# WELLHEAD COMPLETION AND PUMPING EQUIPMENT

## Introduction

The wellhead is the portion of the water well extending above ground. Because of a contamination risk, state law prohibits buried wellheads.

The well cap is designed to keep rainwater, insects, and small animals out of the well. Newer well caps have screened air vents that allow atmospheric air to enter the well as water is withdrawn from the well. This results in a more sanitary water supply. Broken well caps or damaged screens should be replaced. All well caps in Michigan must be approved prior to use.

## Wellhead Completion and Pumping Equipment Rules

### Rule 157(a)

Well caps and seals shall be:

- Weathertight
- Vermin proof
- Provide for venting
- Tightly secured to casing

### Rule 157

A casing vent shall be provided on all well caps and seals

Except:

- Deep well, single pipe packer jet installations
- Flowing wells

### Rule 157

A vent shall be:

- Screened
- Pointed downward
- Terminate 12 inches above ground or floor
- 24 inches above any known flood level

### Rule 151 Room housing pumping equipment or well casing

- Above ground surface or in an approved basement offset
- Pumping equipment may be in a crawl space if water does not accumulate
- Must provide for access to system components for maintenance and repair

### Rule 155 Water Service Lines

- Buried portion under positive pressure at all times
- No check valve at pressure tank unless pipe is protected
- Plastic 160 psi minimum
- Approved materials

### Rule 141 Connection to casing-Above grade

- 12 inches above grade
- Connection may be:
  - threaded
  - welded
  - rubber expansion seal

bolted flanges
well cap
pump base

**Rule 142 Connection to casing-Below Grade**
May be:
- Threaded
- Welded
- Approved pitless adapter
- Not submerged during installation

**Rule 153 Pumps**
- No unprotected openings
- Watertight connection to casing
- Priming not required for ordinary use
- Plastic drop pipe - approved materials, no splices, not used with packer-jet assembly
- Approved lubricants for sub pumps

**Rule 154 Water Suction Lines**
- Approved materials
- Protected by one of the following methods:
  a. Fully exposed 12 inches above floor of basement, basement offset, pump room
  b. Fully exposed 12 inches above ground surface
  c. Concentric piping under system pressure
  d. Concentric piping drained to basement
  (20 feet max length, positive drainage, watertight at casing)

**Rule 140 Pressure tanks**
Bladders, diaphrams, coatings, or lining materials in contact with water must meet the specifications listed

**Rule 156 Pressure tanks**
- Shall be in an approved pump room, well house, crawl space, basement offset, or basement
- Buried tanks must be approved
- If pump can exceed working pressure of the tank, a pressure relief valve shall be installed

**Rule 158 Sampling faucets**
- Down-turned faucet
- Not less than 8 inches above floor
- In a convenient location at the pressure tank or as near to the well as possible

**Rule 156 Venting of gases**
- Toxic or flammable gases shall be vented
- Vent shall discharge to *outside atmosphere*

*The Water Well Equipment Approval List is available for download from the DNRE Well Construction Unit website at [www.michigan.gov/deqwaterwellconstruction](www.michigan.gov/deqwaterwellconstruction).*

# Where in the Well It All Starts: Residential Water Pumps

By Tom McDermott and Dave Greisinger

**Summary:** *Over 1.5 billion people use water wells as their primary source of drinking water. In the United States, 10 million private water wells supply drinking, washing, bathing and irrigation water needs for 23 million people. This article focuses on the electrically powered jet and submersible centrifugal pumps, and water systems that normally deliver this water in the developed world.*

During the 1940s in the United States, electricity generally became available in rural areas due to the expansion of rural electrification under the federal Rural Electrification Administration (REA). As a result, the tiresome job of hand pumping and hauling water from domestic water wells was, in many areas, replaced with motor-driven pumps. Generally speaking, the motor-driven water pumps most in use today are centrifugal pumps and can be classified as either jet pumps or submersible well pumps. Jet pumps are aboveground and can be further broken down into shallow well and deep well jet pumps. Submersible pumps, as their name implies, are submerged in the well water.

## Shallow & deep well jet pumps

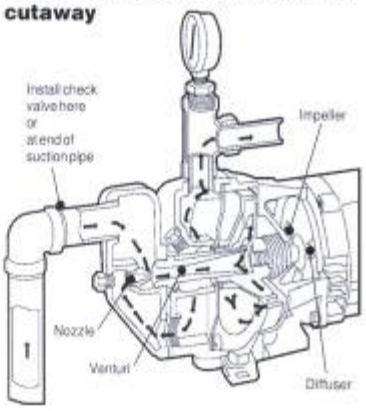
A shallow well jet pump, limited by atmospheric pressure, can lift water about 25 feet. Deep well jets are most effective to about 100 feet. Jet pumps essentially operate on the principal of filling a vacuum. (Imagine sucking on a straw and removing the air and, as this is done, the liquid rises to fill the vacuum that's been created.) Since jet pumps don't pump or evacuate air, they use water in the system to move water from the well to the pump and into the household water system.

Jet pumps draw water from a well by creating a vacuum through the combined efforts of the impeller and diffuser as well as the jet ejector, which is made up of a nozzle and venturi (see *Figure 1*). As the impeller moves water out of the pump housing, it pulls water from the well. This water passes through a nozzle, which constricts the flow of the water through its progressively narrower opening, thereby increasing the speed (velocity) of the water and creating a partial vacuum at the end of the nozzle. In many pump manuals, this is compared to the nozzle on a garden hose. Once the water passes through the nozzle, it moves into a larger-diameter venturi that slows down the water and increases the pressure in the pump. The water then enters the pump housing where the impeller moves a portion of the water into the household water system while some of the water is recirculated by the impeller and used to draw more water out of the well. This recirculated water is referred to as "drive water."

## Spotting the ejector

The fundamental difference between a shallow well jet pump and a deep well jet pump is the location of the jet ejector. A shallow well jet pump has the jet ejector attached to the pump housing and is aboveground like the pump. A deep well jet pump has the jet ejector assembly down in the well, either submerged or close to the pumping level of the water.

**Figure 1. Shallow well jet pump cutaway**

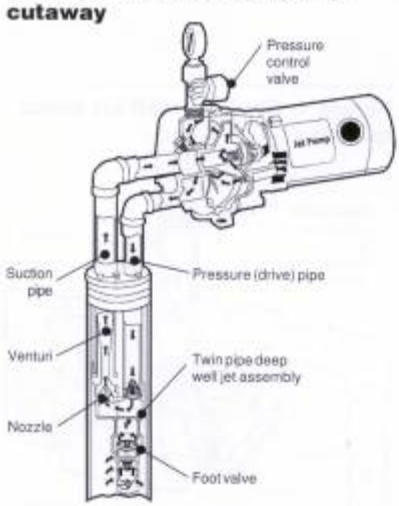



A typical deep well jet pump installation uses a two-pipe system. One pipe is called the pressure or drive pipe that sends drive water from the surface pump (see *Figure 2*) to the jet ejector nozzle, creating a partial vacuum that fills with well water. This drive water along with well water flows up the second pipe (suction pipe) to the pump on the surface. Another type of deep well jet installa-

tion is called a "packer style" and uses the well's casing, usually 2-inch, as the pressure pipe feeding the packer jet assembly—fitted tightly into the well casing—with drive water. The well water and drive water then flow to the surface pump through the suction pipe, as in the two-pipe installation (see *Figure 2*).

The installation of the jet ejector down in the well allows the deep well jet pump to overcome the restrictions of an aboveground jet ejector and the 25-foot suction limit. Both shallow well and deep well jets use foot valves or check valves in drilled-well applications. In driven wells using well points, a shallow well installation uses a check valve near the jet ejector while deep well installations use a foot valve at the bottom of the suction pipe to keep the pipe full of water between pump cycles (see *Figure 2*).

**Figure 2. Deep well jet pump cutaway**




The depth from which the water is drawn and the ability to build significant pressure limit the performance of jet pumps. For example, a typical ½ horsepower (hp) shallow well jet pump will only produce about 8 gallons per minute (gpm) at a 15-foot suction lift at 40 pounds per square inch (psi). Likewise, a typical ½ hp deep well jet pump will only pump 5.5 gpm from a 60-foot water level. Nevertheless, jet pumps remain popular as over 400,000 are sold annually in the United States (see *Table 1*).

**Table 1. Water System Council regional shipments (units)**

| Jet Pumps | | Submersible Pumps | | All Pumps | |
|---|---|---|---|---|---|
| **Year 1999** | | | | | |
| Northeast | 34,619 | Northeast | 91,594 | Northeast | 126,213 |
| Mid-Atlantic | 74,594 | Mid-Atlantic | 150,755 | Mid-Atlantic | 225,349 |
| Southeast | 205,767 | Southeast | 175,347 | Southeast | 381,114 |
| Northwest | 13,538 | Northwest | 44,673 | Northwest | 58,211 |
| Midwest | 76,143 | Midwest | 143,600 | Midwest | 219,743 |
| Southwest | 40,952 | Southwest | 113,910 | Southwest | 154,862 |
| West | 19,806 | West | 28,373 | West | 48,179 |
| **Total** | **465,419** | **Total** | **748,252** | **Total** | **1,213,671** |
| **Year 2000** | | | | | |
| Northeast | 33,739 | Northeast | 87,291 | Northeast | 121,030 |
| Mid-Atlantic | 55,775 | Mid-Atlantic | 140,285 | Mid-Atlantic | 196,060 |
| Southeast | 209,324 | Southeast | 181,808 | Southeast | 391,132 |
| Northwest | 12,633 | Northwest | 49,314 | Northwest | 61,947 |
| Midwest | 75,348 | Midwest | 146,536 | Midwest | 221,884 |
| Southwest | 45,942 | Southwest | 114,557 | Southwest | 160,499 |
| West | 18,550 | West | 27,631 | West | 46,181 |
| **Total** | **451,311** | **Total** | **747,422** | **Total** | **1,198,733** |
| **Year 2001** | | | | | |
| Northeast | 37,862 | Northeast | 89,062 | Northeast | 126,924 |
| Mid-Atlantic | 55,847 | Mid-Atlantic | 147,161 | Mid-Atlantic | 203,008 |
| Southeast | 196,058 | Southeast | 190,473 | Southeast | 386,531 |
| Northwest | 12,613 | Northwest | 40,146 | Northwest | 52,759 |
| Midwest | 66,767 | Midwest | 159,339 | Midwest | 226,106 |
| Southwest | 41,194 | Southwest | 99,314 | Southwest | 140,508 |
| West | 18,809 | West | 30,300 | West | 49,109 |
| **Total** | **429,150** | **Total** | **755,795** | **Total** | **1,184,945** |
| **January—June 2002** | | | | | |
| Northeast | 20,358 | Northeast | 47,244 | Northeast | 67,602 |
| Mid-Atlantic | 36,293 | Mid-Atlantic | 85,397 | Mid-Atlantic | 121,690 |
| Southeast | 95,153 | Southeast | 109,478 | Southeast | 204,631 |
| Northwest | 7,224 | Northwest | 20,098 | Northwest | 27,322 |
| Midwest | 30,521 | Midwest | 76,846 | Midwest | 107,367 |
| Southwest | 24,011 | Southwest | 59,015 | Southwest | 83,026 |
| West | 10,124 | West | 17,335 | West | 27,459 |
| **Total** | **223,684** | **Total** | **415,413** | **Total** | **639,097** |

## *Submersible water well pumps*

Simply put, submersible water well pumps "push" the water out of the well rather than "pull" the water out like jet pumps. Submersible well pumps are complete units with a pump end made up of a series of matching impellers and diffusers called stages, and an attached motor to turn the impellers and diffusers in the pump end. The submersible pump is submerged in the water down in the well and drives the water up the discharge piping to the pressure tank.

Submersible pump performance is a function of capacity and pressure. A submersible pump is designed to deliver certain flows at given pressures from specific pumping levels. The design of the impellers and diffuser determine the capacity and pressure of a submersible pump end. Capacity is, for the most part, based on the width of the impeller and diffuser. The pressure is dependent on the diameter of the impeller, the number of impellers, and the speed at which the impellers rotate. Most U.S. residential submersible pumps are 4-inch pumps coupled with constant speed, 4-inch motors operating at 3,450 revolutions per minute (rpm).

Pump manufacturers normally design their pumps to fall into ranges such as 10-25 gpm. Within these gpm ranges, a number of motor choices will be offered based on the proper combination of capacity to pumping level to horsepower. It's important to remember that horsepower by itself isn't the arbiter of submersible pump performance. Selection of a pump based solely on horsepower is a common error.

Residential submersible pump motors are manufactured in either a 2-wire

or 3-wire configuration. A 2-wire pump motor doesn't have a control box with a motor start capacitor, but rather includes the start capacitor in the submerged pump motor. A 2-wire pump motor is wired directly to the pressure switch and 3-wire submersible pump motors are wired from the well to a wall-mounted control box with relay and start capacitor and then to the pressure switch.

## Weighing the pros and cons

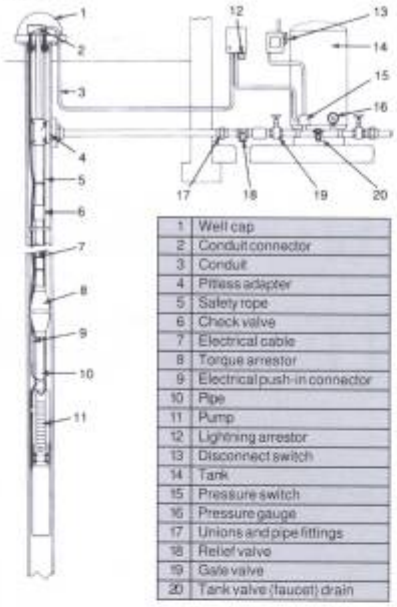
The clearest benefit of the submersible pump over the jet pump is the ability to deliver higher capacities from deeper levels at significant pressures to the household water system. Of course, a negative is that a submersible pump must be pulled from the well to be serviced; not so with a jet pump, unless it's a deep well installation with a faulty jet ejector (see *Figure 3*).

Nationally, submersible water well pumps have become more popular than jet pumps in residential well installations; however, there are areas where jet pumps clearly outstrip submersible pump installations. Generally, jet pumps are more common in warmer climates and areas with higher water tables (see *Table 1*).

## Emerging pump technology

Within the last several years pump manufacturers have recognized an increasing demand from private water system consumers for a "constant pressure" municipal type water system. Essentially, a constant pressure private water system eliminates the pressure and volume fluctuations experienced in traditional private water systems and operates much like a municipal supply. A traditional private water system includes a pump with a fixed pumping capacity and is controlled by a pressure switch which normally turns the pump on and off in a 20 psi range. (A common pressure switch setting is '40/60', that means the pump turns on when the water system pressure drops below 40 psi and the pump shuts off when the system pressure reaches 60 psi.) Because of a constant speed motor a regular jet or submersible pump can't increase volume based on demand. Likewise, because of the 20 psi pressure differential from the pressure switch, a traditional private water system doesn't deliver the normal steady pressure of a municipal water supply.

**Figure 3. Typical components of a submersible pump water system**



| | |
|---|---|
| 1 | Well cap |
| 2 | Conduit connector |
| 3 | Conduit |
| 4 | Pitless adapter |
| 5 | Safety rope |
| 6 | Check valve |
| 7 | Electrical cable |
| 8 | Torque arrestor |
| 9 | Electrical push-in connector |
| 10 | Pipe |
| 11 | Pump |
| 12 | Lightning arrestor |
| 13 | Disconnect switch |
| 14 | Tank |
| 15 | Pressure switch |
| 16 | Pressure gauge |
| 17 | Unions and pipe fittings |
| 18 | Relief valve |
| 19 | Gate valve |
| 20 | Tank valve (faucet) drain |

Using variable speed motor technology, several pump manufacturers have introduced "constant pressure" submersible pumping systems. These systems, still very much in the developing stages, maintain a reasonably constant volume and pressure profile as the demand for water varies.

## Conclusion

This is an exciting time in the private water system and water well pump industry. As larger homes are being built on private wells, with correspondingly larger water supply needs, the challenges of sizing an adequate private water supply system have never been greater. The challenge for the private water system installer is to make sure that the right pump and water system have been installed to produce the water needs—supply and pressure—that the water treatment equipment, plumbing fixtures and lifestyle of the consumer demand.


## Acknowledgment

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# TYPES AND CHARACTERISTICS OF PUMPS USED IN PRIVATE WATER SUPPLY SYSTEMS

| WELL TYPE | PUMP TYPE | NORMAL CAPACITY RANGE (GPH) | PRACTICAL SUCTION LIFT (FT) * | MAX. PRACTICAL PUMPING DEPTH (FT) | USUAL DISCHARGE PRESSURE RANGE (PSI) | REMARKS |
|---|---|---|---|---|---|---|
| SHALLOW WELL | Shallow Well Jet (Jet on pump) | 200-1500 | 20-25 | 25 | 20-40<br>30-50 | 1. Simple in construction.<br>2. Easy to service.<br>3. Can be used with 1 inch & larger wells.<br>4. Less efficient hydraulics. |
| | Piston or Reciprocating | 200-800 | 20-25 | 25 | 20-40<br>30-50<br>40-60 | 1. Adaptable to low capacity & high head.<br>2. Handles air without losing prime.<br>3. No longer widely used.<br>4. Can be used with 1 inch & larger wells. |
| | Straight Centrifugal (Single & multi stage) | 500-2000 | 15-20 | 20 | 20-40<br>30-50 | 1. Suitable for high capacities.<br>2. Efficient hydraulics.<br>3. Can be used with 1 inch & larger wells.<br>4. Simple & easy to service. |
| DEEP WELL | Deep Well Jet (single and multi stage)<br>(Jet in well) | 200-600 | 15-20<br>(ft. below jet) | 200 | 20-40<br>30-50<br>40-60 | 1. Simple in construction & operation.<br>2. No moving parts in well.<br>3. Less efficient hydraulics.<br>4. Can be installed on 2 inch & 3 inch wells.<br>5. Can be located away from well. |
| | Submersible | 200-3000 | Pump & motor submerged | 600 | 30-50<br>40-60<br>50-70 | 1. Suitable for deep settings.<br>2. Adaptable to frost proof installations.<br>3. Efficient hydraulics.<br>4. Available in wide range of heads & capacities.<br>5. Only available for 3 inch or larger wells. |
| | Piston or Reciprocating | 200-800 | 20-25 | 150 | 20-40<br>30-50<br>40-60 | 1. Suitable for deep settings.<br>2. Adaptable to frost proof installations.<br>3. Efficient hydraulics. |

**** Practical suction at sea level. Reduce 1 foot for each 1000 feet above sea level.***

# ELECTRICAL CODE REQUIREMENTS
# FOR WELL & PUMP INSTALLATIONS

## Introduction

The electrical wiring of a water well and pump installation is regulated by the Michigan Electrical Administrative Act (MEAA) (1956 PA 217) for licensing and exceptions, rather than the Michigan Water Well Construction and Pump Installation Code (Part 127, 1978 PA 368). Registered Water Well Drilling and Pump Installation Contractors are exempt from having an electrical license for residential single-family installations only.

Local and state electrical inspectors have authority for enforcement of electrical code provisions. Local health department officials who inspect water wells should refer electrical code violations to the electrical inspector or building official having jurisdiction.

Permits for the electrical circuit for the pump are required to be obtained from the electrical code official. Permits may be obtained by registered well drillers and pump installers.

Electrical hook-ups for water wells serving the public and all other wells that do not serve a single-family dwelling (such as agricultural irrigation wells, fire protection wells, and nonpotable industrial wells) must be performed by a licensed electrical contractor.

The MEAA and the state electrical code are implemented by:

***Michigan Department of Energy, Labor & Economic Growth***
***Bureau of Construction Codes***
***Electrical Division***
***2501 Woodlake Circle, Second Floor***
***Okemos, MI 48864***
***(517) 241-9320***

***Mailing Address: P.O. Box 30254, Lansing, MI 48909***

Michigan's electrical code is the National Electrical Code 1999, with special Michigan amendments. The NEC 1999 and NEC Handbook 1999 are available from the National Fire Protection Association, Batterymarch Park, P.0. Box 9146, Quincy, MA 02269-9959, phone 1-800-344-3555.

**Electrical Code Requirements for a Typical Submersible Pump Installation at a Single-Family Residence:**

**I. Electrical cable from submersible pump to wellhead:**

A. Cable Material: Type UF with surface marking of "submersible water pump cable" or "pump cable."

B. Cable protection: The cable inside the casing shall be protected from damage by the use of cable guards, or by securely attaching the cable to the drop pipe.

**II. Underground electrical cable from well to house:**

A. Cable Material:

1. Direct bury - Type UF or USE.
2. Inside a raceway or conduit - Type RHW, TW, THW, THHW, THWN, XHHW, or ZW.

B. Conduit Raceway:

1. The electrical cable or wiring on the outside of the casing shall be protected by a rigid conduit from the well cap/seal to a point belowgrade.
   a. The rigid conduit must be securely attached to the well cap/seal and must extend belowgrade to the minimum depth required for the cable (See #3 below).
   b. The rigid conduit must be provided with an electrical bushing or fitting at the point where the cable enters and leaves the conduit. This bushing or fitting protects against cable damage due to abrasion.

2. Types of conduit approved for submersible pump installations:
   a. Rigid Metal Conduit - must be galvanized.
   b. Rigid Nonmetallic Conduit - must be grey (color designated for electrical components) PVC plastic, schedule 40 or 80.
   c. Intermediate Metal Conduit

3. Minimum depth of bury:

| Feeder/raceway type | Minimum bury depth |
|---|---|
| Direct bury cable w/no raceway …… | 24 inches |
| Rigid metal conduit from well to building …… | 6 inches |
| Rigid nonmetallic conduit from well to building …….. | 18 inches |
| Any of the above under a driveway or parking area .. | 18 inches |

4. Splices and taps - Direct bury conductors or cables, when underground, shall be permitted to be spliced and tapped without the use of splice boxes. The splices and taps shall be made by approved methods and with identified materials.

**III. Cables under a building**: - Must be installed in a raceway.

**IV. Cables through a foundation or basement wall**:

A. Type UF cable shall not be embedded in poured cement, concrete, or aggregate.

B. The cable must be protected from damage by the use of rigid conduit with approved bushings. The conduit shall be sealed after cable installation to prevent the passage of moisture through the conduit.

**V. <u>Cable from the foundation or basement inside wall to the first point of attachment in the building:</u>**

A. The cable must be enclosed in conduit. The conduit may be any one of the following types:

1. Intermediate Metal Conduit
2. Rigid Metallic Conduit
3. Rigid Nonmetallic Conduit
4. Electrical Metallic Tubing
5. Flexible Metallic Tubing
6. Flexible Metal Conduit
7. Liquidtight Flexible Metal Conduit
8. Liquidtight Flexible Nonmetallic Conduit

B. The conduit shall be used only with those types of fittings identified for such use.

**VI. <u>Grounding Requirements</u>:**

A. Submersible pumps - The frame of the submersible pump motor must be bonded to the equipment grounding conductor installed with the branch circuit.

B. Steel casing with submersible pump.

1. Where a submersible pump is used in steel well casing, the well casing shall be bonded to the pump circuit equipment grounding conductor.
2. The casing may be grounded by one of the following methods:
   a. With the use of a "U" bolt type electrical grounding clamp (a water bond clamp) on the outside of the casing. The ground wire extends from the grounding clamp into the conduit on the outside of the casing and then into the well cap for bonding to the branch circuit equipment grounding conductor. An inhibitor paste should be used on the grounding clamp and casing at the bonding location to prevent corrosion,

OR

   b. For those pitless adapters using a support pipe hanging from the top of the casing, a grounding lug may be tapped into the support bridge resting on the top edge of the casing. The ground wire would extend from the grounding lug in the bridge to the equipment ground wire.
3. Clamp-on saddle type pitless adapters should not be used as the point of attachment (bonding) for the casing grounding conductor. Dielectric corrosion may cause failure of the pitless adapter "U" bolt or damage to the saddle of the adapter.

4. Holes **shall not** be drilled into the casing wall for grounding lug installation. Drilling a hole in the well casing violates R 325.1627 of Part 127, 1978 PA 368.

C. Metal well cap/seals - Where a submersible pump is used, and the well cap/seal is metal, the cap/seal shall be grounded as follows:

1. The grounding conductor shall be installed such that the cap can be loosened and removed without disconnecting the grounding conductor.
2. A grounding lug shall be provided on the inside of the well cap. The grounding lug shall be aluminum or copper.
3. The well cap/seal grounding conductor shall be bonded to one of the following:
   a. The pump circuit equipment grounding conductor.
   b. The equipment grounding bus of the panelboard supplying the submersible pump.
   c. A steel casing which has been grounded as required in VI-B above.

**Electrical Troubleshooting for Pumps**

The examination to become a Michigan Registered Water Well Drilling Contractor or Pump Installer includes a hands-on submersible pump electrical troubleshooting exercise. The exercise tests whether an applicant can correctly diagnose an electrical problem such as a faulty main motor winding, broken motor lead, or damaged wire insulation.

Training on pump troubleshooting is available through the *Ground Water & Wells Fundamentals Course,* co-sponsored by the Michigan Ground Water Association, Inc. and the Department of Environmental Quality. Information about the course dates, location, and cost can be obtained by visiting MGWA's website at www.michigangroundwater.com.

Pump troubleshooting training materials are also available from pump or motor manufacturers. Some examples are Franklin Electric's *Submersible Pump Motor Application, Installation, Maintenance Manual,* available online at www.franklin-electric.com/Manual/contents.html. or Goulds Pump's *Single Phase Service Manual for Jets and Subs,* at www.goulds.com/pdf/GSSINGLE.pdf.