Granite Construction Co. Tank Level Automation System

Honors Thesis

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I. Overview

A. Abstract

Granite Construction proposed a project to improve the offloading system at their regional asphalt plants. The current system for asphalt oil offloading at most of the plants consists of manual operated inlet valves and rudimentary level indication for the storage tanks. There is a large amount of risk involved with filling a storage tank with hot oil via manual operation. Overfilling the tanks could result in expensive inventory loss, property damage, and operator injury. Granite Construction has requested our team to design and implement a system that automatically controls the flow and level of liquid asphalt within the storage vessels. The primary scope of this project consists of implementing horizontal tank level measurement devices and a valve actuator system to fit the needs of the project administrator. Radar level indication was selected to monitor asphalt cement volumes in each tank. The radar data will be continually relayed to the control room by integrating into the existing SCADA system. The system will determine the appropriate actions to take, and actuated valves will be operated automatically. The system will be designed to react accordingly to emergency situations, actuator failures, and operator overrides. Given a $100,000 budget per plant, the system considered in this report meets the MARR of 80% making it economically viable for implementation. This system has the capability to reduce Granite’s annual spills from 10 a year to zero, saving them $935,000 in lost product and clean up costs annually. Granite Construction plans to install the completed system in many of their current asphalt plants. An implementation rate of five systems per year is desired by the project administrator.

B. Introduction

Granite Construction Company is a heavy civil general contractor and construction materials producer that owns and operates 50 aggregate facilities throughout the U.S. producing specialty aggregates, sand/gravel, and asphalt concrete. Granite’s Bradshaw Facility in Sacramento, California is one of its largest producers of asphalt concrete and aggregates, resulting in around the clock loading and unloading of the materials that go into making their asphalt. One of the materials that Granite produces is bitumen oil, or asphalt cement. Bitumen oil is a highly viscous, black oil that flows easily as a liquid at 350°F. When mixed with crushed gravel and aggregate, the bitumen serves as the binding agent in asphalt pavement, seen on roadways. Granite orders this bitumen by the semi load to start the process. Tanker trucks pull into Granites Bradshaw Facility, and go to a weigh station, from there the trucks are directed to an offloading pump where the unaffiliated trucking company has their driver hook up the trailer to the unload pump. Granite then sends out an operator to line the valves up so the driver is unloading into the correct tank. The operator climbs on top of the tank and dips a stick into the tank to get a rough estimate of the current volume of the tank. Then the driver starts the pump
and the 25 to 30 ton truckload unloads in roughly 30 minutes into Granite’s horizontal storage tanks. Currently the Bradshaw Facility has four horizontal tanks with 30,000 gallons of capacity, two of these tanks have an internal divider splitting them in half resulting in effectively six storage tanks. Each tank holds a different quality of bitumen. Bitumen from these storage tanks is then piped to a tumbler where it is mixed with the crushed gravel to create asphalt, varying grades of asphalt require varying quantities and qualities of bitumen. The mixing process is very precise and allows for high grade asphalt. Once the asphalt reaches the desired quality, any excess bitumen is then goes through recirculation lines back to the storage tanks. The problem Granite and many asphalt facilities currently face is that while a storage tank can typically hold the asphalt from one truck there are times when the storage tank is overfilled. This can be due to a plethora of reasons including the recirculation of excess bitumen not being accounted for, as well as unloading of trucks into partially full storage tanks. Overfill is costly and very dangerous. Average grade bitumen is about $500 a ton, meaning any sort of spill has significant financial implications. The primary expense concerning overflow comes from the extensive cleanup process and these cost can varying depending on the climate and location of the facility. The Bradshaw Facility enjoys California's Mediterranean climate and warm weather year round which in turn results in the oil penetrating deeper into the ground during spills which increases the clean up time and costs. These overflows are also extremely dangerous as bitumen is stored at 350 °F, any sort of overflow can put the operator and drivers at risk of severe burns and injury. According to Granite, they have an average of 10 major spills per year with an estimated total of 150 tons of bitumen spilled. A solution and system to reduce, or completely negate spills would greatly increase the safety of the employees and prove to be a financial benefit as well. Ideally, this system would be a complete system where the truck would show up and inform the control room that they are there to unload the oil. The control room operator would then go to a computer screen and accesses the asphalt unload page on the control panel. This unload page would detail the current volume of asphalt cement in the storage tanks and allow the control room operator to select a storage tank. Out in the field, the inlet valves of the storage tanks and the pump would be opened through compressed air actuators or electrical actuators, and the pump would turn on, unloading the truck into the storage tank. A high level alarm on each tank would indicate when the storage tank was full, shutting off the pump and closing the valves to the tank, to prevent overflow. This high level alarm system would be controlled in part by a level indication system that gives continuous measurements and relays the data it collects to the control room and is processed through the current PMII system control and data acquisition (SCADA) system as provided by ASTEC. The level measurement data would then be used to control the actuators, valves, and pump, keeping them open to maintain the flow of bitumen during normal operation or shutting them down in an emergency scenario to prevent overfill. Granite’s budget for an automation system of this nature is $100,000 per facility and the project has to demonstrate that it will meet Granite’s set hurdle rate and MARR of 80%. 
II. Project Objectives

A. Scope

The primary scope of the project was to implement a level indication device to continuously monitor bitumen levels in horizontal storage tanks, and add pneumatic valve actuators to automate the system.

B. Objectives

Granite’s head engineer approached the design team with an open-ended task: design and supply instruction for the implementation of high level alarm system to prevent the overflow of bitumen. The following requirements helped guide the design process:

a. Selection of tank level monitoring device.

b. Tolerance testing of the tank level monitoring device.

c. Selection of the valve actuation system.

d. SCADA system integration for communication between actuation system, tank level monitoring system, and current SCADA system installed at the plant.

e. Meet an internal rate of return of 80% on the upfront costs of the project.

The ambiguity of these tasks allowed for a great deal of freedom to determine the best solution to the design problem proposed. Due to the tank level measurement device guiding the outcomes of the other requirements, several indication devices were considered and the design impacts each device had on the other outcomes were considered. Appendix V details the pugh matrix used to settle on the final device selection. Each of the requirements listed above were then broke down into the constraints that each had to meet, which is detailed in the following section.

C. Benchmarking

Automated level indication systems already exist, Granite has previous experience with different types of sensors and this information was valuable in consideration of our final design selection. Other facilities that handle similar petroleum and mining products were also used as a source of inspiration for various design aspects, system reviews, and common complaints.
D. Constraints and Design Considerations

Level Indication System

With the level indication system serving as the driving factor of the project, it was important that the selected device met as many requirements as would be expected in the standard operating environment. The level indication device was required to withstand the extreme conditions of the storage tank, meaning it had to be capable of operating at temperatures in excess of 350°F and in an environment with highly viscous and sticky asphalt cement. Additionally, due to the high potential of overflow during unloading of a truck into the storage tank, the device needed to give continuous measurements, allowing for constant monitoring of the tank level so that emergency shut off can be executed rapidly at a critically high tank level. The selected device also needed to be low maintenance, ideally one that would not be in constant contact with the bitumen, preventing it from get gunked up as quickly. A device that would need cleaned once or twice a year is much more favorable over one that needs cleaned daily or weekly. The selected device also needed to be easily mounted onto the current tanks, cutting into the tanks to create a new access port to fasten a device to would be costly and would negate the benefits of the current mounting capabilities equipped on the tank. Additionally, the selected device would need to be easily integrated into the current ASTEC PMII SCADA system with relative ease. This would allow the device to communicate with all other automated parts and allow control room operators to spot any issues that may arise during production. Finally, the selected device needed to be cost effective. Not just the initial price of the device was considered, but the maintenance cost, and replacement cost over a projected 10 year life cycle was also important. Ultimately with these considerations in mind the device solutions were narrowed to: pressure sensors, conductance rods, float switches, bobbers, thermal imaging, and non-contact radar. The pugh matrix used for final device selection of non-contact radar is presented in Appendix V. Non-contact radar was preferable over something like thermal imaging for example, because thermal imaging is extremely costly but gave highly unreliable data due to the thickness of the insulation of the storage tanks. Pressure sensors on the other hand were moderately inexpensive but because of Granites past experience with pressure sensors failing after a few months due to solid particulates gunking up the sensor over time, the pressure sensor was determined to be non-viable. Float switches, most commonly seen in stock tanks, also fell to similar demise. Even in stock tanks filled with just water the float switches were
prone to failure and unreliable. Ultimately, radar met the design requirements and the cost could be justified with the longevity of the system.

**Actuator System**
The actuator system had requirements and considerations that were much more well-defined and constrained. Granite currently has the capacity to run either pneumatic or electrically operated actuators. The Bradshaw facility currently has pneumatic rams on the outlet side of the tank operating valves that flow to the tumbler. With this in mind, it was decided that an actuator operated with pneumatics was the best option for easy integration. These pneumatic rams have to meet several requirements. They must operate with 120 PSI of supplied air, as well as supply 107 ft-lb of torque to open and close the valves. This torque requirement comes from the user manual of the valves currently in place. Additionally, the ram must indicate operation status and actuator positioning, such as open, closed, and half open. This indication system must be easily integrated into the SCADA system, not only to communicate the actuator positioning but also to receive commands from the radar during emergency shut down. For safety reasons the valve must have a manual override in the event that a component in the electrical system were to fail. Granite currently manufactures their pneumatic ram systems in house, therefore it was important to determine if it was financially better to continue this practice or to purchase the ram from an external supplier, such as Grainger. The economic section of this report further details the selection process. Ultimately a combination of inhouse and purchased rams were decided upon, as Granite already has experience in building the system to specification and assembling mounting components. Additional consideration of in house built rams was the fact that Granite usually completes these projects during slow season, or downtime when their workers would otherwise be sent home.

**Misc Systems**
The recirculation system posed some constraints as the different grade and qualities of bitumen must be recirculated back into their respective tanks. This results in an increase in the pneumatic valves on the recirculation system. For the tank overflow warning system, a light and sound system was proposed to Granite so that any operators, and truck drivers would be warned of potential overflow and tank level. This system would be easily integrated into the current SCADA system and work in pair with the level indication. The constraints and design considerations discussed above, as well as other noteworthy design considerations encountered during this projects are presented in Table 1 below.
### Table 1. Summary of Design Considerations

<table>
<thead>
<tr>
<th>Item</th>
<th>Consideration</th>
<th>Other Constraints</th>
<th>Possible Solutions</th>
<th>Final Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank Level Measurement Tool</td>
<td>Must withstand temperatures exceeding 350°F, maintain accurate readings when induced to bitumen on measurement surface, must relay measurements to control tower and alarm systems, easily integrated</td>
<td>Cost, Durability, Mounting Ease</td>
<td>Pressure Sensor, Non-Contact Radar Conductance Rod Bobber Thermal Imaging Float Switch</td>
<td>Non Contact Radar Level Measurement</td>
</tr>
<tr>
<td>Actuated Valve Shutoff System</td>
<td>Must provide actuated shut off before tank overflow occurs, must support current asphalt plant SCADA system, Must provide manual shutoff system, must communicate with tank level measurements</td>
<td>Cost, Reliability, Must Use Current valves installed</td>
<td>Electronic or pneumatic Inhouse or Purchased integrated manual override or separate manual valve</td>
<td>Purchased pneumatic ram, custom mounting, with integrated manual override, Hall-effect sensor for open/closed indication</td>
</tr>
<tr>
<td>Tank Overflow Warning System</td>
<td>Must alert flow operations and control tower of tank levels nearing overflow, Must support current asphalt plant SCADA system, must communicate with tank level measurements</td>
<td>Reliability, Visibility, Ease of Use</td>
<td>Warning lights, alarm display, and sound alerts</td>
<td>Combination of lights, alarm display, sound alerts</td>
</tr>
<tr>
<td>Data Processing</td>
<td>Must communicate with all system components and current asphalt plant SCADA system. Open &amp; close valves (including recirculation), turn on pump, and provide level information</td>
<td>Ease of use, Compatibility</td>
<td>ASTEC</td>
<td>To be integrated by ASTEC</td>
</tr>
</tbody>
</table>

### III. Selection Specifications

After selecting the general components of the actuation system and level indication system, the next step was to narrow down the specific brand and model of the various components and source them.
A. Level Indication

Non-Contact Radar was the final design choice due to its capability to withstand high temperatures, and the ease of data processing between the unit and ASTEC’s PMII system. The VEGAPULS 64 radar was the selected radar among several options, and ultimately the decision came down to consumer reviews and the radar being built for the specific application of asphalt monitoring. With abundant customization options, the VEGAPULS allows Granite to upgrade their SCADA system in the future, change the type of tank and mounting method, and change the communication method with ease. The particular set up specification that was chosen is detailed below:

a. VEGAPULS 64
   i. Manufacturer: VEGA
   ii. Process Temperature: -40..200 °C
   iii. Accuracy: ± 1mm
   iv. Threaded Connection: 1 ½” G
   v. Output: 4..20 mA/HART - 2-wire
   vi. Operating Voltage: 12..35 VDC

b. Connecting Flange
   i. 6” ASME B16.5 Class 150 w/ 1 ½” NPT connection.

c. Socket Mounting
   i. Mounting will be 6” in diameter and less than 23.6” in height. See Vega Operating Instructions, Appendix II, pages 22 & 23 for more details.

The VEGAPULS 64 is capable of communicating via bluetooth or via a 4...20mA/HART 2-wire system. A VEGA Tools app available on smart devices, allows for easy system configuration and system monitoring. The particular threading of the radar details the NPT or G type available for this particular model. A simple adapter will be used to mount the 1 ½” threaded radar to the 6” 150# flange atop the tank. Current mounting of the radar device is depicted in Figure 1 and Appendix I.
B. Valve Actuation

a. NFPA Square-Head Tie Rod Aluminum Cylinder
   i. Manufacturer: Grainger
   ii. Stroke Length: 10-14 ½” options
   iii. 1 ½” Bore Diameter
   iv. Adjustable Cushion

b. Piston Mounting
   i. Attachments for Grainger NFPA Square-Head
      1. Rear Cast-Iron Clevis Mounting Kit
      2. Cast-Iron Rod Clevis

c. Valve Attachment
   i. Custom actuator lever
      1. Medium carbon steel or cast-iron steel
Figure 2: Custom Built Valve Actuating Lever.

d. Position Indicator - Hall Effect Position Sensor
   i. Manufacturer: Spectec
   ii. Model: 0221
   iii. Voltage Supply: 8..30 VDC @ 5 mA
   iv. Voltage Output: 0.5..4.5 VDC
   v. Sensing Range: 0.00..1.00”” or -100 to 100 degrees
   vi. Temperature Range: -40..125 ℃
C. SCADA

While Granite’s current automation and data processing company, ASTEC, will handle the integration of the components proposed in this report, it is still necessary to provide some Ladder Logic Diagrams. These diagrams will be able to assist in communicating the functions that this design group and Granite would like to see implemented. Due to the nature and size of ASTEC and their role in asphalt industry, receiving any sort of proprietary code from them allowing for this design team to write its own implementation code is unrealistic. Therefore, the majority of the data processing and implementation is beyond the scope of this project. Instrumentation diagrams and the Ladder Logic that details the functions and desired procedures follows below.
Figure 4: Piping and Instrumentation Diagram For Granite’s Bradshaw Tank Farm

Figure 4 depicts the automation of the valves, where the blue valves would be operated using the pneumatic rams detailed previously. The green outlet valves are currently pneumatically operated and will only need integrated with the rest of the radar, indicator, and pneumatic ram system proposed in this report. The pink valves are valves on the recirculation line, these would also be operated using the pneumatic rams and systems proposed. In total, 14, new pneumatic rams are needed for the system. To control and monitor this system the functional ladder logic diagram in figure 5 details a system overview. Figure 6 details the ladder logic protocols for a filling scenario of the storage tank.
**Figure 5:** Granite Tank Monitoring System Overview

**Figure 6:** Granite Level Indication for Storage Tank Filling
Additional ladder logic and functionality diagrams are presented in Appendix VIII, these additional diagrams detail example scenarios for draining the tank, flushing pipelines, and emergency shutdown procedures. In the emergency shutdown procedures the radar would indicate that either the tank volume is approaching >95% and is at risk for overflow with recirculation and radar error, or that the radar itself is unresponsive and not providing level indication. In the event the radar malfunctions and no signal is received, it is imperative that filling operations are paused because of the increased risk of overflow. The system procedures are similar in both cases, as the SCADA system would turn off the pump connected to the truck offloading, and then the valves to the tank and pump would close immediately. Alarm systems on the ground level would be triggered indicating to the operator and truck driver of potential issues. In the control room a warning would appear on the computer screen of administrators, keying them in on the issue with the automation system and tank level. The full capabilities of ASTEC’s PMIII system are listed in Appendix VI. Granite’s current system is the PMII which is nearly identical to the PMIII, but the PMII has integrated burner controls necessary for operations at the Bradshaw Facility.

IV. Testing

A. Summary

Testing was required to ensure the Vegapuls 64 non-contact radar is capable of withstanding the hazardous environment within the storage tank. If the fluid in the tank were to splash back during filling or were to exceed a critically high fluid level the radar may come into contact with the bitumen in the tank, impeding the radars direct tank reading. By adding an obstruction with similar properties to that of bitumen at 350°F to the base of the radar and conducting test readings, the tolerance of the radar was found. The findings of this testing procedure verify that the Vegapuls 64 radar will return accurate readings even if the radar’s base is obstructed.

B. Methods

The experimental test setup consists of first obtaining a symmetric vessel to be filled with water. This vessel will pose as the storage tank during testing. The vessel is then filled with water to an initial 25% of its capacity. The unobstructed radar is fastened into the testing position and an initial measurement of the fluid within the vessel is gathered and recorded to be used as a control measurement. The completed experimental set up used to gather measurements can be seen in Figure 7.
After obtaining the initial control measurement, the radar is removed from the measuring position and an obstruction is placed over the base of the radar. The obstruction consists of a single layer of the test substance lathered with constant thickness on a sheet of plastic wrap. The plastic wrap is used to prevent direct contact between the radar and the test substance. After placing the initial obstruction on the base of the radar, the radar is fastened to the vessel and an obstructed measurement is then obtained. If the radar returns a measurement consistent to the control measurement obtained, another layer of obstruction is placed on top of the pre-existing obstruction. This process is repeated until the radar no longer returns an accurate measurement. Radar tolerance is found at tank volumes of 25%, 50%, 75%, and 90%.

C. Results

Each measurement reading by the radar was recorded and used to plot the indicated volume as output by the radar vs the amount of obstruction added to the bottom of the radar. Figure 8 depict the storage tank at 25% full which corresponds to the results following. Figure 9 illustrates the trend of the indicated volume as more obstruction is added to the base.
Figure 8: Testing Storage Tank at 25% Full

Figure 9: Thickness of Obstruction vs. Indicated Tank Volume

By use of the results plotted above, the error percentage of the radar may also be found. Figure 10 illustrates the obstruction thickness versus the percent error of the radar.
In observation of the results illustrated in Figure 9 & 10 it can be noted that higher obstruction thickness results in a lower volume percent reading and a higher percent error. This is not ideal for actual operation. Ideally, the more obstruction added would result in a higher tank volume reading. This would increase the factor of safety and add an additional buffer zone. An example of this would be the radar reading 95% full and shutting down the offload pump and closing the valves. Though, in this ideal situation, the radar reads 95% full the actual volume is less than this at 93% full, which increases that safety buffer zone. In the experimentally observed scenario as seen in the figures above the radar would still shut the processes down at its indicated 95% full but the actual tank volume would be 96-97%. However, this poses a relatively minor issue in this application. The bitumen storage tanks will be set to initiate an automated valve shut off at 95% tank capacity. Therefore, for an overflow scenario to occur, the radar would require an accumulation corresponding to a 5% volume difference. This is highly implausible as the obstruction required to reach a 2.5% difference was greater than 50 mm of obstruction. In an actual application scenario the radar isn’t going to see more than 5 to 10 mm of obstruction in its lifetime, which correlates to only a few fractions of a percent variation from the actual tank volume.

D. Radar Conclusions

In analysis of the tolerance achieved by the radar it can be conclude that the Vegapuls 64 non-contact radar is the right choice for this application. The radar will return accurate tank level measurements if exposed to obstructions with thickness beyond 50mm of obstruction, well exceeding the expected obstruction in Granites applications. The radar also has a temperature rating of 392°F, which exceeds the 350°F temperature of
liquid bitumen. Additionally the radar comes threaded making in easily inserted into an adapter and installed on the top of the storage tanks 6” 150 flange as seen in Appendix I. Additionally, a user friendly app comes as part of the product package which will enable the radar to be immediately integrated into the tank level monitoring system, more standard system integration can utilize the 4..20mA hardwired system the VegaPuls 64 is equipped with.

V. Economics

A. Budget

Granite initially allocated $100,000 per plant for a complete system, with the stipulation that prior to actual full scale implementation a minimum acceptable rate of return of 80% would need to be demonstrated. To meet this requirement the cost of the new system components, labor, and SCADA integration had to be compared to the current financial impacts Granite is seeing because of spills.

B. Costs

The economic impact of the current measurement system in place at Granite manifests from the spills. The numbers cited in this economics section come directly from Granite’s own estimates and while some of the values may seem excessive and stretched they are taken as true values because of the experience Granite has in this field, and the ramifications of spills. Granite currently averages 10 spills per year with about 15 tons of lost product per spill for a total of 150 tons of lost product each year per plant. Though bitumen comes in varying grades and qualities, each with varying prices the standard price quoted is $500 a ton. This amounts to over $75,000 in lost product per year. The most expensive part of spills is the clean up costs. These cost of clean up also varies, but it varies because of the weather and climate conditions. In locations that experience cold winter months, spills that occur during the peak summer season are usually cleaned up during the cold winter months. This allows the oil to clump and not penetrate the ground as far, resulting in less extensive labor efforts. In these conditions clean up of 1 ton of bitumen takes about 16 man hours of labor. In locations that enjoy warm weather conditions year round, like the Bradshaw Facility in California's Mediterranean climate, the clean up processes is much more labor intensive. To clean up 1 ton of bitumen in these conditions takes 2 men a full 40 hour week for a total of 80 man hours. The cost of this labor per hour is cited by Granite to be $80/hr. For the Bradshaw Facility this would amount to about $960,000 in cleanup labor per year. This value of $80,000 per month in clean up labor can be expected for other facilities operated by Granite in both California and Arizona. Granite maintains that they do not receive
regulatory fines from agencies for asphalt cement spills due to the benign nature of the product, as it is on all our roadways, and the oil cools quickly so that it only penetrates the ground a few feet before flow slows. The only regulatory fines that are applicable would be if Granite were to clean up the bitumen with diesel fuel. Though this diesel is renown for its abilities to clean up asphalt stuck on trucks and vehicles, the EPA strictly forbids its use in nearly all applications and imposes hefty fines for its use. Granite does not use diesel fuel for clean up and thus is not subjected to fines. Additional economic impact of bitumen spills could stem from personal injury employees or contracted truck drivers may receive due to spills. There is no easy way to obtain hard and set values for personal injury lawsuits and liability Granite may face if someone were to be harmed by spilled bitumen, thus legal fees were also left out of the cost estimations. Ultimately, the estimated impact of the current system is summed to be just over one million dollars due to lost product and clean up costs.

The automation system proposed in this report has three major components that contribute to the overall cost of the system, these components are the physical parts, labor, and sub-contracting ASTEC. The largest cost of the physical parts, and the second largest cost of the whole system, is the VEGAPULS 64. With 6 storage tanks the system needs 6 radars, each costs about $6,000 each for a total of 36% of the budget. Other parts include the pneumatic ram, magnetic sensors for the rams, mounting components, flange adapters for the radar, still-tubing, wiring, and plumbing. The price break down is presented in Table 2. The welding, labor, and installation component of the table includes the time consuming processes of plumbing the lines to the pneumatic rams. Cost for sub-contracting ASTEC is largely variable with time, and thus the value of $50,000 was used as an estimate as it is so large, that it proves it would be very difficult for the designated budget of $100,000 to be exceeded. To summarize roughly half of the budget is set aside for the radars, pneumatic rams, other components, and installation labor, while the second half of the budget is for the integration of the parts into AZTECs SCADA system.
Table 2: Automation System Price Break Down for Bradshaw Facility.

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity/Time</th>
<th>Units</th>
<th>$/Unit</th>
<th>Present Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level Indication</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radar</td>
<td>6</td>
<td>Units</td>
<td>$6,000.00</td>
<td>-$36,000.00</td>
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<td>Still-tube</td>
<td>6</td>
<td>Units</td>
<td>$25.00</td>
<td>-$150.00</td>
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<tr>
<td>150# 6&quot; Flange to 1.5&quot; NPT</td>
<td>6</td>
<td>Units</td>
<td>$75.00</td>
<td>-$450.00</td>
</tr>
<tr>
<td>Welding/Installation</td>
<td>18</td>
<td>hours</td>
<td>$100.00</td>
<td>-$1,800.00</td>
</tr>
<tr>
<td><strong>Valve Actuation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pneumatic Ram</td>
<td>14</td>
<td>Units</td>
<td>$100.00</td>
<td>-$1,400.00</td>
</tr>
<tr>
<td>Steel Mounting</td>
<td>14</td>
<td>Units</td>
<td>$100.00</td>
<td>-$1,400.00</td>
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<tr>
<td>Magnetic Sensor</td>
<td>14</td>
<td>Units</td>
<td>$25.00</td>
<td>-$350.00</td>
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<tr>
<td>Welding/Labor</td>
<td>42</td>
<td>hours</td>
<td>$100</td>
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<td><strong>Sub-Contractor (Aztec)</strong></td>
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<td></td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
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<td>-$95,750.00</td>
</tr>
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</table>

C. Economic Analysis

The project meets is $4,250 under the $100,000 budget meeting the Granite’s requirement. For this project to break even the system would only need to prevent 20 tons of spilled oil in the first year, equivalent to one or two spills. However, the goal is to prevent all spills from occurring. With an estimated 10 spills per year and 150 tons, an automation system that could reduce the number of spills per year 10 zero would result in a savings of $935,000, this results in the IRR being well over the MARR of 80%.
VI. Summary

The primary scope of this project consisted of implementing horizontal tank level measurement devices and a valve actuator system to fit the needs of Granite Construction. Radar level indication was selected to monitor asphalt cement volumes in each tank. The radar data will be continually relayed to the control room by integrating into the existing SCADA system. The system will determine the appropriate actions to take, and actuated valves will be operated automatically. These valves will be made from a combination of inhouse and purchased components. The system will be designed to react accordingly to emergency situations, actuator failures, and operator overrides. Given a $100,000 budget per plant, the system considered in this report meets the MARR of 80% making it economically viable for implementation. This system has the capability to reduce Granite’s annual spills from 10 a year to zero, saving them $935,000 in lost product and clean up costs annually. Granite Construction plans to install the completed system in many of their current asphalt plants. An implementation rate of five systems per year is desired by the project administrator.
Appendices

Appendix I: Tank Drawings
Appendix II: Data Sheets and Instructions

VEGAPULS 64
4 ... 20 mA/HART - two-wire
Radar sensor for continuous level measurement of liquids

Technical data
- Measuring range up to 30 m (98.43 ft)
- Deviation ≤ 1 mm
- Process fitting: Thread from G1/4″, 1/2″NPT, flanges from DN 50, Z" mounting strap, adapter flanges from DN 100, 4"
- Process pressure: -1 ... 25 bar (-100 ... 2500 kPa/
 14.5 ... 362.6 psi)
- Process temperature: -195 ... +200 °C (-321 ... +392 °F)
- Ambient, storage and transport temperature: -40 ... +85 °C (-40 ... +185 °F)
- Operating voltage: 12 ... 35 V DC

Materials
- The wetted parts of the instrument are made of 316L, PP, PTFE or PEEK. The process seal is made of FFKM, EPDM or PTFE.
- You will find a complete overview of the available materials and seals in the "Configuration" at www.vega.com and "VEGA Web".

Application area
- VEGAPULS 64 is a radar sensor for continuous level measurement of liquids.
- The small process fittings offer particular advantages in small tanks or tight mounting spaces. The very good signal housing ensures the use in vessels with many installations such as stirrers and heating elements.

Your benefit
- Maintenance-free operation thanks to non-contact measuring principle.
- High plant availability, because wear and maintenance free.
- Exact measuring results independent of process conditions.

Function
- The sensor emits a continuous radar signal through the antenna. The emitted signal is reflected by the medium and received as an echo by the antenna.
- The frequency difference between the emitted and received signal is proportional to the distance and depends on the filling height. The determined filling height is converted into a respective output signal and outputted as measured value.

Housing versions
- The housings are available as single chamber or double chamber version in plastic, stainless steel or aluminium.
- They are available with protection ratings up to IP 68 (1 bar).

Electronics versions
- The instrument is available with electronics 4 ... 20 mA/HART as well as HART and power pack.

Approvals
- Approvals are planned for the instrument for use in hazardous areas as well as in the ship and food processing industry.
- You can find detailed information of the approvals for all instruments at www.vega.com/downloads and "Approvals".
Adjustment

Adjustment on the measurement loop
The adjustment of the instrument is carried out via the optional display and adjustment module PIUSCOM or via a PC with the adjustment software PACWare and corresponding DTM.

Wireless adjustment via Bluetooth
The Bluetooth version of display and adjustment module enables a wireless connection to standard adjustment units. This can be smartphones/tablets with iOS or Android operating system or PCs with PACWare and Bluetooth USB adapter.

Wireless connection to standard operating devices
Adjustment is hence carried out via a free-of-charge app from the Apple App Store or the Google Play Store or the adjustment software PACWare and respective DTM.

Adjustment via PACWare or app

Adjustment via remote systems
Further adjustment options are possible via a HART Communicator as well as manufacturer-specific programs such as AMG™ or POM.

Electrical connection

Electronics and terminal compartment, single chamber housing

1. Voltage supply/signal output
2. For display and adjustment module or interface adapter
3. For external display and adjustment unit
4. Ground terminal for connection of the cable screen

Specifications

Dimensions

<table>
<thead>
<tr>
<th>Dimensions VEGAPULS 64</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Version thread with integrated horn antennas</td>
</tr>
<tr>
<td>2. Version flange with encapsulated antenna system</td>
</tr>
<tr>
<td>3. Version, plastic horn antenna</td>
</tr>
</tbody>
</table>

Information

You can find further information about the VEGA product line on [www.vega.com](http://www.vega.com).

In the download section at [www.vega.com/downloads](http://www.vega.com/downloads) you'll find operating instructions, product information, brochures, approval documents, instrument drawings and much, much more.

There, you will also find GSD and EXD files for Profinet PA systems as well as DD and CFF files for Foundation Fieldbus systems.

Instrument selection

Under "Specify product" on [www.vega.com](http://www.vega.com) and "Products" you can select the suitable measuring principle and instrument for your application.

You can find detailed information on the instrument versions in the "Configurator" at [www.vega.com](http://www.vega.com) and "Products".

Contact

You can find your personal contact person at VEGA on our homepage [www.vega.com](http://www.vega.com) and "Contact".
NFPA Square-Head Tie Rod Aluminum Cylinders

- Max. operating pressure: 150 psi (4/" and 1 1/4" bores), 250 psi (1 1/2" to 6" bores)
- Temp. range: -20° to 200°F
- Include magnetic piston

Switch-ready cylinders have a replaceable rod gland and fully adjustable cushion to allow a full range of NFPA MG4 interchangeable mounting configurations. 4 internal-threaded sleeve nuts recessed in the head and 4 tapped holes in the cap permit direct mounting. ¾" and 1 1/4" bores are noncushioned and nonmagnetic. Additional NFPA cylinders available on Grainger.com.

---

Mounting Hardware for NFPA Square-Head Tie-Rod Aluminum Cylinders

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Self-Aligning Coupler
PRODUCT DESCRIPTION
SPECTEC's Linear Position Sensor is designed to sense continuous variations in magnetic field and convert field strength to a proportional voltage. The output voltage produced for zero field is nominally 2.5V, with a standard transfer function of +/- 10mV/Gauss. Magnetic sensitivity is in one axis only. Several units can be combined to measure (X, Y, Z) magnet field vectors. Custom ranges, output configuration, sensitivity, and packaging are available on request. Sensors can also be supplied to Inherently Safe standards.

APPLICATION
Position Sensing, Rotation, Angle, Field profiling, ELF, Vibration, Proximity, incoming inspection of magnetic products.

SPECIFICATIONS
Vo, Supply Voltage: 8 - 30 Vdc @ 5 mA
Vo, Output Range: <0.5 - Vo > -4.5 V
Io, Output Range: -1.0 mA (source) Max.
10.0 mA (sink) Max.
Output resistance: 100 Ohms
Input Sensitivity: Std.: 5 mV/Gauss
Med.: 3.25 mV/Gauss
High: 2.5 mV/Gauss
Guate Output Voltage: +/ - 0.75 V
(2.20 to 2.80 V at zero field)
+/ - 30 Gauss equivalent
Frequency Range: DC to 30 kHz
Sensing Distance: 0.00” to >1.00”
@ 3000 Gauss typ
Temperature Range: -40” to +250” F (-40” to 125” C)
Construction: 300 Series Stainless Steel, solid epoxy encapsulation
CE Compliance: EN50011, EN60022-2

INSTALLATION
For mating connector/cable assemblies refer to respective bulletins: 3001, 3003, & 3004 or commercially available alternatives.
## PRODUCT DETAILS

<table>
<thead>
<tr>
<th>ASSIGNED SPECTEC P/N s</th>
<th>Pick-Up Type</th>
<th>Output Logic</th>
<th>Connector</th>
<th>Body</th>
<th>Thread</th>
<th>Thread Length</th>
<th>Overall Length</th>
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<td>0220-01</td>
<td>H Lin</td>
<td>STD.</td>
<td>MS3</td>
<td>K</td>
<td>5/8-18</td>
<td>1.8 (45mm)</td>
<td>3.5 (89mm)</td>
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<td>-02</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1.5 (38mm)</td>
<td>3.0 (76mm)</td>
</tr>
<tr>
<td>-03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.5 (38mm)</td>
<td>3.0 (76mm)</td>
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### Model Variant Options:

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<tr>
<th>0220-xx</th>
<th>H Lin</th>
<th>STU OC</th>
<th>PNP</th>
<th>MS3</th>
<th>MS3B</th>
<th>MC3</th>
<th>B4</th>
<th>K</th>
<th>A</th>
<th>Thread</th>
<th>Thread Length</th>
<th>Overall Length</th>
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</thead>
<tbody>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>5/8-18</td>
<td>1.8 (45mm)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3/4-20</td>
<td>1.5 (38mm)</td>
<td>4.1 (104mm)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>3.0 (76mm)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.0 (101mm)</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>6.3 (127mm)</td>
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</tr>
</tbody>
</table>

Some options are unavailable in certain combinations.
Overall lengths L ≥ 3.5 (89mm) are normally only available in body style K with 5/8-18 thread.
Contact your sales representative for more information.

SPECTEC, Thunderbird International Corp. 406-333-4887 • FAX 406-333-4259, w w w . s p e c t e c s e n s o r s . c o m

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### Typical Performance Data

#### Broadside Approach

![Diagram](image1)

#### Fly By

![Diagram](image2)

#### Shaft Rotation

![Diagram](image3)
Appendix III: Plant Photos

Figure 1: Bradshaw Facility Horizontal Asphalt Cement Storage Tanks

Figure 2: 4” Viking Gear Pump, Positive Displacement Asphalt Cement Offload Pump
Figure 3: Hot Oil Heater, Yellow Box is the Fire Box with 3 Million BTU Heater Blowing on the Pipe. This is made by an ASTEC subsidiary, CEI

Figure 4: Oil Down the Side of the Tank
Figure 5: Asphalt Cement Soft Oil Near Staircase due to recent leak of steel flex line above tank

Figure 6: Top Manways of the Split Tanks
Figure 6: The drum feed side of the tanks. The very lowest insulated pipe is the hot thermal fluid pipe that feeds each tanks hot oil coils to keep the tank warm. The waist high pipe is the liquid AC line that goes from each tank over to the drum feed pump, then through a 3 way valve, then into a 4” micro motion meter. They use this meter for mass flow so they can control the oil content in the asphalt mix. They want to always be within 1/10 of one percent on oil. They slave our pump that pushes the oil to the scale belt on the rock scale so that the right amount of oil meets with the right amount of rock so they maintain a quality product asphalt with the right oil content. The tricky part is that the aggregate reaches the drum with water moisture in it, so if they run at 400 tons per hour and water is 4.5%, we have to burn off 18 tons of water each hour, and then match the oil to the remaining tonnage. The last pipe seen is overhead, that pipe is the recirculating pipe if we have to shut off oil flow to the drum so they don’t damage the pump or any piping with a hammer effect.
Figure 7: Silos and Drag Slat Where Asphalt is Loaded into Trucks, 7 silos store 1,600 tons of finished asphalt product.

Figure 8: Granite Rock Plant that Crushes the Rock and Makes the Sizes for Asphalt
Figure 9: Tunnel Belt Dropping onto Scale Belt, The silver cone over the belt is the scale

Figure 10: Virgin Aggregate Conveyor at the top Dropping into the Drum. The recycle conveyor is the silver one on the right side, behind it is the baghouse, a 90,000 cfm air mover to keep the flame on the burner lit. The ductwork from drum to cyclone is straight up and the drum is to the left.
Figure 11: The burner, it’s a 150 mmbtu burner. The oil lines feeding the drum are shown at the top of the burner covered in insulation.
Appendix IV: Codes and Standards

**ASME:**
- **ASME B30.13 - 2017**: Storage/Retrieval (S/R) Machines and Associated Equipment
- **ASME B16.42 - 2016**: Ductile Iron Pipe Flanges and Flanged Fittings: Classes 150 and 300
- **ASME B31.3**: Chemical Plant and Petroleum Refinery Piping
- **ASME B1.20.1**: Pipe threads, general purpose (Vegapuls Transmitter)

**Valve Actuation**
- **ASME-FCI Standard 87-2**: ensure proper valve closure
- **ASME B16.34**: Valve pressure and temperature ratings

**Flanges**
- **ASME B16.5**: Flat sheet, spiral wound, or other gasket types

**Safety Standards**

**EPA:**
- **NAICS 23**: Establishments primarily engaged in the construction of buildings or engineering projects

**Spill Prevention, Control, and Countermeasure (SPCC) Guidance**: 40 CFR part 112; part of Clean Water Act Section 311

**Emergency Planning & Community Right-to-Know Act (EPCRA)**: 42 U.S.C §11001 et seq. (1986)

**Clean Water Act (CWA)**: 33 U.S.C. §1251 et seq. (1972)
## Appendix V: Constraint Table and Pugh Matrix

<table>
<thead>
<tr>
<th>Item</th>
<th>Consideration</th>
<th>Other Constraints</th>
<th>Possible Solutions</th>
<th>Final Decision</th>
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<tbody>
<tr>
<td>Tank Level Measurement Tool</td>
<td>Must withstand temperatures exceeding 350°F, maintain accurate readings when induced to bitumen on measurement surface, must relay measurements to control tower and alarm systems, easily integrated</td>
<td>Cost, Durability, Mounting Ease</td>
<td>Pressure Sensor, Non-Contact Radar Conductance Rod Bobber Thermal Imaging Float Switch</td>
<td>Non Contact Radar Level Measurement</td>
</tr>
<tr>
<td>Actuated Valve Shutoff System</td>
<td>Must provide actuated shut off before tank overflow occurs, must support current asphalt plant SCADA system, Must provide manual shutoff system, must communicate with tank level measurements</td>
<td>Cost, Reliability, Must Use Current valves installed</td>
<td>Electronic or pneumatic Inhouse or Purchased integrated manual override or separate manual valve</td>
<td>Purchased pneumatic ram, custom mounting, with integrated manual override</td>
</tr>
<tr>
<td>Tank Overflow Warning System</td>
<td>Must alert flow operations and control tower of tank levels nearing overflow, Must support current asphalt plant SCADA system, must communicate with tank level measurements</td>
<td>Reliability, Visibility, Ease of Use</td>
<td>Warning lights, alarm display, and sound alerts</td>
<td>Combination of lights, alarm display, sound alerts</td>
</tr>
<tr>
<td>Data Processing</td>
<td>Must communicate with all system components and current asphalt plant SCADA system, Open &amp; close valves (including recirculation), turn on pump, and provide level information</td>
<td>Ease of use, Compatibility</td>
<td>ASTEC</td>
<td>To be integrated by ASTEC</td>
</tr>
</tbody>
</table>

### Pugh Matrix

<table>
<thead>
<tr>
<th>Key Criteria</th>
<th>Importance Rating</th>
<th>Radar</th>
<th>Pressure Sensor</th>
<th>Conductance Rod</th>
<th>Bobber</th>
<th>Thermal Imaging</th>
<th>Float Switch</th>
<th>Meter Stick</th>
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</thead>
<tbody>
<tr>
<td>Safety (ties into reliability)</td>
<td>8</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>2</td>
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<tr>
<td>Maintainability</td>
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<td>4</td>
<td>3</td>
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<td>Cost</td>
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<td>2</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>10</td>
<td>10</td>
<td>10</td>
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<tr>
<td>Compatibility with current system</td>
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<td>10</td>
<td>8</td>
<td>8</td>
<td>4</td>
<td>8</td>
<td>8</td>
<td>10</td>
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<tr>
<td>Reliability</td>
<td>10</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>0</td>
<td>2</td>
<td>6</td>
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<tr>
<td>Ease of Automation/Data Acquisition</td>
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<td>10</td>
<td>10</td>
<td>10</td>
<td>6</td>
<td>4</td>
<td>0</td>
<td>37</td>
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<tr>
<td>Unweighted Totals</td>
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<td>32</td>
<td>36</td>
<td>40</td>
<td>20</td>
<td>30</td>
<td>30</td>
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<tr>
<td>Weighted Totals</td>
<td>360</td>
<td>214</td>
<td>238</td>
<td>262</td>
<td>110</td>
<td>164</td>
<td>180</td>
<td>370</td>
</tr>
</tbody>
</table>

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Appendix VI: ASTEC PMIII System Details and Capabilities

PMIII Continuous Mix Blending Control

PMIII is the next generation of hot mix asphalt controls. Facility operation has never been easier, faster or more accurate than with this new, ‘hard-PLC’ based control. Expandable and retractable to suit your specific needs, PMIII puts the best of our time-tested software, along with new developments, into the most cutting edge industry hardware.

The complete solution for HMA facility control.

Astec brings you the most powerful, user-friendly control system to date by combining the finest industrial hardware components with a Windows operating platform. Ideal for both new installations and retrofits, the PMIII eliminates traditional consoles and allows monitoring and control of all plant functions from an industrial grade PC. The PMIII is also compatible with DASH, our new data acquisition system, bringing live plant data to your fingertips, wherever you are.
MPIII Blending Controls

- 8 Virgin aggregate VFD bins
- Virgin Aggregate Scale
- 2 recycle bin over 1 recycle belt scale
- 2 mineral filler (volumetric or gravimetric)
- 1 Additive
- 1 Asphalt metering system (temperature compensated)

Baghouse Controls

- Controls pressure drop by automatically adjusting pulse cycle depending on monitored pressure drop

SCIII Silo Controls

- 3 silos over 1 truck scale

- Calibration for all scales, pumps and feeders: operator selectable automatic feeder calibration multiple material calibration for bins
- Unlimited mix design stored on hard disk drive
- Material mix design tolerances
- Material mix start/stop timing
- Communicates material inventories and mix formulas with Astec "WM2000" (WM2000 sold separately)

BCIII Burner Controls

- Commands and monitoring of flame safeguard device
- Controls burner position via "burner profiles" with individual settings for:
  - Combustion Air
  - Controls multiple fuels
  - Controls to operator selectable
  - Final mix temperature
  - Aggregate temperature
  - Baghouse inlet temperature
  - Temperature trending

MCIII Motor Controls

- Start/stop controls for each motor
- Handles all interlocking and sequential starting
- Midstream start/stop and Plant E-Stop
- Optional current monitoring

Package Includes

- Industrial PC
- Console
- Junction box
- Uninterruptible Power Supply (UPS) maintains power on computer after loss of electrical power to enable orderly shutdown of the system
OPTIONAL

- WM2000 Truck Loadout and Management System
- Smart tank farm
- Mineral filler [lime] (up to 4)
- Weigh batchers (up to 5)
- Additional silos (up to 10 over 2 scales)
- Additional virgin aggregate bins (up to 16)
- Recycle Bins (up to 4)

⚠️ For your peace-of-mind, Astec stands by the PMIII by providing emergency support that’s just a phone call away, 24 hours a day, 7 days a week.

⚠️ Specifications subject to change with or without notice.
Astec Controls

 /(products/control-systems.html) 

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Astec, Inc.
Phone: (423) 867-4210  |  Fax: (423) 867-4636
Appendix VII: Gantt Chart and Work Breakdown Structure

For easier viewing here is a link to the complete and connected diagram: https://bit.ly/2H49BkR
Appendix VIII. SCADA Ladder Logic Diagrams