2020 MET Basic Utility Vehicle Irrigation System

A Baccalaureate thesis submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

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April 2020

Thesis Advisor:

Professor Moise Cummings

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ABSTRACT

Our group project is to design a Basic Utility Vehicle. And my individual task is to design a pump and irrigation system for this BUV. The biggest challenge of this project a stable structure system. Since there were groups failed to perform their basic utility vehicle on mud. For instance, weak fabrication and assembly, poor control of the front wheel, extremely complicated structure, restricted cargo area, extremely overload, and heavy ground pressure. All of these factors should be considered during the design and calculation to avoid failures. Basic utility vehicle is a simple, low cost, and low weight vehicle that is convenient to operate, repair, and maintain. As far as I can see, there were many groups' BUV didn't work properly, thus, our goal is to make sure that every step and procedure stay on track and every calculation follows specifications to ensure the stability of vehicle. And then, we will also consider the improvement of efficiency and function.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

Our group project is to design a Basic Utility Vehicle. And my individual task is to design a pump and irrigation system for this BUV. Basic utility vehicle is a simple, low cost, and low weight vehicle that is convenient to operate, repair, and maintain. As far as I can see, there were many groups' BUV didn't work properly, thus, our goal is to make sure that every step and procedure stay on track and every calculation follows specifications to ensure the stability of vehicle. And then, we will also consider the improvement of efficiency and function.

Team member responsibilities:

Connor Brady
-Drivetrain, Engine, and Transmission

Daniel Neuhaus
-Controls, Brakes, Electronics, Acceleration

Samuel Campbell
-Frame/Chassis

Gustavo Lamascid
-Steering and Suspension

Yuanjing Xu
-Irrigation and Pumping

BACKGROUND

Greek financier Peter Kondorgouris began producing a small utility vehicle called the Farmobil, based on a 1957 design by Wilfried Fahr of Switzerland. Using BMW engines, about 1000 were built between 1962 and 1966. The Farco company was taken over by Chrysler in the mid-sixties and they took over distribution in many markets. (2)

RESEARCH

BUV is known as its low-cost mobility that is applied to off-road conditions, usually capable of carrying at least 1500lbs payloads. BUV is rugged but easy to operate (has high torque and does not require clutch shifting), maintain, and repair. BUVs are built with sturdy automotive parts and features such as a 10-horsepower engine, two-wheel drive differential, automotive hydraulic brakes and a controlled of speed up to 20 miles per hour.
In the past, irrigation systems have been developed for irrigation of rectangular fields, but in order to provide for proper operation of the irrigation system, it is generally deemed necessary that a plurality of tracks or guideways be provided in order to physically guide the irrigation system over the land area. Of the number of patented devices that have been developed with track or guideway control in mind, U.S. Pat. No. 3,608,827, to Kinkead is typically representative. (1)
The Institute for Affordable Transportation (IAT) is the pioneer of BUV and the main sponsor. IAT runs the annual BUV Design Competition where engineering students bring their BUVs for competitive evaluations. Also, outstanding BUVs contribute creative ideas and continuous improvements. (2)
In the Africa bush, people's life quality is limited by unaffordable transportation. BUV is a good application and is tailored to meet specific community needs. For instance, faster delivery of food, water, medical care and safe transportation of people and goods through mugged terrain. For agriculture, BUV also can be used to plowing, cultivating, planting, raking, and spreading fertilizer.

SCOPE OF THE PROBLEM

According to the 2020 BUV design specification, for irrigation system, the bed must hold two, but may hold three 55-gallon standard steel drums. The drums must be located on their sides with features to verify they are full. The drums must be located as low as possible in the bed. The drums must not be stacked in any manner. The front of the cargo bed must have a 16-inch minimum high bulkhead between the driver and the cargo. The other side of the bed must be a minimum of 8 inches high. Drums should be easily removable for cargo and not have any holes that would leak water. For water pump, it should have ability to fill 55-gallon drums from within 15 feet of a pond. All pumping equipment and hoses must be carried on the vehicle during the event. Pump driven form PTO device only. (4)

CURRENT STATE OF THE ART

After considering the stability of the whole system, the total weight of the whole system should not be extremely overloading. Thus, the selections of water pump should fill up three barrels with around 1600lbs water. For manual filling up, the efficiency will be low, and our goal is to fill up three barrels within 8 minutes, so filling up manually will be impossible. For gasoline pump, it's a simple and easy system that could fill up three barrels at once, but it's not convenient when people want to fill up individual barrel. For electrical pump, it has relatively higher flow rate to increase the efficiency with simple working principles compared to the manual filling system. The size is small, and the cost will be low. For an integrated pumping system, an integrated motor/controller pumping unit for which the electrical motor, its electronic controller, and load are all combined into a single structural assembly, which is fuel saving and exhaust emission decreasing. Also, integrated pumping system will be flexible to be installed in any position as required. On the contrary, the cost may be relatively higher than other pumping system.

END USER

Since the BUV should be a very common application for people in developing country. Low-cost should be the 1st place factor we need to consider it should be 20% cost of most 4-wheels cars. Low ground pressure leads the vehicle to stay on the top of mud or sand (preventing to get bogged down). Also, low weight is important to BUV for off-road condition since the heavy barrels on the cargo bed. BUV should have good agility and easy operation since it has no gears, no clutch, and no shifter. The good control of the front wheel will help driver to avoid obstacles sharply on poor road conditions.

CONCLUSIONS AND SUMMARY OF RESEARCH

From this research, there is a clear map of responsibilities for me and my groupmates to design our own part of this basic utility vehicle. And now I have a good understanding of the main jobs that BUV does and the main characters that BUV has. For example, from the 2020 design specification, I realized that I don't understand the concept "PTO". And after doing research, I understand "PTO" is called "power take-off pump" which is used with farming machines (and all tractors having a power take-off at 540 repetitions per minute) to convert rotary power into hydraulic power. (5) After reviewing previous BUV projects, we could take advantages of successful experience and rethink better solutions for failed projects. I should specify the schedule to study the structure of irrigation system so that I could select a suitable water pump as soon as possible. Also, I need to calculate the proper area of the cargo bed to carry heavy barrels without any breakdown. Thus, there are still lots of research and concepts we should seek and learn.

CUSTOMER FEATURES

（1） Common material selection:

The frame should be designed to withstand operation with a maximum payload according to specification.

（2） Number of parts

Easy to assemble/disassemble, repair, modify, maintenance.

（3） Overall weight

Stability, easy to operate.

（4） Overall size

Vehicle can be assembled without specialized professionals.

（5） Ground clearance

Materials and parts could withstand the stresses and vibrations from mathematical analysis.

（6） Max payloads: follow the specification.

PRODUCT OBJECTIVES

To get the voice of our customers, the first thing we need to know is the customer features. There might have conflicts between these requirements, which is good thing. We could learn the correlations and weightings between these requirements, then we know which feature is more important according to customers' profiles.

(1) Reliability (4.6/5)

(2) Price (4.2/5)

(3) Safety (4.2/5)

(4) Ease of Maintenance (4.1/5)

(5) Off-Road capability (3.8/5)

(6) Cargo capacity (3.5/5)

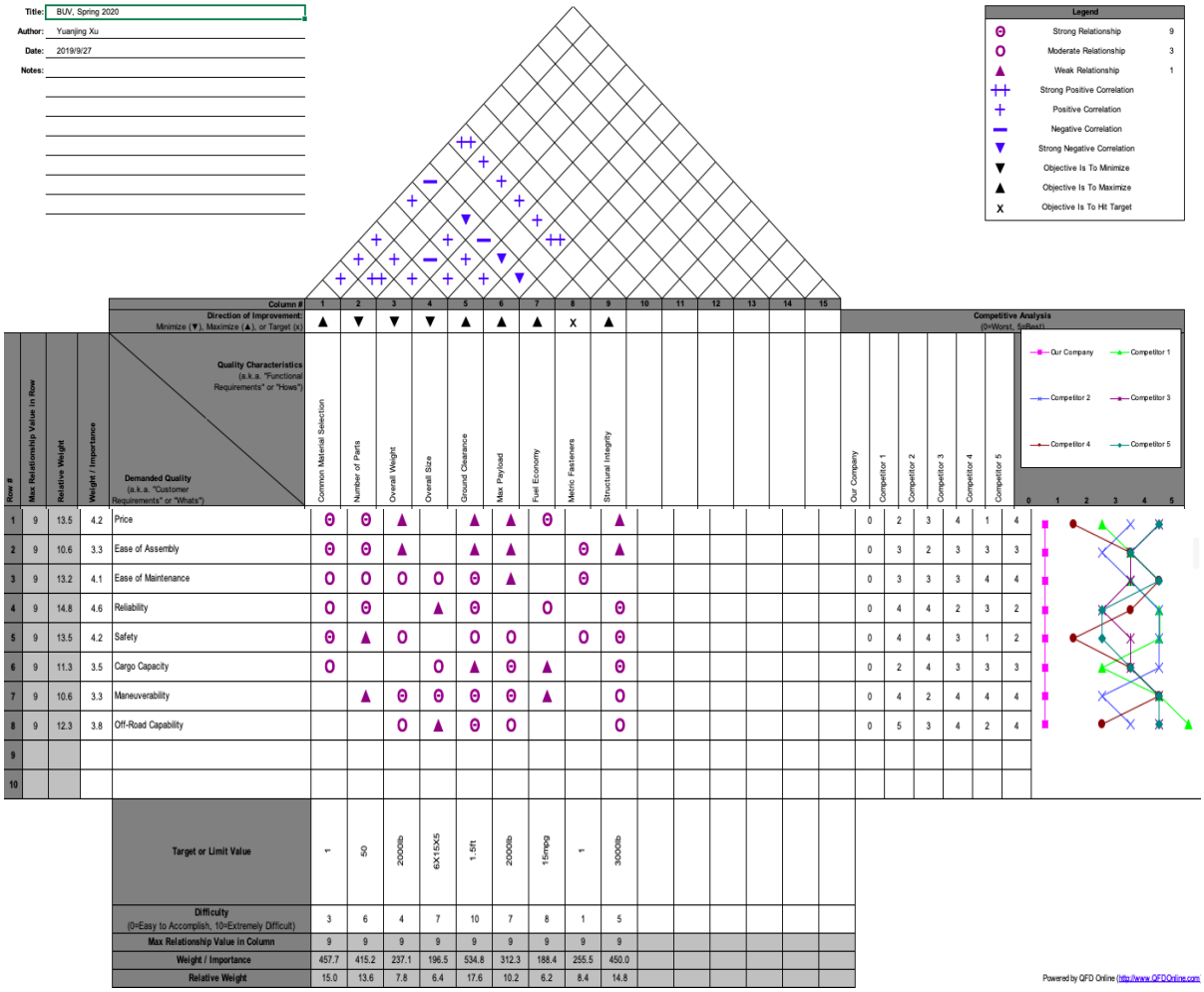
(7) Maneuverability (3.3/5)

(8) Ease of Assembly (3.3/5)

To understanding customers' voices, we got 30 surveys to have an overall customer profile. And then based on the House of Quality, we got reliability, safety, and price as the three most important factors that people would consider.

Product objectives.	Relative weight
Ground Clearance	17.6
Common material selection	15.0
Structural integrity	14.8
Number of parts	13.6
Max payload	10.2
Matric fasteners	8.4
Overall weight	7.8
Overall size	6.4
Fuel economy	6.2

QUALITY FUNCTION DEPLOYMENT



(Figure 1: QFD)

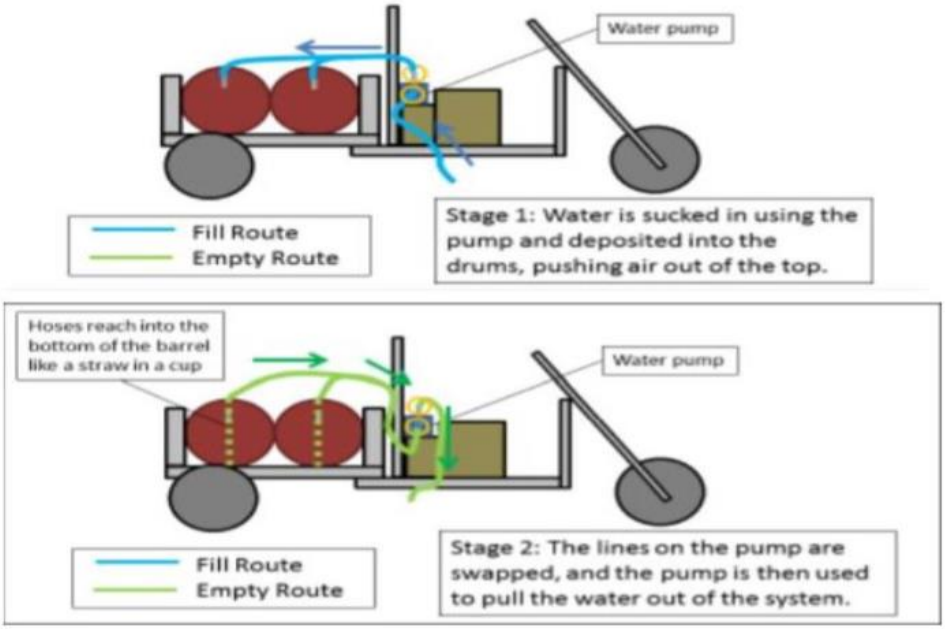
DESIGN

Concept 1

(Figure2-5: 800CC UTV)

This is the 800cc 4 Stroke Utility vehicle 4*4 UTV features a 800cc 4 stroke double cylinder water cooled engine, a shaft transmission, front and rear disc brakes, and electric start. (5)
For this kind of commercial vehicle, the size is relatively small. The cargo bed capacity is about 350 lb. But the dimension is around 106 in * 60 in * 73 in, the space for irrigation system is limited, which would only fit one water barrel in its cargo bed. Nevertheless, the towing capacity is around 2000lbs and the vehicle weight is around 1100lbs which is reliable. The small size and strong SUV chassis design meet the needs of safety and reliability for off-road situations.
If we choose this conceptual design, we would consider installing one larger barrel or arrange two barrels on two levels, but we have not found any designs like this from previous BUV concepts.
The drawback on this vehicle design is that it is too expensive compare to traditional BUVs for third world countries.

Concept 2



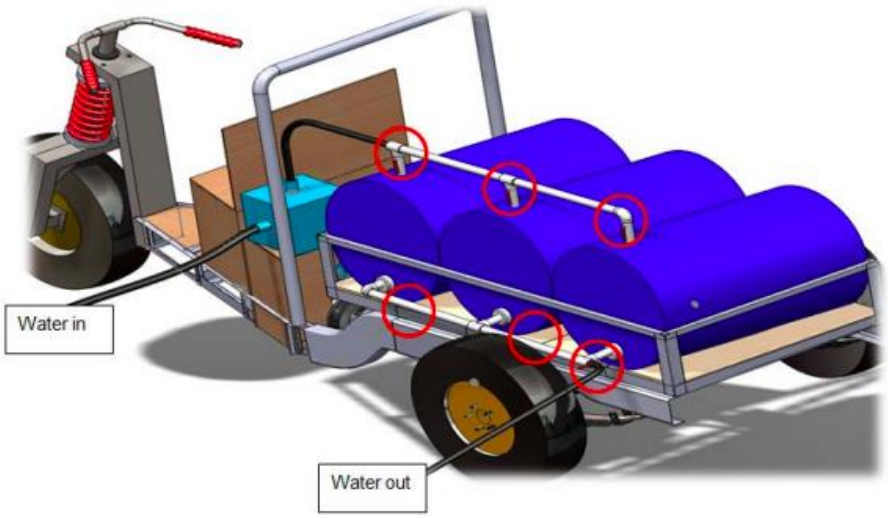
(Figure 6: UC BUV 2014)

This vehicle was comprised of a water pump attached to two 55-gallon barrels connecting a discharge hose. The entrance hole and discharging hole are separate. The gasoline-powered water pump will simply pull water from barrel, and water will flow out through pipe by gravity.

This two-barrel arrangement could decrease the dimension of the cargo bad compares to three-barrel arrangement. So, this concept is more stable and easier to assemble and maintain.

The problem we should concern is that the pump selection. For project of BUV 2014, they used gasoline-powered pump for this irrigation system design, and the pump periodically shutdown after running for a certain time period since the pump was overheating. Thus, if we use two-barrel arrangement, we should select a more reliable, faster pump.

Concept 3



(Figure 7 PVC concept design)

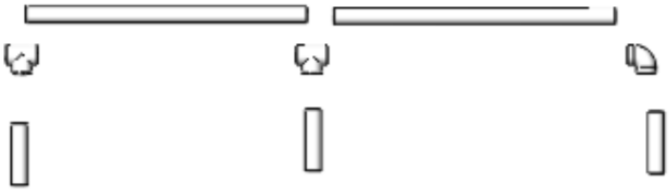
Considering design specification given from IAT competition: The irrigation system should be able to fill three barrels of water to be competitive at the completion of every three laps around the course. Also, this concept of irrigation system is relatively simple and reasonable since the entrance pipe will not be interwoven with the exit pipe. For the pump selection for three-barrel arrangement, I prefer to use PUP as a power source, because this centrifugal pump design has higher flow rate, higher operational speeds allows direct coupling to engine and it increase the kinetic energy of the fluid. And the total of 160-gallon water could be filled into these barrels.

I'd like to use this concept even though it did include some shortages: larger dimension, more weight, better pump to fill three barrels with water in a short time period.

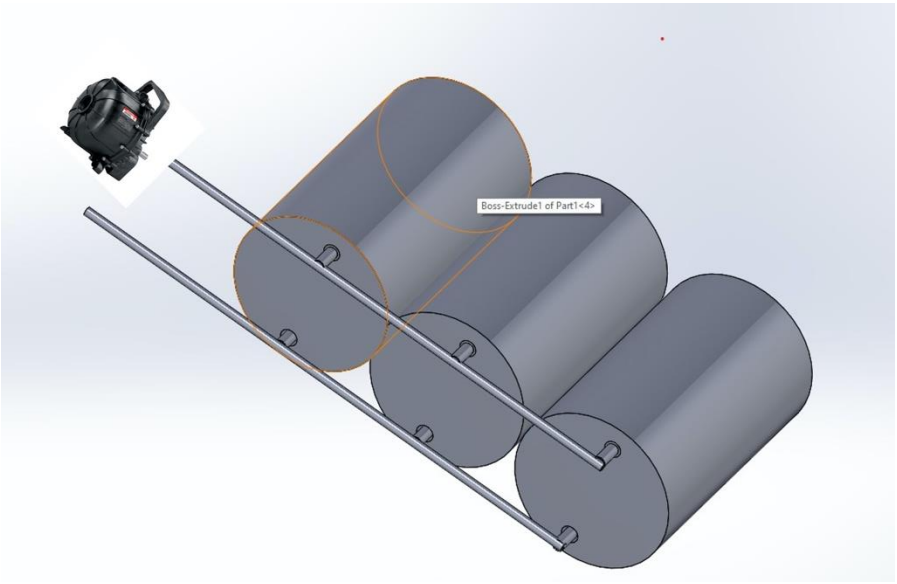
Final Decision and Analysis Appendix A

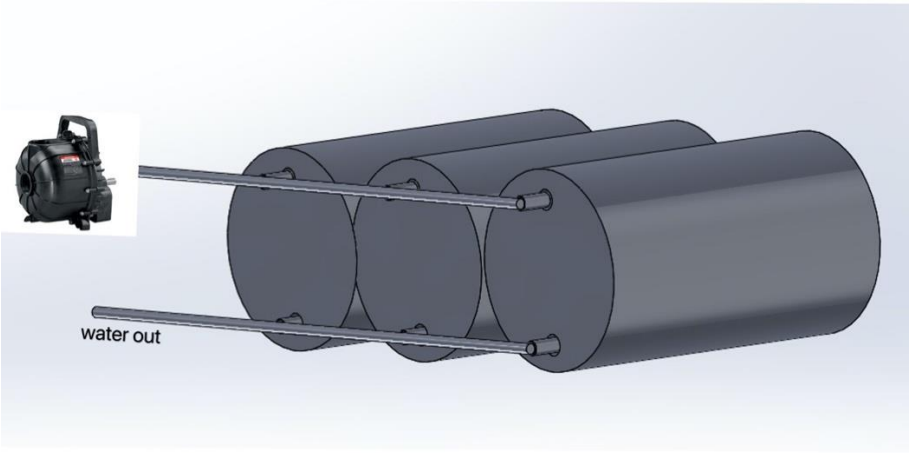
Manufacturing Drawings

Piping and Extra supports

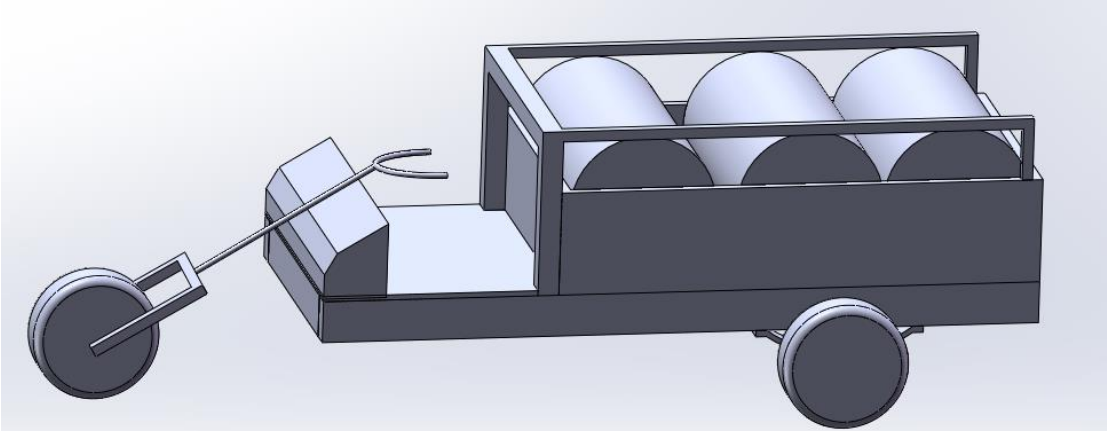


Irrigation system overview

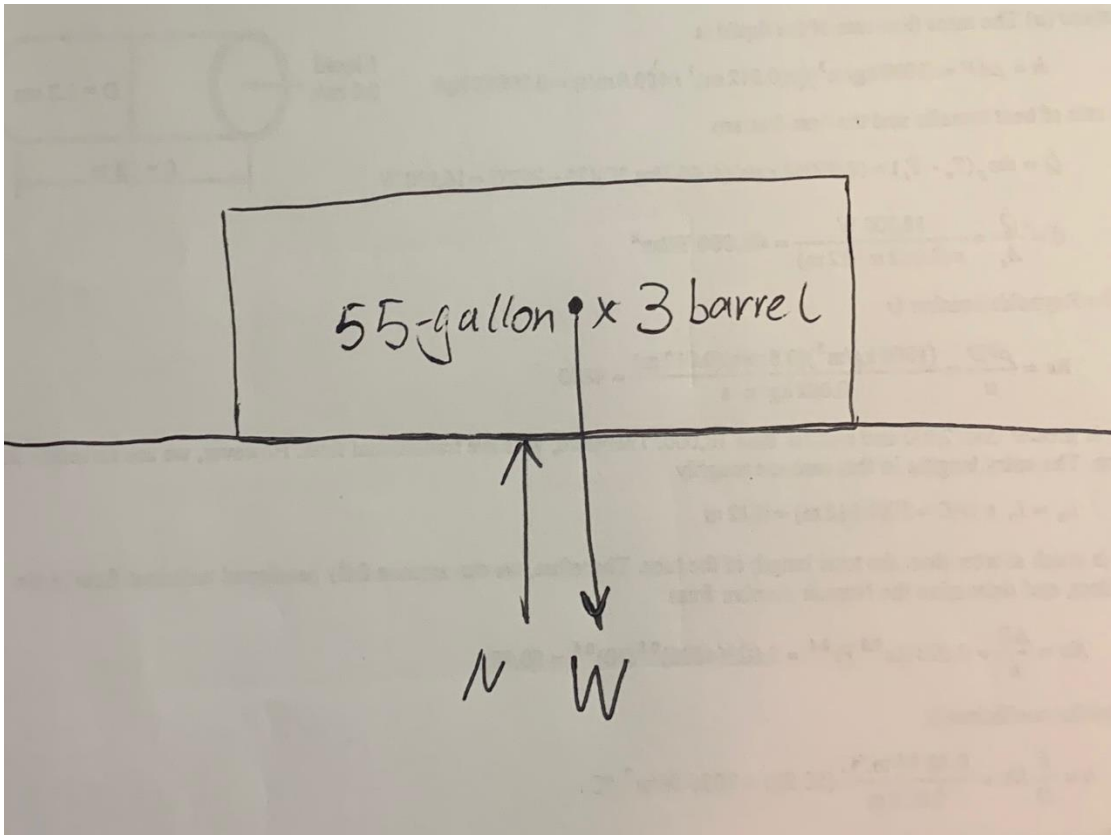




BUV Overview



Draw Freebody diagram, Loading condition, Calculations



Calculations:

Considering design specification given from IAT competition: The irrigation system should be able to fill three barrels of water to be competitive at the completion of every three laps around the course. And every barrel contains 55-gallon water. For this condition, we can use

Hazen-Williams Equation that is usually used to analyze city water system. The Hazen–Williams equation is an empirical relationship which relates the flow of water in a pipe with the physical properties of the pipe and the pressure drop caused by friction. It is used in the design of water pipe systems such as fire sprinkler systems, water supply networks, and irrigation systems. It is named after Allen Hazen and Gardner Stewart Williams. (1)

$$V = k\,C\,R^{0.63}\,S^{0.54}$$

where:
V is velocity
k is a conversion factor for the unit system (k = 1.318 for US customary units, k = 0.849 for SI units)
C is a roughness coefficient (150 for PVC and Plastic)
R is the hydraulic radius
S is the slope of the energy line (head loss per length of pipe or h_f/L) (1)

After considering the stability of the whole system, the total weight of the whole system should not be extremely overloading. Thus, the selections of water pump should fill up three barrels with around 1600lbs water. For manual filling up, the efficiency will be pretty low, and our goal is to fill up three barrels within 8 minutes.

Thus, we use Hazen Williams Equation for water flow in pipe due to gravity:

$$Q = \left(\frac{h_f C^{1.85} d^{4.87}}{10.67L}\right)^{0.54}$$

$$Q = \left(\frac{2*150^{1.85}*1^{4.87}}{10.67*20}\right)^{0.54}$$

$$Q = 11.986 \text{ gal/min}$$

$$Q = 719.16 \text{ gal/hour}$$

Since the flow rate due to gravity is far less than the flow rate of the pump, Q for pump should be far more than 720 gal/hour.

The slowest speed to fill water.

$$\frac{3 * 55 \text{ gallons(for one barrel)}}{8\ minutes} = 20.625 \text{ gpm}$$

1. Water pump selection - needs to fill up 3 barrels in less than 10 minutes.
we use Hazen Williams Equation for water flow in pipe due to gravity:

$$Q = \left(\frac{h_f C^{1.85} d^{4.87}}{10.67L}\right)^{0.54}$$

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The slowest speed to fill water.

$\frac{3 * 55 \text{ gallons(for one barrel)}}{8\ minutes}$ = 20.625 gpm

Design Analysis and safety factors

1. This is a gasoline engine water pump, which can quickly transfer water at a speed up to 35GPM (2100GPH). The gas engine on the pump is applicable during power outages and remote jobsites. And there is a durable cast iron volute and impeller combined with high quality silicon carbide seals ensure long service life.

Price: $179.99

- Powerful 79cc 4-stroke overhead valve gas engine
- 35 GPM (gallons per minute)
- Maximum head lift: 65 ft.
- Intake head lift: 19 ft.
- Low oil alert
- Recoil start (2)

2. PVC Assembly:

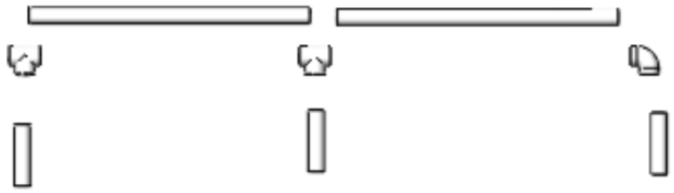
PVC stands for polyvinyl chloride, and it's become a common substitute goods for metal piping. PVC's strength, durability, easy installation, and low cost have made it one of the most widely used plastics.

Technical Details

Part Number	PVC40-PIPE-1500-3FT
Item Weight	1.58 pounds
Product Dimensions	3.7 x 1.2 x 3.7 inches
Item model number	PVC40-PIPE-1500-3FT
Batteries Included?	No
Batteries Required?	No

(FIGURE 8: PRODUCT INFORMATION)

Price: PVC Pipe Sch. 40 1 1/2 Inch (1.5) White/PVC / 3 FT $13.92



(Figure 4: extra support)

Tensile strength of PVC pipe:

Pipe Size	Tensile Strength (lb)	
	Schedule 40	Schedule 80
0.50”	264	344
0.75”	362	487
1.00”	581	727
1.25”	859	878
1.50”	954	1,225
2.00”	942	1,542
2.50”	2,093	2,890
3.00”	2,786	3,839
4.00”	4,119	5,820
5.00”	5,491	6,864
6.00”	7,165	11,384
8.00”	10,384	17,332

Burst pressure of PVC pipe:

Pipe Size	Burst Pressure (psi)	
	Schedule 40	Schedule 80
0.50”	1,900	2,700
0.75”	1,550	2,200
1.00”	1,425	2,000
1.25”	1,200	1,650
1.50”	1,075	1,500
2.00”	900	1,300
2.50”	975	1,350
3.00”	850	1,200
4.00”	700	1,100
5.00”	600	1,050
6.00”	550	925
8.00”	500	875

Collapse pressure:

Pipe Size	Collapse Pressure (psi)	
	Schedule 40	Schedule 80
0.50”	1,600	2,000
0.75”	1,200	1,750
1.00”	975	1,600
1.25”	500	1,400
1.50”	375	1,050
2.00”	225	650
2.50”	300	775
3.00”	200	500
4.00”	100	325
5.00”	100	275
6.00”	75	200
8.00”	50	175

PROJECT MANAGEMENT

BUDGET, PROPOSED/ACTUAL

Project Budget Limit(PROPOSED)

Part	Estimated Cost $
Frame	400
Braking	150
Suspension	175
Power Train	200
Irrigation	200
Steering	200
Controls	100
Miscellaneous	400
Total	1825

List of Standard Components and Pricing (ACTUAL)

1. 1 in. 79cc Gasoline Engine Clear Water Pump - 35 GPM *1 $189.99

2. 55 Gallon Plastic Drum*3 $30

3. Tetra Pond Tubing, Smooth, 1/2-in X 15-ft $ 20
4. Apache Hose 1-1/2" X 20' PVC Suction Hose – 98128010 $ 45
5. 2" X 1" Schedule 40 PVC Reducer Bushing Spigot X Socket, 437-249*3 $4

6. 2" Trap Adapter W/ Nut DWV Fitting, D104-020 *3 $ 15
7. Lasco 1" Schedule 40 PVC Male Adapter SlipxMIPT 436-010 *3 $ 4
8. Lasco 1" Schedule 40 PVC Female Adaptor SxFIP 435-010 $ 1
9. 1-1/2-In X Pvc Sch 40 Adapter 474015Rmc *11 $28
10. Everflow Supplies 600T038-NL Lead Free Full Port Forged Brass Ball Valve With Female Threaded IPS Connections, 3/8" * 4 $ 120
11. American Valve P200 1" PVC Ball Valve IPS Schedule 40, 1-Inch*2 $ 12
12. 1" Schedule 40 PVC 90 Elbow Socket, 406-010*2 $ 5
13. 1/2" Schedule 40 PVC Side Outlet Elbow Fitting - Socket (413-005) by Spears*4 $ 4
14. PVC Pipe Sch. 40 1 1/2 Inch (1.5) White/PVC / 3 FT*2 $ 15

Total : $ 492

SCHEDULE, PROPOSED /ACTUAL

Key Milestones (PROPOSED)

Milestone	Estimated Date
Design Agreement	2019/10/4
1st Submodel Iteration	2019/10/18
Development Sharing	2019/10/25
2nd Model Iteration	2019/11/1
BOM	2019/11/8
System Integration/ Complete CAD Model	2019/11/15
Fabrication	2020/1/17
Testing 1	2020/3/2
Modifications 1	2020/3/4
Testing 2	2020/3/16
Modification 2	2020/3/18
Testing 3	2020/3/25
Modifications 3	2020/3/30
Tech Expo	April_2020
Compete/ Win	2020/4/20

PLAN TO FINISH

Milestone	Estimated Date
Design Agreement	2019/10/4
1st Submodel Iteration	2019/10/18
Development Sharing	2019/10/25
2nd Model Iteration	2019/11/1
BOM	2019/11/8
System Integration/ Complete	
CAD Model	2019/11/15
Fabrication	2020/1/17

We didn't finish whole fabrication due to COVID-19

Process of Fabrication

- Precise measurements (Done)
- Material selection and purchase (Done)
- Fabrication (barrels stabilization, water pump installation, pipe assembly) (Partially done)
- Testing and Proof of Fabrication & Design (Unfinished due to COVID-19)

SUSTAINABILITY AND MATERIAL USAGE

- Install four wooden barricades beside and between barrels as fixtures

- Mounted sealing rubbers to holes of barrels

- Install two hose clamps to lower piping connection.

- Electric water pump installation (Between cargo bed and driver seat.)

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APPENDIX A

Final Decision and Analysis

1 = low satisfaction 5 = high satisfaction

Product objectives		Concept 1	Concept 2	Concept 3
Ground clearance	17.6	3	3	5
Common material selection	15.0	2(too expensive)	3	5
Structural integrity	14.8	5	3	4
Number of parts	13.6	5	4	4
Max payload	10.2	3	4	5
Matric fasteners	8.4	4	4	4
Overall weight	7.8	4	3	4
Overall size	6.4	4	4	4
Fuel economy	6.2	2	3	4
		32	31	39

Thus, our group prefer to choose the third concept as our final configuration.

APPENDIX B

Water pump selection

（Figure7: 1 In. 79cc Gasoline Engine Clear Water Pump - 35 GPM）

This is a gasoline engine water pump, which can quickly transfer water at a speed up to 35GPM (2100GPH). The gas engine on the pump is applicable during power outages and remote jobsites. And there is a durable cast iron volute and impeller combined with high quality silicon carbide seals ensure long service life.
Price: $179.99

- Powerful 79cc 4-stroke overhead valve gas engine
- 35 GPM (gallons per minute)
- Maximum head lift: 65 ft.
- Intake head lift: 19 ft.
- Low oil alert
- Recoil start (2)

（Figure 8 and 9: Pacer Self-Priming Transfer Water Pump）

Pacer Self-Priming Transfer Water Pump is excellent for water and ag chemical transfer, irrigation or clearing flooded areas. Powered by a 160cc Honda GC160 engine. Made of corrosion-resistant polyester with chemically resistant EPDM seals. Self-priming with 25ft. max. suction lift. (3)

Price: $389.99

Key Specs

Item#	109608	**Discharge Port (in.)**	2
Brand	Pacer Pumps	**Self-Priming**	Yes
Manufacturer's Warranty	1 year Limited Warranty	**Impeller Shaft**	Polyester
Ship Weight	50.0 lbs	**Seals**	EPDM
Flow (GPH)	11,700	**Dimensions L x W x H (in.)**	21 x 17 x 15
Max. Total Head (ft.)	120		
Suction Port (in.)	2		

(FIGURE 10: TRUPOW 1/2HP 1450GPH 115-VOLT CAST IRON PORTABLE ELECTRIC POWER)

Price: $98.24

- Made of durable cast iron with brass hose connectors for standard 3/4" hose
- Powerful transfer pump and easy to use; Please also keep the inlet hose primed with water(by use check valve)
- Max flow rate: 1450gph ; Max delivery height: 120ft
- Perfect for water distribution such as watering lawns in gardens or draining waterbeds, clogged sinks, and aquariums
- Package Include: 1x Water Pump, 2x Brass Connectors, 1x Hose Filter, a set of extra replacement brushes

1 = low satisfaction 5 = high satisfaction

Product objectives		Concept 1	Concept 2	Concept 3
Ground clearance	17.6	Irrelevant	Irrelevant	Irrelevant
Common material selection	15.0	4	1	5
Structural integrity	14.8	5	3	3
Number of parts	13.6	4	3	4
Max payload	10.2	3	3	4
Matric fasteners	8.4	4	4	3
Overall weight	7.8	4	4	5
Overall size	6.4	4	4	4
Fuel economy	6.2	5	3	4
		33	25	32

APPENDIX C

Design Specification

Engine, 11 hp. Maximum as advertised by engine manufacturer
Exhaust, muffler, shielding
Gages, Engine temperature
Fuel and fueling provisions that prevent spilling on hot engine
Transmission with reverse
Transmission minimum two speeds, in addition to variable speed drive
Power takeoff ability
Electrical, 12 volt 35 amp minumin automotive alternator
Battery, 12 volt automotive size, not small lawn mower size

Cargo Bed, 16 in front bulkhead, 8 in sides min. must be able to convert to carry cargo

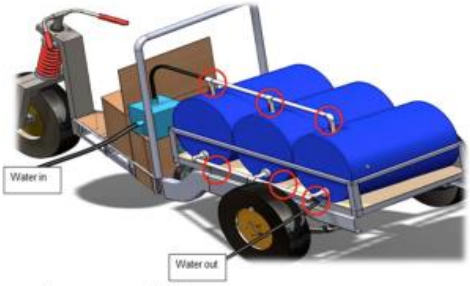
Steel drums positioned on their sides with feature to verify when full. Must remain full
Roll Bar, 36 in above seating surface
Driver and passenger safety helmets
Engine shutoff device with nine inch red flag
Spring return throttle on engine linkage, or on the control valve of hydraulic vehicles
Guarding and padding for safety
Automotive horn
Fire Extinguisher, 5-B-C rating or higher
Safety flag
Brake System redundantcy, except for hydraulic drive vehicled
Parking Brake
Tires
Towing strap, 20 ft. louped ends only no hooks allowed
Trailer Hitch, 15 in. high at ball mount surface, 1-7/8 in ball
Water Pump driven by PTO directily or indirectly, No extra engine for pumping water
Power inverters must have GFCI protecton with test and reset provisions
Name Plate, 4 in font all sides

Deduction from event points for missing design specifications features

APPENDIX D

Basic Utility Vehicle(BUV) Irrigation System

By Yuanjing Xu

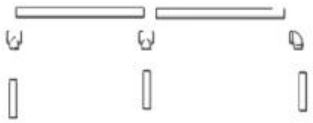


Process of Fabrication

- Precise measurements (Done)
- Material selection and purchase (Done)
- Fabrication (barrels stabilization, water pump installation, pipe assembly) (Partially done)
- Testing and Proof of Fabrication & Design (Unfinished due to COVID-19)

Precise Measurements & Material Selection

- Cargo bed: (Length: 72 inches, Width: 40 inches)
  - Wood panel: length:71.5 inches width: 39.5 inches
  - Four side rails: length: 71 inches, width:38 inches



- Piping connection:
  - Barrels upper hole: diameter: ¾"
  - Barrels lower hole: diameter: 2"
  - 1* 2" PVC pipe
  - 1* ¾" PVC pipe
  - 3* ¾" ball valve
  - 3* ¾" adapter with thread
  - 2* TEES 2" PVC pipe
  - 1* ELL 2" PVC pipe
  - 1* Glue (8 oz. Purple Primer)

- Water pump: electric pump (12 Volts, 15 Amps, 3400 GPH)

Fabrication:

- Wood panels (Stuff in Home Depot helped me to cut)

Fabrication

- PVC Pipe Cutting and lower part installation)

Fabrication

- Lower piping connections details

Fabrication:

- Upper piping connections details

Processing & Plan (to be completed)

- Install four wooden barricades beside and between barrels as fixtures
- Mounted sealing rubbers to holes of barrels

- Install two hose clamps to lower piping connection.

- Electric water pump installation (Between cargo bed and driver seat.)

Processing & Plan (to be completed)

- Install rotor sprinkler Heads to upper piping adapters.

Previous year's design:
(Water taps)

My plan:

Estimated time and budgets

- One week to complete the whole piping system.
  Estimated budget: Sealing rubbers $ 12
  Hose clamps $ 18
  Rotor sprinkler heads $ 35

- One week to install and test electric water pump
  Estimated budget: Electric water pump $ 200

Testing and Proof of Design

Water pump: Time of filling barrels from water source (10 minutes), time of emptying water.

PVC Assembly: broken, leaking, and durability