

Learning Design at White Sands Test Facility

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WHITE SANDS TEST FACILITY

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During the Fall of 2010, I spent my time at NASA White Sands Test Facility in Las Cruces, NM as an Undergraduate Student Research Program (USRP) Intern. During that time, I was given three projects to work on: Large Altitude Simulation System (LASS) basket strainer, log books, and the design of a case for touch screen monitors used for simulations. I spent most of my time on the LASS basket strainer. The LASS system has a water feed line with a basket strainer that filters out rust. In 2009, there were three misfires which cost approximately \$27,000 and about 8% of the allotted time. The strainer was getting a large change in pressure that would result in a shutdown of the system. I have designed a new basket that will eliminate the large pressure change and it can be used with the old basket strainer housing. The LASS system has three steam generators (modules). Documents pertaining to these modules are stored electronically, and the majority of the documents are not able to be searched with keywords, so they have to be gone through one by one. I have come up with an idea on how to organize these files so that the Propulsion Department may efficiently search through the documents needed. Propulsion also has a LASS simulator that incorporates two touch screen monitors. Currently these monitors are in six foot by two foot metal cabinet on wheels. During simulation these monitors are used in the block house and need to be taken out of the block house when not in use. I have designed different options for hand held cases for storing and transporting the monitors in and out of the block house. The three projects previously mentioned demonstrate my contributions to the Propulsion Department and have taught me real world experience that is essential in becoming a productive engineer.

Nomenclature

A	=	cross-sectional area
Ca	=	cavitation number
C _r	=	mesh correction factor
C _v	=	valve flow coefficient
DR	=	Discrepancy Report
G	=	specific gravity
GPM	=	gallons per minute
IPA	=	isopropyl alcohol
JSC	=	Johnson Space Center
LASS	=	Large Altitude Simulation System
LOX	=	liquid oxygen
OCR	=	optical character recognition
Δp	=	pressure difference
P	=	pressure
P _v	=	vapor pressure
psi	=	pounds per square inch

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- Q = flow rate
- ρ = density
- ROV = remotely operated valve
- TPS = Test Preparation Sheet
- USRP = Undergraduate Student Research Program
- V = velocity
- WSTF = White Sands Test Facility

I. Introduction

Designing new cars, robots, tools or even rockets and space craft is what some engineers dream of as children. I still enjoy the thought of designing these items or other devices that may someday help people work faster and more efficiently.

Efficiency can streamline procedures, increase productivity and decrease costs. Businesses and NASA can attain more goals by being more efficient with properly learned design skills and practice early on at the basic level.

During the Fall of 2010, I was a NASA Undergraduate Student Research Program (USRP) Intern at White Sands Test Facility in the Propulsion Test Department in Las Cruces, NM. In my 15 weeks there I was given three projects: basket strainer, module log books and simulator case. The projects pertain to the Large Altitude Simulation System (LASS) which test fires rockets at a simulated altitude. These three projects were about making the tests and other duties more efficient. My efforts not only helped Propulsion use their time more efficiently, but these projects were centered on what I enjoy, design. Having the opportunity to learn more about design from real designers with real application is invaluable to my future.

II. LASS Basket Strainer

Rocket engines sometimes need to be tested in a simulated altitude environment because of the lower pressures at these heights. These altitudes can be simulated at White Sands Test Facility (WSTF) Propulsion Test Department. In the 400 Test Area, they have the LASS system which NASA states (<http://www.nasa.gov/centers/wstf/propulsion/altitude.html>) can simulate altitudes up to 100,000 ft while the rocket is being fired, and up to 250,000 ft if the rocket is not being fired. This is all accomplished by steam and mechanical vacuum pumps.

The steam is created from water being pumped at 570 pounds per square inch (psi) through an 8" pipe to three steam generators (modules). Each module is a rocket engine in itself. The modules run off of Liquid Oxygen (LOX) and Isopropyl Alcohol (IPA) and each module consumes 270 gallons per minute (GPM) of LOX and 170 GPM of IPA. When the modules are running water is pumped inside the modules themselves at a rate of 2700 GPM; which creates steam at approximately 530 °F. The steam that is produced is then used to create a vacuum in the test stand by sucking out the air inside the test stand like an aspirator, see Fig. 2. (http://www.nasa.gov/centers/wstf/pdf/269972main_NEWprop_400_area_large_alt_sim_sys.pdf)

Some of the 8" water line that feeds the steam generators has been replaced with 8" stainless steel pipe, but the water tank and other piping is over 40 years old and made of carbon steel. Therefore there is rust in the water being fed to the steam generators. The rust is filtered out by a basket strainer placed in the 8" pipe line. Figure 1 shows the location of the steam generator, basket strainer and a Test Stand in the 400 Area. If you were to zoom in to where the basket strainer arrow

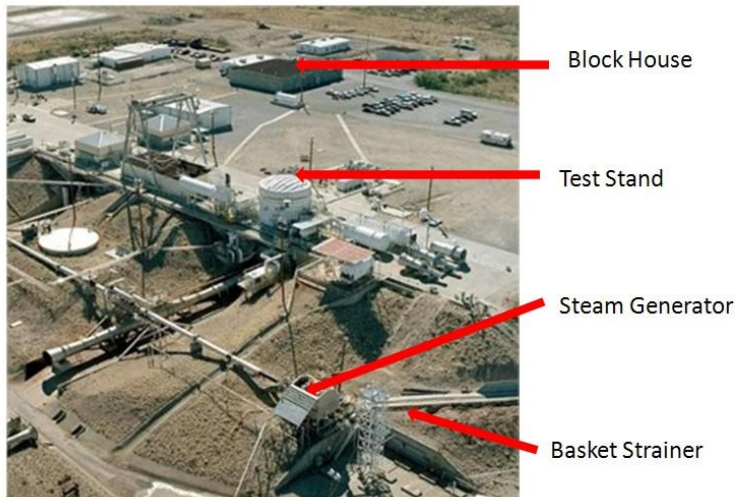


Figure 1. Propulsion Department, 400 Test Area

is pointing, Fig. 3 represents what the basket strainer looks like with the side cut away. The basket strainer is a 12” Keckley Cast 316 Stainless Steel Style SSGFV which is bolted directly in line with the 8” water line. As the water flows into the strainer it flows into and through the basket. The basket filters out the rust and the clean water flows downstream as shown in Fig. 3. By the water traveling through the strainer the flow has changed from one side of the strainer to the other. This has created a change in pressure from one side to the other. There is a pressure gauge that measures the difference in pressure from one side to the next, and LASS has a procedure which will manually shut down the system if the difference in pressure (Δp) is too large.

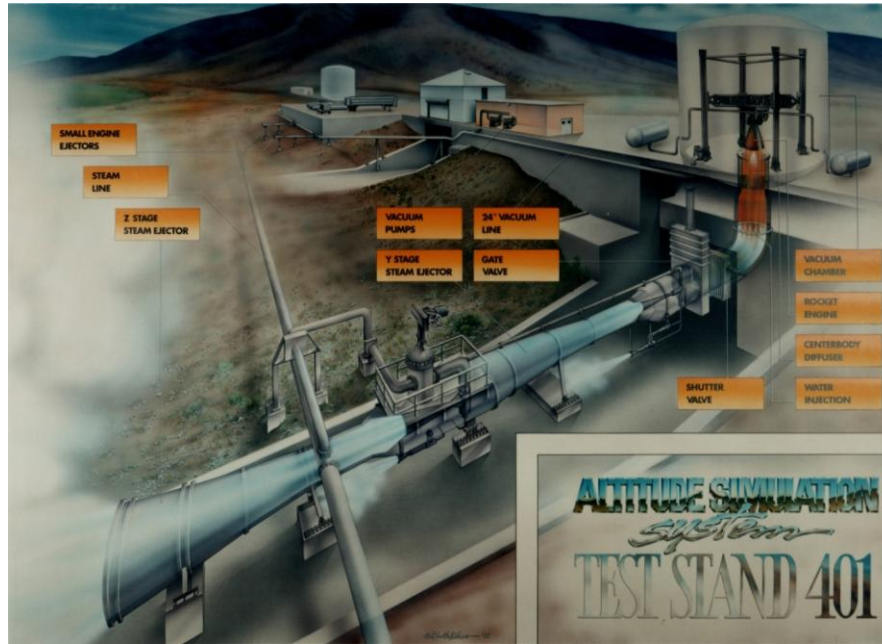


Figure 2. Test Stand 401 Diagram

The basket strainer was installed in the spring of 2009. During 2009, the LASS system had three misfires out of 12 runs. Shut down should occur if the Δp reaches approximately 9 psi, and the misfires were due to a large Δp across the strainer. Another issue is the failure of the basket itself. During cold flow tests the strainer was put into a situation where it had collapsed. If the system was firing the failure of the basket as shown in Fig. 4 could cause unwanted debris downstream which could damage the steam generators. These misfires accounted for 8 minutes and 7 seconds lost of the 300 allotted minutes the LASS can run per year. It costs over \$200,000 per hour to run the system, see Fig. 14, so this lost time cost over \$27,000.

The manufacturer, Keckley, states in their brochure at 2700 GPM our basket strainer will only see a Δp of 0.35 psi

(http://www.keckley.com/pdf/StainerBulletin_March_24_2006.pdf). I am assuming that is a best case scenario and tested with clean water and a clean filter. Keckley also gives an equation; see Eq. (1), of how they calculated their pressure drop.

$$\Delta p = G \cdot \left(\frac{Q}{C_v} \right)^2 \cdot C_r \quad (\text{Equation 1})$$

In this equation G is the specific gravity of water (1) and Q is the flow rate (2700 GPM). C_v is the valve flow coefficient (4980) and C_r is the correction factor for the mesh (1.2) in which Keckley provides both. G

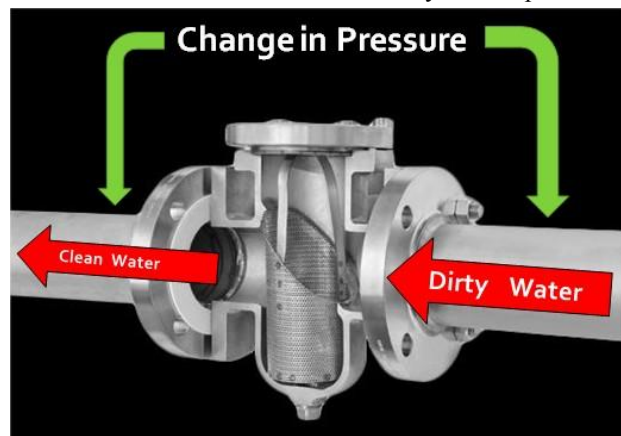


Figure 3. Basket Strainer



Figure 4. Basket Failure

and C_r will stay the same and will not be changed because we cannot change water's specific gravity and the mesh size needs to stay the same. The flow rate needs to stay at 2700 GPM to not only make enough steam, but more importantly to cool certain parts inside the steam generators so they don't melt. The variable C_v is 4980 when the basket is clean, but when the basket starts to get dirty and the mesh starts to fill with rust the value decreases. As the value decreases the larger Δp will get. There are two variables that we can try to manipulate in order to keep a small Δp . Flow rate (Q) and valve flow coefficient (C_v) can be manipulated.

Flow rate, see Eq. (2), can be changed by varying velocity (V) or area (A). Also C_v can be changed in a fashion that should increase the value above 4980 so as the basket gets dirtier it takes longer for the value to get small enough in order for the large Δp . The following sections will explain different ideas and option that have been considered in order to vary the two variables.

$$Q = VA \quad (\text{Equation 2})$$

A. Varying the Flow Rate (Q)

Since Q depends on the velocity and area we can vary these. If we were to increase the area of flow then the velocity would decrease. Now if we were to add another strainer (increase area) so two strainers were parallel with each other, in theory each one would receive half the flow (see Fig. 5). The converging outlet can only move 2700 GPM therefore each strainer is supplying half the flow, 1350 GPM, because in each pipe the velocity is theoretically half the initial velocity.

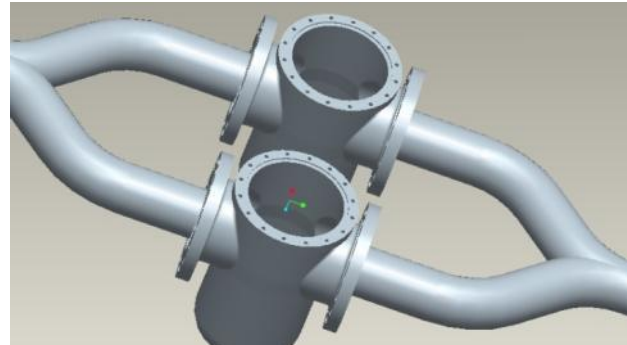


Figure 5. Parallel Strainers

In this scenario we are decreasing Q therefore decreasing Δp as seen in Eq. (1). Not only will Δp be decreased but we have also increased our basket area which would trap twice as much rust before decreasing the C_v value that is too small. This potential solution can solve the large Δp issues, but it is very expensive. The cost of a Keckley strainer that matches the current strainer is approximately \$31,000. This price doesn't include the converging and diverging pipe fittings to connect the 8" pipe to the strainers, replacing the concrete box area beneath the basket, and retro fitting the remote operating valve and drain pipe.

B. Varying the Valve Flow Coefficient (C_v)

The valve flow coefficient is described as "the flow of water through a valve at 60 °F in US gallons per minute at a pressure drop of 1 psi" (http://www.engineeringtoolbox.com/flow-coefficient-factor-d_238.html). It is possible to

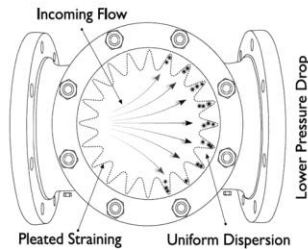


Figure 6. Pleated Top View

increase C_v of a basket that will fit into the current housing. This means the basket can collect rust longer therefore the longer; it will take for the filter to get a C_v number low enough to create a large Δp . This can be done by designing a different basket that will fit into the current strainer, so there will not be any configuration changes to the piping. If we increase the net flow area of the basket then theoretically we have increased C_v . As stated earlier this prolongs our run time as the filter gets choked down by the accumulating rust. As seen in Fig. 6 a pleated basket will help increase the C_v value.

Pleating the basket solves two problems. The first is that it increases the net flow area because it adds more surface area. we can also increase the size of the holes in the perforated sheet that backs the mesh and we can do this because the pleats add more strength. The original perforated sheet with 1/8" holes had a 43% total open area, and the new basket with 5/16" holes has a 62% total open area.



Figure 7. Pleated Basket

Including the mesh and perforated sheet the original basket had a net free open area of 144.6 in² and the pleated basket has a net free open area of 482.9 in². This increases the net flow area by 234%.

The pleats will also increase the strength of the basket which will help prevent the basket from buckling and failing which allows dirty water to flow to the steam generators.

C. Removing Rust

As the rust accumulates in the basket it needs to be cleaned out. With the current configuration this process has to be done manually. The lid has to be removed, filter pulled out and cleaned, and the lid put back on. This process takes about 1 hour. The basket strainer already has a drain hole in the bottom with a remote operated valve (ROV) attached, but it only drains the clean water from the bottom of the bowl. I wanted to utilize the ROV that was already in place to remove the rust. There were a couple different ideas that I went through to use the ROV. All of them use the idea of a bottomless basket as seen in Fig. 7.

The first was to use a large donut shaped rubber ring to seal the bottomless basket's outside edge against the housing's inner wall, see Fig. 8. The rubber ring would have a metal wedge shaped ring inserted into it. The metal wedge would have a bolt run up the center to a fixed hole on the bottom of the basket. As the bolt is tightened and the wedge is drawn up this will flare out the sides of the rubber ring creating a seal. The rust would be free to fall to the bottom of the housing and out the drain when the valve opens.

The second idea also uses a large donut shaped rubber ring. This ring would be wedged in between the basket and the strainer housing also, but this idea would use the shape of the bottom of the bowl, see Fig. 9. A bolt would be attached to the pipe nipple threaded through the bottom. This bolt would run up through the center of the basket and attach to a fixed hole on the bottom of the basket. As the nut is tightened on the bolt the basket gets pulled down into the housing. When the rubber seal and basket get pulled into the curvature of the housing it is squeezed in between the basket and the housing wall creating a seal.

This donut ring in these two designs would make sure the basket did not have any movement side to side. There are concerns with these two designs that need to be addressed. First the rubber ring for either of these designs is a custom made ring. Our machine shop on site can machine out a seal; however the material has to be kept very cold during the machining process and we need to use a soft 40 durometer material, so that increases the complexity of machining. This potentially makes the process very time consuming and expensive. The second issue is getting the basket sealed at the upper ring and lower ring at the same time. You could run into a situation where you need to pull down the basket more to seal the top ring, but there isn't any more squeeze room at the bottom. Third if this ring were to fail there would be a possibility of a large chunk being sent downstream. On Fig. 9 the bolt that is attached to the middle of the pipe nipple takes up room in the middle of the pipe. The attachment takes up needed room and area for the water and rust to drain out. I wasn't fond of using these ideas because of too much uncertainty. I did not know of any application like these two ideas so there is uncertainty in how well the large donut ring would work or seal. Also getting the correct amount of squeeze on the seal could be troublesome because the inside of the housing is a cast piece and imperfect.

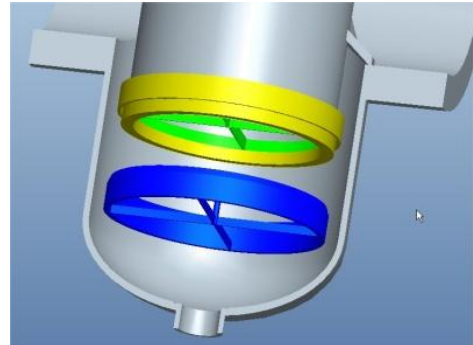


Figure 8. Wedge Seal

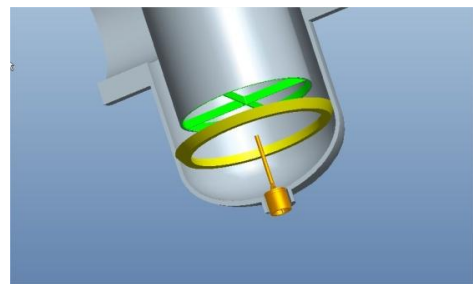


Figure 9. Pull Down Seal

The third design I decided to incorporate into the system. This option simply welds a funnel to the bottom of the basket. This funnel would have a spout on it that would be inserted into the pipe nipple threaded up through the bottom. When the spout was inserted into the pipe it would create a seal with two o-rings, see Fig. 10. This design does not allow movement of the basket from side to side, and also it gives some working room for error on the basket. There should be about one inch of pipe above the top o-ring and one inch below the bottom o-ring which allows for tolerance stack up. After looking at this design I realized there could be water trapped in the housing beneath the bottom of the basket from the top of the funnel on down. To alleviate this problem, I decided to drill holes into the funnel's spout to allow water to drain in. There are 300 holes around the spout that are 1/32" in diameter which will drain the water below the funnel.

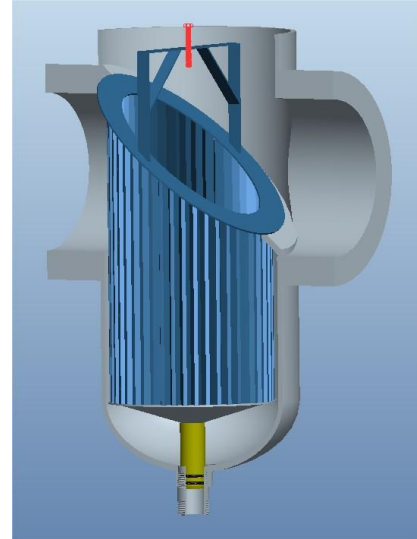


Figure 10. Basket with Funnel

D. Other Areas of Concern

There were more areas of this basket design that may be problematic. When the basket failed or when the Δp was too large we did not know how the water flowed or what was actually happening. Was the basket moving? Where did the majority of the rust accumulate? Where did it accumulate first? We could speculate on what was happening but it was not known for

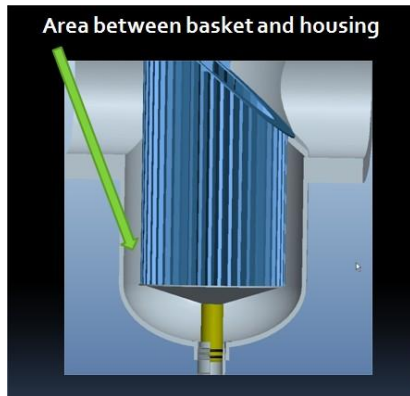


Figure 11. Housing area

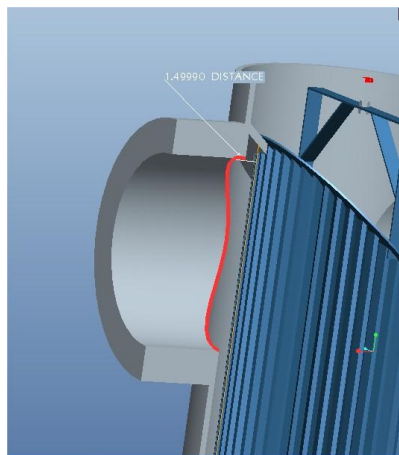


Figure 12. Curtain Area

sure. I did make some assumptions when looking into some possible problematic areas and that was to take a worst case scenario look at the flow. I assumed that the basket section directly in front of the outlet pipe would clog up first. That would make all of the 2700 GPM flow down into the basket and then back up and out into the outlet pipe.

The other assumption I made was by using a calculation done at WSTF in the fall of 2009 by Thomas Hansen and John Hennigan. I assumed they correctly found the amount of mesh used to correlate a Δp . In this calculation they used parallel orifice flow approximation to calculate the percent of mesh being used. With this calculation they came close to the manufacturer's Δp calculation. When only 43 in² of mesh was being used they approximated a Δp of only 4.55 psi. This is an acceptable Δp because the manual shutdown range is around 9 psi. I used the 43 in² to make judgment on other areas.

The first area I looked at was if there was enough area between the basket and the housings inner wall, see Fig. 11. I took the area inside the housing and subtracted the area of the pleated basket. This total area was 75 in². This area is about 30 in² more than 43 in² and the 8" schedule 80 inlet and outlet pipe which equals 45.66 in². The second area that I looked at was the area between the outlet pipe entrance and the basket. If worst case scenario happened where the entire screen was blocked in front of the outlet pipe then all the flow would have to go through the area between the outlet pipe entrance and the basket in which I'll call the curtain area, see Fig. 12. I wanted to be conservative with this area so I assumed that 25% would see no flow because the top area will see very little flow. I also assumed a non pleated basket and then I only added the area of four pleat sections or triangles. I wanted this area to be greater than 43 in² because if it was less it could create a Δp larger than 4.55 psi. It turned out to be the same area as the 8" schedule 80 pipe that supplies the strainer. Even with being conservative I found the curtain area to equal 45.4 in² and the 8" pipe equalled 45.66 in². Therefore I see this as being adequate space for the water to flow through without causing a large Δp . The reason I say this is because the area is similar to the pipe so theoretically the water velocity should be similar. Also if I assume the parallel orifice flow calculation to be a good representation of the amount of mesh being used then I can assume an open area that is equal or larger to be adequate area.

Not only did I do a side by side comparison of the area to the 43 in², but I also looked at a possible other limiting factor of liquid flow. A phenomena that can restrict liquid flow is cavitation. Cavitation occurs when the pressure is dropped low enough (due to high velocities) that the liquid forms bubbles and then collapses. When this occurs the liquid cannot be pushed any faster, and therefore this becomes a limiting factor.

$$Ca = \frac{P - P_v}{\frac{1}{2} \rho V^2} \quad (\text{Equation 3})$$

There is a cavitation number (Ca) that can be calculated (see Eq. 3) and when it is equal to one, the liquid should be cavitating¹. In this equation P is the pressure of the water inside the basket strainer, P_v is the vapor pressure of the liquid, ρ is the density and V is the velocity. Assuming that 2700 GPM is flowing through the area, I used Eq. (2) to find the velocity and saw that the cavitation number is approximately 227 which is nowhere near one. Therefore, cavitation is not a limiting factor in this area.

E. The Chosen One

By examining my options I found that having two strainers side by side is expensive and you would have to still manually remove the rust unless you spent more money on two baskets similar to the funnel design. The two other designs that used the donut shaped rubber ring had some uncertainty that I was uncomfortable with. The first was the making of the rubber ring. It could have been problematic in the manufacturing process. Additionally we don't know how well this idea will work since there are not any standards with this custom made seal, and we don't know the life of the seal. By using standard o-rings and standard glands we know they will work for our application. If the o-rings need replacing they are a standard o-ring and only cost \$0.57 a piece.

After careful consideration I chose to use the pleated basket with the funnel attached at the bottom because of cost and known reliability of the o-rings. I considered all areas of concern not to be problematic in the future. Improvements to the basket include: a stronger handle (compare Fig. 10 with Fig. 4) that will not allow the basket to have any upwards movement, pleating the basket which increases area 234% and strengthens the basket from buckling or failing. The pleats and the slightly smaller diameter basket increased the curtain area by 2 in². There was an improvement in the ability to remove rust remotely by using the funnel attachment which also doesn't allow any lateral movement of the basket.

The basket and o-rings were ordered offsite, but the funnel spout and the pipe nipple that the spout inserted into was custom made at the WSTF Machine Shop. The grand total for this basket totaled to approximately \$3,000.

Cavitation is an issue that needs to be looked at in the drain pipe. The current drain configuration probably cavitated at the ROV when it was opened. The new pipe nipple has a smaller diameter than the valve and we have possibly now moved the cavitation from the valve to the pipe nipple at the bottom of the basket strainer. The drain pipe should be looked at in the future to make sure cavitation has not eroded the interior pipe wall.

III. Module Log Books

White Sand Test Facility has been in place since the mid 1960's and our steam generators or modules were used to test for the Apollo Program and have been used all the way through to the present day. As a government facility there is paper work to describe everything that has had problems and to describe any work that has been done on the modules. This is good in the fact that there is a paper trail and history of each module, so you should be able to see if there are reoccurring problems or if certain items have been fixed or modified. The two forms that would be able to educate a person about the history of the machine would be a Discrepancy Report (DR) and a Test Preparation Sheet (TPS). The TPS's and DR's have been kept since the beginning, so there are records of these documents, and we want to put together a log book for each module.

As of right now when we look for a document we look through electronic records. Before there were electronic records the documents were on Microfilm. Later the Microfilm was scanned and converted to electronic files. Currently, to search and view these files we use a Microsoft Internet Information Server, WebXtender.

Within WebXtender you can search for the documents by TPS or DR numbers, date, close date, title, author or key words. With these documents having multiple indexes, finding a particular document should not

TPS#	DATE COORDINATION	DATE SIGNED	TITLE	PREPARED BY	Document ID	Pages
4-ALT-081950	06-21-06	06-21-06	INSTALL RING GEAR ON CARRIER ASSY.	D. SANTNER	23422	5
4-ALT	06-21-06	06-21-06	PDS	PDS	115592	2
4-ALT	06-21-06	06-21-06	PDS	PDS	115349	1
4-ALT-001	06-21-06	06-21-06	PDS	PDS	75127	1
4-ALT-001	06-21-06	06-21-06	PDS	PDS	75086	4
4-ALT-001	06-21-06	06-21-06	PDS	PDS	63294	2
4-ALT-002	06-21-06	06-21-06	PDS	PDS	75134	33
4-ALT-002	06-21-06	06-21-06	PDS	PDS	63306	2
4-ALT-003	06-21-06	06-21-06	PDS	PDS	63309	2
4-ALT-004	06-21-06	06-21-06	PDS	PDS	110651	3
4-ALT-004	06-21-06	06-21-06	PDS	PDS	63315	9
4-ALT-005	06-04-06	06-04-06	PDS	PDS	161383	7
4-ALT-005	06-21-06	06-21-06	PDS	PDS	63342	3
4-ALT-006	06-21-06	06-21-06	PDS	PDS	75149	2
4-ALT-006	06-21-06	06-21-06	PDS	PDS	63344	2
4-ALT-007	06-21-06	06-21-06	PDS	PDS	114307	12
4-ALT-007	06-21-06	06-21-06	PDS	PDS	77820	7
4-ALT-007	06-21-06	06-21-06	PDS	PDS	79151	19
4-ALT-007	06-21-06	06-21-06	PDS	PDS	73334	14

Figure 13. WebXtender View

be a problem. Currently there are a total of 8,285 TPS and DR documents that are associated with Propulsion 400 Test Area. Unfortunately, there are some shortcomings of the use of WebXtender. First the documents that were on Microfilm were stored with no indexing except the TPS or DR number. There are dates that show up but they do not match what is on the paper. The other fields have PDS in them which is the company that had done the scanning, see Fig. 13. As you can see, without the indexing it can be very difficult to search for a particular document that is needed. To even complicate matters we don't think all TPS's and DR's are in the system.

These documents are currently being transferred to a site wide drive (W drive). This will consolidate the files but they are not being indexed in any way or fashion except by TPS or DR number. Unfortunately this isn't necessarily solving our problems. I have asked when all the documents will be put in the system and there is not a known time line.

A. Getting the Documents

Our thought is that if we can download all of the documents from WebXtender then we can use our own Optical Character Recognition software (OCR) to read through the documents in order to search through them. There are a few obstacles you have to overcome. First you can access and download and save the documents, but WebXtender doesn't allow me to do a batch export. You have to save them one by one, and this can be very time consuming since there is 8,285 documents. Second is that the older documents have been hand written, so OCR programs are not able to recognize hand writing. I talked to a few companies that archive documents for governments and private businesses, and they informed me that the OCR technology is not advanced enough to recognize cursive hand written documents. To make matters even worse, the documents that were scanned were papers from the bottom of a multilayered carbon copy, so the quality is poor.

Even with these obstacles there are ways to organize the documents. Downloading them can be done two different ways. The first way is to pay the department that has access to do a batch export to download them for us. The alternative option is to download them one by one, but use a program that will run the process through a loop so it will do it over and over again by itself. Microsoft had a macro recorder come with older versions of Windows, but they no longer have this program in the current operating system. This macro recorder will record all mouse movements, clicks, keystrokes, delays and etc. The macro recorder then would give you script of what you recorded. You are then able to manipulate the script to make it run how you want. For instance you can make it run in a loop over and over again.

I looked online for a reliable free macro recorder, but I was only able find a trial version. I was able to get the program to run through about 10 to 15 iterations before it would encounter a problem, so it will take more tweaking to make it reliable.

B. Sorting the Documents

Once we have the documents downloaded we can then search through them. Johnson Space Center (JSC) has a Google search engine that we can use to search through the documents and possibly OCR them while it searches. This will allow you search with keywords. Dealing with the documents that are older is going to be a bit trickier. A potential issue is that we won't be able to separate out the documents pertaining to the steam generator only. The TPS and DR numbers should be in numerical order, so therefore a person can go into the documents and see what years are in certain number ranges then organize them by years.

This does not ultimately solve the problem and allow a person to quickly look up documents and separate out the steam generator documents. It does give an easier starting point by having the years separated. If a person knows that a particular module has not had certain issues in the last ten years then they could easily navigate to the years prior to that. Having the hand written documents will still make the user manually look through documents to find specific information. Technology has not advanced far enough to have a computer read poor quality handwriting.

Altitude Support Estimates			
Current Site Electrical Cost	0.02711	/Kw	
Current Alcohol Cost	\$ 5.72	/Gal	
Current Diesel Cost	\$ 3.50	/Gal	
Current LOX Cost	\$ 0.44	/Gal	
Current Labor Cost	\$ 54.00	/hr	
Current water pumping Cost	\$ 0.00023	/gal	
Electrical Demand Charge	\$ 19.80	/Kw	
Note: Estimated costs will vary with fuel, propellant and electrical costs change /hour			
LASS - Per Module			Cost/hr
Alcohol	170 GPM	\$ 5.72 /Gal	\$58,344.00
LOX	300 GPM	\$ 0.44 /Gal	\$ 7,920.00
Diesel	8 GPM	\$ 3.50 /Gal	\$ 1,680.00
Electric	250 HP	186.4 Kw	\$ 6.78
Manpower *	17 mhrs	\$ 54.00 hrs	\$ 918.00
Site water pumping	1000 GPM	\$0.00023 /gal	\$ 13.80
Injection Water	1500 GPM	\$0.00023 /gal	\$ 20.70
Total			\$68,882.58 /hour
1 Module Per Hour	\$ 68,882.58		
1 Module Per Hour minus Labor	\$ 67,964.58		
3 Modules minus Labor	\$ 203,893.73		
3 Modules plus Labor	\$ 204,811.73		
3 Modules per Minute	\$ 3,413.53		
3 Modules per Second	\$ 56.89		

Figure 14. LASS Expenses

IV. Simulator Case

The Propulsion Department in the 400 Test Area runs the LASS tests from the block house as seen in Fig. 15. Altitude Support estimates running LASS at a cost of over \$204,000 per hour (see Fig. 14) it is not a system that you want to have mishaps or human error during the firings. One way to prepare is to have the personnel use a simulator. This simulator allows personnel to go through the steps and different scenarios. Currently the simulation is done with two 19" touch screen monitors. These monitors are mounted in a six foot by two foot cabinet on wheels and are not located in the block house. The cabinet is quite bulky for only two 19" monitors. The goal is to run the simulation inside the block house to give the most real-life feel. This means the bulky cabinet would have to be moved in and out of the block house which can be done, but it is difficult because there is a step at all entries.

My project was to design a case that could house the two monitors. The ideal placement of the monitors would be to set them on a desk as seen in Fig. 15.

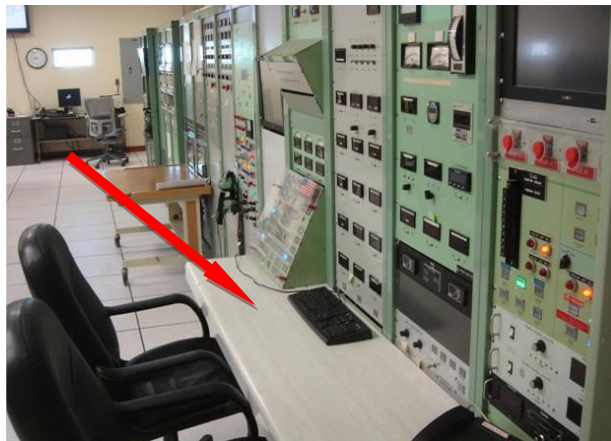


Figure 15. Block House Desk Top

A. Obstacles

One of the obstacles in designing a case was the size of the desk area. The desk area maximum depth area was only 19.5". With this depth I had to be careful in not getting too much overhang over the outer edge of the desk. If it did overhang you could bump it or might be unstable because my ideas hinged the two monitors at the front the case putting weight towards the front.

Another issue was the height of the case and monitors when they were being used. I wanted the case to block the sight of the instrument readings as little as possible. Keeping the case or monitors as low as possible will help this issue.

The last issue is the weight of the case. I need to keep the weight of the case as low as possible because the weight of the monitors combined is 34 pounds, and if I'm not careful the weight could get heavy enough that carrying and placing the case on the desk could be troublesome.

B. Designs

In general I am looking at designing a case that will look like a long briefcase. Addressing the height issue, I thought the best option would be to place the monitors side by side in a bracket that would hinge at the bottom of the monitors. I wanted them in a bracket that would hinge so you could bring them up to a position that would reduce the glare off the screen and be able to be seen easily. My first design idea was to have the bracket with the monitors rest on a double hinged lid. The lid would be a bi-folding lid so it could be positioned in a manner that the bracket could rest on the lid itself. This design is simple, doesn't have any complicated hinging system and utilizes the lid for support see Fig. 16.

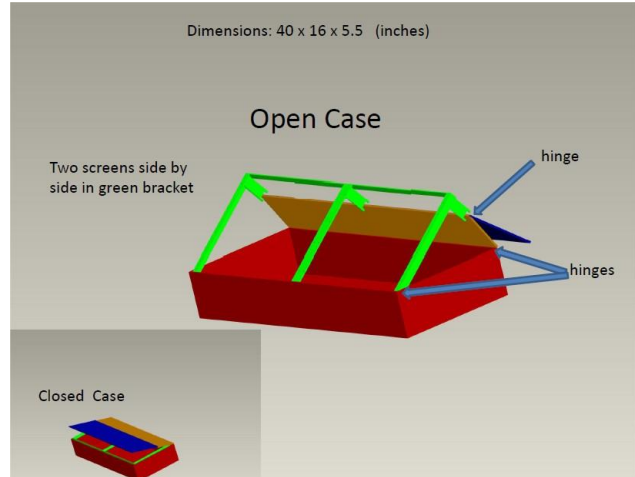


Figure 16. Non Adjustable Height

There are two problems with this design. The first is that the height is not adjustable. The viewing angle can not be adjusted for each user. One user may want to sit down for use and another may want to stand up, so the viewing angles would be different, especially for tall people compared to shorter people. The second problem is that the bi-folding lid sticks out at the back making it harder to sit on the desk top within the 19.5".

The second design would implement a lid stay that would attach to the side of the case and the top of the bracket. The lid stay would then hold the monitors at a particular angle and the lid could be removed. I had a custom case manufacturer give a quote of \$625. This solves the space issue pertaining to the lid being in the way when folded back, but the monitors angle is still not adjustable.

The third design tweaks the first design. There is still a bi-folding lid, but there are ratcheting hinges that allow for different heights of the monitors see Fig. 17. The hinges on the monitor are not pictured but they would attach to the side of the case and the top of the bracket allowing for an angle of 11° to 89° range of adjustment. The lid folds back on itself to give the case more room on the desk, but the lid will get in the way for the monitors at a lower angle. Instead of having a bi-folding lid the solution would be to make the lid completely removable.

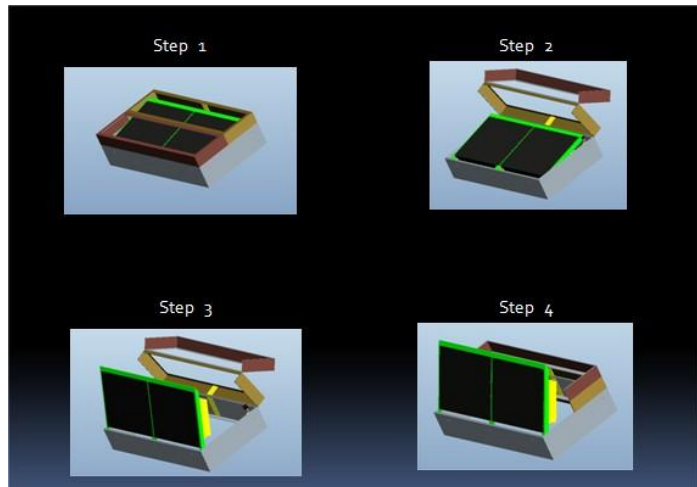


Figure 17. Case with Ratcheting Hinges

The last issue dealt with was weight. The two custom case manufactures uses wood covered with fiberglass and their weights were approximately 40-45 pounds. If the case seen in Fig.17 was made of 1/8" aluminum sheet metal and the top and bottom panels were made of a fiberglass panel the weight could get down to approximately 35 pounds.

V. Conclusion

Designing the basket strainer is what I spent the majority of time working on. In the end I chose the pleated basket with the funnel because it increased my area, gave us a way to remotely remove the rust and also kept the cost to a minimum.

The module log books' documents need to be compiled and categorized so they are able to be searched through efficiently. Currently, there is not a good way to go through the documents and make a log book for each individual module due to the older documents without manually going through them and reading them.

Designing the simulator case has not been completed but I suggest a case that hinges the monitors together and is adjustable. In order to work properly, the lid will probably need to be removed completely. Currently the sheet metal that is formed and riveted is the lightest idea, but I am not sure on the cost of having one manufactured compared to using the wood and fiberglass.

These projects illustrate how design was my main focus during my time spent as an intern at White Sands Test Facility. During these 15 weeks I was able to get the basket for the strainer manufactured. During the design of these projects I became more skilled about conveying my thoughts to others. I learned about the cavitation of a liquid, about o-rings and how to select and design their glands. I discovered how important details are like tolerance stack up, the clearance of fits, meeting code for pressure vessels and procedures at NASA and why they are in place.

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