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CHECKLIST 8

FOREWORD

Greenhouse Electrical Design Considerations provides an introduction to the principles of electricity for owners, designers and builders of greenhouses. This document is offered to help develop electrical systems that are economical, efficient and safe, and is not intended to create specifications, replace codes or set standards.

Review of these considerations will assist in developing a checklist of items to plan the electrical elements of a new greenhouse range or renovating, retrofitting or expanding an existing greenhouse. It may even be worthwhile to review existing electrical systems with this document.

BASIC ELEMENTS OF ELECTRICITY

Electricity works much like water

The basic elements of electricity work very much like water. Water moves through pipes, pushed along by water pressure. Electricity moves through wires, pushed along by a force called *potential*. Electric potential is measured in units of volts and is analogous to water pressure. We get water pressure from a water tower; the voltage forcing electricity through our power wiring comes from a utility company's generating plant.

When we need to move large volumes of water, we use a large pipe like a water main. The electrical term analogous to gallons in our water example is *current* (measured in Amperes; usually abbreviated to amps). As with a water main we need large wires to carry large currents; the main electric wires coming into a greenhouse can be as big around as a man's thumb.

You may have noticed that no matter how far you open a faucet, finally a certain amount of water flows out, but no more. Plainly, something keeps the kitchen from flooding every time we run a glass of water. The pipes in the plumbing system resist the free flow of the water. There is friction as the water flows past the walls of the pipe. Electricity faces resistance to its flow through a wire and in fact, *resistance* is the electrical term for the force that works against the free flow of electricity. Resistance is measured in units called ohms.

Having followed water and electricity together this far, let's consider doing some useful work with both. As an example, we could hook up a garden hose and wash down a patio. If we just let the water run out the end of the hose, we get plenty of water, but not much cleaning action on the patio. However, if we connect a nozzle to the hose, we get a high-pressure stream of water that can do useful work. Plainly, pressure and volume are related when it comes to doing work. It's the same with electricity. Voltage (pressure), and current (gallons), work together when we use electricity to do useful work. In electrical terms, the ability to do work is called *power*. Power is measured in watts, and we compute it by multiplying volts and amps together. For instance, if we force half an amp of current through a light bulb at a potential of 120 volts we get 60 watts of light.

Ohm's Law

There is a simple formula that relates electrical current, potential, and resistance. It's called Ohm's Law, after its discoverer. Ohm established that Potential = Current x Resistance. Stated in terms of the units we use to measure these quantities, voltage, current and resistance all have one-letter synonyms that are widely used. These are:

Electrical Quantity	Synonym/Variable Name
Potential (volts)	E
Current (amps)	I
Resistance (ohms)	R

Using these variable names, we can write Ohm's law as: **E = I x R**. We can also write our formula for power (P) as **P = I x E**.

Ohms law and a little algebra can be used to get answers to many common electrical questions. We can solve this basic equation to get results in ohms, volts or amps:

E = I x R (result in volts). If we measure the resistance of the filament in a light bulb and find it to be 240 ohms, and if we turn the bulb on and measure the current flowing at 0.5 amps, what would we expect the voltage to be?

I = 0.5, R = 240 ohms, I x R = 0.5 x 240 = 120 volts

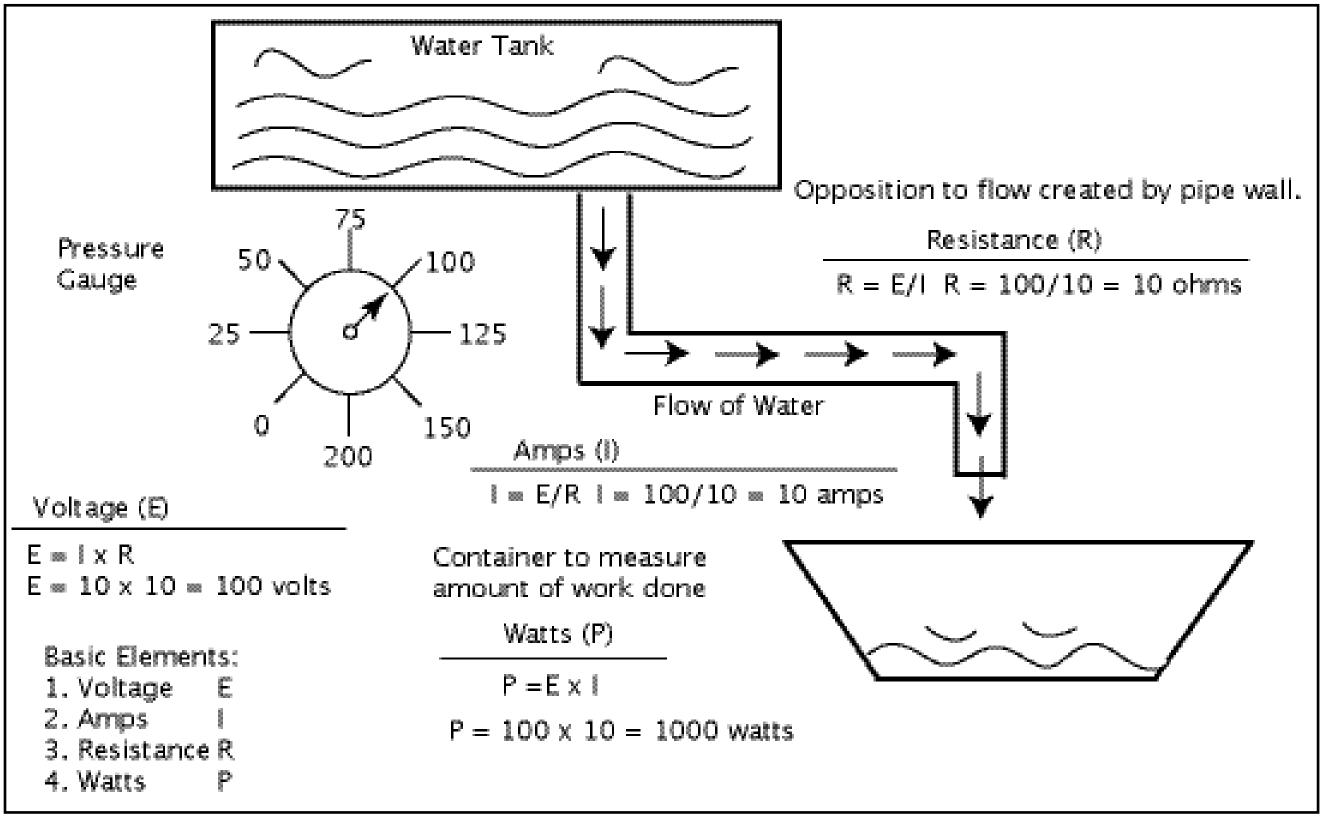
I =E/R (result in amps). If we measure the coil on a space heater at 50 ohms and the heater operates at 120 volts, how much current will the heater draw when we turn it on?

E = 120 volts, R = 50 ohms, E / R = 120 volts / 50 ohms = 2.4 amps

R = E/I (result in ohm). Say we knew the heater in the last example drew 2.4 amps at 120 volts, how would we calculate the resistance of its coil?

I = 2.4 amps, E = 120 volts, E / I = 120 volts / 2.4 amps = 50 ohms

The illustration below sums up our water analogy, Ohm's law, and the basic principles of electricity.



DESIGN CONSIDERATIONS

OVERVIEW

A *safe* and *efficient* electrical system is of the utmost importance for the proper operation of greenhouse equipment. Because greenhouses can cover very large areas, efficiency considerations require special attention. In a greenhouse, equipment can easily be hundreds of feet from the circuit breaker panel that feeds it power. This means there may be hundreds of feet of wire between the equipment and its power source. As we discussed in Basics, above, wires have resistance and resistance works against voltage. This effect, called voltage drop relates directly to the efficiency of the equipment we connect with electrical wiring. For example, an incandescent light bulb loses over 3% of its brightness if it is operated just 1% below its rated voltage. Voltage drop also has another effect: the voltage doesn't just disappear, it gets converted into heat that is wasted even though you pay for it on your utility bill.

While there's no way to completely eliminate voltage drops and other inefficiencies, you can minimize them by working with a design engineer who is familiar with greenhouses. A design engineer will work with you to provide an electrical system that meets your requirements for safety, efficiency, adequacy, convenience and spare capacity.

Once you have a system design, you will work with an electrical contractor who can install the designed system. His work and the materials he uses will be inspected by your local inspection authority, often the building department.

You'll need to coordinate both the design and installation phases of your electrical system with your local electric utility. Only they can tell you if they can provide the type of system you require, with the capacity you need.

CHECKLIST FOR ELECTRICAL DESIGN
A basic electrical design includes the following elements:

1. **Load schedule -** This is an inventory of all the electrical equipment in your project. The total electrical demand of this equipment determines the size of electrical service you'll require.
2. **Main service and branch panel board layout -** This shows the location and size of your service entrance components and any additional circuit breaker panels you will need. The service entrance is where the wires from the electric utility enter your property, and includes a large switch or circuit breaker that can disconnect your entire premises from the electric grid.
3. **One line power diagrams -** These diagrams show how your equipment will be assigned to individual circuit breakers and breaker panels. These plans show the number and the sizes of the wires that will carry power to your equipment.
4. **Conduit and wiring layout -** This diagram shows where conduits will be routed, the sizes of the conduits and number and sizes of the wires that will be run in each conduit.
5. **Control schematics and diagrams -** These plans show the interface between control devices (like thermostats or computers) and the equipment they control (like exhaust fans and heaters).

The design engineer will produce the plans and drawings above as a set of blueprints. You can give copies of these blueprints to several electrical contractors and get competitive bids on an apples to apples basis. Given these plans, the contractor can give you an accurate estimate of the time and materials needed for your project. Just as important, these plans provide a record to work from for future expansion, maintenance and trouble-shooting.

LOCATION OF MAIN SERVICE
The location of your main service or service entrance, must be coordinated with your electric utility. A central location minimizes wire lengths and reduces both the costs of voltage drops and of wire itself. A centrally located main service is your most efficient and economical alternative.

TYPES OF POWER SYSTEMS
A power system is the form in which your electric utility provides you with electric power. There are four common types of power systems:

1. 115/230 Volt, 1 Phase, 3 Wire
2. 115/208 Volt, 3 Phase, 4 Wire
3. 115/230 Volt, 3 Phase, 4 Wire
4. 277/480 Volt, 3 Phase, 4 Wire

The first type above is commonly used in houses and small businesses. The three-phase systems that make up the rest of the list are used in schools, medium to large businesses and industrial plants. Though three phase power is not available everywhere, it has technical advantages in a greenhouse and you should consider it.

Don't be afraid to consider the type 4 power system above. The higher voltages offered mean that voltage drops are less significant. Because power is the product of volts and amps, a higher voltage means we can deliver the same total power while using fewer amps. The practical benefit of reduced amperage is reduced wire size. By raising the pressure, we can get all the water we need through a smaller pipe.

THREE PHASE POWER ADVANTAGES

Three phase power offers the greenhouse owner some significant advantages:

1. Three phase motors are less expensive than single phase motors for motors of one horsepower or larger.

2. Three phase motors are mechanically and electrically simpler than single phase motors. This means they are more reliable.

3. A three phase motor is more efficient than a single phase motor.

4. A three phase system can use smaller wires and conduits than a single phase system.

The following table shows the current used by the same size motor in different power systems. The advantages of higher voltages and three phase systems should by obvious.

H.P.	Volts	Phases	Current Draw
1	120	1	16 amps
1	230	1	8 amps
1	208	3	4 amps
1	230	3	3.6 amps
1	480	3	1.8 amps

STANDBY GENERATORS

Because a greenhouse can lose and gain heat so rapidly, it is critically dependent on a constant supply of power for its heating and cooling systems. Because a power outage of more than a few minutes can mean the loss of your livelihood, you must consider a standby generator when you plan your electrical system.

If no funds are available initially for a generator, include it in your plans anyway. Your design engineer can make provisions for switching between utility and generator power when you are able to add a standby generator. Automatic transfer systems are available which start the generator, allow the engine to warm up and the generator to come to full power and then connect the generator to your greenhouse equipment. When utility power returns, these systems reverse the process and shut down the generator.

Note: As you make your plans, always refer to any generator as a standby generator, not an emergency generator. Emergency generators are used in places like hospitals where human life could be at risk if the power failed. The regulatory requirements for an emergency generator are much more stringent and costly than for a standby generator.

CROP LIGHTING
As mentioned earlier, voltage drops have a disproportionate effect on the light output of incandescent lamps. If the electrical system delivers a voltage below the *rated operating voltage* of the lamps, they cannot deliver the intended amount of light. Though the light loss can be significant, it is often undetectable to the human eye. Only careful design can ensure the expected performance.

HIGH EFFICIENCY MOTORS
Though high efficiency motors cost more than standard motors, the energy savings they offer easily outweigh the cost difference. A one horsepower high efficiency motor can pay for the cost difference in only four months of typical greenhouse use: eight hours a day of operation at seven cents a kilowatt-hour for electricity.

A high efficiency motor is built using more copper wire and iron than a standard motor. It runs cooler than a standard motor.

GROUND-FAULT CIRCUIT INTERRUPTERS
A ground-fault circuit interrupter, or GFCI, is a safety device that protects people from possible electric shock hazards. A typical GFCI is built into an electrical outlet. These devices kill power to the outlet if they detect an electrical fault that could deliver a shock to a person. Many personal appliances like blow dryers now have a GFCI built into their power cords.

The National Electrical Code (NEC), which regulates electrical wiring has begun to require ground-fault circuit interrupters in more and more locations; particularly in damp locations in contact with earth or concrete. The NEC is revised every three years and it is likely that the trend toward GFCI protected outlets will continue in future revisions.

CHECKLIST

- ☐ Demand all work be done in accordance with the National Electric Code and local codes.
- ☐ List all possible equipment requiring electricity, including portable units.
- ☐ Visit with your electric utility company about your proposed project and timing.
- ☐ Identify and locate licensed electrical contractors to obtain quotations and check possible schedules for per forming work.
- ☐ Verify load schedule with equipment suppliers and furnish this information to both the designer and contractor.
- ☐ Locate a design engineer to prepare your drawings and system design to include:
  - ☐ Load schedule
  - ☐ Main service and branch layout
  - ☐ Power diagrams
  - ☐ Wiring layout
  - ☐ Control diagrams
- ☐ Obtain material and labor bids from Electrical Contractors given design plans.
- ☐ Review all bids with design engineer and possibly the utility company, then select your contractor (the earlier the better).
- ☐ Do not allow contractor to vary from the design unless the drawings are changed by the designer.
- ☐ When inspectors are on site, you, the designer and the contractor should be available to assist.
- ☐ Check each device for proper operation when it is installed and wired.
- ☐ Check all extra electrical outlets and circuits.

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