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SPRING 2017

Quarterly Publication of the Engineers' Society of Western Pennsylvania

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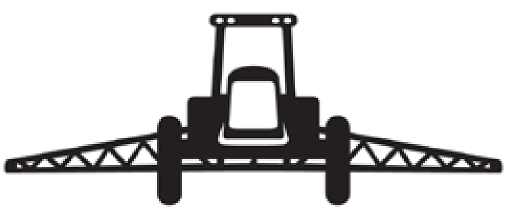
IN THIS ISSUE...



The Pittsburgh ENGINEER is the offical publication of the Engineers' Society of Western Pennsylvania (ESWP). Pittsburgh ENGINEER is published quarterly and is direct mailed to approx. 4,000 readers. Past issues are available online at the ESWP website, eswp.com

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Guest Editor Column

Don Olmstead

As a baby boomer, I am fairly typical; I grew up in the suburbs, raised by parents who grew up on the farm during the depression, went to war, and moved to the city for work. I have a lot of good memories of returning to those farms while growing up, and occasionally getting some valuable life lessons. Like doing the work that needed to be done when it needed to be done, staying up all night if necessary. That steers are crazy. And that there is a right way and a wrong way to milk a cow. To this day, I remember that kick!

For me, this issue is one of connection and contrast to a fondly remembered past. And what contrasts!

I remember my mother's stories of getting a generator, which made working in the barn easier at night, and made it possible to hear weather forecasts, which came to their prairie area after World War II. The development of an air fleet made weather reporting a government priority and farmers benefited. After finishing 11th grade, my father bought a quarter section (160 acres) which he farmed with a four horse team. While he was a competent mechanic and electrician, fuel and equipment were expensive, and there was little to spare during the depression, so he drove a team. Two years of wheat rust (a fungus) discouraged him; he turned the acreage over to his father and went to war. That was the end of his farming career, but not his interest in farming.

When I visited the family farms as a boy, the farms had modernized, but there were still remnants of bygone days. There was an ice house, where meat was stored amid blocks of ice and buried in sawdust for insulation. The outhouses were still in service, but the good ones had toilet seats. There was a sling to get hay into the loft of the barn, although they had abandoned it for a conveyor. There were the same concerns expressed about weather and prices and kids leaving that I heard as we prepared for this issue. The stories may have changed a bit – deer damage to crops is quite topical around here, for example.

The old-timers in this area tell of a rich agricultural past, and have some really interesting stories. The townhouses of Washington's Landing sit where stockyards once were, where farmers in this area would bring a truckload of hogs, and leave with a truck full of manure. The hogs would be driven up to Troy Hill and over to Spring Garden for slaughter. Stories of families working together in hard times.

Don Olmstead

The sense of farming heritage runs deep here. We still have farm families whose land has been in the family for generations, and for whom farming is not just a vocation but an identity.

One thing that I learned from this issue is that farmers as a group, are still the hardest working people you can ever hope to meet, are consistently generous, patient, and easy to get along with, in spite of having more uncertainty in their lives than most of us. I am grateful that they love what they do, and that they do it so well!

After returning from war, my father the returning radio operator and POW went to work, eventually got a Bachelor of Science degree and then took the exams for engineering licensure, which he received at the tender age of 52. If he were here today, the electrical engineer and security system expert in him would have been fascinated with the developments – I think the drone would have had the biggest "Wow" factor for him. But autosteer tractors, no-till agriculture, and future developments such as central tire inflation system all would have intrigued him. There are developments which we did not have time to touch, such as the growth of goat farming and high speed seeding. He would see the possibilities and delight in discussing them.

We hope you enjoy this issue as much as we did in preparing it!

Farming Challenges and Developments in Western Pennsylvania

Don Olmstead

Thiele Farm, Cabot, PA. Drone view showing impact of contours on field configuration Photo by William Thiele.

The western Pennsylvania area is agriculturally diverse. Most of the farms are still small, with two hundred acres being a typical size. Field size and configuration is controlled by terrain; fields of 7-8 acres are common, and a field of 50 acres is unusually large. Fields are also irregularly shaped, following contours. Figure 1 depicts how contours may affect field shape.

Soil type is variable, as are moisture conditions, which are in part a reflection of the terrain. Crops include wheat, corn, soybeans, vegetables, orchard crops, hay, meat and dairy. Technology varies; there are still hold-outs relying on draft animals and century old tools, and there tech savvy types embracing state-of-the-art technology.

Although there are some large consolidated farming operations with thousands of acres as seen out west, Western Pennsylvania has largely missed the trends in other areas; for example the large piggeries, cattle stock yards, large scale poultry production, and contract agriculture, in which the purchasers owns the animal that the farmer raises. The smaller family operations predominate.

The advent of technology saves time and production, but the cost of equipment requires the typical farmer in this area to have a day job. The cost of equipment and land is a significant barrier to entry.

Farming has evolved from independent individual family or informal extended family cooperatives solving problems with his little outside help as possible, to users of supplier-consultants and on-line resources, developing and adapting strategies for optimizing yield out of each acre and each animal. Common themes that emerged: cost control, yield, soil health, and the impact of urbanization and traffic. With respect to their equipment, it is the same as any other business; reliability, timely service and ease of service, are priorities, as well as transportability. It's definitely not Charlotte's Web, or Babe, or the Ponderosa.

Consultants

The Thiele family have been dairy farming on the same land since 1868. A nutritionist comes in twice a month to test the feed and adjust the ration recipe. An agronomist comes in annually and recommends a fertilizer program. A veterinarian comes in once every 4 weeks, and works with the nutritionist to optimize herd health. Although they do not use a parts service, some of the larger farms in the area do.

There are also government resources and advisors, including the Farm Service Agency, and the Natural Resource Conservation Service (formerly the Soil Conservation Service) at the federal level. The latter offers soil survey, conservation assistance, farmland protection, grazing lands conservation, and design services, such as for heavy use areas for cows, and manure storage. The Penn State Extension Service, and County Conservation Districts also offer support. The latter offers erosion control and manure management support. PADEP engages in educational outreach and enforcement.

Soil Health

One focus of farming is the developing and maintaining of well structured, porous, uncompacted soil. This is being accomplished by: technology, for example, modified design of tires on farm equipment, to better distribute load without loss of traction; best practices, for example, no-till agriculture; and use of certain cover crops such as tillage turnips which have a deep tap root, and help loosen the soil at depth.

Both tilling and plowing have the advantage of eliminating existing ground cover in preparation for a crop, and leveling, and eliminating rodent holes. Plowing creates a horizontal compaction layer from dragging the steel across the subsoil on an angle. This is referred to as a plow pan that crop roots cannot penetrate, reducing yield.

Tilling and plowing have largely fallen out of favor in this area, due to erosion concerns and harm to soil. No-till agriculture has been around the 70's, and predominates in this area. No-till results in a less consolidated and healthier soil, resulting from the action of earthworms and the decay of roots from past crops, which create conduits for moisture and air to the crop roots.

Vertical tillage (or minimum till) is an alternative to no-till. Discs and shanks are run in straight lines instead of on an angle. The idea is to chop and size crop residue to accelerate decomposition while moving a small amount of soil. One farmer noted that vertical tilling can bring a lot of rocks to the surface, which then need to be picked to protect other equipment. So this is not a practice likely to find favor in areas with glacial till.

No-till requires more chemical usage to suppress whatever cover is growing, and more aggressive rodent control techniques; for example, the aptly named Rodenator.

Soil health is improved with more crop rotation. Interseeding, the planting of a second crop such as clover after a cash crop is growing, is a variation of concept. Interseeding is promoted as improving soil fertility, helping with nutrient retention over winter, and providing competition for weeds, which helps reduce chemical usage. Efforts at interseeding have had limited success in this area. One farmer commented that for him aerial interseeding proved ineffective due to our small and irregular fields, and that narrow wheeled mechanical equipment fare no better. This equipment runs between rows of a maturing crop but does not do well at turns, which are everywhere with our small fields, and the equipment is difficult to keep between the rows where the terrain rolls. Crop damage results.

Urbanization and Traffic

Urbanization and traffic were described as two problems. The nature of our topography has resulted in farmers having dispersed fields, requiring transportation for some equipment (e.g., sprayers and seeders) over local roadways. See Figure 2. However, a 20-foot head on a combine has to be detached and towed by a second vehicle. See Figure 3. Folding heads that can be transported over the road with the harvester are not provided by domestic suppliers, but overseas suppliers like Geringhoff are meeting this need.

Figure 2: Kinze seeder folded for transportation and storage

Figure 3: Soybean harvesting head for a John Deere combine, on trailer, towed separately from the combine.

Driver impatience with slow-moving farm equipment over local roadways was reported as an increasing problem. Although one farmer who described a rear-ending incident he experienced almost had a note of satisfaction in his voice; he was hauling manure.

TECHNOLOGY

Global Positioning Systems and Data Logging

Perhaps the most prevalent technology development in agriculture is the use of global positioning systems (GPS). These have become ubiquitous, seeing use in tractors, seeders, sprayers, and harvesters. An operator navigates to prevent overlapping or gaps in application of chemicals, fertilizer or seed between rows. See Figure 4.

Figure 4: Apache Sprayer, showing view during operation and summary screen after spraying. Red indicates zones of overspraying and purple indicates zones of underspraying, largely speed related.

Data gathered can be analyzed to inform next season. For example, a combine harvester may correlate yield at a point to a set of coordinates. The yield data can then be used by the agronomist to inform recommendations for fertilizer application rate, seeding density, and crop type and variants. Complementary GPS data from other sources, such as a soil survey can refine the recommendations. As a result, a moisture resistant crop variant might be seeded in a low spot or in the vicinity of a seep, a shade tolerant variety might be preferred in another location, and some spots don't can't be improved.

Auto Steer Equipment

Auto Steer farm equipment uses the driver to initiate turns, but the navigation of a row is autonomous. In addition to prevent overlapping or gaps in application of chemicals, fertilizer or seed between rows, Autosteer also helps with underapplication and overapplication, which can result from changes in grade and corresponding changes in speed.

The much-anticipated autonomous (driverless) tractors are being viewed guardedly. There are demonstration units but this is not yet commercially available. Supervised applications are likely to see acceptance first, for example, an autonomous machine that is supporting a machine with an operator. A tractor pulling a grain wagon to receive harvested material from a combine as it works would be an example.

Figure 5: Receiving corn from a combine. Photo from Cory Stuchal.

Electronics

Advanced electronics is not without disadvantages. A common complaint is that electronics in farm equipment has not been adequately hardened for the farm conditions, including pressure washing, compressed air blowing, dirt and vibration. Typical failures include sensors, solder breaks in a module, or connections. When a sensor gets replaced, the equipment may need to be reprogrammed by the equipment supplier. Problems are common at terminations and exacerbated on equipment handling corrosive material such as fertilizer. In the case of a fertilizer spreader, a perfectly serviceable piece of equipment maybe put away for the winter, and be inoperable by spring due to oxidation or corrosion of electronic components. See Figure 6.

Figure 6: Corrosion on an after-market weigh cell on a fertilizer spreader after 1 year of service

Applications for hydraulics are expanding. More advanced electronics allows in-cab adjustments to be made while the machine is in use instead of shutting down, loosening bolts, and making adjustments manually. Attachments plug into connectors on the rear of the tractor, thus sharing the tractor's oil, filter, and cooling system. See Figures 7 and 8.

Figure 7: An owner configured, rebuilt 60 ft seed drill with hydraulics, compressed air and electronics. Photo from Cory Stuchal.

Figure 8: Front of the seed drill. Is it a trailer hitch or a docking station? Photo from Cory Stuchal.

Tires

There have been several developments on farm tires. Dual tires are not popular in this area because of the narrow roads. Single tires with a square tread profile, larger-diameter, and lower pressure, allow a larger traction surface to be deployed within a narrow footprint. The systems also reduce soil compaction.

Fluid filled tires, which provide weight and traction and were used in the past are avoided now. They have less flexibility than air filled tires, which means a smaller footprint and more soil compaction. If weight is needed, it is easy enough to attach.

More dealers are providing half-track systems to mitigate soil compaction.

Other Tools

- Utility vehicles have partially displaced pickup trucks, due to their lower cost, greater accessibility, ease of entry and exit, and lower operating costs.
- Skid steer vehicles have partially displaced tractors, due to their versatility, ability to work in tight spaces, and numerous attachments.
- Portable power tools have improved in both power and battery life, and have come into nearly universal use.
- Drones are a very affordable rapid field scouting tool, which can be used to identify areas of crop distress, locate animals, or find a damaged section of fence. See Figure 9
- Mobile devices and online resources have been enormously useful. A farmer can instantly access a weather forecast, pricing on crops, new equipment ideas, planting recommendations, veterinary tips, and so on.
- While not new, sidehill combine harvesters see a lot of use in this areas. These are combines that have a hydraulic system that compensates for running sideways on grades up to 18%, or even 23%.

Figure 9: Drone view of a cornfield. The field to the left is the pasture. The field to the right is soybeans. The dark areas of the corn field are the "healthier" areas. The paler parts indicate a nitrogen deficiency and/or lack of rain. Photo from William Thiele.

Summary

Agriculture in Western Pennsylvania is technology friendly, technology rich, and progressive. It is subject to the same competitive pressures and trends that industry experiences. Costs have also increased, putting more pressure to be efficient and productive. Agriculture is experiencing the same trends of consolidation, and increasing automation.

Looking ahead, one OEM engineer offered the following examples of development in the pipeline:

- Increasing use of AI to help optimize farming operations.
- The "internet of things" is gaining momentum, meaning information from sensors on equipment will be uplinked for access by the manufacturer, the dealer, and the customer, to help manufacturers and dealers understand duty cycles and failure modes and impending failure mode, and so large operators can monitor where their fleet is and what it is doing remotely
- Increased vehicle speeds while planting/harvesting and in transport on roads to improve efficiency
- A central tire inflation system where the pressure is automatically reduced while in the field (minimize compaction and maximize traction) and increased while on the road (maximize ride quality and fuel efficiency).
- An obstacle in deployment of new technology is initial cost and the cost to service. "Frugal" design is a response to this - where there is a renewed emphasis on reliably providing in a cost effective manner just what the customer needs

Ed Note: This article was the product of a number of conversations with farmers in Butler County, an equipment dealer, and anybody willing to talk. Among those I spoke with, the interest in technology was deep, there was generosity in sharing time, and there was curiosity about engineering and what it can contribute.

Harnessing Tractor Guidance Systems

by Chriss Swaney

William "Red" Whittaker has always been able to see the future. It is his innovative spark and dogged tenacity that propelled him into becoming the world's most renowned roboticist.

The Carnegie Mellon University Robotics Institute Professor has developed more than 60 robots to explore contaminated nuclear plants, abandoned mines, active volcanoes, Anarctic glaciers, the moon, and perform other work. He's even helped pioneer driverless cars now boldly moving through Pittsburgh streets.

But it is also no secret that Whittaker, who owns a 900-acre farm near Somerset, did the first Harvester automation some 20 years ago. "That was the forebearer that transformed tractor guidance and ignited the movement. Tractor guidance and the related operator assistance features are transformational because they increase accuracy, speed, productivity and enable night operation," said Whittaker, who proudly displays his patent for the New Holland 2550 on his office wall.

Whittaker recalls that his foray into agricultural engineering came as a result of his own need for farm equipment that could be used efficiently at night.

"I was running off course at night while mowing hay on my farm, and I eventually ended up in nearby woods brushing off loose branches and twigs from my face," recalled Whittaker. His concern for improving equipment for his own farm and other farmers led him to find a research sponsor. After getting turned down by several companies, he landed support from New Holland, now a global manufacturer of agricultural machinery. The original New Holland Co. was founded in New Holland, PA.

William "Red" Whittaker

Whittaker is famous for seeking to solve everyday problems for the working world, from farmers to miners. The motivation for his Groundhog robot for example, which maps abandoned mines, came after a 2002 Pennsylvania coal mining accident that trapped nine coalminers for 77 hours underground in the Quecreek mines. For decades, his research has centered on creating mobile robots in unpredictable environments such as natural terrain and outdoor conditions.

"I'm keeping my day job as a university researcher, but I do spend my spare time farming," said Whittaker. "Farming is both challenging and grueling" he added.

Like most expert farmers, Whittaker raises most of the corn, oats and hay to feed his beef cattle herd. He has a herd of Hereford/Angus mix, and is also raising 30 Holstein bull calves. Pennsylvania produces 200,000 to 230,000 Holstein bull calves a year. The dairy-type ribeyes are smaller and have less external fat than a beef-type ribeye. "Again, it is all about seeing the future and making something happen," said Whittaker, a 2010 winner of the prestigious William Metcalf Award from the Engineers' Society of Western Pennsylvania.

Dr. Red Whittaker received his B.S. degree in Civil Engineering from Princeton University and his M.S. and Ph.D. degrees at Carnegie Mellon University.

Seen at the ESWP Annual Engineering Awards Banquet. ..
A. Past Presidents and former Metcalf Award recipients Harold Hall (L) and Tony DiGioia; B. Guest speaker Phil Bourque (L) with ESWP Director Greg Cerminara; C. Master of Ceremonies Rick Sebak; D. ESWP President Dan Cessna presents Deb Lange with the 2017 Metcalf Award; E. Engineer of the Year Jim Foringer with his wife Becky; F. Vic Bertolina receiving his IBC Honorary Member Pin for 25 years of service; G. ESWP Treasurer Tammi Halapin (L), ESWP 1st Vice-President Bob Ward chat with Guest Speaker Phil Bourque; H. Phil Bourque (L) with ESWP 2nd Vice-President David Borneman; I. Vocalist Jeff Jimmerson performs the National Anthem. See more photos online at eswp.com

ESWP Member News

More than 75 firms are represented in the Corporate Member program of the Engineers' Society of Western Pennsylvania (ESWP). Memberships are available at 3 levels: Gold, Silver and Bronze. Gold members are entitled to 14 memberships that can be exchanged by employees; Silver, 9; and Bronze, 5 — annual dues are $2400, $1700, and $1000 respectively. In addition, ESWP Corporate Member Firms may add 2 additional individuals in our Under-35 age category at no additional cost. More information can be found at eswp.com. Please contact the ESWP Office (412-261-0710) for additional details.

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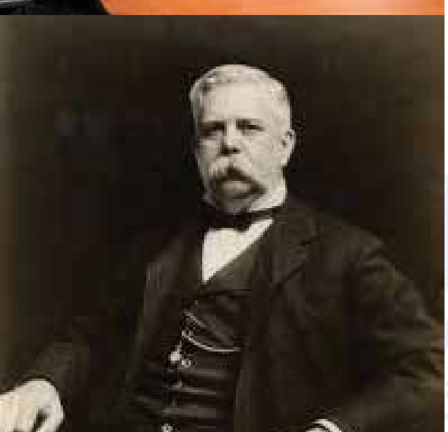

THIS YEAR, AT ESWP

Our Mission

Advance the engineering profession and position Western Pennsylvania as a Center for Engineering Excellence and Innovation

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Seek and prepare the next-generation of engineers

Offer professional development and networking opportunities

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Highlight achievements from a diverse spectrum of engineering and related fields

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- Develop and distribute exceptional publications

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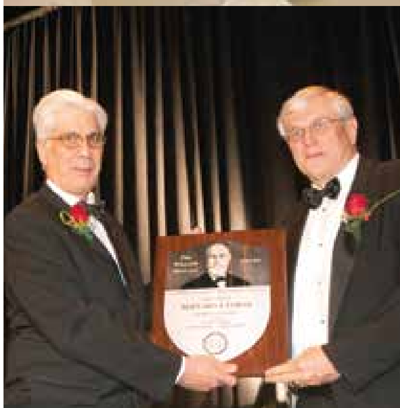

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A New Type of Agriculture – Medical Marijuana in Pennsylvania

On April 17, 2016, Pennsylvania's medical marijuana act (2016 Act 16) was signed into law by Governor Tom Wolf. Administered by the Department of Health, it is expected to be fully implemented by 2018.

The program allows the development of facilities to grow and dispense medical marijuana for patients who are residents of Pennsylvania and under a physician's care for the treatment of a serious medical condition. Applications for medical marijuana growers/processors and dispensaries are now available on the department's Medical Marijuana Program website, and permit applications were accepted until March 2017. In the first phase of the program, there will be up to 12 permits issued for grower/processors across Pennsylvania's six medical marijuana regions, and up to 27 permits issued for dispensaries.

The law will create opportunities for engineers, botanists, chemists and other professionals. We spoke to PAMCS, Fuss & O'Neill, a Connecticut engineering firm, and Cannabis Design Build, out of Quarryville, Pennsylvania, for some insights into the technology issues and solutions that will arise in Pennsylvania, and the opportunities.

Size of the Market

In March, 2016 ProCon.org reported medical marijuana patients for 23 states at an average of 8.06/1000 (range 0.1 to 19.4) http://medicalmarijuana.procon.org/view.resource.php?resourceID=005889 . With an estimated population of 12.8 million, this corresponds to 100,000 patients, with as few as 1300 and as many as 250,000. The Pennsylvania Medical Cannabis Society (PAMCS) estimates that when the program is fully implemented, the number of users will be at the high end of this range. For more information on marijuana use, see https://www.cdc.gov/mmwr/volumes/65/ss/ss6511a1.htm.

Regulatory

Act 16 imposes restrictions that have implications for facilities design in Pennsylvania, in particular:

- In Pe16nnsylvania, medical marijuana may only be dispensed in the form of a pill, oil, in topical form, a form deliverable by vaporization or nebulizer, tincture or liquid. Leaf forms are proscribed and edible forms are discouraged. Processing makes product appearance a moot point; therefore, trimming, drying and curing can be streamlined.

- In Pennsylvania, medical marijuana may only be grown, stored, harvested and processed in an indoor, enclosed, secure facility which includes electronic locking systems, electronic surveillance and other features required by the PA Department of Health.
- A grower/processor is required to contract with an independent laboratory to test the medical marijuana product at harvest and final processing.

Temporary regulations have followed.

In addition to these regulations, the American Herbal Products Association (AHPA) Cannabis Committee, formed in 2010, has drafted a model rule for regulators addressing best practice rules to address four operational stages of Cannabis production and distribution: cultivation and processing; manufacturing and related operations; laboratory practice; and dispensing. See: http://www.ahpa.org/Portals/0/pdfs/AHPA_Recommendations_for_Regulators_Cannabis_Operations.pdf

Overview

Many of the issues that cultivators of medical marijuana face are common to any form of agriculture – such as pests, disease, maintaining environmental conditions and odor control. The differences are what make medical marijuana cultivation interesting – the product is high value, highly regulated, tightly controlled, small scale, energy intensive, and labor intensive, compared to conventional agriculture.

Medical marijuana growing is a hybrid of technology and practices from the agriculture, food processing, and pharmaceutical sectors. Concern for pest control is an example – access to different areas of the operation is controlled to prevent cross contamination, sanitizing stations are provided between rooms, disposable booties, hair nets and latex gloves are used, equipment, floors and walls are sanitized between uses, and stainless steel equipment typical of commercial food processing is used. Rats and mice will eat marijuana plants and can carry disease; rodent prevention measures are aggressive. Integrated Pest Management (IPM), a program espoused by the USEPA, was frequently referenced. IPM focuses on pest prevention and minimizes use of chemical controls, involves an array of tools such as pest-specific biological controls and habitat manipulation, and adjusts based periodic monitoring of pest and natural-enemy populations and other indicators.

Design

There is no standard approach to medical marijuana cultivation. Some practices are widely known, but cultivators also have guarded practices for optimizing characteristics or yield. There will likely be disagreement with this section.

Typical grow operations are 15,000 to 50,000 sf. The growing cycle is 12 or more weeks.

Following initial germination, cuttings are typically used to reproduce the plants, which preserves genetic homogeneity.

Plants may be grown in soil, a soil like media, or hydroponically. Whatever method is used, it has to accommodate moving the plants around, for reasons discussed below.

Initially, lighting is intensive, with a 1000 W bulb illuminating between 15 and 60 sf, 18 to 24 hours per day. After a period of rapid growth, the light cycle is changed, to 12 hours, and less intense, to promote flowering. Light spectrum also changes, and accordingly type of lighting, with metal halides preferred for growth and high pressure sodium lights preferred for flowering. Green spectrum lighting, which is not absorbed by the leaves, but is visible to the eye, is used for inspection during dark periods. Emergency lighting, to prevent degradation of the plants during a power outage, may also be provided.

What is a “Serious Medical Condition”?

In summary, a “serious medical condition” as defined by Pennsylvania’s 2016 Act 16 is:

1. Cancer.
2. Positive status for HIV/AIDS
3. Amyotrophic lateral sclerosis.
4. Parkinson's disease.
5. Multiple sclerosis.
6. Spinal cord damage with intractable spasticity.
7. Epilepsy.
8. Inflammatory bowel disease.
9. Neuropathies.
10. Huntington's disease.
11. Crohn's disease.
12. Post-traumatic stress disorder.
13. Intractable seizures.
14. Glaucoma.
15. Sickle cell anemia.
16. Pain for which conventional therapeutic intervention and opiate therapy is contraindicated or ineffective.
17. Autism.

Carbon dioxide (CO2) augmentation of the atmosphere is used to promote growth. CO2 is typically added from bottles. Monitoring of the CO2 in the atmosphere is required for worker protection. This practice is not specific to cannabis; according to a variety of sources it has been used effectively for tomatoes, cucumbers and lettuce, and for flowers and ornamental plants.

The intensive nature of cultivation, the high value of the product is a strong driver for pest control, and the ultimate use of the product means a lot of effort is put into pest management, and limited chemical controls may be applied, so optimizing environmental conditions for growth is key. Spider mites, pythium (a fungus like microorganism, a.k.a. root rot) and fungus gnats (vector for transmission of pythium) are serious threats. Air filtration, and UV sterilization of return air are essential. Filters are changed regularly. Commercially available natural pest controls may be used, such as ladybugs, nematodes (microscopic, predatory, burrowing worms), and praying mantis.

These considerations all have implications for the HVAC system. Intense lighting means cooling is required, CO2 augmentation and odor control means that makeup air rate needs to be minimized, evapotranspiration means humidity levels are high, minimizing conditions that favor pests means that humidity must be controlled, and filtration and UV for pest control adds pressure drop and heat load. Further, the grower wants an optimum temperature for growth. The robustness of the HVAC system, and careful control thereof, is arguably the heart if the system, along with lighting. Multiple split systems are common, for both uniformity of control and redundancy. For more information, see: http://www.achrnews.com/articles/133817-hvacs-growing-role-in-the-marijuana-industry

The HVAC system produces condensate, which can be reused. Many of the cultivation practices were developed in states that have limited water, so this is a common practice. Typically condensate will be passed through a reverse osmosis system, which purifies and sterilizes.

The differences in light and space requirements mean that plants get moved from room to room, which are typically around 2000 sf. After each move, rooms are sterilized.

When the plants area ready to flower, they are watched closely, and if the plants have been grown from seed, the male plants are removed, to prevent pollination. This is not required when working from cuttings. When the females remain unpollinated, they produce trichomes, fine hair-like structures rich in the desired rosins and oils.

Aroma is increases as the plant matures. Makeup air is exhausted through carbon for odor control, typically.

After harvest, there is a short drying phase, and then a curing phase, which enhances the yield of the rosins and oils. Curing is followed by refinement, through extraction by solvents such butane, liquid propane, or supercritical CO2.

The Commonwealth requires that plant waste be rendered unusable. Typically the plant waste is ground and mixed with soil, cat litter or other material. The grower has another goal; they want to ensure that the waste are unsuitable for propagation of pests, so additional measures may be applied.

Product labeling is required. Products must be labeled with information provided by independent, third party laboratories. However, growers will likely will have their own in-house capabilities, for quality control and corroboration.

Controls

Indoor cultivation of medical marijuana utilizes a variety of light types and light cycles, multiple and redundant HVAC units for climate control, watering and fertilizing. Data logging is required for each crop; accordingly strong trending capability is desired. Medical marijuana, among other crops, benefits greatly from a precision controlled environment, in regard to yield, crop quality, and consistency.

Integrated environmental control is familiar to anyone involved in building automation, but in horticulture this is a more recent development. An integrated platform simplifies life for the operators and a number of them are available. Figure 1 shows an HMI within an indoor growing operation for a non-cannabis crop.

Figure 1: HMI for an indoor growing operation. This is not a cannabis crop but many of these indoor growing elements are common to cannabis cultivation. Photo supplied by Priva North America, Vineland Station, Ontario, Canada. Priva is based in Holland and supplies climate control technology for buildings and horticulture.

Loss prevention is also key, for a product that grows, is dried and cured, and subject to weight variation. Therefore, precise weight checks occur at various points. Other measures for loss prevention include secured access to various areas of the facility by PIN codes, locks and magnetic swipes, training for grow staff, video surveillance, night vision, and more.

Conclusion

Pennsylvania is early in its medical marijuana program. Legal sales could begin as early as mid-2018. Progress in other states, notably Colorado, should aid the roll-out of this program. Engineers and contractors and interested parties are positioning themselves to serve this market.

The options for cultivation are many, specific cultivation practices are refined and guarded, control is sophisticated, and the amount of information available is vast. Costs of production are high and the value of the product is lucrative. Growers, chemists, and technology providers stand to benefit; and engineers with them.

Ed Note: For some photographs of a grow house in operation, see: https://www.canadiangeographic.ca/article/photos-inside-medical-marijuana-grow-operation

SAVING UNWANTED HORSES:
The Rizzo Solution

by Chriss Swaney

Paul Rizzo and daughter Rachelle are engineering brighter futures for unwanted rescue horses on their 100-acre Murrysville farm.

Pleasant Valley Rescue Ranch, a horse sanctuary run by the Rizzo family, is dedicated to providing shelter and support to unwanted horses, both temporarily or permanent for those not attractive enough for adoption. At present, the rescue facility supports seven Quarter horses ranging in age from 12 to 22.

"Each horse has a unique personality that can include unflinching loyalty, a full understanding where they fit in the herd hierarchy, a memory that remembers all the good and bad interactions with humans, and unparalleled patience and understanding if treated with respect and dignity. All horses are the product of their environment and their treatment from foaling to what happened yesterday! Indeed, they are not humans, but they have more human characteristics than humans realize,'' according to Paul Rizzo, a civil engineer, president of Rizzo Associates and the 2005 winner of the prestigious Metcalf Award from the Engineers' Society of Western Pennsylvania (ESWP).

Like most engineers, Paul Rizzo is a problem solver. The problem: A typical horse has a lifespan of 20 years and several owners. While most find loving owners who cherish them, some fall victim to abuse and neglect. In fact, more than 100,000 horses in the U.S. are unwanted and the problem is inflamed by the mandated closure of U.S. slaughter houses.

An estimated 147,000 unwanted horses were shipped in 2013 to slaughter houses in Canada and Mexico. And those export numbers have surged since then.

Paul Rizzo

Rachelle Rizzo

But it's places like the Rizzo rescue ranch that are making a small dent in the lives of these most vulnerable, unwanted equines. As members of the national Unwanted Horse Coalition, a broad alliance of equine organizations that have joined under the American Horse Council to educate the horse industry about the problem of unwanted horses, the Rizzos are leading the charge to make the public aware of the problem.

"We have a half dozen or more volunteers who come and help us exercise the horses,'' said Rachelle Rizzo. And the Rizzos are also actively cultivating the best agricultural engineering practices by keeping several fields fallow to improve grazing pasture for the rescued horses. They also work incessantly to properly handle all horse manure. The Pennsylvania DEP does little to force farmers to manage manure runoff which spoiled some 5,706 miles of Pennsylvania streams in 2015, the latest figures available.

"My father, Paul Rizzo, operates the farm machinery,'' said Rachelle Rizzo, who feeds and waters the horses at 5 a.m. before heading to work at her father's engineering firm. Yearly, the seven rescue horses consume 5,000 pounds of grain, 11 tons of round hay bales and 40 tons of square hay bales.

Since the 1890s, when a young America turned from the frontier farm and began to embrace a manufacturing economy, the worlds of science, business, labor, and agriculture have come together in this country – sometimes at collision speed – to produce a cornucopia of new goods and services. The Rizzo family is spurring further agricultural agility and productivity with their horse rescue operation.

Advances in Technology Meet Challenges in the Animal Feed Industry

By Jonathan Cowles

The world population is relentlessly increasing. From the years 1820 to 2017 the world population grew from one billion people to 7.5 billion and is projected to be 9 billion by 2050. The increasing population places pressure on the agriculture industry to produce the food crops and livestock to fulfill humans' need for energy and nutrition. At the same time, competition for land use, diversion of crops for ethanol production, and growing awareness and concern for environmental, health, and food safety issues have provided challenges to increasing food production.

These facts have resulted in frequent predictions of worldwide famine. Fortunately, the agriculture industry has shown the ability to continuously increase efficiency in both food crop and animal farming production to meet demand. The animal feed segment of the agriculture industry has certainly done its part to improve production of beef, pork, poultry, milk and eggs since its origination in the 1800's.

The animal feed industry was spawned from the necessity to dispose of human food by-products from other industries. By-products such as molasses, meat scraps, brewer's by-products, and soybean meal had limited commercial use or were dumped in rivers and streams as waste. Chemical analysis confirmed the basic nutritional value of these "wastes". The 1st US feed mill was started in 1875 to combine ground corn and wheat with these by-products to produce formulated feed. There are now over 6,000 feed mills in the US ranging from small commercial mills producing less than 100 tons of feed per week to large integrated feed mills producing over 20,000 tons per week.

Over this time of growth there have been great improvements in the efficiency of bringing animal protein to market. For example, over 16 pounds of finished feed was once required to produce a 4 pound chicken whereas today less than 7 pounds of feed is required. And not only does it take less feed, but the chicken will reach that weight in half the time.

WL Port-Land Systems (WLPLS) is a Pittsburgh based design/build firm that is one of a handful of companies in the US that specializes in the design and construction of today's highly efficient feed mills. WLPLS works closely with its customers to design the various systems necessary in the production of animal feed at a feed mill. These systems include receiving, whole grain and ingredient storage, liquid storage & delivery, batching, pelleting, and finished feed loadout as well as ancillary systems such as automation control, steam supply, compressed air supply, warehousing and maintenance. There is a significant amount of process engineering required to properly design these systems to fully meet the customer's needs.

> "There is a significant amount of process engineering required to properly design these systems to fully meet the customer's needs"

Incoming whole grain (corn or wheat) and other ingredients (both in bulk and liquid form) are transported to the feed mill by truck and frequently also by rail. The receiving system in a feed mill receives and transports those ingredients to external storage silos and tanks or directly into work bins inside the feed mill building structure. The material is conveyed and distributed via multiple means including screw conveyors, drag conveyors, belt conveyors, bucket elevators, gravity conveyance, pneumatic conveyance, gates, diverters and rotary distributors.

Whole grains are the primary ingredient in animal feed and make up 60-70% of the finished feed. They require high storage capacities and thus are contained in external storage silos of concrete or steel construction. The other feed ingredients have a lower inclusion percentage in the finished feed and thus are stored in work bins inside the feed mill with individual bins dedicated to the various ingredients. The amount of storage required depends on the design production capacity. There needs to be sufficient storage capacity to accommodate the differences between receiving and production operations (e.g. receiving may operate 8 hours/day for 5 days/week vs. feed production that may be a 24/7 operation), allowances for maintenance and operational downtime, etc.

Whether or not the facility will receive ingredients by rail is a key factor in the design of receiving and storage systems. A facility with rail will typically require significantly higher conveyance capacities and storage requirements. Contracts with rail companies will require the facility to receive unit trains with a minimum number of cars and will require the entire train to be unloaded in a maximum time period. These requirements drive up the storage capacity and conveyance rates that are required. There is also significant investment required for the storage track needed for rail cars during the receiving/unloading process. Despite these costs the reduced bulk cost of rail versus truck delivery can produce a payback worth the investment.

Whole grain is reclaimed from the external storage bins and conveyed to the grinding system. These whole grains are ground in order to improve mixing characteristics with subsequent ingredients, improve animal growth performance and improve pellet quality for pelleted feeds. Typical mean grinding size ranges from 300-1200 microns depending on the animal species for which the feed is being produced.

Grinding is accomplished with either a roller mill or a hammermill. There are pros and cons for each with regards to cost of equipment, maintenance and energy. However, in terms of the ground grain produced, hammermills generally are able to produce a finer mean particle size at the tradeoff of greater size variation when compared to product from roller mills. Ground grain is conveyed to dedicated bulk ingredient bins inside the feed mill building with the other stored feed ingredients.

Feed formulations are developed to meet the specific nutritional needs of the animal species and the age of the animal. The batching system is controlled by the plant automation system and combines the ingredients in the ratio required by the feed formulation recipe called for by the operator. Feeder screws convey ingredients one at a time from the bulk bins to scale hoppers of up to 12 ton capacity where the amount of each ingredient is weighed to ensure the correct amount. The scale hopper discharges into a mixer for blending after all ingredients have been weighed. While the mixing is taking place, the next batch is similarly weighed in the scales. This process repeats up to 20 times per hour.

After mixing, each batch of mixed feed (also called mash) is conveyed up to the top of the feed mill where it is distributed into storage bins. These bins act as surge bins for the pelleting system. The pelleting system equipment primarily consists of steam conditioners, pellet mills and pellet coolers. Conditioners blend steam with the mash to raise the moisture level and temperature of the mash. This softens the feed particles modifying the physical structure and activates natural adhesives in the ingredients in preparation for the subsequent pelleting operation and improves digestibility. The pellet mill uses rollers and dies to extrude the mash into small pellets. Feed in the form of pellets can improve digestibility of the feed and reduce selective feeding by the animal.

The pellets exiting the pellet mill are at approximately 180°-190°F with 16-17% moisture content. The pellets need to be cooled and the moisture content lowered to about 13%. This is accomplished with either a horizontal or counterflow cooler. An induced draft fan draws ambient air through a bed of pellets in the cooler. Since ambient air is used, the minimum discharge temperature is limited to around 5°-10°F above the ambient air temperature. Residence time and airflow rates are adjusted to achieve the desired moisture.

Pellets are often conveyed to liquid application equipment after they have been cooled. This equipment applies liquids such as animal fat, vegetable oil, liquid enzymes, etc. for purposes of creating additional nutrient value or to improve feed digestibility. It is also possible to apply liquids at the mixer, but some liquid ingredients can be negatively affected by the heat applied in the conditioner or can have a negative impact on pellet quality. Pellet quality is defined as the durability of the pellet to resist excessive breakage or the generation of fine particles. Applying liquids after the pelleting process avoids these effects.

The final step in the process is the finished product packaging and/or bulk loadout. Finished feed can be packaged into bags or tote sacks for delivery to customers in smaller quantities, or can be bulk loaded into specially designed feed trucks for delivery directly to the animal grow out farms.

The primary structure in a feed mill facility is the feed mill tower. The majority of the value added process steps in producing animal feed occurs in this structure. For most large feed mills the structure is made of concrete and is constructed using the slip formed concrete construction method. Slip form concrete construction is common for feed mills, silos, grain elevators, stacks, and other tall structures.

"the feed mill is a complicated manufacturing facility with multiple systems and components that must work together to produce the finished feed"

Slip forming is a construction method where concrete is poured into a form that is continuously moving vertically. This creates a continuous, non-interrupted, cast-in-place concrete structure with superior performance characteristics to construction using discrete form elements such as jump-forming. The form is raised by hydraulic jacks that grip steel pipe or rods which are supported and become encased by the hardened concrete. The forms raise at a rate that allows the concrete to sufficiently cure by the time it emerges from the bottom of the form.

The slip form rises at a typical rate of 12-18 inches/hr. With most feed mill towers between 140-180 feet tall, the slip form process from the first to last concrete pour only takes 5-7 days. This can save significant schedule time versus other construction methods.

WLPLS utilizes 3D building information modeling (BIM) software for the design and layout of the feed mill. BIM is an intelligent model-based process that allows us to more effectively plan, design and construct the facility. As described above, the feed mill is a complicated manufacturing facility with multiple systems and components that must work together to produce the finished feed. Using the virtual model we are able to do such things as identify potential clashes between equipment and structures, and ensure sufficient space is available for maintenance access.

BIM also provides improvements in change management and customer communications. Since BIM model data is stored centrally any modification to the model will automatically replicate in floor plans, sections and elevations on the construction drawings. The 3D visualization capabilities of BIM have made it much easier to have effective design reviews with customers. Customers are able to quickly understand the facility layout when viewing the model and can provide meaningful feedback earlier in the design process when it is easier to make changes.

The combined improvements in feed science, nutrition and technology, animal science, and operational efficiency have had a tremendous effect on the ability of the agriculture industry to meet increasing demand in the face of increasing obstacles. It is likely improvements will continue into the foreseeable future making today's predictions of future famine as inaccurate as similar predictions made decades ago.

About the author...
Jonathan Cowles, P.E. is Engineering Manager for WL Port-Land Systems. He has been involved in in design, fabrication and construction of equipment and systems for material handling and material processing in a wide range of industries since 1991. Jon has held positions in engineering, project management, engineering management and operations management for Svedala Industries (now Metso Minerals), Heyl & Patterson and Westinghouse Electric Company.

HARVESTING SUCCESS: *Horses in Our Lives*

by Chriss Swaney

"My kingdom for a horse" –

The cry of Shakespeare's Richard III in the heat of battle in which he first lost his horse, then the victory, and finally the horse has been placed here in a different sense. This is no cry of distress, but a call of enticement to all.

The Swaney family has been enticed and enchanted by horses for the past 30 years. My father spent his youth riding and driving hackney ponies in Lexington, Ky. My mother took riding lessons every Saturday morning in Schenley Park . My brother was a squadron commander in the famed Black Horse Cavalry Troop at Culver Military Academy, and I spent my summers in the winner's circle at county fair horse shows nationwide.

Chriss Swaney

I showed Miss Chausette (socks in French), a Morgan-Arab mix in English pleasure classes; Teresa's Pride, a three-gaited American Saddlebred in equitation classes and Brigadoon, a five-gaited American Saddlebred in performance classes. The American Saddlebred, the peacock of the show ring, is descended from riding-type horses bred at the time of the American Revolution.

My fondest show ring memory was when Mr. and Mrs. John W. Chapman of Lakeview Farm gave me the opportunity to show their talented roadster pony, Johnny Dollar, at the Pennsylvania National Horse Show in Harrisburg. We were crowned reserve champions in the single roadster pony hitch class.

No matter where we showed our horses, there was always a fairground engineer to control the air quality in the barns, the fairground electrical systems, the design of the agricultural structures we showed in and management of the water systems on the grounds. I guess they were what you call today agricultural engineers. But we simply referred to them as the "blue ribbon" guys who helped grease the engines of a successful show ring summer.

Chriss Swaney is a freelance writer, and member of the ESWP Publications Committee. Chriss is a frequent contributor to the Pittsburgh ENGINEER.


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