Sprayer Attachment for Zero Turn Lawn Mower

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Bachelor of Science

in Mechanical Engineering Technology

by

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ABSTRACT

This senior design project with the University of Cincinnati explores and develops a product used to spray liquid herbicide for residential lawns with a zero turn lawn mower. Spraying for weeds can help prevent the spread of pest weeds that can damage lawns. In this report the design process and material selection for the products will be shown. There will also be conceptual designs and actual designs for the project. This thesis was prepared for the University of Cincinnati Mechanical, Engineering Technology field of study.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

A drawback to owning a zero-turn lawn mower is the ability to add attachments like a typical riding lawn mower. Do-it-yourself lawn enthusiasts who have zero-turn lawn mowers are limited to these attachments due to the configuration of these types of mowers.
My project is to design and build a sprayer system that is attachable and detachable for my specific zero-turn lawn mower. The sprayer is to be used specifically for spraying weeds.

BACKGROUND

Zero-turn lawn mowers are known for their ability to turn 360 degrees without having to stop and back up or go forward. One of the downfalls to having a zero-turn lawn mower is not being able to have attachment such as lawn sprayers, aerators and other pull behind applications for lawn care. This is due to how the steering system works with a zero-turn lawn mower.

The weight distribution of the mower is often more in the back of the mower because of the location of the engine. Having a tongue weight of a pull behind application could cause tipping of the mower. The biggest concern is the habit of driving the zero-turn mower. The steering system is in the rear wheels, making able to spin 360 degrees. If there is a pull behind application and the rider makes a turn to go the other direction, this could create a collision and damage the machine.

RESEARCH

SCOPE OF THE PROBLEM

Zero-turn lawn mowers are known for their ability to turn 180 degrees without having to back up or go forward. (1) With this kind of drive system, making attachments such as tow behind sprayers, spreaders, and aerators can be difficult due to the weight distribution of the mower and it's form of steering. Having the steering integrated in with the drive wheels, the mower cannot safely tow unless the towed device is fixed onto the mower and there is a caster wheel to hold up the device, so it can maneuver without binding up. This however can become bulky and time consuming to attach and detach.

Zero-turn mowers are becoming more popular for homeowners because they are comfortable, have great handling and can mow lawns quickly and efficiently. (2) With the way a zero-turn lawn mower works, using a typical tow-behind sprayer can cause damage to the mower and sprayer if the user isn't carful. With this danger, it is not recommended to tow equipment with zero-turn lawn mowers.

For some homeowners, dandelions and other broadleaf weeds are among the most troublesome turf pest problems in lawns. (3) Some lawn enthusiast take measures into their own hands by spraying for these weeds using common off the shelf weed killer concentrate. Other use a paid service to spray their lawns every month. This paid service can be expensive

and have the liberty to spray on a specific schedule. For homeowners who tackle their own weeds, common sprayers are tow-behind options due to the typical lawn tractor style. With zero-turn mowers becoming more popular some homeowners are finding that the tow-behind sprayers are troublesome to mess with on a zero-turn style lawn mower.

Applying herbicides isn't just as easy as point and spray. There can be many factors to consider for a spray boom for a moving sprayer. Some of those factors can be spray drift, too heavy or little of a spray, and little or too much pressure. Droplet size is dependent on the interaction of nozzle type, size, and pressure. (4) Having a lower spray pressure can result in a thicker spray which could over treat the area causing pollution and damage to non-targeted plants. On the other hand, too much spray pressure can cause the spray to be light and airy, allowing the spray to not cover the plant sufficiently or evaporating too quick. Spray drift is the physical movement of the herbicide to any other site other than the one intended for. Spray drift also increases with wind and when too small of droplets compromise the spray pattern. (5) Spray drift is also dependent on the nozzle selection and pressures.

CURRENT STATE OF THE ART

Currently, broadcast sprayers are typically pull behind applications for homeowners with lawn tractor. These sprayers are usually attached using a pin hitch on the back of the lawn tractor. Ranging in tank size of 15 to 25 gallons, these sprayers can have a spray width of 84 inches to 100 inches. Also, these sprayers can be equipped with spot sprayers for additional hard to reach areas. See figures 1 and 2.

Figure 1. Agri-Fab 15-gallon tow-behind sprayer (6)

Figure 2. Northstar 31-gallon tow-behind sprayer and spot sprayer (6)

In addition to the tow-behind sprayers, All-Terrain Vehicle (ATV) mounted sprayers are available. This sprayer style is bloomless or has one to two nozzles for broadcast spraying. In figure 3, you can see the two nozzles are attached to a hitch receiver and the spray tank is mounted to the storage area of an ATV. However, not every homeowner owns an ATV or has access to an ATV.

Figure 3. Northstar ATV Boomless broadcast and spot sprayer 26-gallon. (8)

Finally, one company has produced a sprayer system for a zero-turn mower that sits on the front of the mower. In figure 4, this sprayer has a 100-inch spray boom in the front of the

mower. With various nozzles, this sprayer can spray a large area quickly claiming to minimize spray drift. This product also features a on and off switch that is easy to access by foot and a foldable boom. I think this product is intended to stay attached to the mower at all times and is about $1000.00 USD.

Figure 4. Tide Industries Zero-Spray (9)

These sprayers are all meant to be pulled behind the lawn mower or ATV except for one. This one is in the front of the lawn mower. The design of figure 4 could possibly get the chemical all over the lawn mower. This also may be harmful to the operators raspatory system beings the operator is behind the spray path.

END USER

This product is intended for the common homeowner, specifically homeowners with zero-turn lawn mowers, who would like to keep their yard weed free and greener by applying herbicides themselves. This type of sprayer can be used for medium to larger sized lawns. This product is also to help reduce the need of buying extra vehicles or special purpose devices to apply the herbicide of the user's choice. By mounting a spraying tank to the front of the mower, the user can see the liquid level at all times and the user does not have to worry about sharp turns binding up a tow-behind style sprayer. The spray boom is to be located in such area that reduces the chance of getting the lawn mower wet with chemicals and to also provide the best spray coverage.

CONCLUSIONS AND SUMMARY OF RESEARCH

Homeowners who own zero-turn lawn mowers can come to a disadvantage to keeping their lawn free of broadleaf weeds. Currently there is one purchasable method for a direct mounted sprayer. Costing roughly $1000.00 USD, this sprayer has some design flaws which could hurt the lawn mower and or harm the operator. With zero-turn mowers becoming popular, a device such as an attachable and detachable sprayer could be a useful tool to the lawn enthusiast who wants a weed free lawn. Things to consider with a spraying device is spray drift, and amount of spray to be distributed. Too much liquid spray could cause pollution and

may harm other plants other than the targeted weeds. Not enough spray could not distribute the herbicide effectively, thus waiting time and product. Spray drift could also cause other plants to be affected by the broadleaf weed killer possibly making a landscape appearance look rough.

CUSTOMER FEATURES

Using a customer survey to determine key features of the sprayer system, data was collected for the following questions. See table 1 and 2. Refer to appendix a for survey and survey results.

How important is each feature to you for a zero-turn spraying system? 1 = Not important 5 = Very Important	
	Average response
Initial investment cost	3.667
Efficiency	4.5
Ease of use	4.5
Tank capacity	4.1667
Size of spray path	4.5
Attaching/ Detaching	4.6667

Table 1. Showing average data from question one of survey

How satisfied are you with current spraying technology? 1 = unsatisfied 5 = Very satisfied	
	Average response
Initial investment cost	3
Efficiency	2.6667
Ease of use	2.6667
Tank capacity	2.8333
Size of spray path	3
Attaching/ Detaching	3.6667

Table 2. Showing average data from question two of survey

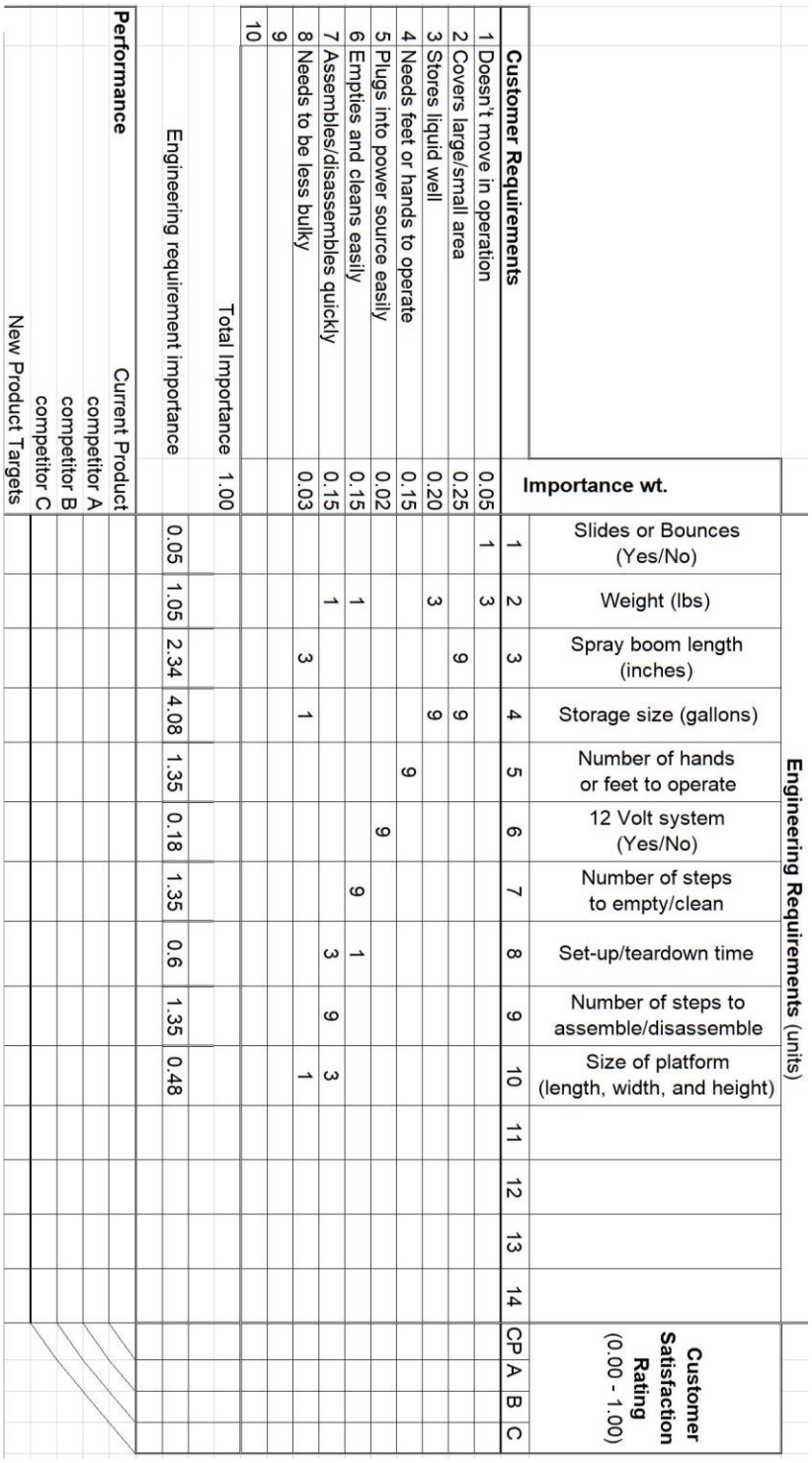
PRODUCT OBJECTIVES

Product objectives	Importance weight
Covers large/small area	25.00%
Stores liquid well	20.00%
Needs feet or hand to operate	15.00%
Empties and cleans easily	15.00%
Assembles/ disassembles quickly	15.00%
Doesn't move in operation	5.00%
Needs to be less bulky	3.00%
Plugs into power source easily	2.00%

Table 3. Importance raking of product objectives.

From the house of quality, the most important objective is how big the spray path is. Similar to the spray path, the storage of the liquid is also the most important. This can be related to tank size and tank material. These objectives can be addressed by seeing what is available to buy at a store or website under chemical spray tanks.

QUALITY FUNCTION DEPLOYMENT



Customer Requirements	Importance wt.	Slides or Bounces (Yes/No)	Weight (lbs)	Spray boom length (inches)	Storage size (gallons)	Number of hands or feet to operate	12 Volt system (Yes/No)	Number of steps to empty/clean	Set-up/teardown time	Number of steps to assemble/disassemble	Size of platform (length, width, and height)					Customer Satisfaction Rating (0.00 - 1.00)			
		Engineering Requirements (units)																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	CP	A	B	C
1 Doesn't move in operation	0.05	1	3																
2 Covers large/small area	0.25			9	9														
3 Stores liquid well	0.20		3		9														
4 Needs feet or hands to operate	0.15					9													
5 Plugs into power source easily	0.02						9												
6 Empties and cleans easily	0.15		1					9	1										
7 Assembles/disassembles quickly	0.15		1						3	9	3								
8 Needs to be less bulky	0.03			3	1						1								
9																			
10																			
Total Importance	1.00																		
Engineering requirement importance		0.05	1.05	2.34	4.08	1.35	0.18	1.35	0.6	1.35	0.48								
Performance																			
Current Product																			
competitor A																			
competitor B																			
competitor C																			
New Product Targets																			

Interaction Matrix

Engineering Requirements		Slides or Bounces(Yes/No)	Weight (lbs)	Spray boom length(inches)	Storage size (gallons)	Number of handsor feet to operate	12 Volt system(Yes/No)	Number of stepsto empty/clean	Set-up/teardown time	Number of steps toassemble/disassemble	Size of platform(length, width, and height)	0	0	0	0
Engineering Requirements		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Slides or Bounces(Yes/No)	1		3								1				
Weight (lbs)	2				9				1	1	3				
Spray boom length(inches)	3										9				
Storage size (gallons)	4									3					
Number of handsor feet to operate	5														
12 Volt system(Yes/No)	6														
Number of stepsto empty/clean	7								9	3					
Set-up/teardown time	8									9					
Number of steps toassemble/disassemble	9														
Size of platform(length, width, and height)	10														

DESIGN

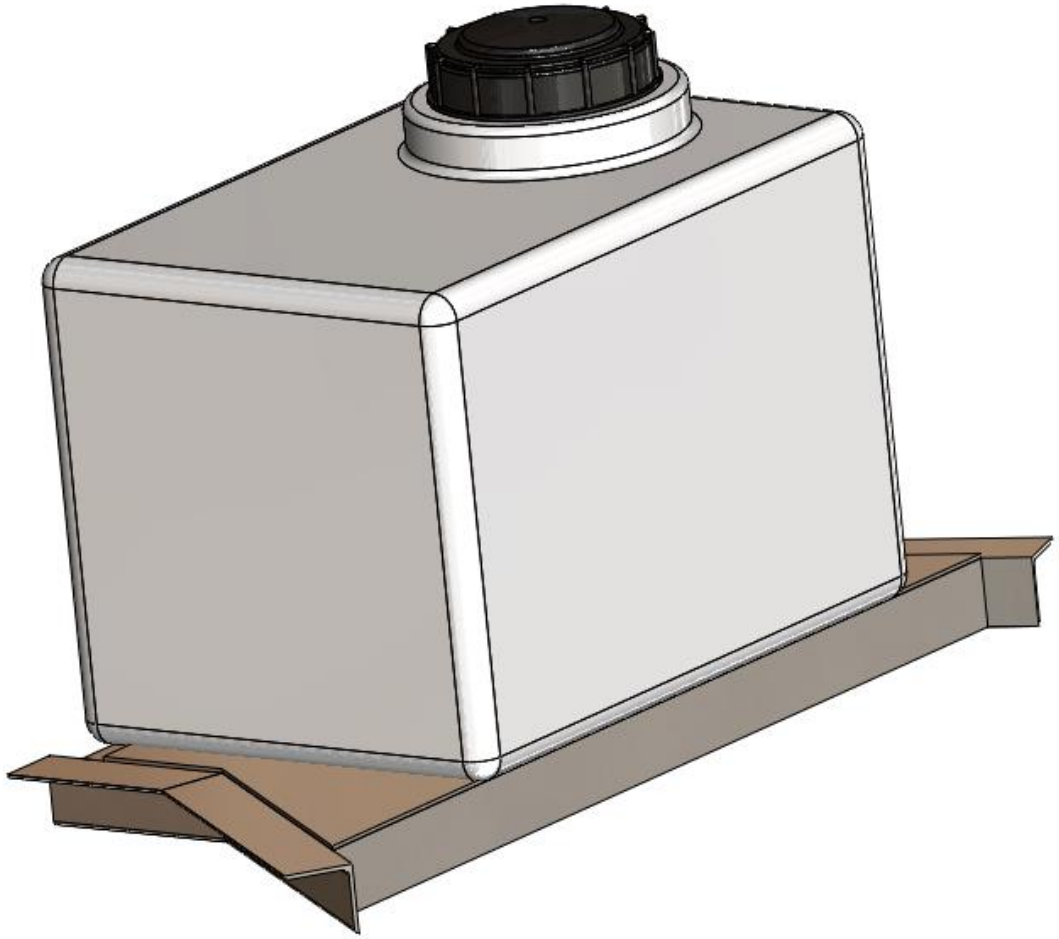


Figure 5. Concept 1

Figure 5 has an angled steel frame that could be easy to take on and off the mower easily. It has a cover on the top of the frame. The extra weight of the cover on the top of frame is unnecessary and could be done without.

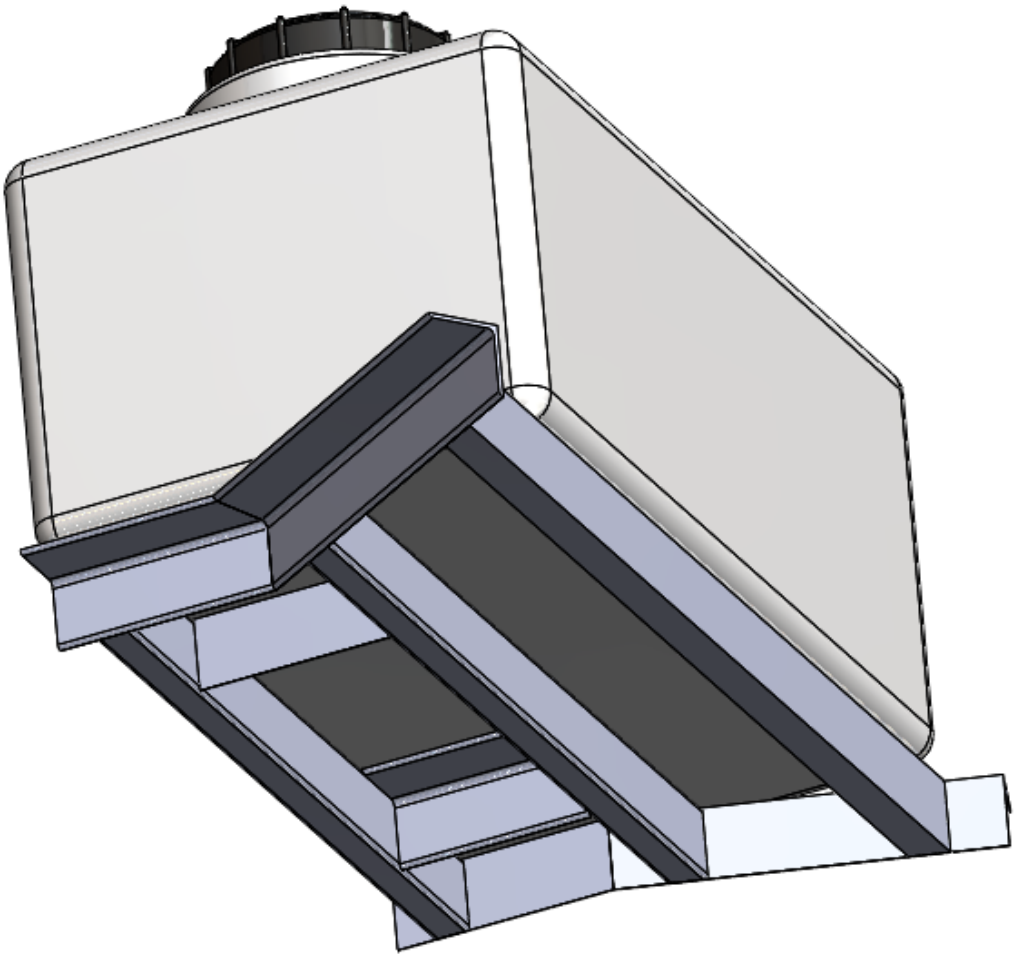


Figure 6. Concept 2

Figure 6 is a concept selection that seems easy to take on and off and has proper supports for the tank. Similar to concept 1 it has a angled steel frame but it does not have the cover on top of the frame.

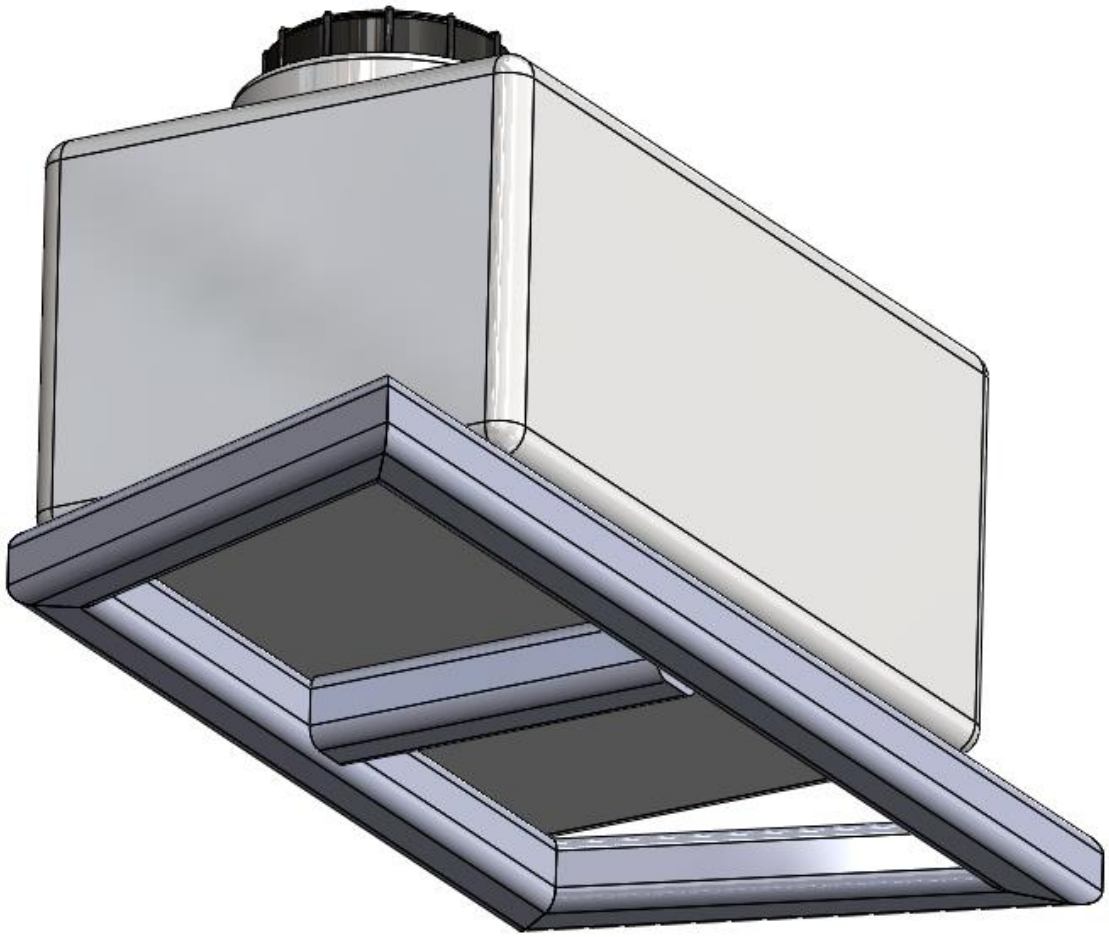


Figure 7. Concept 3

Figure 7 has a tubular frame and only 2 supports. Due to weight this concept was not used.

Figure 8. Concept of sprayer boom. 70 inches long, four nozzles 20 inches apart.

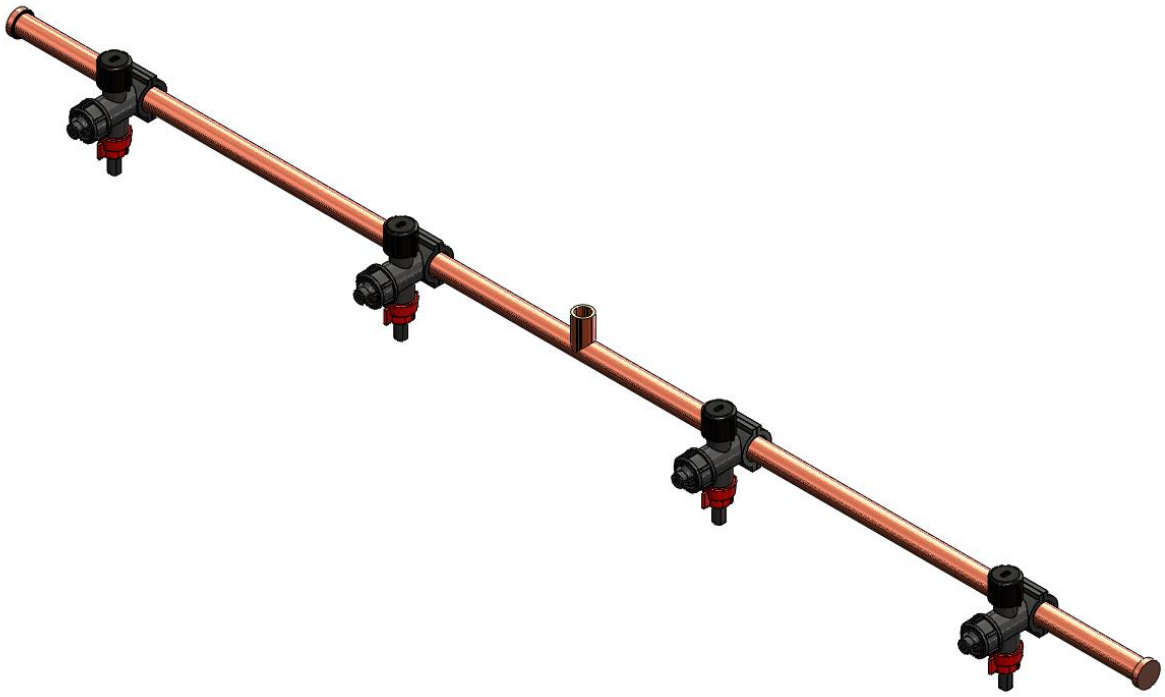


Figure 9. Spray boom, 54 inches, four nozzles 15 inches apart.

Listed above is the concept drawings for the design. These concepts have slight changes in tank size, boom size and framing sizes. Each frame has a different design for load distribution. The spray boom is pretty simple. It is a tube with nozzles clamped to the tube.

ACTUAL DESIGN SELECTION

For the actual design, there were some slight modifications. Upon getting the tank, the bolt pattern did not line up exactly to the specifications of the manufacture, so some extra work was done to accommodate the proper fitting of the tank. The final design was determined by cutting and welding the angled steel onto the mower itself. There were specific angles for the mower that could not be calculated accurately, so fabrication was done without a drawing of the frame. This worked out okay because after the frame was welded, an accurate drawing was produced. During fabrication, there needed to be some extra supports in the front so there would not be any tipping during operation. This didn't add a lot of weight to the attachment. Figures 10 though 12 show the final design.

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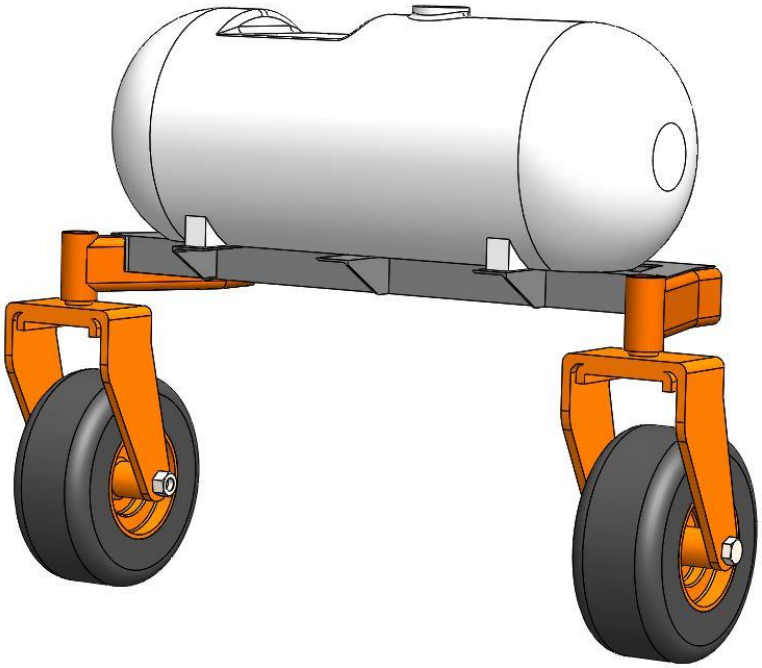

Figure 10 Front view

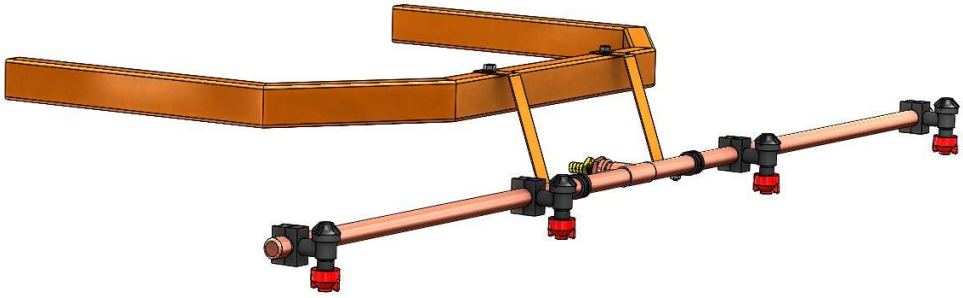

Figure 11 Boom at rear of mower

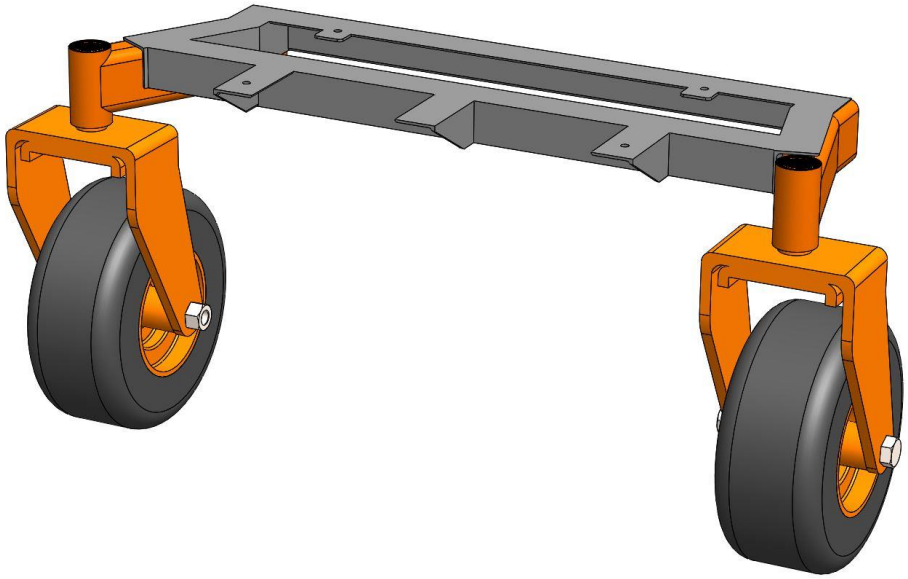

Figure 12 Front view of frame without tank

LOADING CONDITIONS

Loading conditions was done in ANSYS software. It was tested using a max of 500 lbs. The resultant graphs are in figures 13 and 14. I assumed uniform weight distribution because the tank was the same size as the frame.

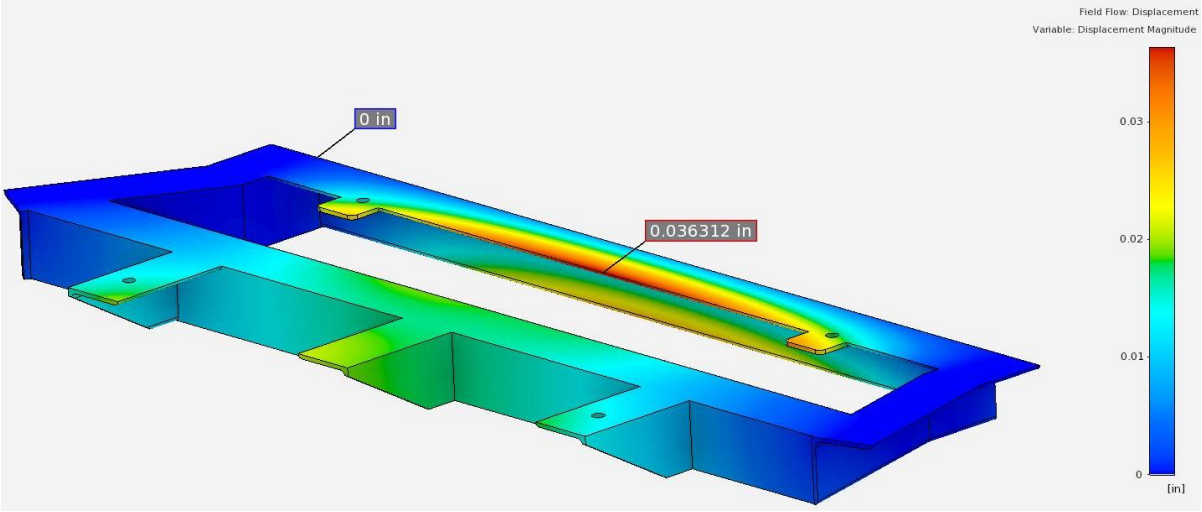

Figure 13 Displacement of loading conditions

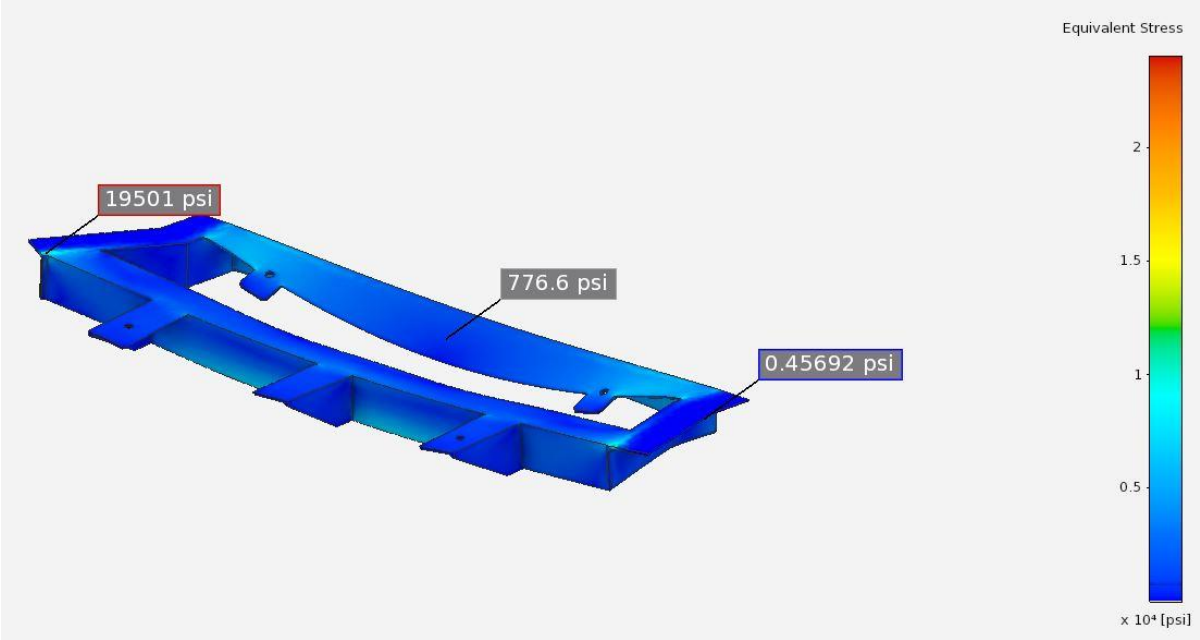

Figure 14 Equivalent stress

DESIGN ANALYSIS

For the design analysis of the sprayer system, Fluid dynamics were considered. The pump purchased had a 10-foot pump head with a flow rate of 2.2 gallons per minute at 70 psi. The design had to have a friction loss under 10 feet in order to work properly. In appendix A are the calculations used to obtain the losses in the piping system.

COMPONENT SELECTION

½ inch automotive heater hose was used to deliver the fluid to the rear attached spray boom. This heater hose is made of thick nylon reinforced rubber. The spray boom was made of ¾ inch type L copper pipe. Both components can withstand higher pressures and chemicals. The spray nozzles are agricultural grade spraying equipment. This let me assume that the tips are chemical safe and that the droplet size of the liquid is correct. There are many different types of spray tips, but I chose the common tip for spraying weeds. The tank was a 16 Gallon chemical resistant tank made for spraying. A 16 gallon tank was chosen because the typical yard assumed was less than a quarter of an acer. A simple on/off foot switch was wired into a master shut off switch so that hands free operation was achieved.

BILL OF MATERIALS

3/4" Type L Copper Pipe 10'
(2) 3/4" Copper Pipe Cap
3/4" Copper Adapter
3/4" Copper Tee
16 Gallon Tank
2.2 GPM Pump
(5) Red Nozzle Tips
(5) Tee Jet Mounts
Agitation Kit
Lock Nuts
Slide Terminal
On/Off Switch
Connect Wire
10' Hose
1/2" to 3/4" Hose barb
Vibration Clips
Angle Steel 10’

PROJECT MANAGEMENT

BUDGET, PROPOSED/ACTUAL

The budget for this project is set to $350.00. Here is the cost breakdown.

Items	Price
3/4" Type L Copper Pipe 10'	$20.48
(2) 3/4" Copper Pipe Cap	$2.96
3/4" Copper Adapter	$6.68
3/4" Copper Tee	$3.08
Tax	$2.53
Total Sale	$35.73
Items	
16 Galon Tank	$42.99
2.2 GPM Pump	$89.99
Tax	$10.13
Total Sale	$143.11
Items	
(5) Red Nozzel Tips	$44.25
(5) Tee Jet Mounts	$31.40
Total	$75.65
Items	
Agitation Kit	$19.99
Total	$21.74
Items	
Lock Nuts	$1.53
Slide Terminal	$2.96
On/Off Switch	$12.69
Connect Wire	$2.95
10' Hose	$5.90
Total	$27.93
Items	
1/2" to 3/4" Hose barb	$9.36
Total	$10.55
Items	
Vibration Clips	$7.71
Total	$8.77
Items	
Angle Steel	$18.00
Grand Total	**$341.48**

SCHEDULE, PROPOSED /ACTUAL

Proposed

Proposal	Fall 2018
Have all parts ordered	March 1 2019
Start of Assembly	March 11 2019
Prepare for Tech Expo	April 15 2019
Finish report by	May 3 2019

Actual

Proposal	Fall 2018
Have all parts ordered	March 1 2019
Start of Assembly	March 11 2019
End of Assembly	March 25 2019
Prepare for Tech Expo	April 15 2019
Finished Report	May 1 2019

PLAN TO FINISH

When testing, the 1/128th acer was used. Because a gallon is 128 ounces and the test area to be sprayed is 1/128th of an acre, the number of ounces collected equals the gallons per acer. (10) When conducting the experiment, the sprayer sprayed about 16-20 gallons of water which would equal about 16-20 gallons per acer. This may seem like a lot but considering that most lawns assumed are only ¼ of an acer. During the testing phase, the spray pattern was checked for uniformity and was checked by spraying on a dry sections of road or pavement. Water was used in all tests, no chemicals were released. After the tests, the spray pattern was uniform and covered very well. After testing, clean up was simple and disassembly took less than five minutes.

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APPENDIX A

Customer Survey
Zero-Turn Spraying System Attachment

This survey will be used to prioritize various features to maximize customer satisfaction. The system in question will address issues for home owners who have a zero-turn lawn mower, who want to spray for weeds to keep their grass weed free and greener with liquid solution. This spraying system is meant to mount on the front of a zero-turn mower for faster spray application. The system is also meant to be detachable when not spraying.

How important is each feature to you for a zero-turn spraying system?

Please circle an appropriate answer.	**1 = Low importance**				**5 = High importance**	
Initial investment cost	**1**	**2**	**3**	**4**	**5**	**N/A**
Efficiency	**1**	**2**	**3**	**4**	**5**	**N/A**
Ease of use	**1**	**2**	**3**	**4**	**5**	**N/A**
Tank capacity	**1**	**2**	**3**	**4**	**5**	**N/A**
Size of spray path	**1**	**2**	**3**	**4**	**5**	**N/A**
Attaching/ Detaching	**1**	**2**	**3**	**4**	**5**	**N/A**

How satisfied are you with current spraying technology?

Please circle an appropriate answer.			**1 = Unsatisfied**		**5 = Very satisfied**	
Initial investment cost	**1**	**2**	**3**	**4**	**5**	**N/A**
Efficiency	**1**	**2**	**3**	**4**	**5**	**N/A**
Ease of use	**1**	**2**	**3**	**4**	**5**	**N/A**
Tank capacity	**1**	**2**	**3**	**4**	**5**	**N/A**
Size of spray path	**1**	**2**	**3**	**4**	**5**	**N/A**
Attaching/ Detaching	**1**	**2**	**3**	**4**	**5**	**N/A**

How much would you be willing to invest in the product? $_____
What features would you like to have or prefer on this style sprayer? Please list your preferences below or on the back of this sheet.

APPENDIX B

Knowns:
Pump head – 10 ft
GPM 2.2 Q = $4.9x10^{-3}$ ft^3/s
PSI - 70
¾" pipe length – 5.25 ft
Hose dia. - .0417 ft
Hose area - .001364 ft^2
Pipe dia. - .0654 ft
Pipe area - .003361 ft^2
Water properties
P = 1.94 $slug/ft^3$
μ = $1.9x10^{-5}$ lbf sec/ft^2
K values
Tee fitting = .69
Hose to pipe = .13
Y fitting = .14

Velocity of hose

$$V_{hose} = \frac{Q}{A} \rightarrow \frac{4.9x10^{-3}\ ft^3/s}{.001364\ ft^2} \rightarrow V_{hose} = 3.59\frac{ft^2}{sec}$$

Velocity of pipe

$$V_{pipe} = \frac{Q}{A} \rightarrow \frac{4.9x10^{-3}\ ft^3/s}{.003361\ ft^2} \rightarrow V_{pipe} = 1.45\frac{ft^2}{sec}$$

Reynolds number for hose

$$Re_{hose} = \frac{\rho V_{hose} d_{hose}}{\mu} \rightarrow \frac{(1.94)(3.59)(.0417)}{1.9x10^{-5}} \rightarrow Re_{hose} = 500.47$$

Reynolds number for pipe

$$Re_{pipe} = \frac{\rho V_{pipe} d_{pipe}}{\mu} \rightarrow \frac{(1.94)(1.45)(.0654)}{1.9x10^{-5}} \rightarrow Re_{pipe} = 500.47$$

$$f_{hose} = \frac{64}{Re_{hose}} \rightarrow \frac{64}{500.47} \rightarrow f_{hose} = .1278ft$$

$$f_{pipe} = \frac{64}{Re_{pipe}} \rightarrow \frac{64}{500.47} \rightarrow f_{pipe} = .1278ft$$

$$\frac{f \times L_{hose}}{d_{hose}} \times \frac{V_{hose}^{\ 2}}{2(32.2)} \rightarrow \frac{.127(8.25)}{.0417} \times \frac{(3.59)^2}{2(32.2)} \rightarrow = 5.08ft$$

$$\frac{f \times L_{pipe}}{d_{pipe}} \times \frac{V_{pipe}^{\ 2}}{2(32.2)} \rightarrow \frac{.127(5.25)}{.0417} \times \frac{(1.45)^2}{2(32.2)} \rightarrow = .338ft$$

Sum of friction in fittings

$$\sum K \times \frac{V_{hose}^{\ 2}}{2(32.2)} \rightarrow .96 \times \frac{3.59^2}{2(32.2)} \rightarrow .192\ ft$$

$$\sum K \times \frac{V_{pipe}^{\ 2}}{2(32.2)} \rightarrow .96 \times \frac{1.45^2}{2(32.2)} \rightarrow .032\ ft$$

Total friction force

$$Total\ friction = 5.05 + .338 + .192 + .032 \rightarrow = 5.643$$

SPRAY APPLICATION CHART

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800-445-8360

Spray Nozzle	Uses	Pressure Range (PSI)	Part Number	Droplet Size (PSI) 30	40	50	60	70	80
ESI-Six Stream		15-60	FC-ESI-110015	S	S	S	S	S	S
			FC-ESI-11002	S	S	S	S	S	S
			FC-ESI-110025	S	S	S	S	S	S
			FC-ESI-11003	S	S	S	S	S	S
			FC-ESI-11004	S	S	S	S	S	S
			FC-ESI-11005	S	S	S	S	S	S
			FC-ESI-11006	S	S	S	S	S	S
			FC-ESI-11008	S	S	S	S	S	S
			FC-ESI-11010	S	S	S	S	S	S
			FC-ESI-11015	S	S	S	S	S	S
Hi-Flow		20-80	HF140-08	UC	UC	UC	XC	XC	XC
			HF140-10	UC	UC	UC	XC	XC	XC
			HF140-15	UC	UC	UC	XC	XC	XC
			HF140-20	UC	UC	UC	XC	XC	XC
			HF140-30	UC	UC	UC	XC	XC	XC
			HF140-40	UC	UC	UC	XC	XC	XC
			HF140-50	UC	UC	UC	XC	XC	XC
			HF140-60	UC	UC	UC	XC	XC	XC
Ultra Lo-Drift		20-115	FC-ULD120-015	XC	VC	VC	C	C	C
			FC-ULD120-02	XC	C	C	C	M	M
			FC-ULD120-025	XC	C	C	C	M	M
			FC-ULD120-03	XC	C	C	C	M	M
			FC-ULD120-04	UC	UC	XC	XC	XC	VC
			FC-ULD120-05	UC	XC	XC	XC	VC	VC
			FC-ULD120-06	UC	XC	XC	VC	C	C
			FC-ULD120-08	XC	VC	VC	C	C	C
3D Nozzle		10-90	FC-3D100-015	F	F	F	F	F	F
			FC-3D100-02	M	F	F	F	F	F
			FC-3D100-025	M	M	F	F	F	F
			FC-3D100-03	M	M	M	F	F	F
			FC-3D100-035	M	M	M	M	M	F
			FC-3D100-04	M	M	M	M	M	M
			FC-3D100-05	C	M	M	M	M	M
			FC-3D100-06	C	C	M	M	M	M
			FC-3D100-08	C	C	M	M	M	M
GuardianAIR		20-115	FC-GA110-015	XC	C	C	M	M	M
			FC-GA110-02	VC	M	M	M	M	M
			FC-GA110-025	VC	C	M	M	M	M
			FC-GA110-03	XC	VC	C	C	M	M
			FC-GA110-035	VC	C	M	M	M	M
			FC-GA110-04	VC	C	C	M	M	M
			FC-GA110-05	XC	C	C	C	M	M
GuardianAIR Twin		30-115	GAT110-02	C	M	M	M	M	M
			GAT110-025	UC	VC	C	M	M	M
			GAT110-03	VC	C	M	M	M	M
			GAT110-035	XC	C	C	M	M	M
			GAT110-04	VC	C	C	M	M	M
			GAT110-05	VC	C	C	M	M	M
			GAT110-06	XC	C	C	C	M	M
			GAT110-08	VC	C	C	C	M	M

Spray Nozzle	Pressure (PSI)	Flow Rate (GPM)	Speed (MPH) - 20 Inch Spacing — Gallons per Acre: 2.5	5	7.5	10	12.5	15	17.5	20	22.5	25	27.5	30	32.5
015	15	0.09	10.9	5.5	3.6	2.7	2.2	1.8	1.6	1.4	1.2	1.1	1.0	0.9	0.8
	20	0.11	12.6	6.3	4.2	3.2	2.5	2.1	1.8	1.6	1.4	1.3	1.1	1.1	1.0
	30	0.13	15.4	7.7	5.1	3.9	3.1	2.6	2.2	1.9	1.7	1.5	1.4	1.3	1.2
	40	0.15	17.8	8.9	5.9	4.5	3.6	3.0	2.5	2.2	2.0	1.8	1.6	1.5	1.4
	50	0.17	19.9	10.0	6.6	5.0	4.0	3.3	2.8	2.5	2.2	2.0	1.8	1.7	1.5
	60	0.18	21.8	10.9	7.3	5.5	4.4	3.6	3.1	2.7	2.4	2.2	2.0	1.8	1.7
	70	0.20	23.6	11.8	7.9	5.9	4.7	3.9	3.4	2.9	2.6	2.4	2.1	2.0	1.8
	80	0.21	25.2	12.6	8.4	6.3	5.0	4.2	3.6	3.2	2.8	2.5	2.3	2.1	1.9
	90	0.23	26.7	13.4	8.9	6.7	5.3	4.5	3.8	3.3	3.0	2.7	2.4	2.2	2.1
	100	0.24	28.2	14.1	9.4	7.0	5.6	4.7	4.0	3.5	3.1	2.8	2.6	2.3	2.2
	115	0.25	-	15.1	10.1	7.6	6.0	5.0	4.3	3.8	3.4	3.0	2.7	2.5	2.3
02	15	0.12	14.5	7.3	4.8	3.6	2.9	2.4	2.1	1.8	1.6	1.5	1.3	1.2	1.1
	20	0.14	16.8	8.4	5.6	4.2	3.4	2.8	2.4	2.1	1.9	1.7	1.5	1.4	1.3
	30	0.17	20.6	10.3	6.9	5.1	4.1	3.4	2.9	2.6	2.3	2.1	1.9	1.7	1.6
	40	0.20	23.8	11.9	7.9	5.9	4.8	4.0	3.4	3.0	2.6	2.4	2.2	2.0	1.8
	50	0.22	26.6	13.3	8.9	6.6	5.3	4.4	3.8	3.3	3.0	2.7	2.4	2.2	2.0
	60	0.24	29.1	14.5	9.7	7.3	5.8	4.8	4.2	3.6	3.2	2.9	2.6	2.4	2.2
	70	0.26	-	15.7	10.5	7.9	6.3	5.2	4.5	3.9	3.5	3.1	2.9	2.6	2.4
	80	0.28	-	16.8	11.2	8.4	6.7	5.6	4.8	4.2	3.7	3.4	3.1	2.8	2.6
	90	0.30	-	17.8	11.9	8.9	7.1	5.9	5.1	4.5	4.0	3.6	3.2	3.0	2.7
	100	0.32	-	18.8	12.5	9.4	7.5	6.3	5.4	4.7	4.2	3.8	3.4	3.1	2.9
	115	0.34	-	20.1	13.4	10.1	8.1	6.7	5.8	5.0	4.5	4.0	3.7	3.4	3.1
025	15	0.15	18.2	9.1	6.1	4.5	3.6	3.0	2.6	2.3	2.0	1.8	1.7	1.5	1.4
	20	0.18	21.0	10.5	7.0	5.3	4.2	3.5	3.0	2.6	2.3	2.1	1.9	1.8	1.6
	30	0.22	25.7	12.9	8.6	6.4	5.1	4.3	3.7	3.2	2.9	2.6	2.3	2.1	2.0
	40	0.25	29.7	14.9	9.9	7.4	5.9	5.0	4.2	3.7	3.3	3.0	2.7	2.5	2.3
	50	0.28	-	16.6	11.1	8.3	6.6	5.5	4.7	4.2	3.7	3.3	3.0	2.8	2.6
	60	0.31	-	18.2	12.1	9.1	7.3	6.1	5.2	4.5	4.0	3.6	3.3	3.0	2.8
	70	0.33	-	19.6	13.1	9.8	7.9	6.5	5.6	4.9	4.4	3.9	3.6	3.3	3.0
	80	0.35	-	21.0	14.0	10.5	8.4	7.0	6.0	5.3	4.7	4.2	3.8	3.5	3.2
	90	0.38	-	22.3	14.9	11.1	8.9	7.4	6.4	5.6	5.0	4.5	4.1	3.7	3.4
	100	0.40	-	23.5	15.7	11.7	9.4	7.8	6.7	5.9	5.2	4.7	4.3	3.9	3.6
	115	0.42	-	25.2	16.8	12.6	10.1	8.4	7.2	6.3	5.6	5.0	4.6	4.2	3.9
03	15	0.18	21.8	10.9	7.3	5.5	4.4	3.6	3.1	2.7	2.4	2.2	2.0	1.8	1.7
	20	0.21	25.2	12.6	8.4	6.3	5.0	4.2	3.6	3.2	2.8	2.5	2.3	2.1	1.9
	30	0.26	-	15.4	10.3	7.7	6.2	5.1	4.4	3.9	3.4	3.1	2.8	2.6	2.4
	40	0.30	-	17.8	11.9	8.9	7.1	5.9	5.1	4.5	4.0	3.6	3.2	3.0	2.7
	50	0.34	-	19.9	13.3	10.0	8.0	6.6	5.7	5.0	4.4	4.0	3.6	3.3	3.1
	60	0.37	-	21.8	14.5	10.9	8.7	7.3	6.2	5.5	4.8	4.4	4.0	3.6	3.4
	70	0.40	-	23.6	15.7	11.8	9.4	7.9	6.7	5.9	5.2	4.7	4.3	3.9	3.6
	80	0.42	-	25.2	16.8	12.6	10.1	8.4	7.2	6.3	5.6	5.0	4.6	4.2	3.9
	90	0.45	-	26.7	17.8	13.4	10.7	8.9	7.6	6.7	5.9	5.3	4.9	4.5	4.1
	100	0.47	-	28.2	18.8	14.1	11.3	9.4	8.1	7.0	6.3	5.6	5.1	4.7	4.3
	115	0.51	-	-	20.1	15.1	12.1	10.1	8.6	7.6	6.7	6.0	5.5	5.0	4.6
04	15	0.24	29.1	14.5	9.7	7.3	5.8	4.8	4.2	3.6	3.2	2.9	2.6	2.4	2.2
	20	0.28	-	16.8	11.2	8.4	6.7	5.6	4.8	4.2	3.7	3.4	3.1	2.8	2.6
	30	0.35	-	20.6	13.7	10.3	8.2	6.9	5.9	5.1	4.6	4.1	3.7	3.4	3.2
	40	0.40	-	23.8	15.8	11.9	9.5	7.9	6.8	5.9	5.3	4.8	4.3	4.0	3.7
	50	0.45	-	26.6	17.7	13.3	10.6	8.9	7.6	6.6	5.9	5.3	4.8	4.4	4.1
	60	0.49	-	29.1	19.4	14.5	11.6	9.7	8.3	7.3	6.5	5.8	5.3	4.8	4.5
	70	0.53	-	-	21.0	15.7	12.6	10.5	9.0	7.9	7.0	6.3	5.7	5.2	4.8
	80	0.57	-	-	22.4	16.8	13.4	11.2	9.6	8.4	7.5	6.7	6.1	5.6	5.2
	90	0.60	-	-	23.8	17.8	14.3	11.9	10.2	8.9	7.9	7.1	6.5	5.9	5.5
	100	0.63	-	-	25.0	18.8	15.0	12.5	10.7	9.4	8.3	7.5	6.8	6.3	5.8
	115	0.68	-	-	26.9	20.1	16.1	13.4	11.5	10.1	9.0	8.1	7.3	6.7	6.2

Spray Nozzle	Pressure (PSI)	Flow Rate (GPM)	Speed (MPH) - 20 Inch Spacing — Gallons per Acre: 2.5	5	7.5	10	12.5	15	17.5	20	22.5	25	27.5	30	32.5
05	15	0.31	-	18.2	12.1	9.1	7.3	6.1	5.2	4.5	4.0	3.6	3.3	3.0	2.8
	20	0.35	-	21.0	14.0	10.5	8.4	7.0	6.0	5.3	4.7	4.2	3.8	3.5	3.2
	30	0.43	-	25.7	17.1	12.9	10.3	8.6	7.3	6.4	5.7	5.1	4.7	4.3	4.0
	40	0.50	-	29.7	19.8	14.9	11.9	9.9	8.5	7.4	6.6	5.9	5.4	5.0	4.6
	50	0.56	-	-	22.1	16.6	13.3	11.1	9.5	8.3	7.4	6.6	6.0	5.5	5.1
	60	0.61	-	-	24.2	18.2	14.5	12.1	10.4	9.1	8.1	7.3	6.6	6.1	5.6
	70	0.66	-	-	26.2	19.6	15.7	13.1	11.2	9.8	8.7	7.9	7.1	6.5	6.0
	80	0.71	-	-	28.0	21.0	16.8	14.0	12.0	10.5	9.3	8.4	7.6	7.0	6.5
	90	0.75	-	-	29.7	22.3	17.8	14.9	12.7	11.1	9.9	8.9	8.1	7.4	6.9
	100	0.79	-	-	-	23.5	18.8	15.7	13.4	11.7	10.4	9.4	8.5	7.8	7.2
	115	0.85	-	-	-	25.2	20.1	16.8	14.4	12.6	11.2	10.1	9.2	8.4	7.7
06	15	0.37	-	21.8	14.5	10.9	8.7	7.3	6.2	5.5	4.8	4.4	4.0	3.6	3.4
	20	0.42	-	25.2	16.8	12.6	10.1	8.4	7.2	6.3	5.6	5.0	4.6	4.2	3.9
	30	0.52	-	-	20.6	15.4	12.3	10.3	8.8	7.7	6.9	6.2	5.6	5.1	4.7
	40	0.60	-	-	23.8	17.8	14.3	11.9	10.2	8.9	7.9	7.1	6.5	5.9	5.5
	50	0.67	-	-	26.6	19.9	15.9	13.3	11.4	10.0	8.9	8.0	7.2	6.6	6.1
	60	0.73	-	-	29.1	21.8	17.5	14.5	12.5	10.9	9.7	8.7	7.9	7.3	6.7
	70	0.79	-	-	-	23.6	18.9	15.7	13.5	11.8	10.5	9.4	8.6	7.9	7.3
	80	0.85	-	-	-	25.2	20.2	16.8	14.4	12.6	11.2	10.1	9.2	8.4	7.8
	90	0.90	-	-	-	26.7	21.4	17.8	15.3	13.4	11.9	10.7	9.7	8.9	8.2
	100	0.95	-	-	-	28.2	22.5	18.8	16.1	14.1	12.5	11.3	10.2	9.4	8.7
	115	1.02	-	-	-	-	24.2	20.1	17.3	15.1	13.4	12.1	11.0	10.1	9.3
08	15	0.49	-	29.1	19.4	14.5	11.6	9.7	8.3	7.3	6.5	5.8	5.3	4.8	4.5
	20	0.57	-	-	22.4	16.8	13.4	11.2	9.6	8.4	7.5	6.7	6.1	5.6	5.2
	30	0.69	-	-	27.4	20.6	16.5	13.7	11.8	10.3	9.1	8.2	7.5	6.9	6.3
	40	0.80	-	-	-	23.8	19.0	15.8	13.6	11.9	10.6	9.5	8.6	7.9	7.3
	50	0.89	-	-	-	26.6	21.3	17.7	15.2	13.3	11.8	10.6	9.7	8.9	8.2
	60	0.98	-	-	-	29.1	23.3	19.4	16.6	14.5	12.9	11.6	10.6	9.7	9.0
	70	1.06	-	-	-	-	25.1	21.0	18.0	15.7	14.0	12.6	11.4	10.5	9.7
	80	1.13	-	-	-	-	26.9	22.4	19.2	16.8	14.9	13.4	12.2	11.2	10.3
	90	1.20	-	-	-	-	28.5	23.8	20.4	17.8	15.8	14.3	13.0	11.9	11.0
	100	1.26	-	-	-	-	-	25.0	21.5	18.8	16.7	15.0	13.7	12.5	11.6
	115	1.36	-	-	-	-	-	26.9	23.0	20.1	17.9	16.1	14.6	13.4	12.4
10	15	0.61	-	-	24.2	18.2	14.5	12.1	10.4	9.1	8.1	7.3	6.6	6.1	5.6
	20	0.71	-	-	28.0	21.0	16.8	14.0	12.0	10.5	9.3	8.4	7.6	7.0	v6.5
	30	0.87	-	-	-	25.7	20.6	17.1	14.7	12.9	11.4	10.3	9.4	8.6	7.9
	40	1.00	-	-	-	29.7	23.8	19.8	17.0	14.9	13.2	11.9	10.8	9.9	9.1
	50	1.12	-	-	-	-	26.6	22.1	19.0	16.6	14.8	13.3	12.1	11.1	10.2
	60	1.22	-	-	-	-	29.1	24.2	20.8	18.2	16.2	14.5	13.2	12.1	11.2
	70	1.32	-	-	-	-	-	26.2	22.5	19.6	17.5	15.7	14.3	13.1	12.1
	80	1.41	-	-	-	-	-	28.0	24.0	21.0	18.7	16.8	15.3	14.0	12.9
	90	1.50	-	-	-	-	-	29.7	25.5	22.3	19.8	17.8	16.2	14.9	13.7
	100	1.58	-	-	-	-	-	-	26.8	23.5	20.9	18.8	17.1	15.7	14.4
	115	1.70	-	-	-	-	-	-	28.8	25.2	22.4	20.1	18.3	16.8	15.5
15	15	0.92	-	-	-	27.3	21.8	18.2	15.6	13.6	12.1	10.9	9.9	9.1	8.4
	20	1.06	-	-	-	-	25.2	21.0	18.0	15.8	14.0	12.6	11.5	10.5	9.7
	30	1.30	-	-	-	-	-	25.7	22.0	19.3	17.1	15.4	14.0	12.9	11.9
	40	1.50	-	-	-	-	-	29.7	25.5	22.3	19.8	17.8	16.2	14.9	13.7
	50	1.68	-	-	-	-	-	-	28.5	24.9	22.1	19.9	18.1	16.6	15.3
	60	1.84	-	-	-	-	-	-	-	27.3	24.2	21.8	19.8	18.2	16.8
	70	1.98	-	-	-	-	-	-	-	29.5	26.2	23.6	21.4	19.6	18.1
	80	2.12	-	-	-	-	-	-	-	-	28.0	25.2	22.9	21.0	19.4
	90	2.25	-	-	-	-	-	-	-	-	29.7	26.7	24.3	22.3	20.6
	100	2.37	-	-	-	-	-	-	-	-	-	28.2	25.6	23.5	21.7
	115	2.54	-	-	-	-	-	-	-	-	-	-	27.5	25.2	23.2

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