Design and Implementation of an Integrated Mobile Ag Chemical Storage and Metering System for Use on Existing Agricultural Equipment

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Motivation: Minimize downtime due to unequal filling intervals by matching the capacity of the planter with the capacity of the chemical stored by the system. A self contained and flexible mobile agricultural chemical storage and metering system allows for several applications on the farm. The final design of this project will be a feasible product for commercial production.

Project Goals:

- 1000 gallon storage capacity
- Self contained unit to allow for single point hookup to implement
- Allow for flexibility in pumping and metering devices to allow for application of several differing solutions without having to change components
- Utilize existing equipment to make project more feasible on a commercial level
- Compatible with variable rate technology (VRT)

Benchmark:

- The Agri-Products System
  - Up to 800 gallon storage capacity
  - $2585 MSRP
  - Approx. 17.5 ft width (limits mobility)
  - No loader attachment

Design Parameters:

- John Deere 4960 Tractor Specifications:

Engine Speed (rpm)	1800
PTO Speed (rpm)	800
PTO Size (in)	1.75
Ground Speed (mph)	5.6

- Tractor Loading:

	Applied Load (lbs)		Available Tire Load (lbs)	Allowable Added Weight (lbs)	
	Planter Unfolded	Planter Folded		Planter Unfolded	Planter Folded
Front Axle	7220	3880	10020	2800	6140
Rear Axle	14480	27060	29760	15280	2700

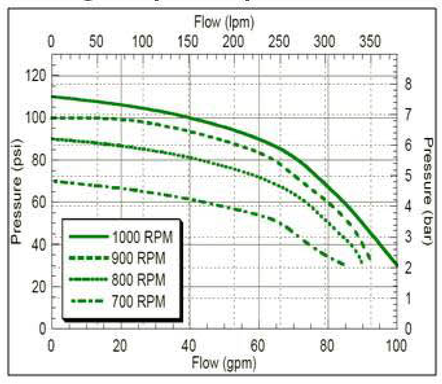
- Design for operator comfort and safety
  - Operator station panel can operate valves electronically
  - Additional lights for greater night visibility
- Compatibility with existing VRT monitors
- Multiple fill points for convenience
- Use existing saddle tanks to hold additional chemical
- Maximum desired width of 16 ft
- Loader Specifications:
  - Standard John Deere 840 loader assembly
  - Maximum load of 9200 lbs

Design Process:

- Limiting design factor is flow rate, due to high application rates with low pressure delivery
  - Assumed line losses were minimal
  - Application rate

Number of Rows	Row Spacing (in)	Application Width (ft)	Min Application Rate (gal/acre)	Min Flow Rate (gpm)	Max Application Rate (gal/acre)	Max Flow Rate (gpm)
24	30	60	15	10.2	71	48.2

- Pump Selection:
  - PTO mounted, belt driven centrifugal pump
  - Stainless steel components



- Flow Meter:
  - Operating range = 1-60 gpm
  - Power supply and signal compatible with modern VRT monitor
- Regulating Valve:
  - 2” solenoid actuated butterfly, open loop control
  - Power supply wiring compatible with modern VRT monitor
  - Maximum operating pressure = 300 psi

- Frame Design:
  - Saddle tanks supports located in existing mounting holes in the bottom of the loader mast
  - Loading assumed to be 3g at saddle tank support end
  - Deflection of saddle tank supports

$$\delta = \frac{-PL^3}{3EI}$$

    - Maximum deflection = 0.157 in
  - Stress in saddle tank mounts

$$\sigma = \frac{|M|}{S}$$

    - Maximum stress = 25,030 psi
  - Weld calculations

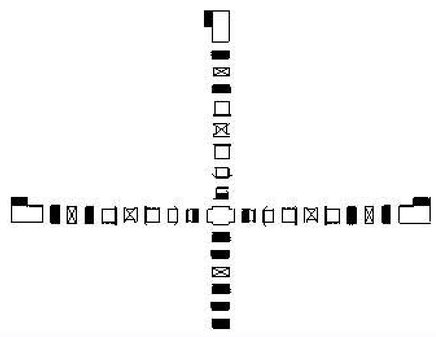
$$f_{a=}\frac{P\ x\ L}{Z_w} \qquad f_{s=}\frac{P}{L_w} \qquad b = \frac{\sqrt{{f_a}^2 + {f_s}^2}}{0.707 f_{allow}}$$

fs (lbs/in)	fa (lbs/in)	fallow (psi)	b (in)
111.5	1092.2	13000	0.12

- Factors of Safety

$$FS = \frac{x_{actual}}{x_{allow}}$$

FS σ	FS weld
1.44	3.75



Build Process:

- Modified loader frame mounts by fabricating and welding saddle tank supports
- Re-worked and moved battery box assembly
- Built new steps for alternate location
- Installed saddle tanks with appropriate mounting hardware
- Wired new components into operator station controls and monitor
- Fabricated the quick disconnect front tank support and installed front tank
- Routed new plumbing components, including pump and metering valves
- Attached loader to purchased mounting brackets with mast
- Paint and finish work, including hose clamps and new lighting mounts

- Issues
  - Clearances between new and old components
  - Accounting for quantity and sizing of all fittings
  - Part shipping and delivery dates

Final Product:

- Project Limitations
  - Front visibility issues
  - Unable to transport system more than 50% full due to dynamic loading concerns
  - Tight entrance and egress from tractor cab
- Verification of Design
  - Perform electrical check by operating system valves and lights from operator station (Completed)
  - Verify metering system by calibrating closed loop system of the flow meter and regulating valve
  - Check and record nominal system pressures at minimum and maximum flow rates
- Parts List
  - Approx. 40 components with 145 separate parts

System Parts List and Pricing

Tractor Parts (Plumbing and Metering Equipment) Suction and Fill Equipment

Quantity	Description	Part #	List Price	Cost
1	2" Regulating Valve Raven	063-0172-177	$728.15	$728.15
1	1" On/Off Applicator Valve	MVE100CF	$414.77	$414.77
1	1.5" Flow Meter Raven	RFM60P	$441.86	$441.86
1	PTO Pump Ace	PTOC-150-1000-21SB	$1,115.00	$1,115.00
3	2" Electric On/Off Valve Banjo	VE204FP	$641.78	$1,925.34
5	2" Poly Ball Female Threads Shutoff	V200FP	$70.75	$353.75
150	2" Suction Hose	390-200	$6.35	$952.50
20	1.25" Suction Hose	390-125	$4.40	$88.00
25	Banjo Super T Bolt Clamps	TC224	$8.39	$209.75
2	2" Male Quick x 2" female NPT Shutoff	VSF204FP	$66.76	$133.52
3	2" Female Quick x 2" Hose Shank	200C	$17.49	$52.47
25	2" Male Thread x 2" Hose Shank	HB200	$3.69	$92.25
1	2" Poly Cross	CR200	$29.15	$29.15
3	2" Poly Pipe tee threads	TEE200	$11.64	$34.92
3	2" Male Quick x 2" Male threads	200F	$7.37	$22.11
1	2" Quick Cap	200CAP	$17.49	$17.49
3	2" Poly Pipe coupling	CPLG200	$10.46	$31.38
3	2" Male Thread x 2" Hose Shank 90° elbow	HB200-90	$7.48	$22.44
1	1.5" Male Thread x 2" Hose Shank	HB150/200	$4.63	$4.63
3	2" Male Threads x 1.25" Male Threads	RN200-125	$3.40	$10.20
1	1.25" Female Threads Tee	TEE125	$6.51	$6.51
1	2" Male Threads X 1.25" Female Threads	RB200-125	$3.59	$3.59
1	2" Female Quick x 2" Male Threads	200B	$17.49	$17.49
1	1.25" Male Threads X 1.25" Barb	HB125	$1.81	$1.81
2	1" Flange X 1.25" Barb	M100125BRB	$1.62	$3.24
7	1.5" Male Threads X 1.25" Hose Barb	HB150/125	$2.70	$18.90
			Sub Total :	**$6,731.22**

Tractor Parts (Agitation and Return Equipment)

Quantity	Description	Part #	List Price	Cost
1	2" X 1" Poly Reducer	RB200-100	$3.59	$3.59
10	1" Male Thread x 1" Hose Shank	HB100	$1.47	$14.70
4	1" Manual Poly Ball Valve	V100FP	$39.09	$156.36
1	1" Poly Cross	CR100	$15.97	$15.97
3	1" Male Quick x 1" Male threads	100F	$5.59	$16.77
3	1" Female Quick x 1" Hose Shank	100C	$12.26	$36.78
3	1" Electric shutoff valve (flange)	VE100FP	$414.77	$1,244.31
6	1" Flange X 1" Hose Shank	M100BRB	$1.62	$9.72
3	3/4" Male Thread x 1" Hose Shank 90° elbow	HB075/100-90	$1.51	$4.53
			Sub Total :	**$1,502.73**

Tractor Parts (Mounting and Tanks)

Quantity	Description	Part #	Price	Cost
1	John Deere 840 Loader	-	$7,800.00	$7,800.00
1	Agri Products Cross Mount tanks (250 gal)	-	$2,192.00	$2,192.00
1	Agri Products round tank (500 gal)	-	$1,573.00	$1,573.00
1	Extra steel needed for alterations	-	$1,000.00	$1,000.00
			Sub Total :	**$12,565.00**

Total System Cost = $20, 800

Conclusions:

- The goal of designing a self contained and flexible mobile ag chemical storage and metering system that would mount to existing equipment was achieved in the given time frame. The final product met the capacity target and significantly improved on the width as compared to the benchmark system.
- This system will be used on a working grain farm not only to test the usefulness and longevity of the design, but also to increase the overall capacity of the farm.
- Further refinement of the design is desired, especially in the areas of improved front visibility and operator access.
- Lessons Learned:
  - Every large assembly can be broken into manageable sub-systems where detailed hardware selection early in the design process make final assembly more streamlined and easier to manage.
  - Project management with contributors is a more involved process than originally anticipated.

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