46mm End Cap: Cost Savings

A Baccalaureate thesis submitted to the
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Bachelor of Science

in Mechanical Engineering Technology

by

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Thesis Advisor:

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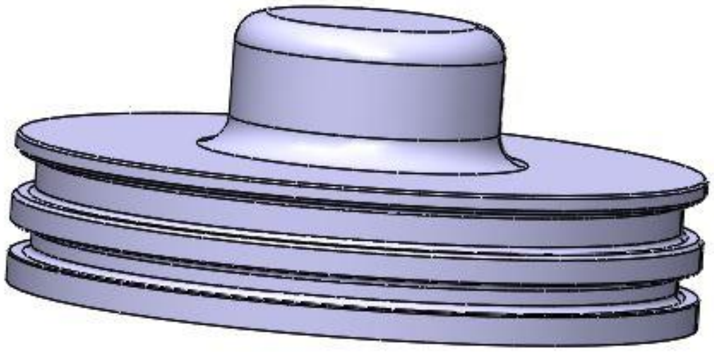


Figure 1

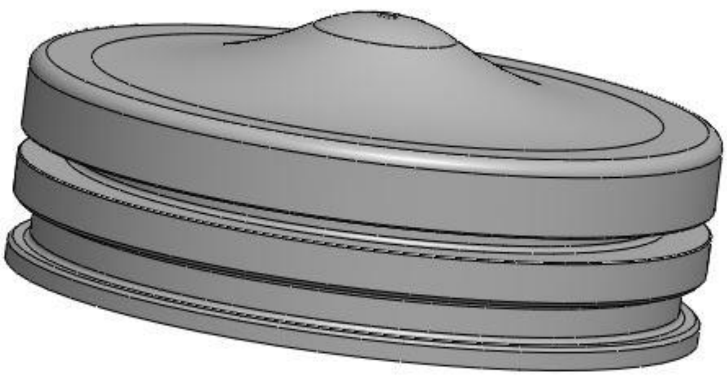


Figure 2

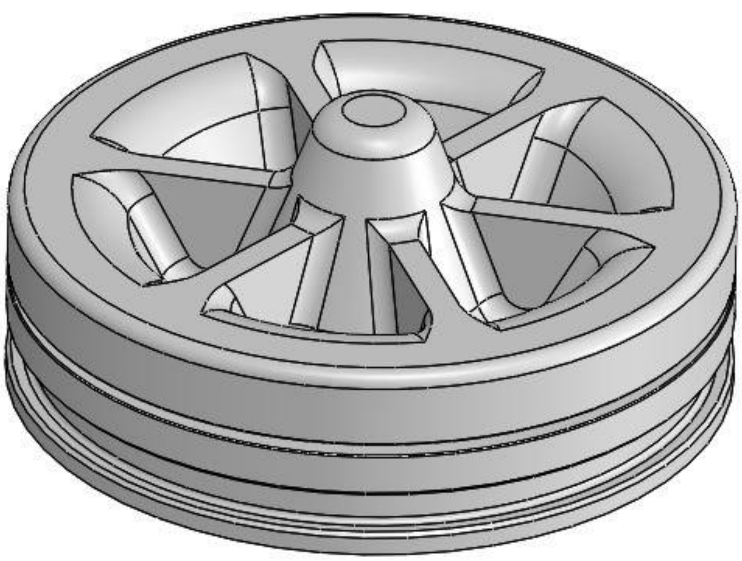


Figure 3

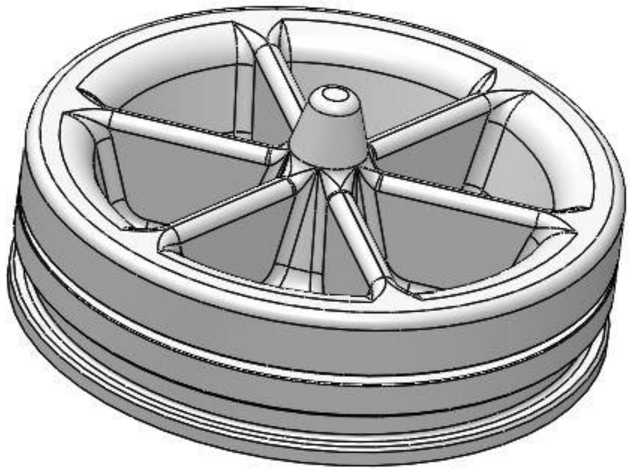


Figure 4

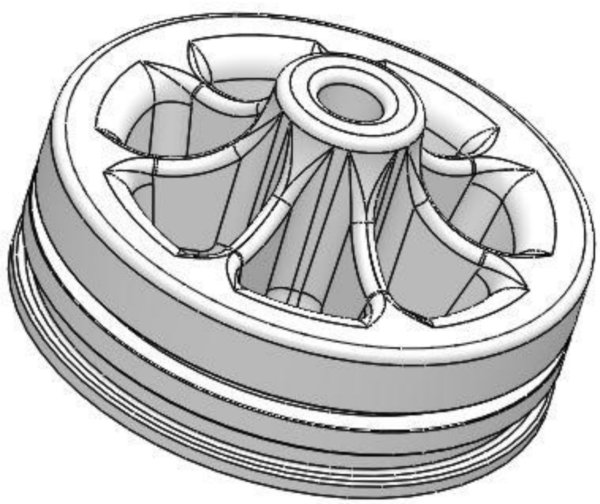


Figure 5

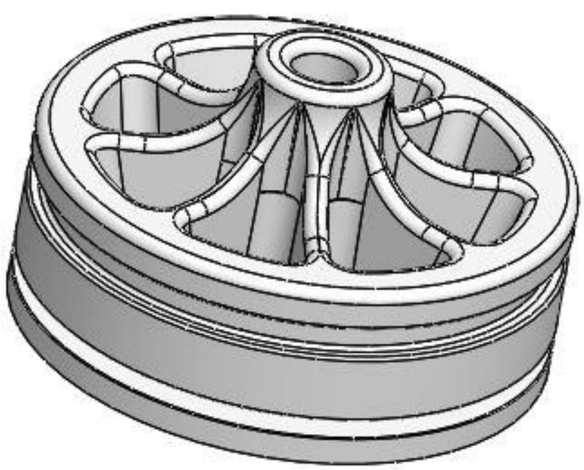


Figure 6

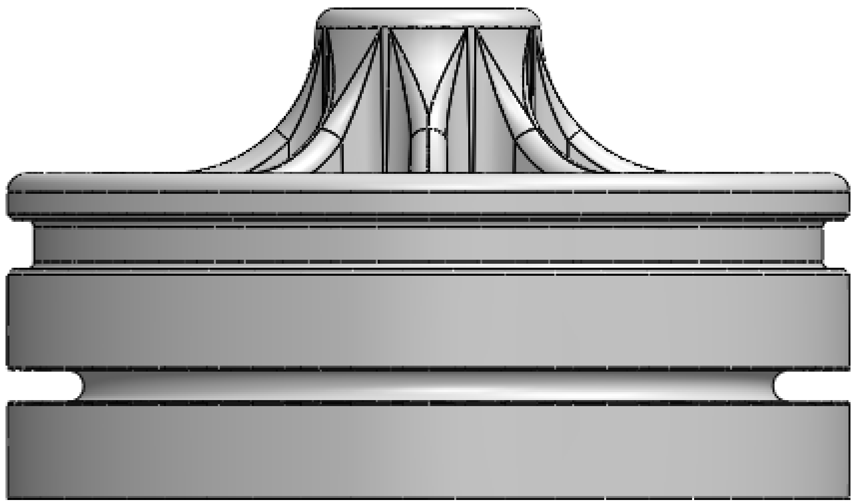
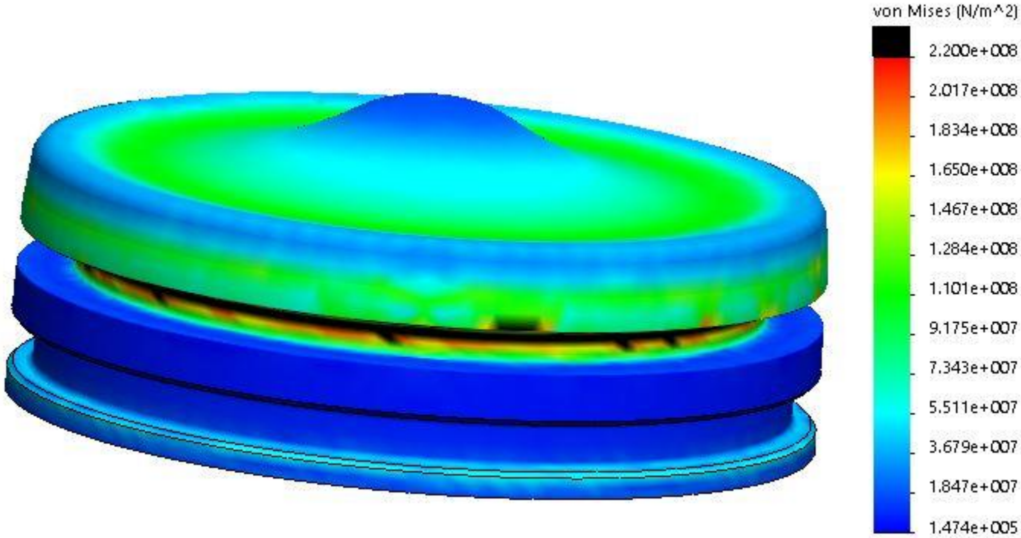
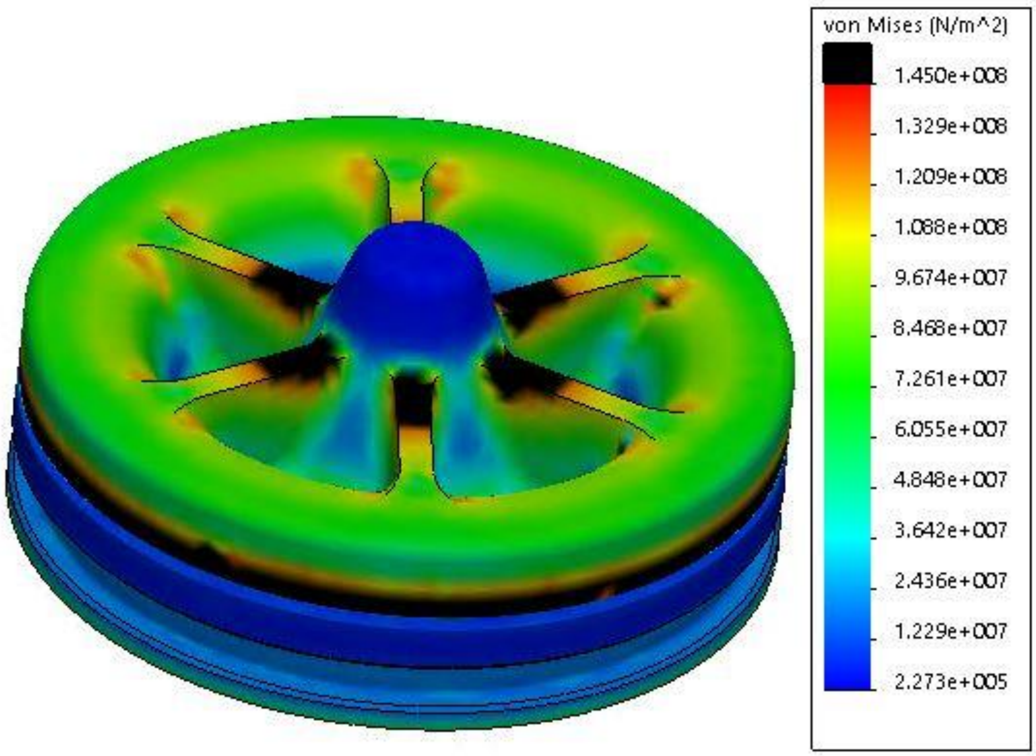


Figure 7

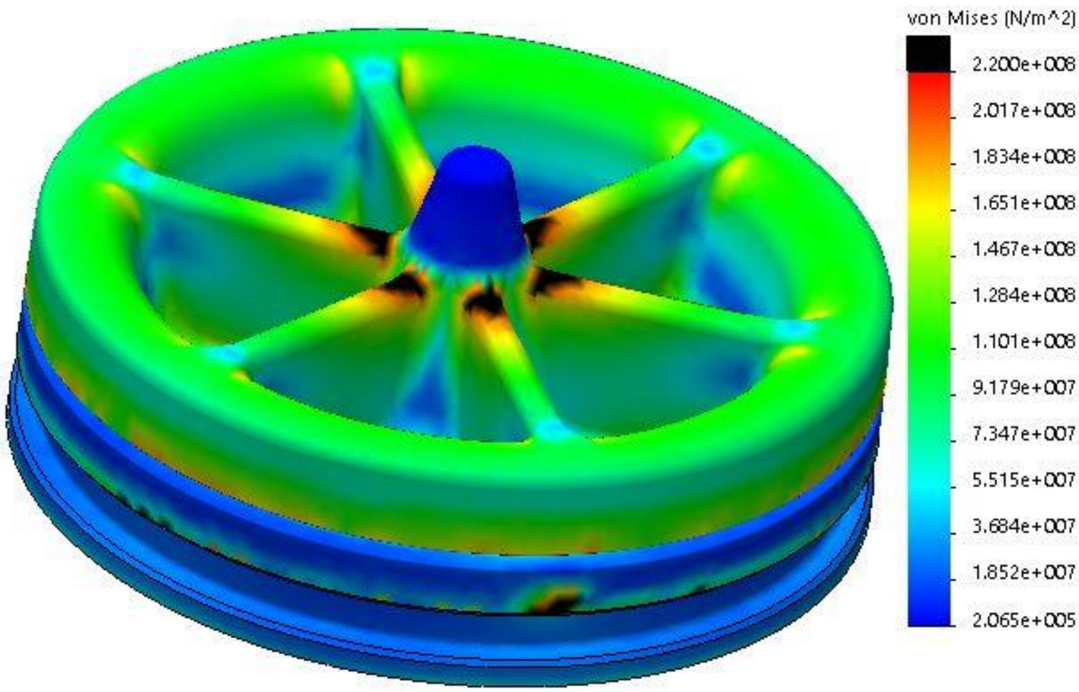
LIST OF FEA (FINITE ELEMENT ANALYSIS)



FEA 1



FEA 2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1.651e+008
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1.284e+008
1.101e+008
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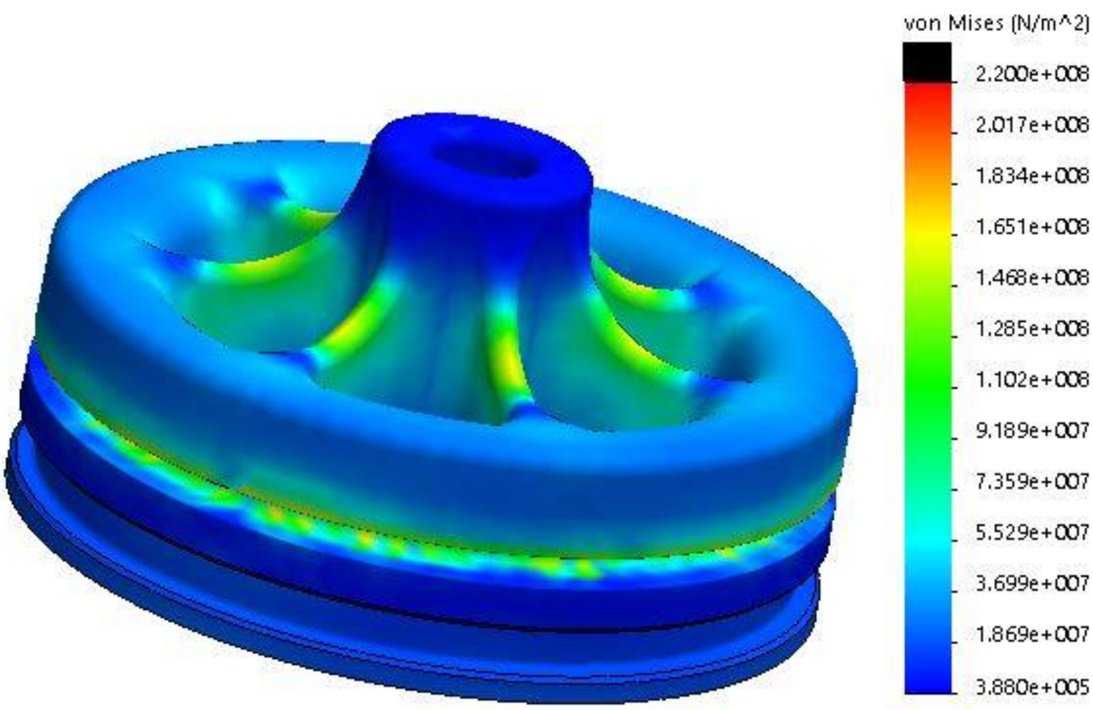
FEA 3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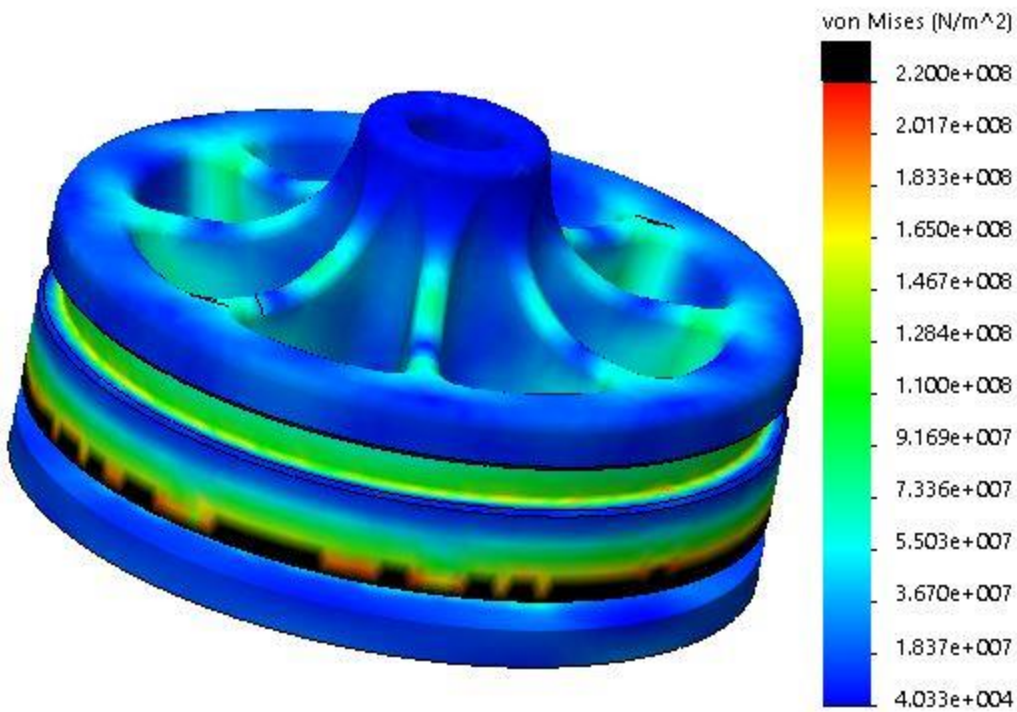
FEA 4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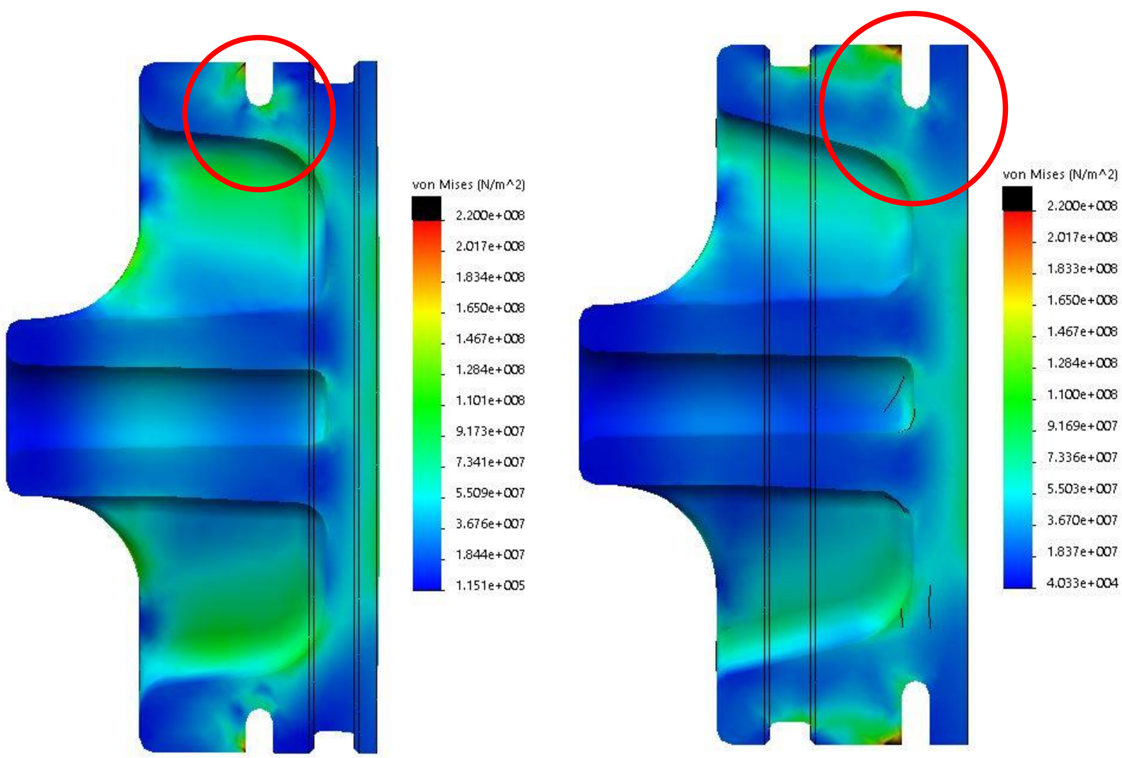
FEA 5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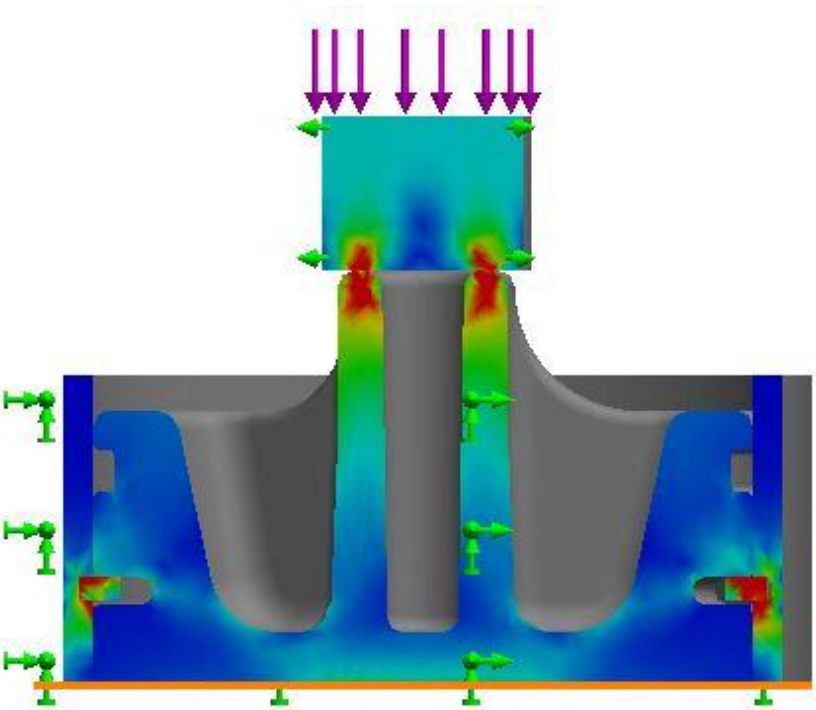
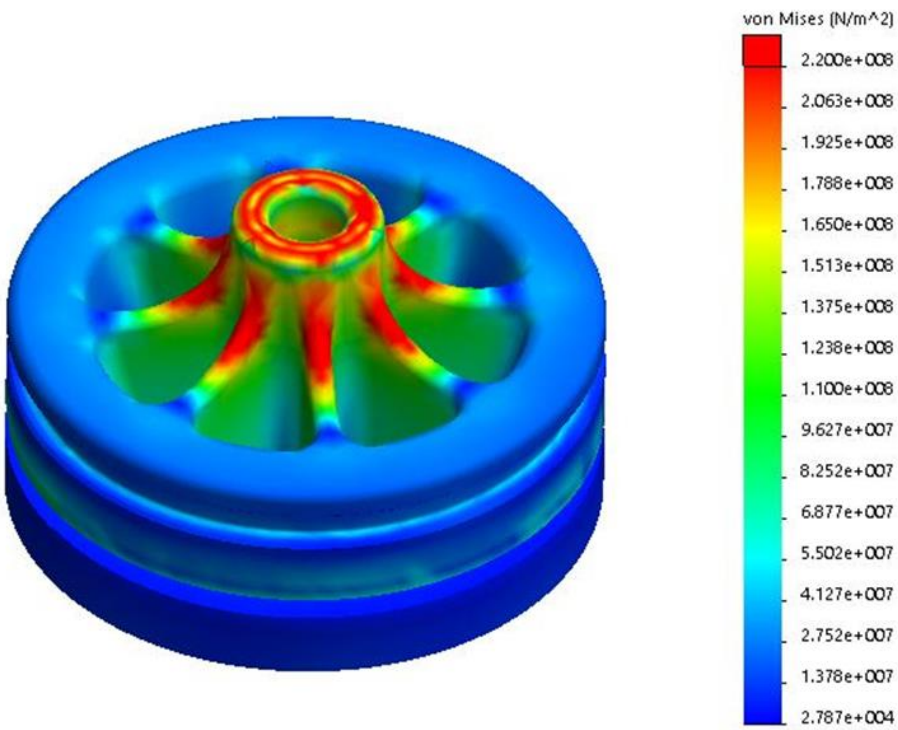
FEA 6



FEA 7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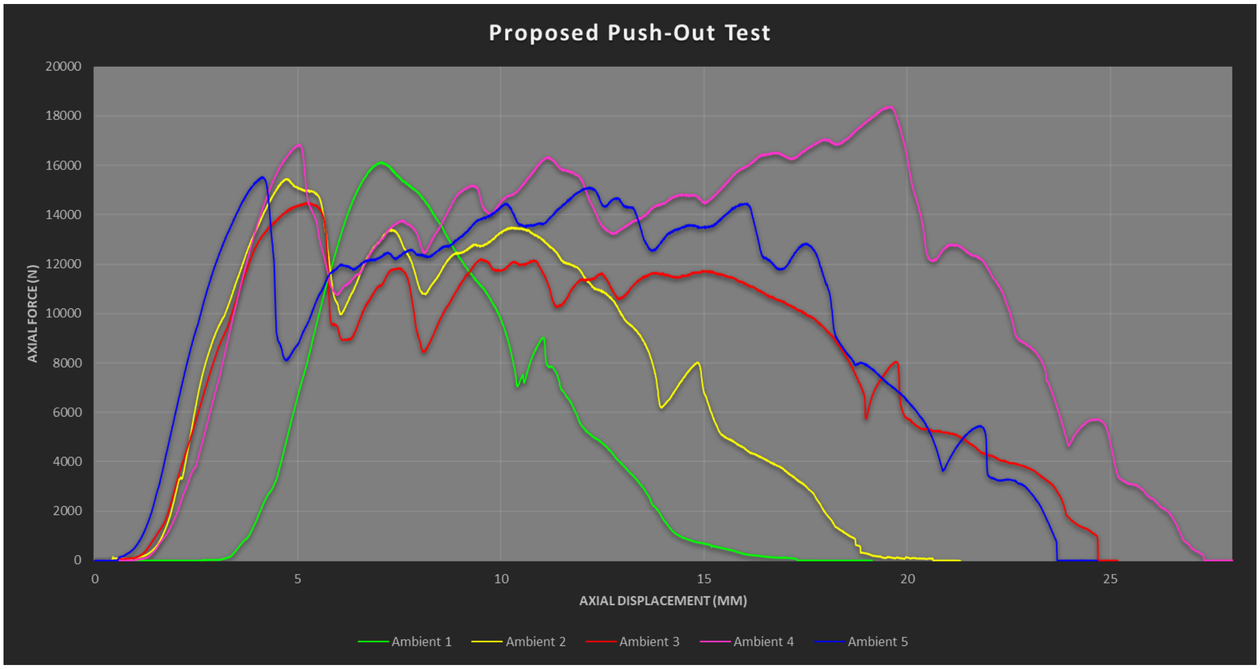
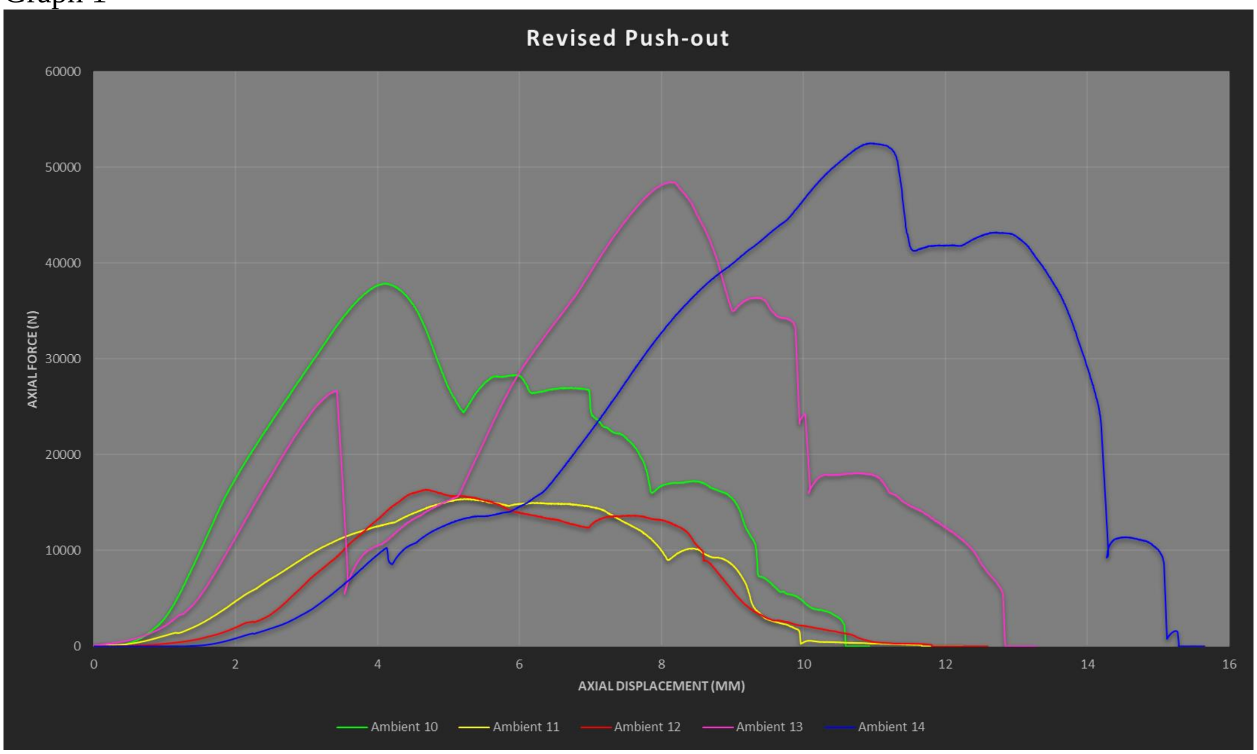
9.627e+007
8.252e+007
6.877e+007
5.502e+007
4.127e+007
2.752e+007
1.378e+007
2.787e+004

FEA 8

AXIAL PUSH OUT GRAPHS



Graph 1



Graph 2

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

At Bilstein, we use a lot of components that are machined from heavy steels or billet aluminum. Two components that are quite expensive are external reservoirs end caps and seal package housings. Both of these components are extremely critical in the sealing characteristics of the damper. The reservoir end cap is used to keep pressurized oil from leaking out while the seal package is made to allow the piston rod to slide in and out while keeping dirt out and providing an adequate oil seal. If these components can be made through injection molding instead of CNC machined parts, we could potentially save 100’s of thousands of dollars each year.

BACKGROUND

In the past, there has been some research to try and move to a hybrid endcap, hybrid being a part that is mostly plastic with some metal support. (1) The research didn’t progress much further than initial concepts and I am looking to pick up from there. It would be preferred if the part could be manufactured as a single piece that is made entirely of plastic although a hybrid design is still an option.

Whichever path this project pursues, the part will still need to hold up to extreme durability testing to ensure proper function and reliability. Some of the more demanding tests that this part will experience are; test lab durability, on-vehicle durability, leak testing, and DOT testing.

The test lab durability test is a standard test that we do in house where the damper is mounted on a hydraulic servo machine and stroked according to a specific test profile that incorporates both high and low frequency oscillations. The on-vehicle durability test is done at the customer proving grounds where the damper is fitted on a vehicle and tested across many different driving conditions, many of which are extremely harsh. Both of the durability tests will provide alternating loading to this part due to the internal pressure changes of the damper. This means the part will need to have good fatigue strength if it is to stay intact throughout the life of the vehicle.

Leak testing and DOT testing are both forms of thermal testing where the damper is heated/cooled to specific temperatures and evaluated. The leak test is done to ensure the damper does not leak gas or oil at extreme temperatures and maintains consistent performance curves pre and post-test. DOT testing is something we need to pass in order to ship our products as non-hazardous. This test requires that no part of the damper becomes a projectile when heated to extreme temperatures. This is specifically crucial to this part since its main job is to contain both gas and oil under all exposed conditions.

RESEARCH

SCOPE OF THE PROBLEM

In the automotive world, OEMs are starting to design more optimal suspension geometries to gain more travel and clearance with the same or similar packaging. From a shock absorber stand point, this means they are wanting the most amount of damper travel within a space that is already too tight. The way to achieve this level of travel is to design the damper with an external reservoir to limit the dead space at the end of travel.

Every damper that uses an external reservoir also needs a reservoir endcap and currently, these endcaps cost $0.98 apiece. With many of the projects requiring this component and the average monthly demand being 13,050 pieces, we are spending about $153,468 on these components. If the per piece price of each cap could get reduced to $0.34, Bilstein could save $100,224 per year. (2)

CURRENT STATE OF THE ART

Currently this component is being made of SAE 12L14 and like stated before, costs $0.98 to manufacture. (2) There are some concept ideas to reduce cost although they haven't been prototyped and all involve a two piece design.

After doing some ultimate tensile testing of the current design, the parts maintained a consistent push off force of 30-35kN with one outlier holding to 45kN. (3) The current test spec states the required push off needs to be at least 20kN. The new design will be held to a target of 35kN.

The current crimp design is also showing to be a possible weak point. The current reservoir crimp is slightly different from crimps used in other parts of the plant and I intend to design the new parts using an existing but different crimp than the current design.

END USER

The end user for this project can be classified two ways, the main beneficiary of the cost savings or the end user of the product. For this project my main focus will be on the main beneficiary of this new redesign since the project is based on a cost savings.

In this case, the end user could be thyssenkrupp Bilstein or thyssenkrupp Bilstein's customers, OEMs like FCA, Ford, GM, and Tesla. If the cost of the finished product does not change, then the end user would be thyssenkrupp Bilstein, cutting the component cost in half could save Bilstein an estimated $100,000 per year based on projected sales. If the cost of the finished product is adjusted for the individual component savings, then the end user would be the OEM customer. Lastly, if the end user focuses on the actually user of the product, then the end user would be the OEM customer.

For this project, I will be using thyssenkrupp Bilstein because this will be a cost savings on the production side. Once the part has been in production and has shown good results, it can then be optimized further which will hopefully reduce costs again which can then be passed on to the OEM customers as cost savings for both parties.

CONCLUSIONS AND SUMMARY OF RESEARCH

The demand for 46mm external reservoir dampers has been increasing over the last few years and there is an opportunity for Bilstein to capitalize on a less expensive component that is common amongst many dampers. If this component can be manufactured for $0.34 as opposed to the current $0.98, Bilstein could be looking at a savings of over $100,000 per year. These numbers are based on current projected demand in 2019 and should be expected to increase as new products roll out with similar designs. (2)

CUSTOMER FEATURES

- Safety
- Performance
- Cost
- Maintains Similar Crimp Geometry
- Environmental Impact
- Ease of manufacturing

ENGINEERING CHARACTERISTICS

- 20kN push out force
- Current production crimp geometry
- Injection molding

PRODUCT OBJECTIVES

1- Redesign current production part (5)

2- Reduce cost from 95 cents to somewhere between 30 and 40 cents (5)

3- Meet all required performance test specs (4)

4- New design must be safe to handle and install (5)

5- New design must provide safe use/operation throughout life (5)

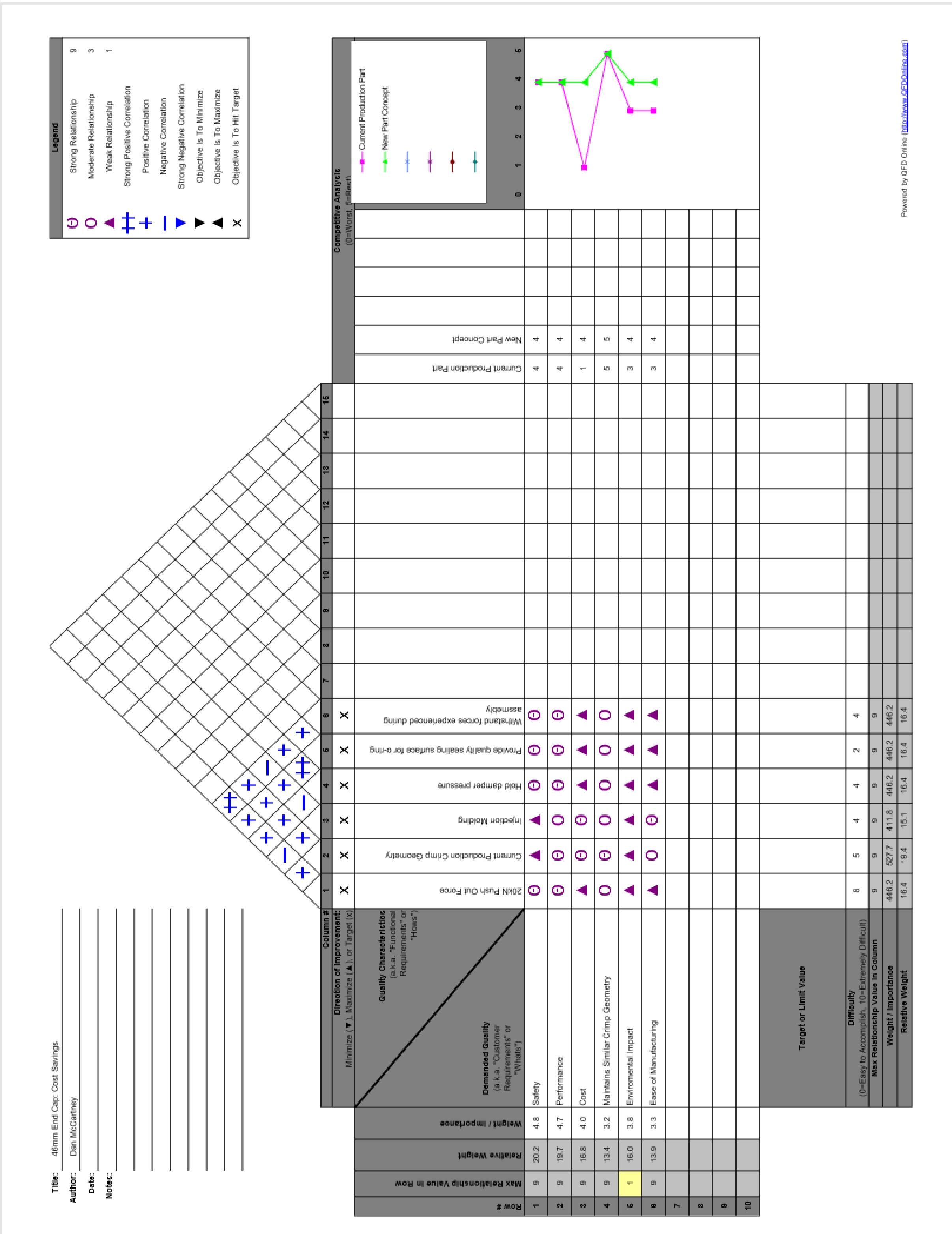
6- Design for ease of manufacturing with respect to injection molding (3)

7- Use current crimp geometry if applicable (2)

*relative weight noted in parenthesis, maximum value of 5

QUALITY FUNCTION DEPLOYMENT

HOUSE OF QUALITY



DESIGN

This design has been difficult to optimize and due to the primary objective of cost savings, the attempt to make this part entirely out of plastic was heavily pushed throughout the entire design process. This process started with a plastic part that was very similar in size and shape to the current steel part, shown in Figure 1. The only major difference at this point was the type of closure being used. The current design is crimped in place although crimping is not feasible for a plastic component unless visual defects are permissible. The new design was built around a new type of closure, that being the use of a constant section ID-OD lock snap ring. This new ring will maintain the same permanent style locking while allowing the load exerted by the pressure to distribute across a larger surface area. The ring has been designed by a supplier to ensure proper form and function. They were provided with the mating geometry constraints and the required forces which can be found below.

$$Tube\ ID\ (D) = 46mm$$
$$Cross\ Sectioanl\ Area\ (A) = \frac{pi * D^2}{4} P * A = 1661mm^2$$
$$Max\ Damper\ Design\ Pressure = 150bar$$
$$Safety\ Factor = 2$$
$$Max\ Allowable\ Pressure\ (P) = 300bar$$
$$Max\ Push\ Out\ Force\ (F) = P * A = 300bar * 1661mm^2 = 50kN$$
$$Snap\ Ring\ OD = 48mm$$
$$Snap\ Ring\ ID = 42mm$$

The initial “concept”, shown in Figure 2, was known to be an impractical design but it was used as a starting point to locate the best place to remove material. The material chosen for this was going to be PA6 or PA66 (Nylon) with glass fiber reinforcement. Assuming 6.5mm of material above the snap ring the shear strength of the material will need to be about 58MPA translating to roughly 116MPA of tensile strength of the material. The material chosen for this was a PA66GF50, or 50% glass reinforced PA66 nylon.

$$\tau = .5\sigma$$
$$P = \frac{F}{A} = \frac{50000}{42 * pi * 6.5} = 58MPa$$
$$\sigma = 116MPa$$

After running an FEA, results shown in FEA 1, it was clear that large amounts of material could be removed from the center of the part. Figure 3 shows a modified version of Figure 2 that has been hollowed out. Removing material also required the addition of ribs for rigidity, this design started with 6 ribs about 2mm thick. After running an FEA on the Figure 3 design, the need for more material above the snap ring was required. Many of the sharp edges were broken to aid in stress disbursement.

The design shown in Figure 4 incorporates the above changes as well as a slightly thinner wall thickness to aid in manufacturing, per the advice of an injection molding supplier. This design, shown in FEA 3, was still falling short of the strength requirements. In order to increase the strength of this part, the idea was to add material in the center of the part to direct the load around a central piece that was closer to the outside edge, reducing stress in the ribs. This was not possible without hollowing out the center core due to manufacturing restrictions. This lead to one of the more drastic redesigns which is shown in Figure 5.

The Figure 5 design was very promising from a SolidWorks simulation stand point and this part was shared with colleagues for more formal simulation testing. Upon receipt of the results, the part was showing signs of extreme bending due to the thin wall condition between the snap ring groove and the inner wall of the part. In an attempt to fix this issue, the snap ring groove and O-ring groove were switched allowing for higher stiffness in the snap ring groove, these differences can be seen in FEA 6.

With the switch in groove location, the amount of material between the grooves needed to be increased to prevent a failure due to shearing through the groove shelf. This caused some slight plastic deformation at the edge of the groove shown in FEA 5 although the stress was not high enough to cause major concern. This design did cause problems for a mating component though. The tube that will be holding this part would not have sufficient material to withstand the 300 bar. To fix this, the snap ring location on the tube needed to move approximately 3.5mm. The 3.5mm adjustment needed to translate over to the plastic component because it needs to sit flush with the end of the tube. Figure 7 shows the component with the compensation for the above noted change of 3.5mm.

The Figure 7 design has been handed off to colleagues in Germany for official FEA testing. The design is expected to pass although the formal FEA is an internal requirement so parts will not be ordered until results are received. This part is also being quoted by suppliers so prototypes should be ready to order once the FEA results come back from Germany.

TESTING

TEST PLANS

- Axial push out
- Hydraulic pressure test
- Full damper durability
- DOT non-hazardous goods

RESULTS

- Axial push out
    - Original test – Inconclusive
        - Results for 5 specimens shown on Graph 1
        - Failure occurred at much lower load than expected
        - New FEA, FEA 7 and FEA 8, with identical loading condition resulted in strong correlation to test data
        - Shows that the FEA and physical testing are similar, providing positive feedback for future testing
    - Second test – Promising
        - Results for 5 specimens shown on Graph 2
        - Used a secondary fixture to distribute the load
        - 3 out of 5 samples showed good results
        - 2 of out 5 samples were unexpectedly low
            - Could have been due to the reuse of tubes from previous testing
            - Snap ring groove could have been damaged
            - Tube end could have been flared slightly
        - Results were more promising than initial push out
- Hydraulic pressure test
    - Not completed
- Full damper durability
    - Not completed
- DOT non-hazardous goods
    - Not completed

PROJECT MANAGEMENT

BUDGET, PROPOSED/ACTUAL

-Proposed
The budget for this project is set at $100k, this will include all aspects of the project which are listed below.

- Engineering hours
- Prototype tooling
- Prototype parts
- Validation testing

-Actual
Total spent so far $23,000

- Engineering hours- $12,000
- Prototype tooling- $6000
- Prototype parts- $800
- Validation testing- $4000
- Misc costs- $200

SCHEDULE, PROPOSED /ACTUAL

-Proposed
’19 CW51 – Design finalized
CW52 – Prototype parts quoted and kicked off
’20 CW03 – Write and submit prototype validation tests
CW08 – Receive prototypes parts
CW09 – Submit parts for testing
CW15 – Tech Expo

-Actual
’19 CW51 – Design finalized
‘20 CW01 – Prototype parts quoted and kicked off
CW10 – Write and submit prototype validation tests
CW08 – Receive prototypes parts
CW10 – Submit parts for testing
CANCELED – Tech Expo

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APPENDIX A