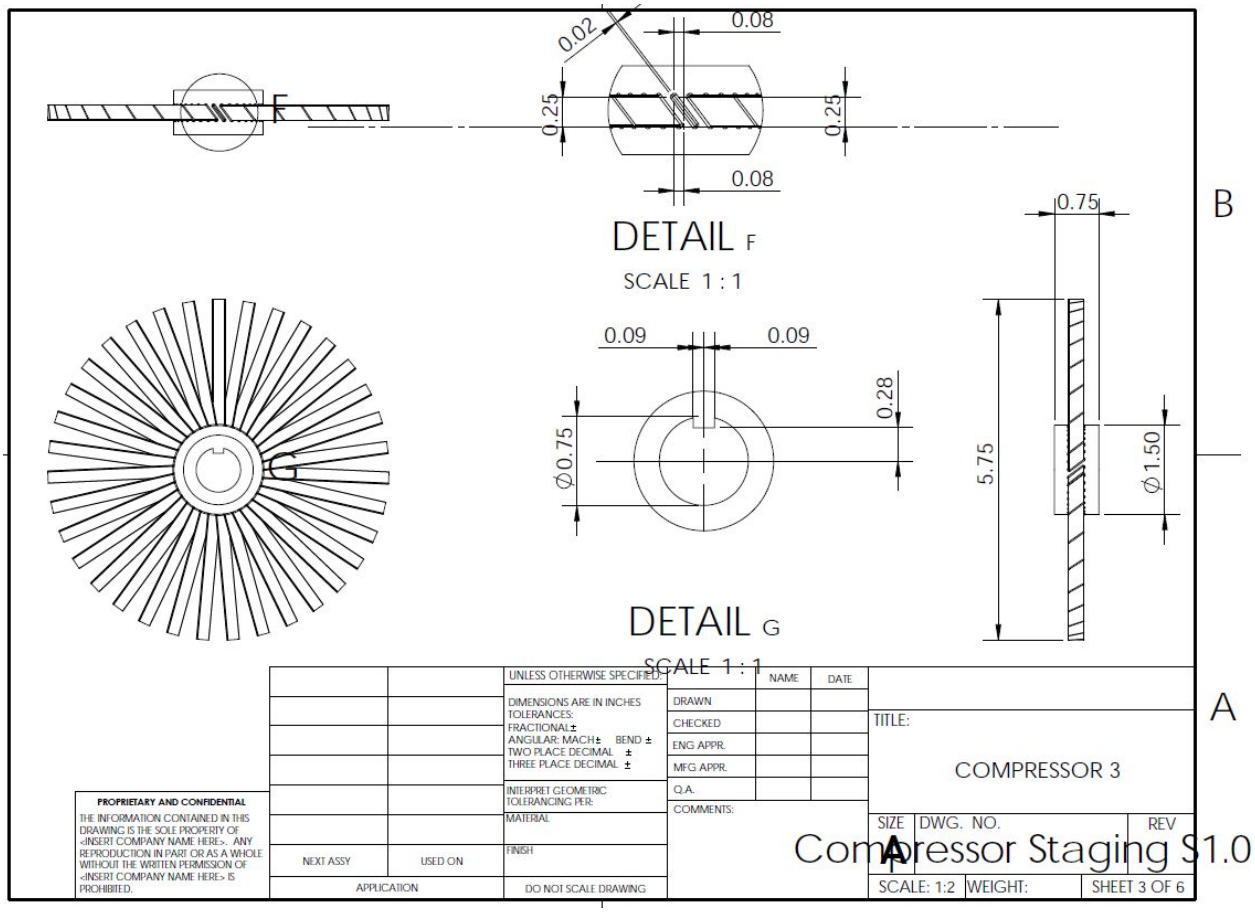


Figure 12: Compressor 3 S1.0

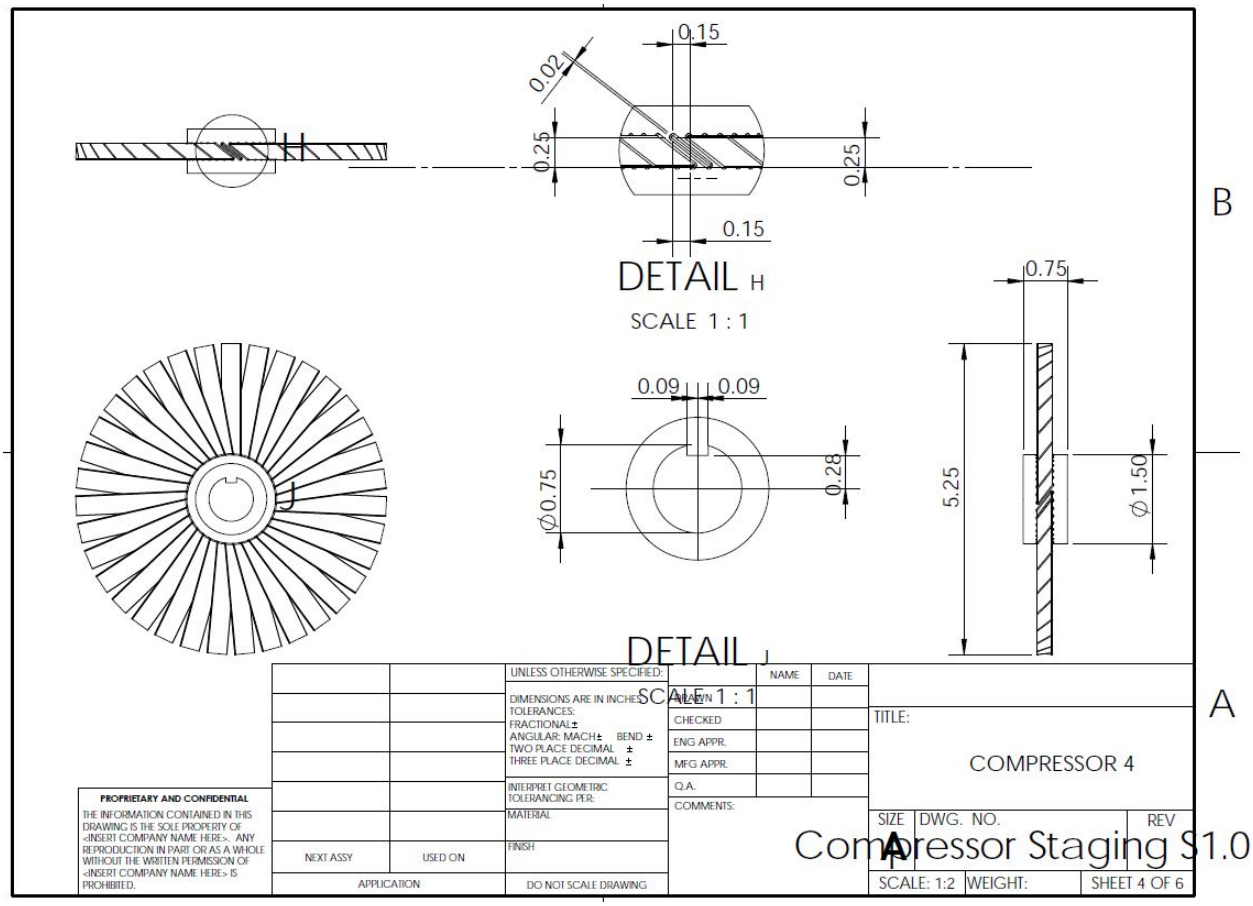


Figure 13: Compressor 4 S1.0

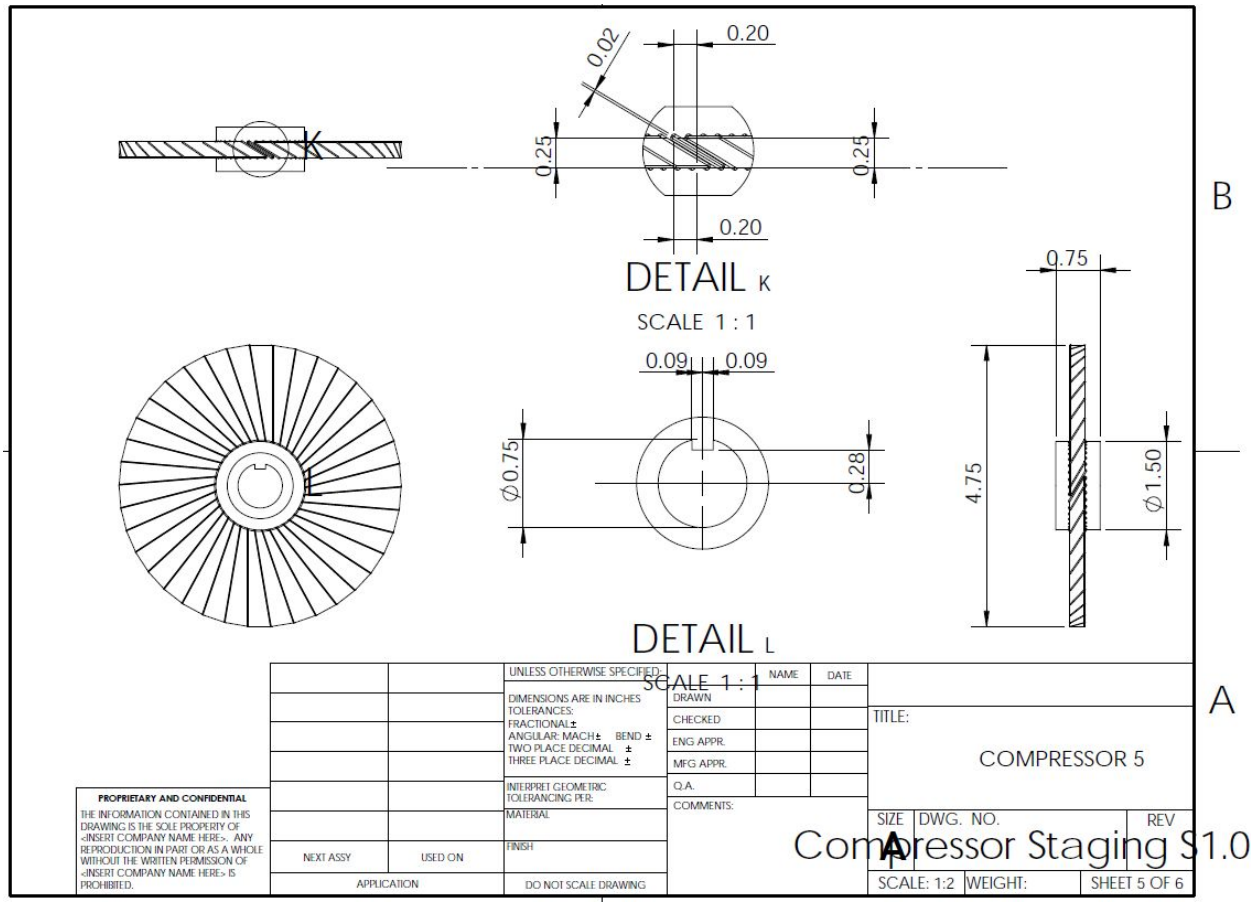


Figure 14: Compressor 5 S1.0

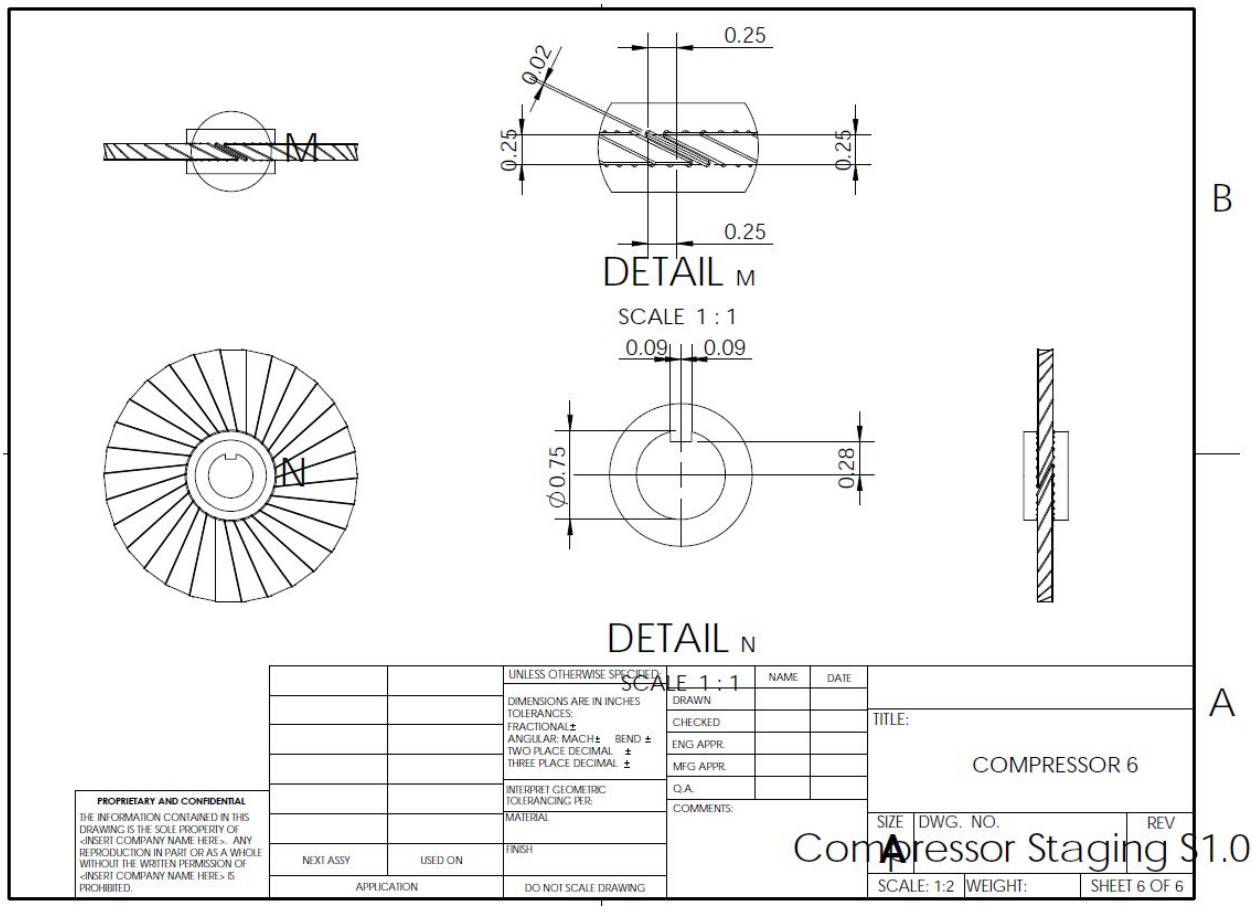


Figure 15: Compressor 6 S1.0

## 8.3 WBS

Table 2: WBS