People Caring About Water

Pumps, Control Panels, and Wastewater; What Could Possibly Go Wrong

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NOWRA
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Troubleshooting Pumps and Controls

- Introduction
  - When the force of gravity works against us
    - we use electricity to move sewage
  - And
    - we use pumps to inject air into water

2

Troubleshooting

- And
  - When our system fails to renovate and disperse wastewater
  - We need to diagnose the problem and provide a repair

Control Panel after Lightning Strike

http://www.strikecheck.com/2017/07/24/surge-lightning-damage-electronics/

3

Objective for this Session

- Demonstrate the methods used to determine the cause of problems associated with pumps and controls
  - Electrical
  - Mechanical
  - Hydraulic

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Primary Focus

- 120 VAC systems
  - typical power requirement needed for residential sewage treatment and dispersal
- Single pump operations
  - duplex pump systems are a little more complicated
- To share my experience about pumps and controls
- However, my focus is not to make you an electrician
  - electricity and water do mix, but you might not like the results

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Disclaimers and Reminders

- Turn off power when working inside a control panel.
- Voltage always follows the path of least resistance.
- It takes less than ½ amp of current to stop your heart
- Know your limits
- Mention of brand names does not mean an endorsment

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The Tools of our Trade

- Beyond the common tools
  - shovel, hand tools, etc…
- We need
  - clamp-on amp meter
  - wire splicing tools
  - stopwatch
  - float hook

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Clamp-On Amp Meter

- Much better than multimeter for measuring amperage
  - clamp around wire to get amperage
  - only measure one wire of two wire curcuit

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Why Measure Amps

- Pumps
  - too many amps, bearing failure
  - too little amps, water leak
  - no amps, the pump is not working
  - troubleshoot why breaker is tripping

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And, a Multimeter for Voltage and Continuity

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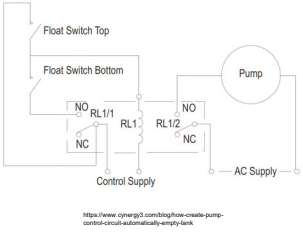
However,

- The most important tool of our trade
  - is to understand how the controls function
    - in other words “how do they work”
  - this knowledge give us the power
    - to determine what it is “not doing”



https://www.cynergy3.com/blog/how-create-pump-control-circuit-automatically-empty-tank

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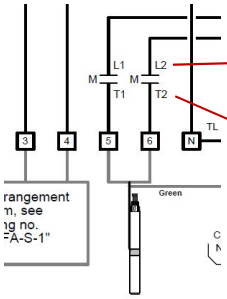
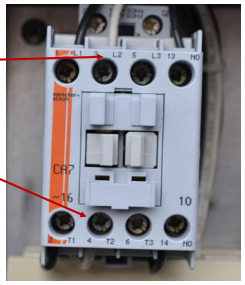
Troubleshooting Requires a Good Wiring Diagram





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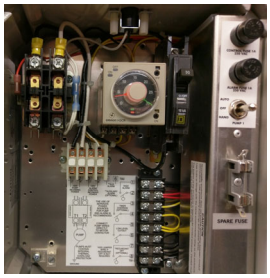
Even Better when the Wiring Diagram is Pasted Adjacent to the Terminals

- Hard to lose a wiring diagram when it is glued to the panel board
  - – may be difficult to read in 10 years
  - – so encourage the homeowner to file system paperwork
    - where it can be found



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A Philosophical Moment

- From an educational perspective
  - – it is difficult to separate
    - design
    - installation
    - troubleshooting
- A large part of troubleshooting
  - – is determining whether
    - the design and/or installation is part of the problem
- So,
  - – we need to have a good foundation in all three topics

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Pumps

- Generate pressure
  - – water moves from high pressure to low pressure
- Pump selection is based on
  - – pressure required
  - – flow rate required
  - – other design factors
- Issues
  - – electrical
    - capacitors (run, start, split phase)
    - water intrusion at terminals
    - blown windings
    - short to casing
  - – mechanical
    - bearings
    - seals
    - corrosion
    - clogging

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Controls

- Devices that operate the system in the absence of an operator
  - – activate pump as needed
- Basic controls include
  - – floats
    - or other depth measurement device
  - – timers
  - – valves
  - – circuit breakers
- Measurement devices include
  - – event counters
  - – elapse time meters
  - – pressure gauges
  - – flow meters

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A Review of Fundamental Questions

- What type of system are you working on?
  - – pump to a treatment system (aka, ATU or media filter)
  - – pump to gravity trench
  - – pump to low pressure distribution (LPD)

  Lower Pressure, Higher Flow Rate Centrifugal Pump
  - – pump to subsurface drip dispersal

  Higher Pressure, Lower Flow Rate Turbine Pump

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A Review of Fundamental Questions

- What controls the pump?
  - – is it a demand dosed with a piggyback float switch
  - – is it a demand dosed with a control panel
  - – is it a timed dosed, where is the control panel located

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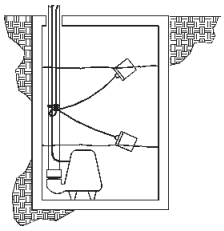
Demand Dose

- Generally used to transfer effluent to the next component
  - at high-water level in dose tank
    - pump activates
  - at low-water level
    - pump de-activates

Missing the Alarm Float, Pump Should not be on Bottom of Tank, and Pump Tank should have Two Days of Volume



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Demand Dosed Panel

- Much simpler
  - basic components include
    - motor contactor
    - breakers
    - hand-off-auto switch
    - alarm
  - panel allows for easy connection of alarm float and pump on-off float

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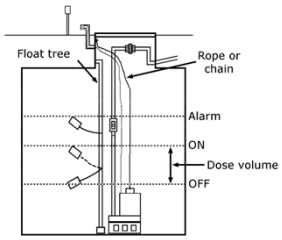
Timed Dose

- Generally used for pressurized distribution of effluent
  - timer determines when the dose will occur
    - pump activates
  - after pre-determined elapsed time
    - pump de-activates



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Timed Dosed Panel

- More complex
  - basic components include
    - timer
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    - alarm
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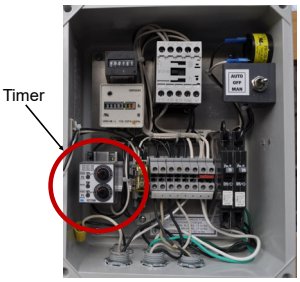

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More Fundamental Questions

- The appearance of the control panel
  - does it look damaged, any fried connections, chewed on, etc…
  - has it been “MacGyvered”
  - is it a NEMA 4x box
    - are the components that penetrate the box NEMA 4x
- What about the conduit leaving the control panel
  - whacked by lawn mower or weedeater
  - separated by soil settling
  - is there any exposed wiring

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More Fundamental Questions

- What are the symptoms when in Auto Mode?
  - breakers trip when pump is activated
  - breakers trip after a few minutes of pump operation
  - tripped breaker is independent of pump operation
  - nothing happens
  - pump activates, does not produce water

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More Fundamental Questions

- What does the pump do when you switch it to “hand”
  - pump works fine
  - pump does not activate
  - motor starter closed, pump does not activate
  - pump activates, but vibrates
  - pump activates, does not produce water

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More Fundamental Questions

- Any evidence that the system was failing before it failed
  - does the event counter and/or elapse time meter correspond to the volume of wastewater generated
  - did homeowner notice anything odd about the system
  - any occasional high-water alarms that resolved during low water usage
  - is there evidence of high water levels in the tank

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Getting Started

- Is the problem caused by the pump or by the controls?
  - if the pump will not operate on manual (hand)
    - it could be the pump
    - or it could be the power supply to the pump
- Question
  - does the power supply to the pump go through a float?
    - check the float for continuity
    - if do not have continuity, replace the float

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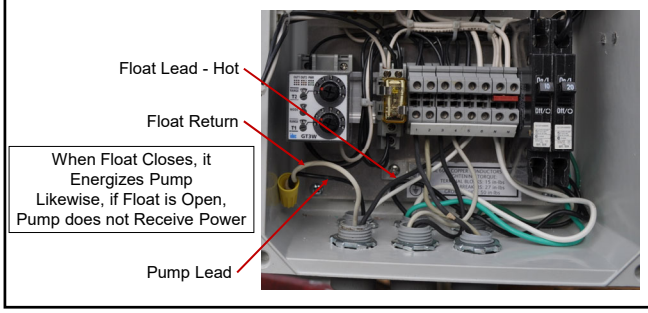
Low-Level or Redundant Off Float



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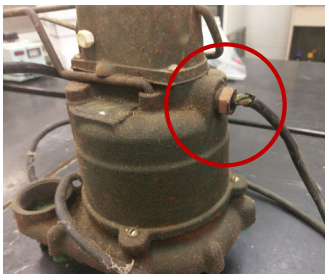
Trips the Breakers Immediately

- Disconnect the power
- Pull the pump and place on a solid surface
- Mechanical
  - spin the impeller
  - inspect the casing and wire leads



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Trips the Breakers Immediately

- Still disconnected from power…
- Check for short to casing
  - set multimeter to resistance
  - see if there is continuity between leads and casing

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Trips the Breakers in a few Moments

- Leave pump in place
- Disconnect power at breaker
- Find the pump power conductor
  - manipulate it so that you can check it with clamp on amp meter
- Clamp on the amp meter
  - around one lead
- Reconnect the breaker
- Turn on the pump and read the amperage
- May need to pull the pump to get the nameplate amperage

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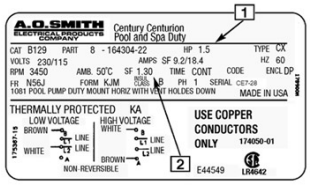
Compare Amperage to Nameplate



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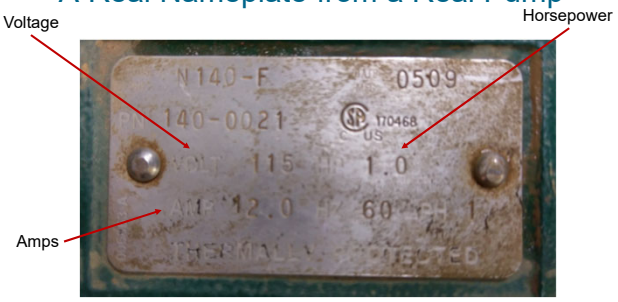
A Real Nameplate from a Real Pump



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High Amperage

- Could be caused by
  - failing bearings or seals
  - locked rotor
  - stringy material wrapped around impellor
- Not caused by clogged pipes
  - centrifugal pumps generate pressure, not flow
  - if water is not flowing, pump amperage will drop
    - **Not Intuitive**

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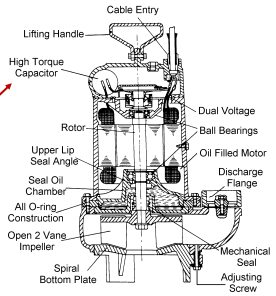
Testing the Pump

- Other pump tests can be performed with a multimeter
  - however, you will need more information about the motor and the capacitors
  - and testing the winding insulation requires a high-voltage source



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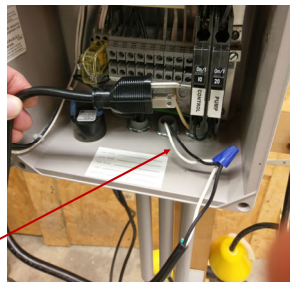
Testing the Pump

- Directly connect the pump to a known power supply
  - removes the motor starter, floats, and other controls from the circuit
  - if pumps works, then it is one of the controls

Pump Leads Disconnected from Terminal Strip and Connected to a Plug



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Quick Focus on Pumps

- Most of our pumps
  - are submersible, centrifugal, and robust
  - must be effluent-rated
- Most of our pumps
  - cannot handle solids
  - unless they are grinders or positive displacement

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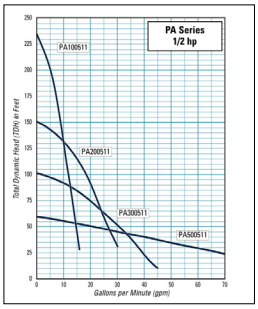
Pump Curves

- Every pump, blower, and compressor has a pump curve
  - this is how we determine the pressure and flow the pump can produce
  - if our pump is on the edge, it will fail sooner

$$\frac{\text{Flow (gpm)} \times \text{Head (feet)}}{3960 \times \text{pump efficiency}} = \text{Horsepower}$$



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We Also use Pumps to Move Air

- Aerobic treatment units move air through water
  - oxygen transfer
- These systems fail for all the usual reasons
  - wear and tear
  - capacitors
  - moisture intrusion
  - air filters
  - insects, pollen, mice

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Blowers and Compressors

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Aerobic Treatment Unit Aeration System

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Controls

- Troubleshooting controls can be much more interesting
  - as long as you are paid by the hour
- Controls make decisions in place of an operator
  - when they make the wrong decision, we have to troubleshoot

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Basic Controls Troubleshooting

- If it is electrical, its got to have power
  - to operate the pump
  - to close relays
  - to use as a signal
- The ways we lose power
  - tripped breakers
  - loose connections
  - failed switches

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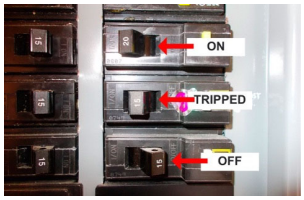
Tripped Breakers

- Don't just reset it
  - figure out why it tripped
    - direct short to ground
    - overload condition
    - pump pulling too many amps
    - is the breaker failing
    - is it a GFCI



http://www.mcgarryandmadsen.com/BlogEntries/2013/6/16_My_circuit_breaker_wont_reset_-_Whats_wrong.html

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Ground Fault Circuit Interrupts

- Fast acting circuit interrupter
  - compares the current from the power lead to its neutral
  - if difference is greater than approx. 5 mA, circuit is opened, within 1/40 of second
- Pumps must be GFCI rated for your protection

https://www.homedepot.com/p/Square-D-Homeline-15-Amp-Single-Pole-GFCI-Circuit-Breaker-HOM115GFICP/100153356

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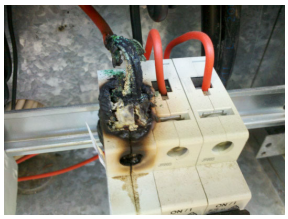
Loose Connections

- Most of the time
  - loose connections are not this obvious
  - usually have to find failed wire splices deep within the system



https://mancoelectrical.com.au/loose-electrical-connections-fire-hazard/

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Connecting Aluminum and Copper Wire

- Aluminum corrodes when in contact with copper
  - loosen the connection
  - creates arching
- Splice with NEC 110.14 approved connectors
  - made for Al/Cu connections
  - has dielectric grease to prevent corrosion

https://www.thisoldhouse.com/how-to/10-wiring-problems-solved

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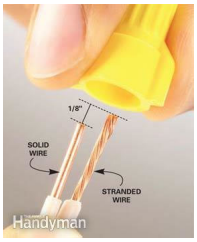
Connecting Solid to Stranded Conductors

- The solid wire
  - is very stiff, will not twist with the flexible stranded wire
  - stranded wire will wrap around the solid wire
  - provide extra stranded wire for a tight wrap



https://www.familyhandyman.com/electrical/wiring/how-to-make-safe-wire-nut-connections/view-all/

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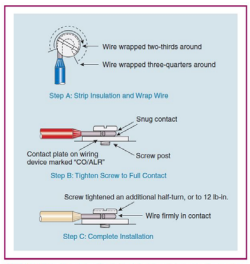
NEC Handbook 14th Edition



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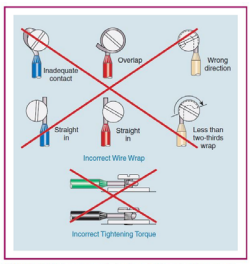

EXHIBIT 110.4 *Incorrect methods of terminating aluminum wire at wire-binding screw terminals of receptacles and snap switches. (Courtesy of Underwriters Laboratories Inc.)*

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Failed Switches

- Floats are the weakest component of our industry
  - they are just not very happy about being continuously submerged in sewage

https://tgwastewater.com/spi-junior-m-navigator-standard-duty-mercury-float-switch-20a401fp-10ardnop-normaly-open

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Question

- Is the float being used to power the pump?
  - does the power for the pump flow through the float?
- The float must be rated for that amperage during switch closure

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Float Operation

- Normally-Open
  - switch is open when the float is hanging down
  - switch is closed when the float tilts to a preset angle
- Normally-Closed
  - switch is closed when the float is hanging down
  - switch is open when the float tilts to preset angle

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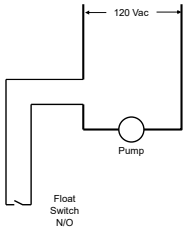
One Float Pump Control System

- One float activates and terminates pump
  - float must have a wide angle between changing switch position
  - water level rises/falls, closes switch, activates/deactivates pump



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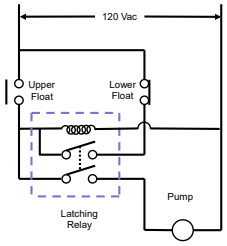
Two Float Pump Control

- Requires a latching relay
  - a latching relay allows on switch (upper float) to activate pump
  - and second switch (lower float) to deactivate pump



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Check Floats for Continuity

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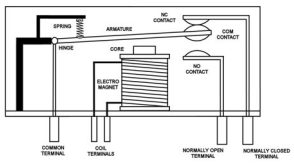
Other Switches that Fail

- Relays
  - a means of energizing a high power circuit with a low power signal
  - these devices have switch closures that
    - can arc-weld closed
    - the contacts can corrode
    - or the coil can just die of old age



http://www.globalo.com/relays/relays.html

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Motor Contactors

- Heavy duty relays
  - receives signal from
    - float
    - timer
    - PLC
  - and coil pulls in contacts complete the circuit to the pump
  - should close with a "snap"
    - no chatter

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Valves

- Valves can be
  - mechanical
  - electrical
- They have moving parts
  - so they will wear out
  - suffer electrical surges

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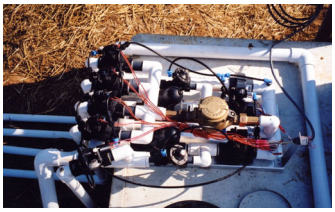
Diaphragm Valves

- Seven diaphragm valves in this four zone drip controller
  - four zone valves
  - two filter backflush valves
  - one forward flush valve



Lots of headache if this thing gets zapped

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Diaphragm Valves

- Very common application
  - resistant to effluent
  - can handle some solids
- Failure modes
  - does not seal, effluent goes through it
  - does not activate, solenoid fails

Often called solenoid valves, but they are really solenoid-operated valves

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Troubleshooting Question

- How does the diaphragm valve change state?
  - inlet pressure hold diaphragm closed
    - water pressure in bonnet chamber
  - solenoid opens plunger
    - equalizing pressure on both side of diaphragm
    - more pressure on bottom of diaphragm
    - inlet water pressure opens valve
  - solenoid closes
    - pressure re-builds in bonnet chamber

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Diaphragm Valve Troubleshooting

- Leaking through valve
  - check seats
  - check O-rings
  - check solenoid plunger
  - check for solids in small passageways
- Solenoid does not respond
  - check for power
  - could be a relay in control panel

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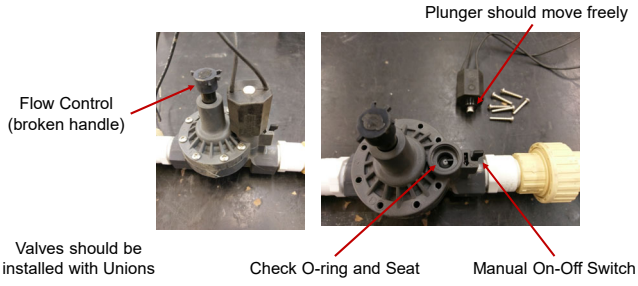
Diaphragm Valve Disassembly



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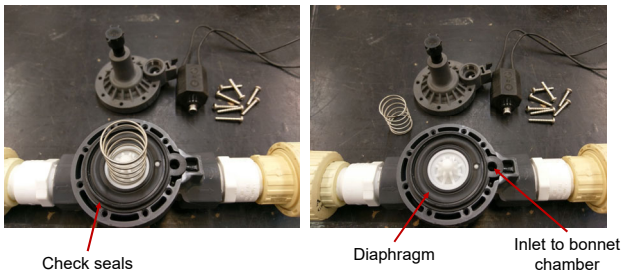

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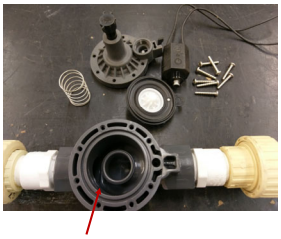

- Rebuild kits can be purchased from manufacturer
  - if needed
- Use petroleum jelly on seals and O-rings
  - just a light coat
- Need a clean work space
  - keep soil particles away from seals and O-rings

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Check Valve or Backflow Preventers

True Union – for easy service

Unions on both ends for easy service

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Orifice Flow Controls

- Uses an engineered cross-section and water pressure to regulate flow
- Can be used to provide equal flow across a manifold
- Can be used to divide flow across components

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Orifice-Based Flow Divider

- Four to One Recirculation
  - four parts are recirculated back into the treatment system
  - one part goes to the pump tank for dispersal
- Must be level
- Must have scum removed

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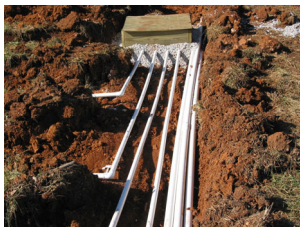
LDP with Top Loading Manifold

- Low pressure distribution system
  - orifices sized to deliver uniform application of effluent along length
- Troubleshooting
  - check pressure
  - snake out lateral



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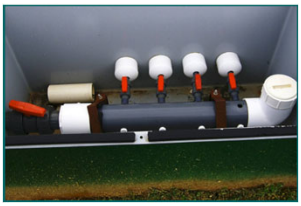
Orifice Dividing Flow Across Manifold

- Pump to Gravity
  - four gravity trenches
  - goal is for each trench to receive the same volume of effluent
- Remove scum and scale
- Check for increase in hole size
  - edges will get worn away



70

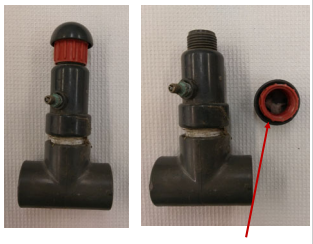
Air/Vacuum Relief Valves

- For onsite wastewater treatment
  - A/V are more of a drip dispersal issue
  - they let air out when the pump activates
  - they let air in to prevent a vacuum from drawing in mud through the emitters

71

When Troubleshooting Drip Systems

- A/V valves need to be checked
  - scum build up prevents the valve from sealing
  - resulting in a continuous flow of water



72

Pump and Float Cables

- Cables are routed through a small gap in the riser
- Cables are not protected

73

Connecting Romex to Round Cable

- No splices should be open to atmosphere of tank
  - this is not acceptable
  - as a matter of fact
    - it just plain dumb
- Solid copper spliced to stranded copper with electric tape

74

Romex vs Cable

- Romex is a brand
  - generally represents a bundle of three solid copper conductors
    - black (load)
    - white (neutral)
    - bare (ground)
  - please note flat jacket

- Use Romex to go from house breaker panel to your control panel

75

Romex vs Cable

- Cable is a general term
  - generally represents a bundle of stranded conductors
    - black (load)
    - white (neutral)
    - green (ground)
  - please note round jacket

- Use stranded wire bundles (round cables) to serve pump and floats

76

Wire Insulation and Jackets

- What is the difference between wire insulation and jackets
  - A jacket is an outer sheath that protects the wire or cable core from mechanical, moisture and chemical issues
  - Insulation is a coating that is extruded or taped onto bare wire to separate conductors from each other electrically and physically

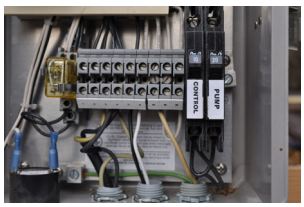
Should have "W" for moisture resistant

https://www.omnicable.com/cable-services/cable-knowledge/2017/05/04/basics-of-wire-and-cable-jackets-vs-insulations

77

Use Mechanical Connectors

- If you have to connect solid copper conductors to stranded conductors
  - minimize the use of wire nuts



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Electrical Details

- Surge protection for the control panel
  - use appropriate grounding
  - cannot make a panel lightening proof, but can make it resist near misses.
- Ground fault interrupts
  - electricity and water do mix
- Separate circuits for pump and pump controls
  - if pump trips circuit breaker, then alarms still works

79

Cables and Conduit

- One cable – one conduit
  - between control panel and pump tank
  - pull defective pump or float out and "fish" the new cable through conduit

80

Well, There's Your Problem

- The sad part is that it really worked for a while

81

No, This is Just Wrong

- But it is fixable
  - Set a post, mount a control panel
  - Use existing conduit
  - to route pump and floats
  - seal the conduit
  - install union to make pump easier to pull

82

Or, At least

- Convert it to a junction box

83

Or, Better Yet

- Mount a control panel on the side of the house
- Place the pump in a filtered vault
- Use glands as conduit seals and strain relief
- Don't attach the floats to the standpipe

84

Wrap-Up

- When troubleshooting
  - we are often working on a system that someone else installed
- This can uncover some shoddy work
  - which is why you have to fix the problem
- Here are some consideration for you
  - as you scratch your head and wonder how it every worked at all

85

People Caring About Water

Questions

NOWRA
National Onsite Wastewater Recycling Association

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