YR1101
Project DC to DC converters baseplate mechanical load specification:

A Major Qualifying Project Report:
Submitted to the faculty of the
WORCESTER POLYTECHNIC INSTITUTE
In partial fulfillment of the requirements for the
Degree of Bachelor of Science By:

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In Partnership with
SynQor, Inc.
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Approved:

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Abstract:

DC to DC converters are electronic devices, which are supplied with a power source such as batteries or another type of power source and deliver another regulated voltage level as an output. As with any power electronic circuitry, DC/DC converter do not transform all input power to output power; a portion of input power is dissipated as heat. In order to dissipate that heat very often these converters are encapsulated, injected with thermo compound and also have a base plate, which is used for customer assembly to their systems or to have a heatsink attached to it.

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Chapter 1: Introduction

SynQor is a world-class supplier of DC-DC power converters solutions. Their products are designed to exceed the rigorous quality and performance requirements of today's leading-edge communications, computing, medical, industrial, and military applications. In addition, SynQor offers the lowest total cost of ownership by providing unmatched reliability, service, technical support and manufacturing flexibility.

SynQor's innovative products are designed to exceed the demanding performance, quality, and reliability requirements of today's power electronic engineers that are developing leading-edge infrastructure hardware. SynQor's total commitment to quality, customer satisfaction and continuous improvement drive their business processes and lay the foundation for their success.

SynQor was founded in October 1997 by M.I.T. professor Dr. Martin F. Schlecht, who believed that a technology known as "synchronous rectification" would revolutionize the decades old industry of DC/DC power converters. The introduction of SynQor's first open-frame, high-efficiency power converters was in. SynQor promptly began full scale manufacturing in its original Hudson, MA facilities and soon expanded their reach across Europe and Asia. Their expanding product line grew as fast as their list of customers.

Today SynQor operates from its new 102,000 sq. ft. corporate headquarters in Boxborough, MA. Their broad product line now includes thousands of part numbers, which serve a variety of diverse industries and applications.

Between all of Synqor products a large variety of units are offered in an encased form, mostly for the OEM industry. These can be fully encased products or products with a base plate and plastic frame assembly on the PCB unit top side.

These units are mostly assembled into systems by the threaded inserts on the baseplate. Either direction the product is assembled to a system or attached to a heatsink there are mechanical forces stressing the baseplate / frame assembly.

To improve even more customer satisfaction, SynQor wants to have available to customers a maximum force/load information they could apply or attach to some of the encapsulated DC-DC power converters.

Chapter 2: Background

2.1. Introduction

The objective of this project is to develop a process and equipment as needed in order to make available a maximum weight specification that products with base plates can support and share that information with the customer upon request at first and disclose on their datasheets in the future.

2.2. Objective barriers

SynQor wants to be the first DC/DC converter manufacturer to have this type of information available. As this is a new type of information but not specified or required by safeties certifications such as UL, CE, TUV, etc. there are no limitations nor guidelines to be based on. It is a complete new creation of a process which will be incorporated to the company product mechanical test qualification.

2.3. Product encapsulated construction.

The product (i.e. unit) after all electrical components are assembled and it is ready for encapsulation. Should look like the following figure.

Figure 1: open frame unit examples

The unit is then inserted into a custom plastic case (Ticona Vectra S471) dots of Epoxy (Eccobond G909) are deposited along the corners of the unit to anchor it to the case. Then a baseplate is placed over the case also with epoxy along its entire perimeter. The unit goes into an oven to cure the epoxy, then the assembly is filled with thermo compound and the unit goes into another curing cycle at 150^{o}C for 30 minutes.

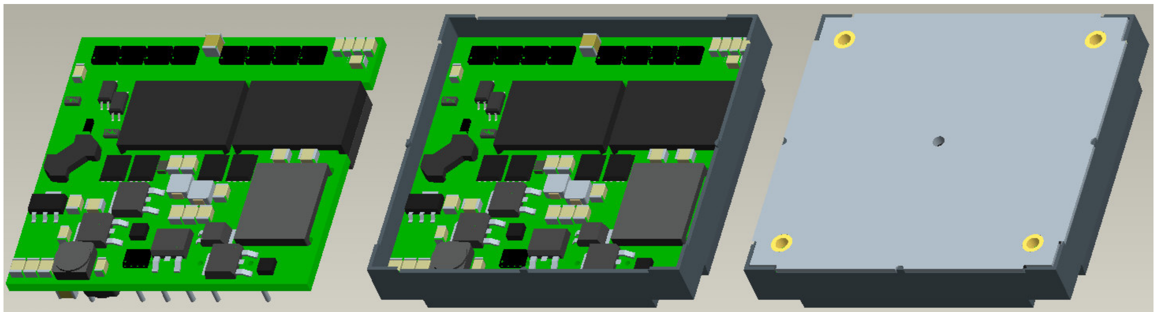


Figure 2: encapsulation steps

Figure 3: encapsulated units examples

2.4. The Problem.

Few customers asked questions about mechanical load over SynQor products, but that was not enough to spend money as after SynQor analyzed their systems they would give a positive recommendation to use or not the product or a solution to the possible problem resulting in zero consequences.

A field failure due to mechanical overload to a unit sparked the internal questioning and interest in analyzing and getting some real numbers on mechanical stress on base plated products.

There was no specific method to approach the problem so the first thing would be to list possible failures. During the test method one of these will fail first, that one would be the main failure mode, and observed to see if it can be improved if necessary.

- Baseplate bond separation from plastic case or ring-frame.
- PCB bond separation from plastic case or ring-frame.
- Solder joint failure from pin to PCB.
- Baseplate thread failure (threaded baseplates)
- Baseplate threaded insert ripped from plate. (threaded baseplates)
- Baseplate flange deformation (flanged baseplates)

2.5. The Problem solution study.

In order to collect enough data for analysis some possible solutions had to be studies and compared.

SynQor could acquire new equipment. Off-the-shelf tensile strength equipment cost over $5,000.00. Off the shelf equipments usually are not flexible and do not fit all demands, they do have the good characteristic of being plug'n play as well as easy to use.

Outsource test service is a good option for low quantities testing and certified tests. Some labs do have plenty capability of doing tensile strength tests. NTS test labs, a good certified test service Lab, service and report would cost $450.00 per batch and SynQor would have to deliver the product adapter plate for around $350.00.

The company has a large amount of different products to test so it would not be suitable to send out all of them for testing.

Design of custom equipment is the best solution for this project. Synqor equipment design/parts/manufacturing budget is +-$3,500.00. The custom equipment can be designed to be as flexible as possible matching all products and SynQor expectations

Chapter 3: Methodology

3.1. Method description

First approach was to fully understand the requirements, the problem and the expected results of the work to be done.

The objective was clear; the company had to quantify an average load the clients could safely apply to the products.

Researching processes and competitors data was done but there is no specific standard, process nor certification for that type of requirement.

After comparing various possibilities, processes and working to fit into certain budget range the design of new equipment and the generation of a new internal process was considered the best solution to the project.

The first study was made of various failure possibilities and listed the major “mechanical fuses”. The weakest spot was uncertain but the most probable it would be the breakage of the bond between the Vectra plastic frame and the aluminum plate.

The approach method to resolve and do the project was divided in:

- Understanding the problem
- Understanding the possible failures.
- Research on known standards, certifications, test labs and competitors specifications
- Research on current processes, equipments and test laboratories.
- Decision in what type of process, equipment and service
- Sketch of process and problem solving
- Equipment design
- Process development
- Collect data and analysis
- Study product behavior based on data analysis and conclusion of the project.

After the decision was made in the development of a new process and equipment a rough description of the new process had to be made.

The company had to create a piece of equipment capable of anchoring well the unit while pulling the baseplate apart from it.

In order to do the equipment concept design, we had to list all possible variances of products, test conditions, environment and future changes possibilities to avoid equipment major redesign making it as much flexible as possible.

After the equipment was designed the conceptual process was created to be easily performed by company technicians and process done and data collected in same conditions the company specifies to customer product usage; these parameters were such as, environment, temperature conditions and some cases air cleanliness and humidity as for military and medical products.

Chapter 4: Equipment design

4.1. Equipment requirements

First all equipment requirements had to be listed in order to design it and also to outline the process.

Basically the equipment has to be able hold the unit through the i/o pins and be able to pull the unit apart through the base plate. During all that process time the tensile force has to be recorded until failure is to be found. Please see list of possible failures in section 2.4.

The equipment has also to be able to:

- Withstand temperature ranges from -10C to 85C (just for data comparison between low and higher temperature performance of the epoxy bond), the equipment has to be able to fit inside the temp cycle chamber in order to be able to do that. All qualification and data collection is at product operating temperature, this low and high temperature testing would only be for Synqor records.
- Equipment shall be flexible and spacious enough to fit all types of encapsulated and baseplated products. Products size range from 1.4x1X.5 to 4.7x3.2X.5.
- Equipment shall fit into a standard batch oven. Not specifically required for our goal, but in case the qualification group wants to perform tests at specific temperatures.
- Equipment shall fit into a temperature cycle chamber. Not specifically required for our goal, but in case the qualification group wants to perform tests at specific temperatures.
- Load applied should be easy to control. Design in a way of a possible upgrade with an automated equipment, (i.e. servo motor, piston, etc.)
- Load cell should be able to measure compression and tension. Possible equipment application in converting it into a press to test products under a mechanical load.
- Load cell must be able to measure forces up to 250lbs. this number was dictated as a product failed at a customer application with a load of approximately 90lb.

- Software shall read, display and record data in order to make it easier to compare the load values.

4.2. Equipment Design

The equipment was design using Pro Engineer software. As the company project budget was not at the higher end. Some of the parts were limited to what was in the company's model shop stock and due to cost; the possibility in automate or buying an off the shelf press to adapt was discarded.

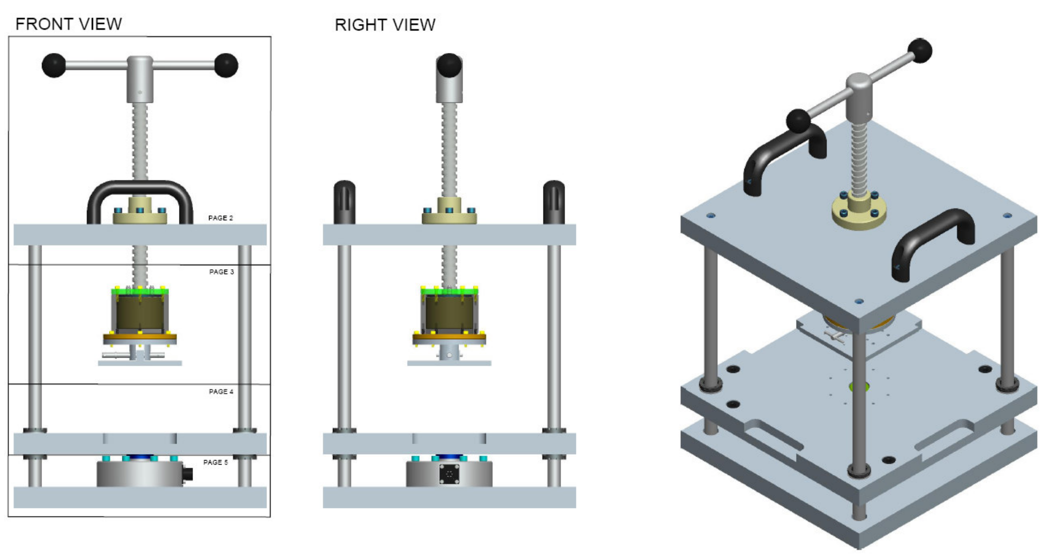
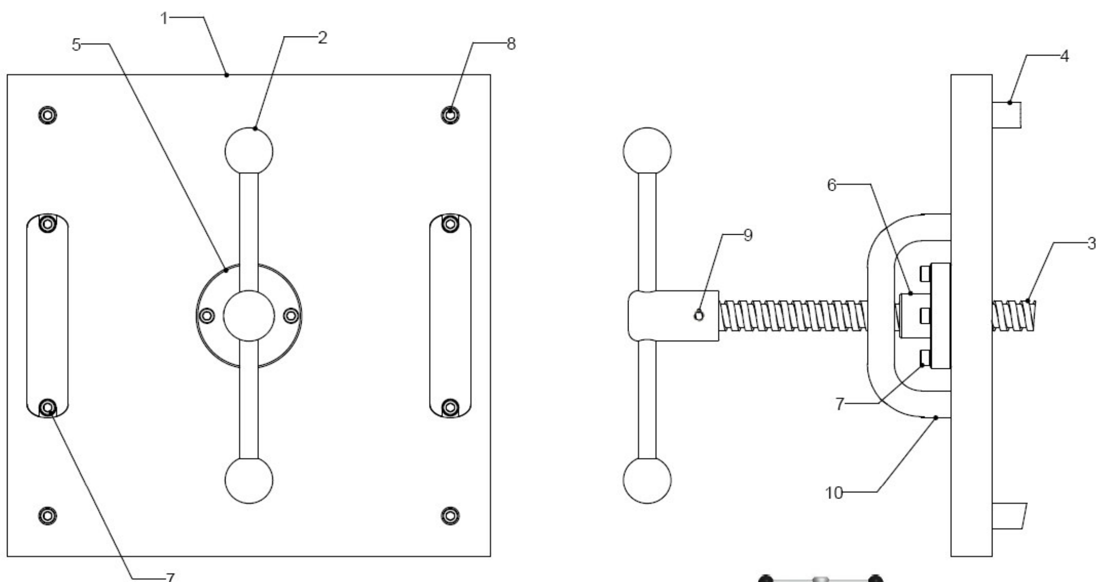


Figure 4: Base plate puller design model

The concept of the Base plate puller is that we need to fix the product by the pins and somehow pull the baseplate until it separates from the unit or any other machanical visible failure.

Three 1" square foot aluminum plates where chosen to be the fixture base, top and product assembly plate, all linked by four 5/8" hardened steel shafts on the corners. Top and bottom plate fixed to each other and center plate can move in between plate through linear ball bearings, but on this case the stroke would not be noticeble as it is attached to the load cell bolted to the bottom plate. These 1" thick plates were an overkill as the equipment is not going to see more than 250lb on the experiment, but they were chosen, and the equipment was overdeigned in a way that if the company needs to make tests with larger units in the future and to convert the equipment to a press. As the plates are that thick we could also disconsider any worpage of the plates due to mechaniccal force.

Figure 5 shows the top assembly of the equipment. An Acme threaded rod is to be the Z axis. Acme threaded rods can last longer than ISO threaded rods, run smother and are stronger. The rod is also more precise, so in the case SynQor wants to upgrade the equipment with a servo motor in the future, that would make the upgrade easier. A T-handle is attached to the top end of the screw, so the technitian could operate the equipment manually. Two handles were placed on the top plate to facilitate moving and carrying the equipment.

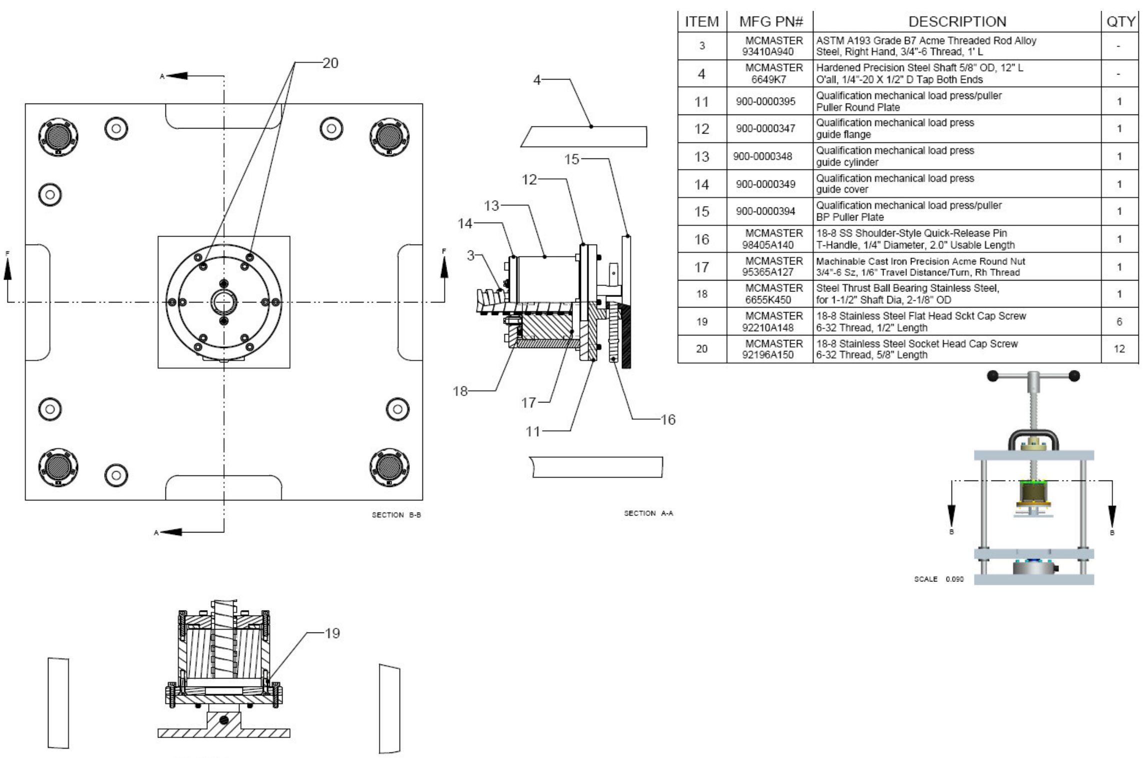


ITEM	MFG PN#	DESCRIPTION	QTY
1	900-0000344	Qualification mechanical load press top plate	1
2	MCMASTER 6049K130	Steel Handle with Nylon Ball Knob Double Straight, 1-3/8" Diameter, Solid Hub	1
3	MCMASTER 93410A940	ASTM A193 Grade B7 Acme Threaded Rod Alloy Steel, Right Hand, 3/4"-6 Thread, 1' L	1
4	MCMASTER 6649K7	Hardened Precision Steel Shaft 5/8" OD, 12" L O'all, 1/4"-20 X 1/2" D Tap Both Ends	4
5	MCMASTER 95082A643	Mounting Flange for Precision Acme Round Nut Fits Nut Sz 1"-18, 2.62" OD, Steel	1
6	MCMASTER 95072a113	Bronze Precision Acme Round Nut 3/4"-6 Size, 1/6" Travel Distance/Turn, Rh Thread	1
7	MCMASTER 92196A543	18-8 Stainless Steel Socket Head Cap Screw 1/4"-20 Thread, 1-1/8"	8
8	MCMASTER 92196A541	18-8 Stainless Steel Socket Head Cap Screw 1/4"-20 Thread, 7/8" Length	4
9	MCMASTER 92311A533	Type 18-8 SS Cup Point (or Cone Point) Socket Set Screw 1/4"-20 Thread, 1/4" Length	2
10	CARR LANE CL-116-PHRC-4	ALUMINUM PULL HANDLE W/ #1/4 MOUTING HOLE	2

Figure 5: upper BP puller assembly

Figure 6 shows the assembly that pulls the product base plate. There were not many options of ACME nuts for the threaded rod chosen, which is one of the reasons why that assembly is quite large.

The ACME round nut was installed at the end of the rod and locked with two set screws on the side (not shown). Around that nut, there is a sleeve (13) with a bottom (11) and top (14) plate. That sleeve assembly is able to spin free and has some play to help assembly and alignment to the unit base plate adapter (15). When the equipment is at work the nut spins with the screw but in between the nut and the top-plate from the sleeve, there is a thrust bearing (18) that enables the sleeve assembly to not turn and not twist the product. The product base plate adapter plate (15) is attached to the sleeve assembly with a ¼" locking pin (16).

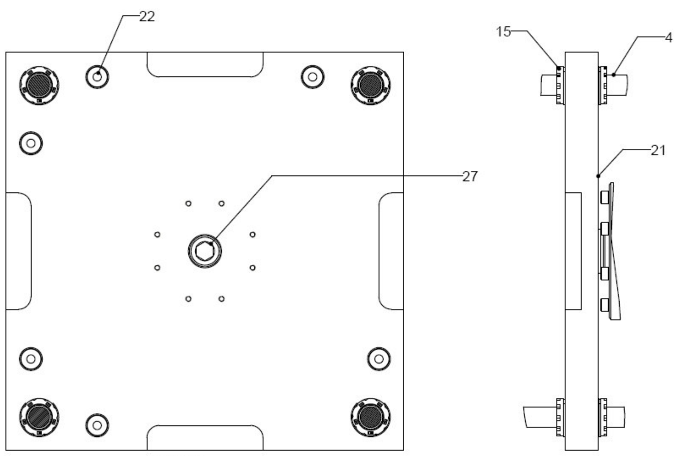


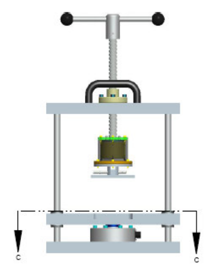
ITEM	MFG PN#	DESCRIPTION	QTY
3	MCMASTER 93410A940	ASTM A193 Grade B7 Acme Threaded Rod Alloy Steel, Right Hand, 3/4"-6 Thread, 1' L	-
4	MCMASTER 6649K7	Hardened Precision Steel Shaft 5/8" OD, 12" L O'all, 1/4"-20 X 1/2" D Tap Both Ends	-
11	900-0000395	Qualification mechanical load press/puller Puller Round Plate	1
12	900-0000347	Qualification mechanical load press guide flange	1
13	900-0000348	Qualification mechanical load press guide cylinder	1
14	900-0000349	Qualification mechanical load press guide cover	1
15	900-0000394	Qualification mechanical load press/puller BP Puller Plate	1
16	MCMASTER 98405A140	18-8 SS Shoulder-Style Quick-Release Pin T-Handle, 1/4" Diameter, 2.0" Usable Length	1
17	MCMASTER 95365A127	Machinable Cast Iron Precision Acme Round Nut 3/4"-6 Sz, 1/6" Travel Distance/Turn, Rh Thread	1
18	MCMASTER 6655K450	Steel Thrust Ball Bearing Stainless Steel, for 1-1/2" Shaft Dia, 2-1/8" OD	1
19	MCMASTER 92210A148	18-8 Stainless Steel Flat Head Sckt Cap Screw 6-32 Thread, 1/2" Length	6
20	MCMASTER 92196A150	18-8 Stainless Steel Socket Head Cap Screw 6-32 Thread, 5/8" Length	12

Figure 6: center BP puller assembly

The attachment style of product base plate adapter plate (15) to bottom sleeve assembly plate (11) has some play and compensates from any product assembly to PCB misalignment or any flatness imperfection and parallelism misalignment the product assembly may have. Any misalignment, like not pulling the unit base plate from the center or angle misalignment will affect the test results, but not enough to throw off completely the data collected. After so many samples we could have a solid average to be based on.

Figure 7 shows the center plate design. The Center plate is attached to the load cell with a center bolt. It has 4 fixed alignment linear ball bearings (15) that will help if a different load cell is needed or if the equipment is converted into a press. The plate has 8 8-32 threaded holes to bolt the product assembly test board to it. Six bushing are also installed into the plate in case SynQor needs to make a bigger plate for a larger product. These bushing will facilitate alignment from any new plate to the equipment

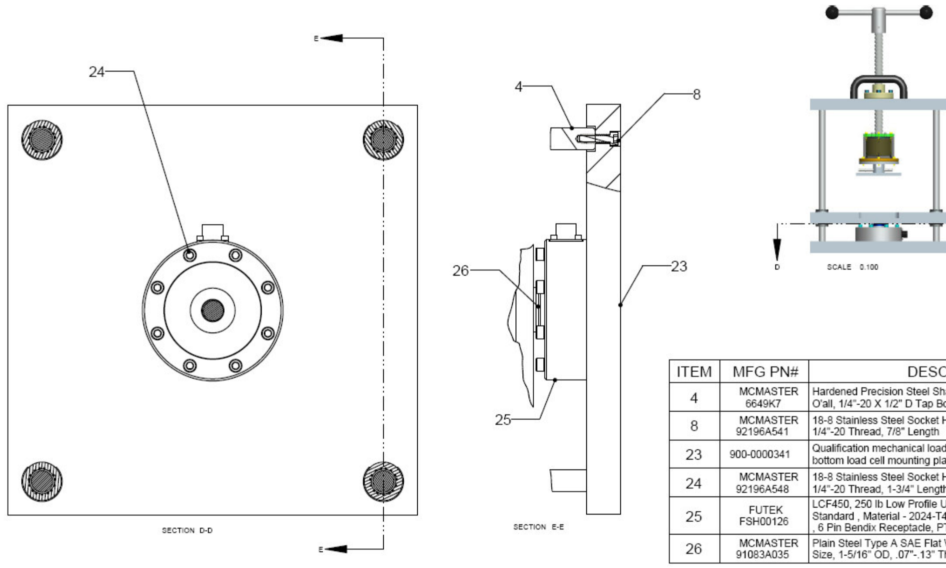




ITEM	MFG PN#	DESCRIPTION	QTY
4	MCMASTER 6649K7	Hardened Precision Steel Shaft 5/8" OD, 12" L O'all, 1/4"-20 X 1/2" D Tap Both Ends	-
15	MCMASTER 6064k59	Fixed-Alignment Linear Ball Bearing Closed, High-Temperature Steel, 5/8" ID with external Retaining Ring (RING #9968K25)	4
21	900-0000342	Qualification mechanical load press test base alignment plate	1
22	CARR LANE CL-B-1000	1144 Steel w/ black oxide finish, Bushing for 1/4" Ø pin	6
27	MCMASTER 91251A495	Black-Oxide Alloy Steel Socket Head Cap Screw 5/8"-18 Thread, 1" Length	1

Figure 7: center Plate

Figure 8 shows the bottom plate assembly of the equipment. The load cell is bolted to the plate by eight ½-20 screws. The load cell futek model LF450, 250lb is a great tool for this application. It can withstand the temperature range, not required but desired. It has a low profile design. It works on tension and compression loads in the case the equipment is retrofitted to a press. It has a good result tolerance. The Company had worked with Futek load cells in the past and that was taken into account as well. The Futek Company also offers a software data collector and adapter, which could convert the load cell with an USB output. So the results instead of being monitored through an oscilloscope we could analyze record and plot the data straight out of any computer. The software was really user friendly and had lots of versatility to it.



ITEM	MFG PN#	DESCRIPTION	QTY
4	MCMASTER 6649K7	Hardened Precision Steel Shaft 5/8" OD, 12" L O'all, 1/4"-20 X 1/2" D Tap Both Ends	-
8	MCMASTER 92196A541	18-8 Stainless Steel Socket Head Cap Screw 1/4"-20 Thread, 7/8" Length	4
23	900-0000341	Qualification mechanical load press bottom load cell mounting plate	1
24	MCMASTER 92196A548	18-8 Stainless Steel Socket Head Cap Screw 1/4"-20 Thread, 1-3/4" Length	8
25	FUTEK FSH00126	LCF450, 250 lb Low Profile Universal Pancake Standard , Material - 2024-T4 5/8-18-Thread , 6 Pin Bendix Receptacle, PT02A-10-6P	1
26	MCMASTER 91083A035	Plain Steel Type A SAE Flat Washer 5/8" Screw Size, 1-5/16" OD, .07"-.13" Thick	3

Figure 8: bottom BP puller assembly

Figure 9 shows the complete machine and assembled equipment.

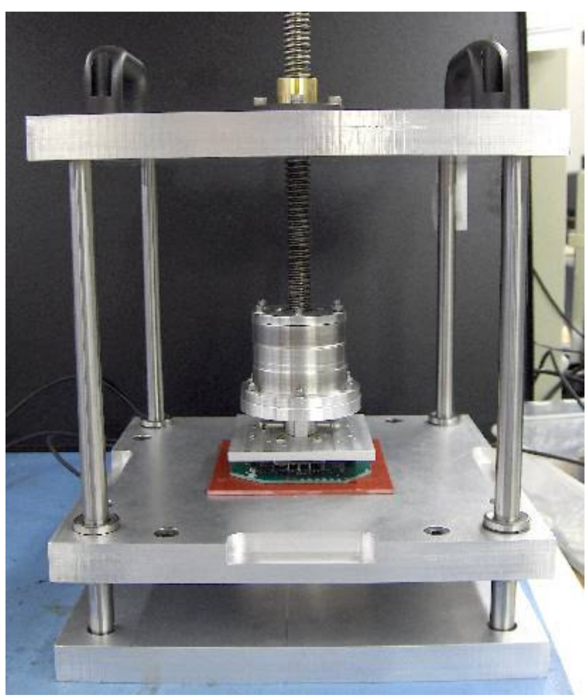


Figure 9: BP puller equipment

Figure 10 shows a product assembled to the test board and that is assembled to the center plate through the eight 8-32 screws. There is a spacer fiberglass board in between the test board and the aluminum bottom plate. That FR-4 spacer board is to avoid any shorts from test board to the fixture. One of the tests to be tried would be to electrically monitor the unit while the Base plate is being pulled from the unit.

Figure 10: product and product test board assembly

The equipment is design to be very versatile and to easily be modified to any new product the company creates.

Chapter 5: New Process

5.1. New process method

This new process will be part of the mechanical tests performed in qualifying the SynQor, Inc., DC-DC converter. The intent and purpose for these tests were to demonstrate and document to a reasonable level, the product quality, reliability and performance with pull force applied to base plate.

The new process methodology was based on product operating conditions; but the equipment was overly design to withstand other tests that the company wants to do to push the limits of its product and detect any other flaws it may have.

All testing shall be performed with a room temperature environment of 23^{o}C and an average Relative Humidity (RH) of 37%. This specification is for industry products only; military product would have different specification if required.

Select units and then visually inspect with 7x visual scope for any defects. After units passed inspection all units should be attached to the SynQor 034-2000016 test PCB, All pins soldered into plated holes. Use lead free solder, gloves and safety glasses all the time during this process.

Another visual inspection shall be conducted on all parts, and they must be then mounted into custom Pull test apparatus.

Attach top of unit (base plate) with mounting screws to custom pull plate and connect to upper pull plate with lead screw with the 1/4" locking pin.

Zero the Futek load cell on the software (tear function) and start data capture. (The software will start to record the data in lbf at a set frequency rate, and it has the capability in plotting a graph lbf x time)

Next manually operate the lead screw using the 'T' handle at an even rate until unit failure.

After the units are processed with the above procedure for pull testing they must be visually inspected only for Input and output pin damage or damage at PCB.

5.2. New process results

The software records the amount of force and can plot the data vs. time. The peak value shown in the chart is when the failure occurred. Data must be compared with other units.

Ten units of each size product are to be mechanically destroyed using this method. The results will be compared and an average number will be set with a percent safety factor to be determined.

Based on the average peak values, the specification will be finalized and shared with the customer on a required base.

Figures 11 through 19 shows various plots of data collected of different unit sizes.

After all units processed with the new process described before for pull testing they were visually inspected only for Input and output pin damage or damage at PCB. Data was gathered and saved from each test. The only failure noticed was the base plate bonding break away from the plastic case. The components, solder joints or pins were not damaged during tests.

For encased units the maximum pull force was 128 lbs. And minimum force was 70lbs. The numbers collected and overall results were very satisfactory.

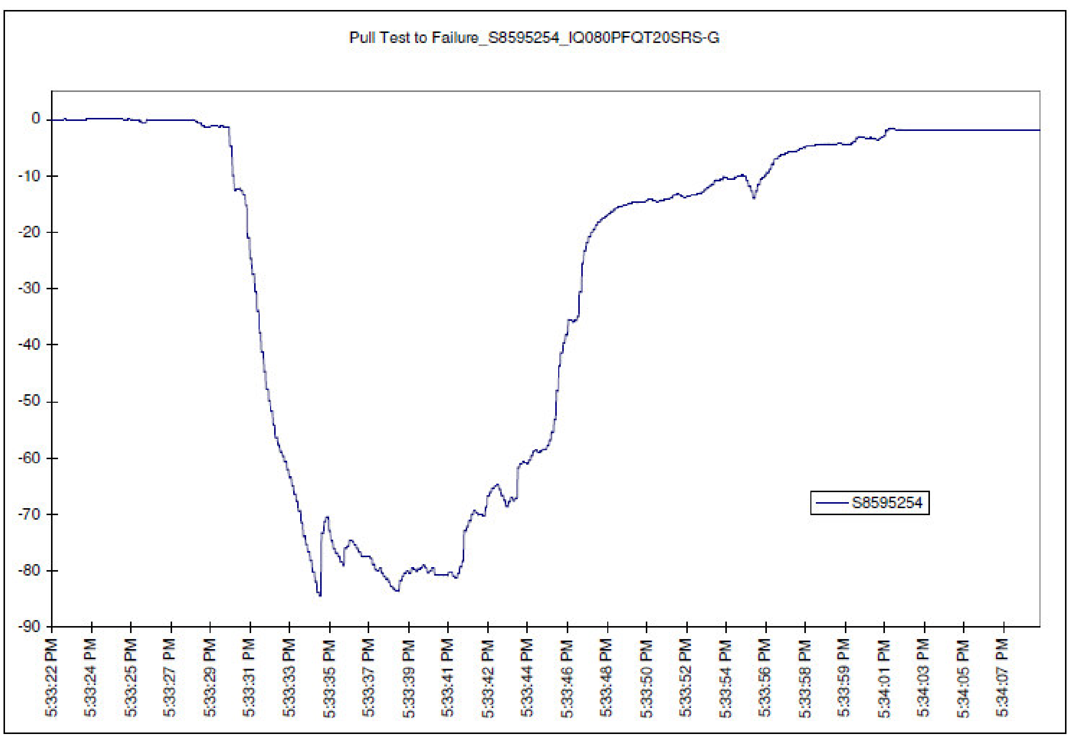


Figure 11

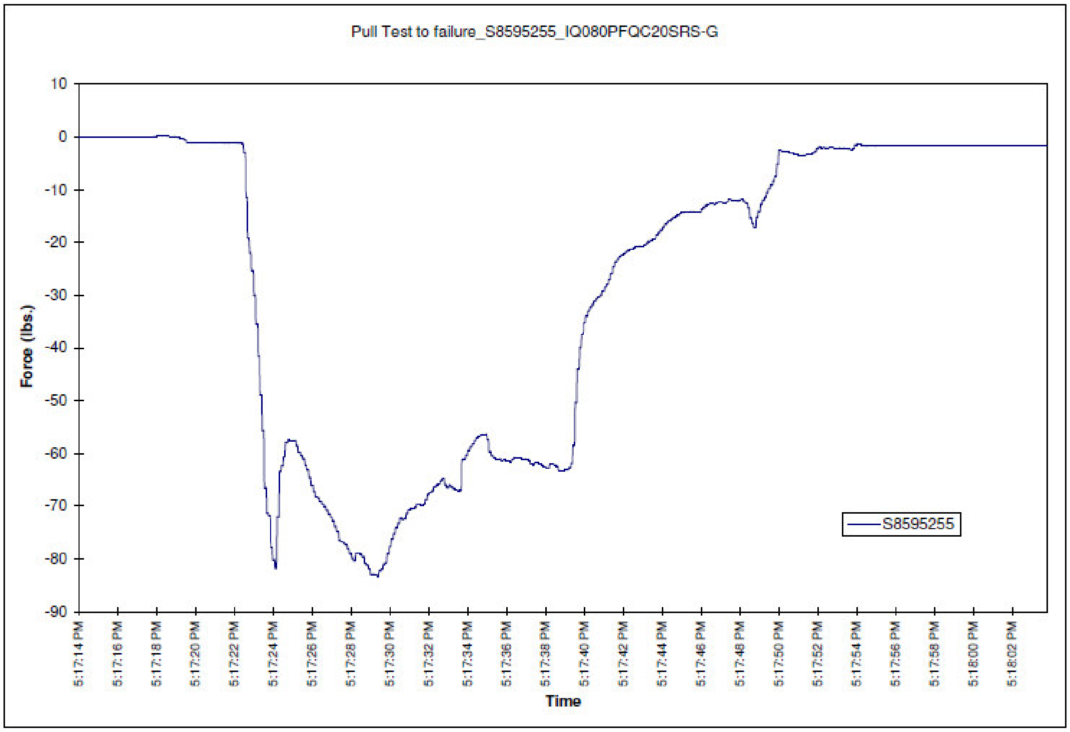


Figure 12

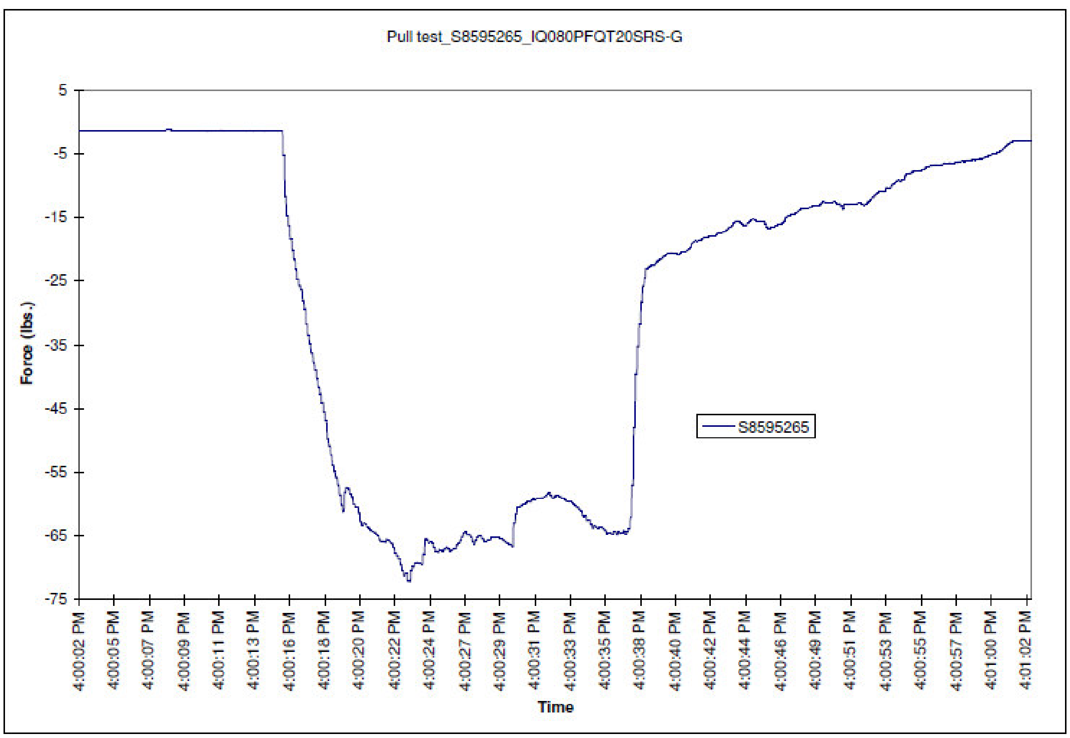


Figure 13

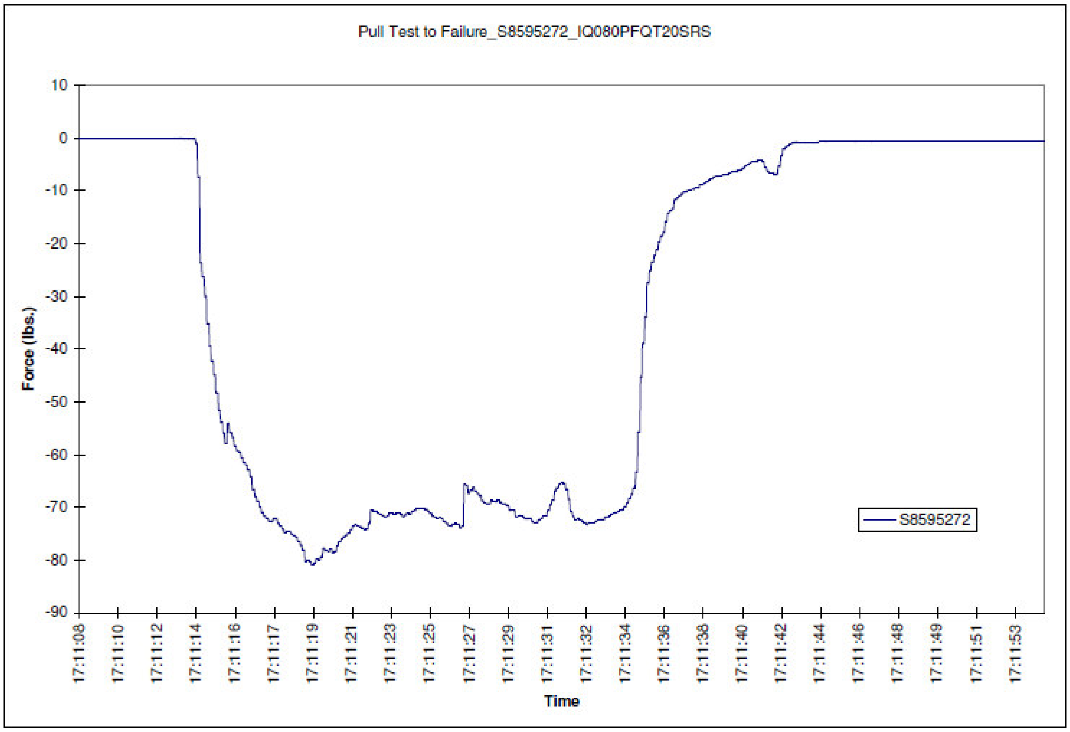


Figure 14

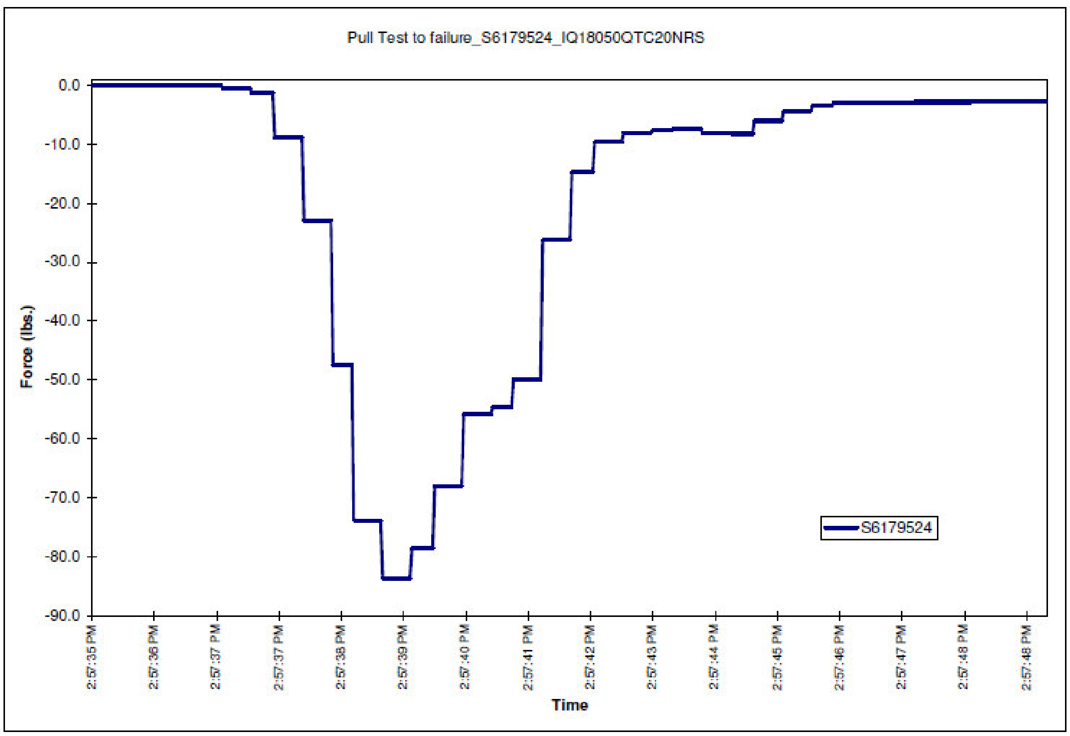


Figure 15

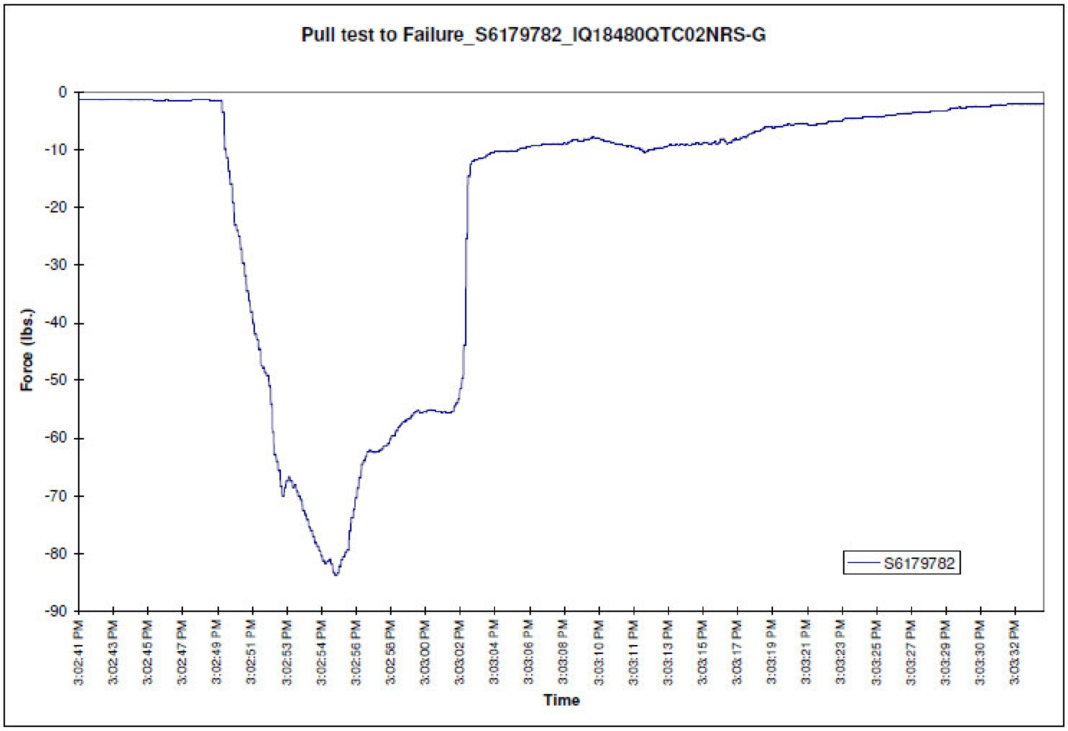


Figure 16

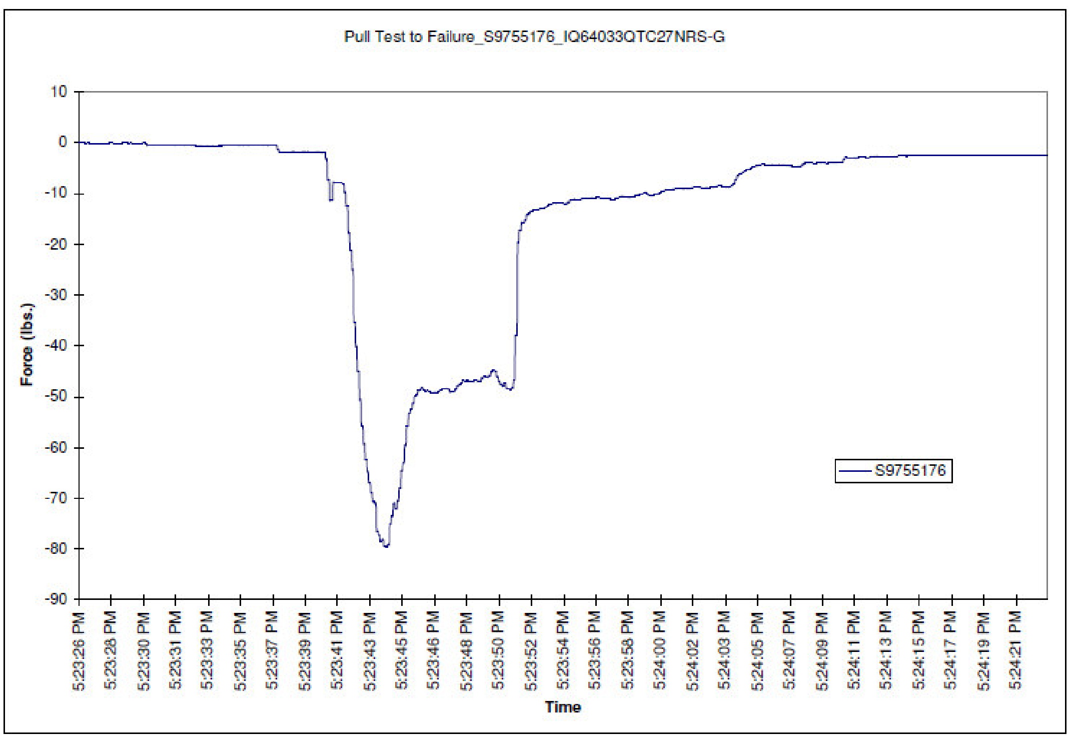


Figure 17

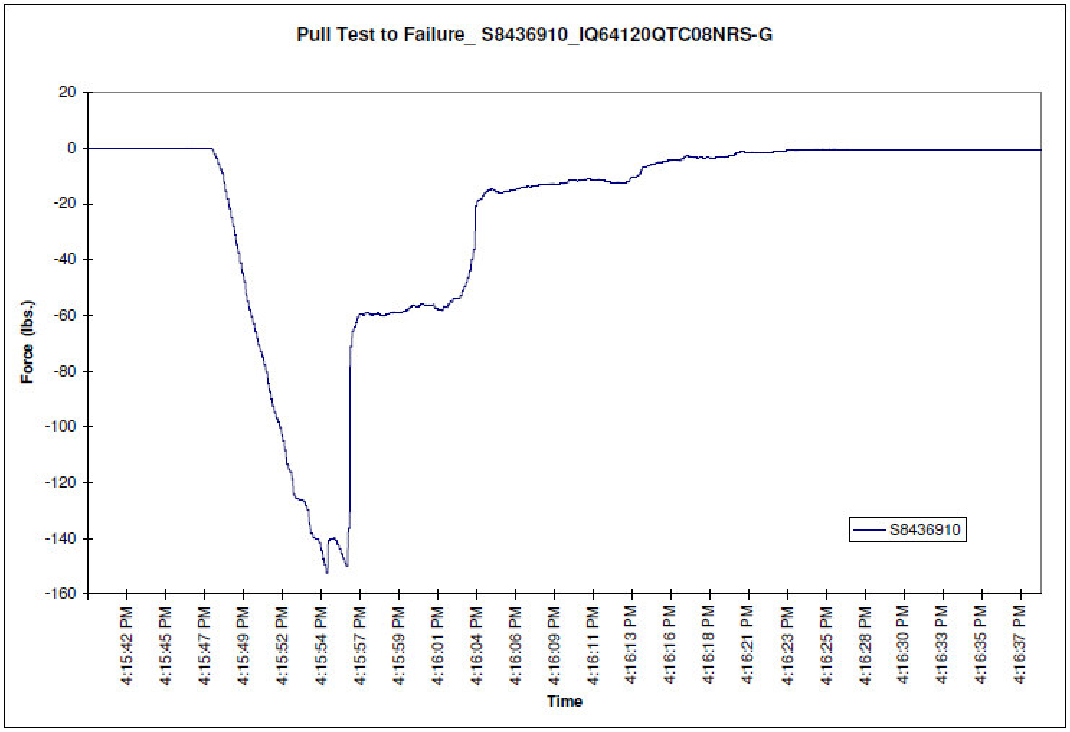


Figure 18

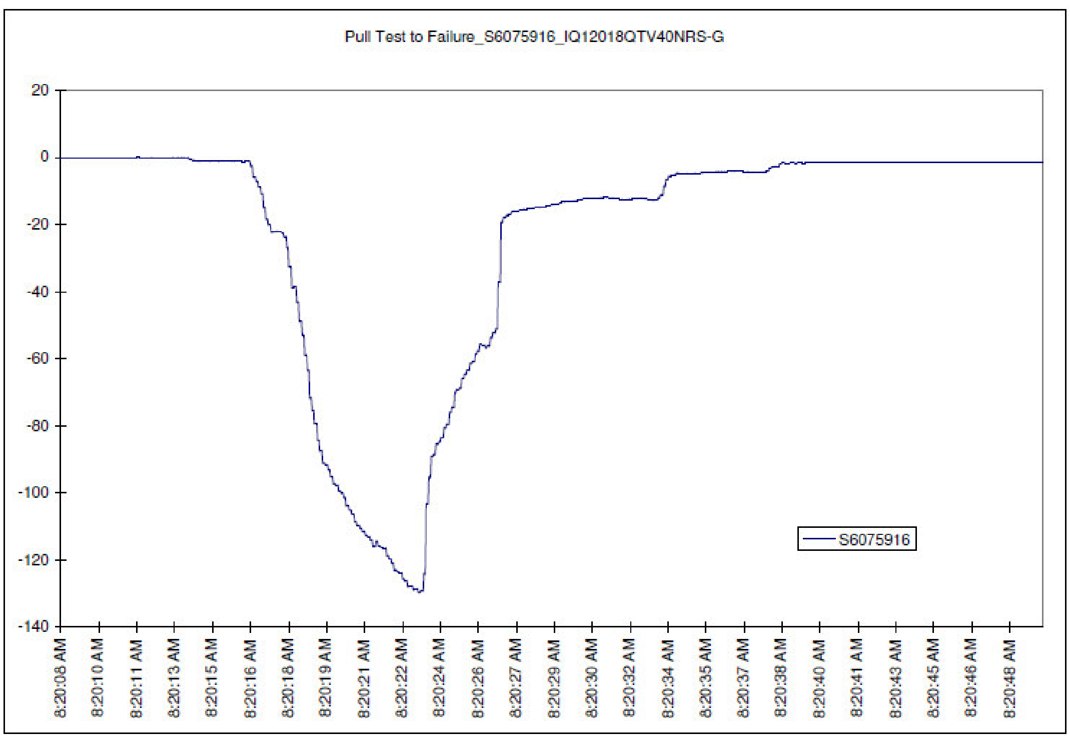


Figure 19

Nine (9) products were allocated and tested to failure, 7 standard encased (QTC / QTA) units and two units that were encased with flange configuration (QTV). Below is the list of the maximum force applied, Failure tested, serial numbers and part number that were used in this testing:

Maximum Force applied until Failure	F=Failure S=Sustained	Serial Number:	Part Number:
84	F	S8595254	IQ080PFQTC20SRS-G/-1
83	F	S8595255	IQ080PFQTC20SRS-G/-1
70	F	S8595265	IQ080PFQTC20SRS-G/-1
80	F	S8595272	IQ080PFQTC20SRS-G/-1
84	F	S6179524	IQ18050QTA20NRS-G/-A
83	F	S6179782	IQ18480QTV02NRS-G/-A
79	F	S9755176	IQ64033QTC27NRS-G/-1
152	F	S8436910	IQ64120QTC08NRS-G/-1
129	F	S6075916	IQ12018QTV40NRS-G/-A

Test equipment used for this test activity is listed below

Line #	Equipment Name	**Barcode ID**
1	Dyna 4x/8x Visual Scope	EQ003208
2	Futek (model: LCF450)	EQ003431
3	SynQor custom Pull test apparatus	EQ003430

Each unit was carefully inspected prior to the testing. Using a 4X visual scope, each unit was viewed for any defects, workmanship issues, or abnormalities.

These nine units were enough for the quality and reliability group qualify the equipment approve the new process and incorporate it to the product mechanical qualification tests.

The company is currently investigating a good number of products to do the destructive test.

Chapter 6: Recommendations and Conclusions

6.1. Conclusions

The new Equipment and new process was approved by the company qualification department and will be incorporated to the product mechanical qualification process.

The mechanical type failure was what expected (breakage of the bond between the aluminum plate and plastic case) and the average pull out force as well.

Overall the project goal was achieved.

6.2. Recommendations

Increasing the number of units tested would be a good way to get a better understanding in the data and force average collected.

Performing this tests on a regular bases on a sample like 1 unit per 10000 or more would be a good way also to test and monitor raw material and processes as well. If the number is not within the new specification, some wrong might be happening with the encasement process. Like not enough epoxy dispensed around the baseplate or curing time x temperature profile incorrect. Some other considerations may apply, like a bad batch of epoxy or contamination of the substrate surfaces bonded.

Chapter 7: References

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www.wpi.edu

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