THIS INFORMATION NEEDS TO REPLACE
CHAPTER 7 (SUBMERSIBLE PUMPS) OF THE
OPERATION AND MAINTENANCE MANUAL,
QIKIQTARJUAQ WATER PUMPING UPGRADE,
OCTOBER 2009

NEW SUBMERSIBLE PUMPS

QIKIQTARJUAQ
TRUCKFILL STATION

QIKIQTARJUAQ, Nunavut

JUNE 2010

OWNER:	GOVERNMENT OF NUNAVUT
GENERAL CONTRACTOR:	KUDLIK CONSTRUCTION INC.
MECHANICAL & ELECTRICAL Contractor:	SIFEC NORTH INC.

Project History

Owner:	**Government of Nunavut** **Community Government Services** **Projects Division** **P.O. Box 379** **Pond Inlet, Nunavut** **X0A 0S0** **Tel: (867) 899-7317** **Fax: (867) 899-7328**
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Chapter 1 Mechanical

1.1 INSTALLATION REPORT

1.1.1 Description of New Pumps

In june 2010, original GrundFos Pumps 7.5HP have been replace by New GrundFos Pump 15HP Model 230S150-4, 208V 3PH.

Here are some number following first pump start up :

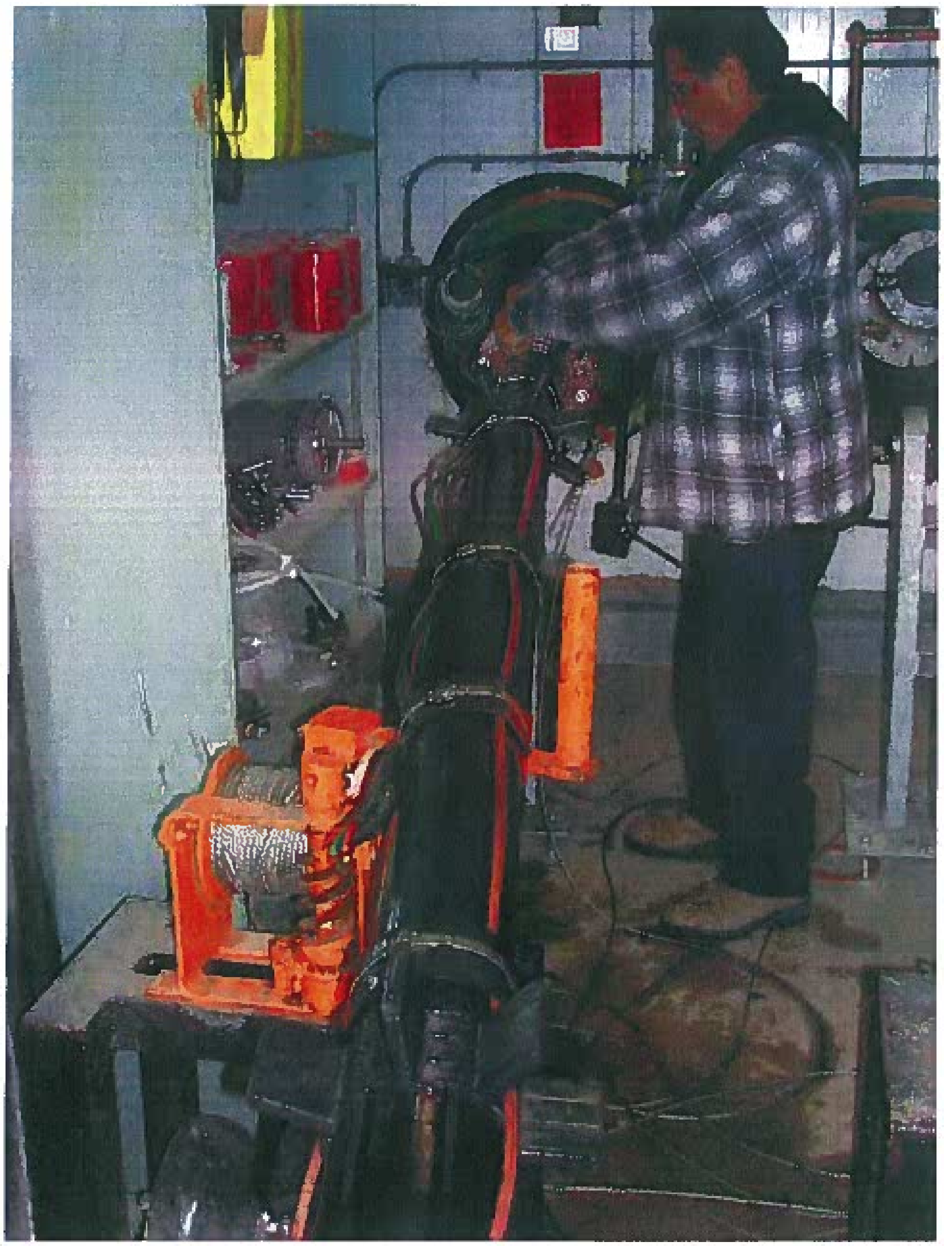
- Typical flow no filter in line with 7.5 HP pumps :
  - 250 gal/min.
- Typical flow no filter in line with new 15 HP pumps:
  - 325 gal/min
- Typical flow with new filter in line with new 15 HP pumps:
  - 260 gal/min
- Typical flow with new filter in line after 5 truck fill with new 15 HP pumps:
  - 200 gal/min

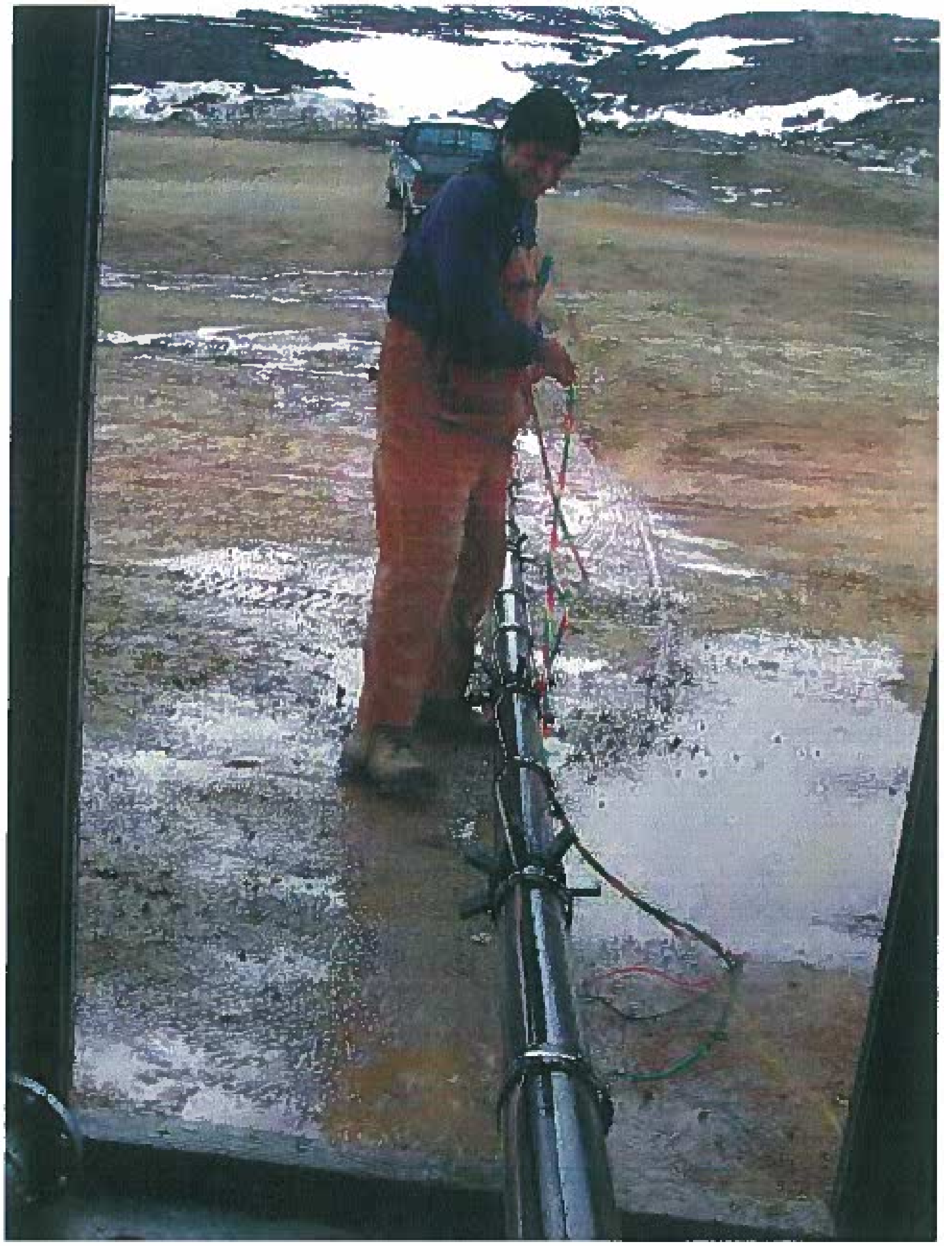
1.1.2 Description of Soft Start

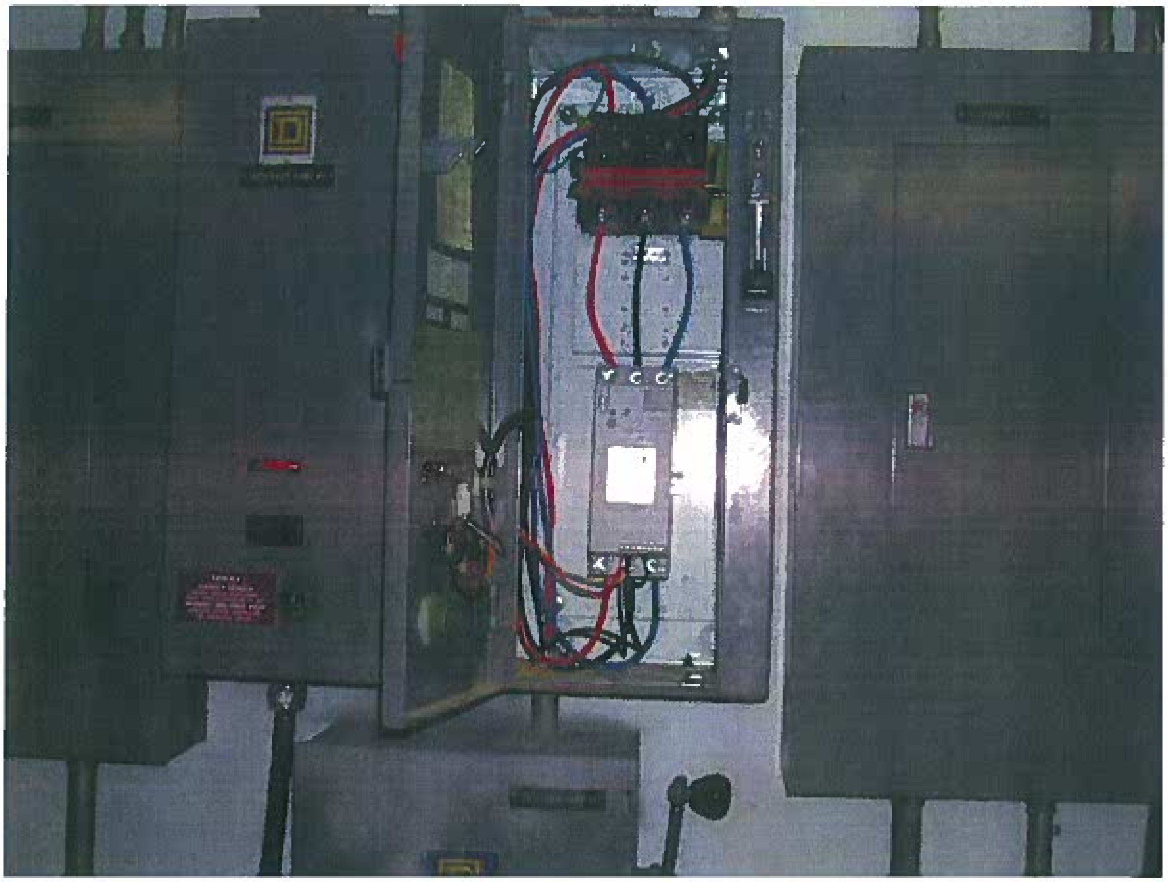
New soft start installed on each pump is performing great and should give great protection for pump.

- rotation protection
- voltage unbalance and/or lost of phase
- Precise over load curve
- load unbalance protection
- soft ramp to full speed
- Maintenance free (no mechanical contact)

1.1.3 Pictures







Chapter 2 O&M

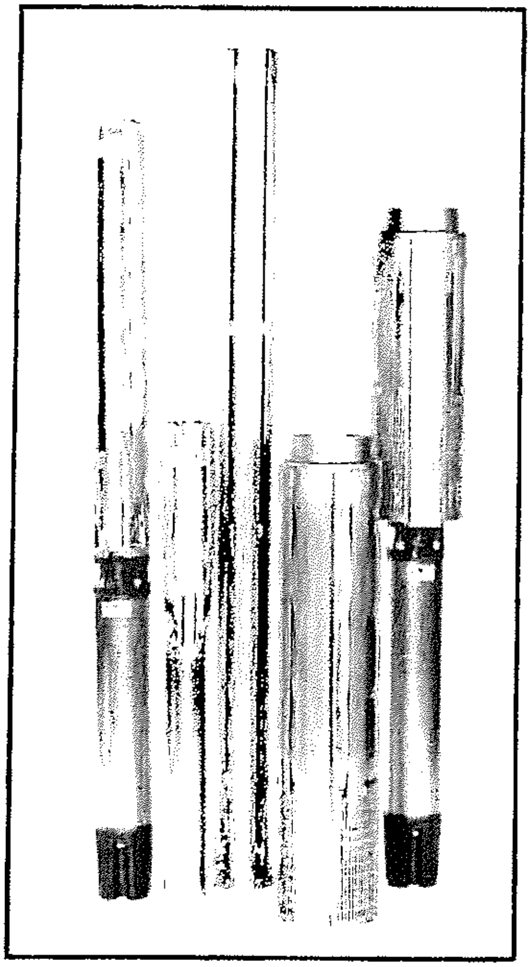
2.1 MECHANICAL & ELECTRICAL– O&M

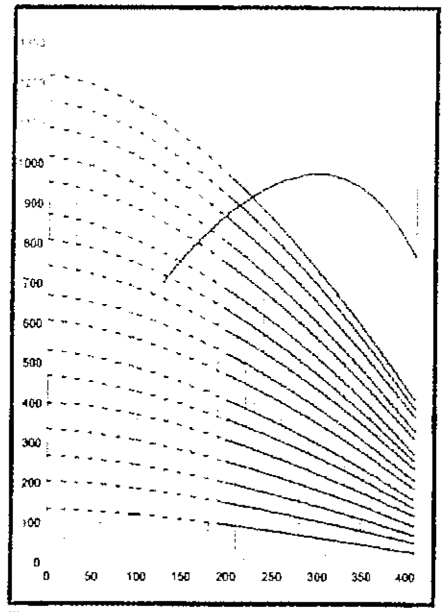
2.1.1 Grundfos Pump 230S150-4

2.1.2 Allen-Bradley SoftStart #150C60NBD

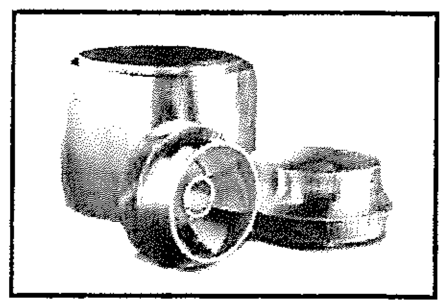
Performance Curves and Technical Data

6-Inch, 8-Inch & 10-Inch Submersible Pumps



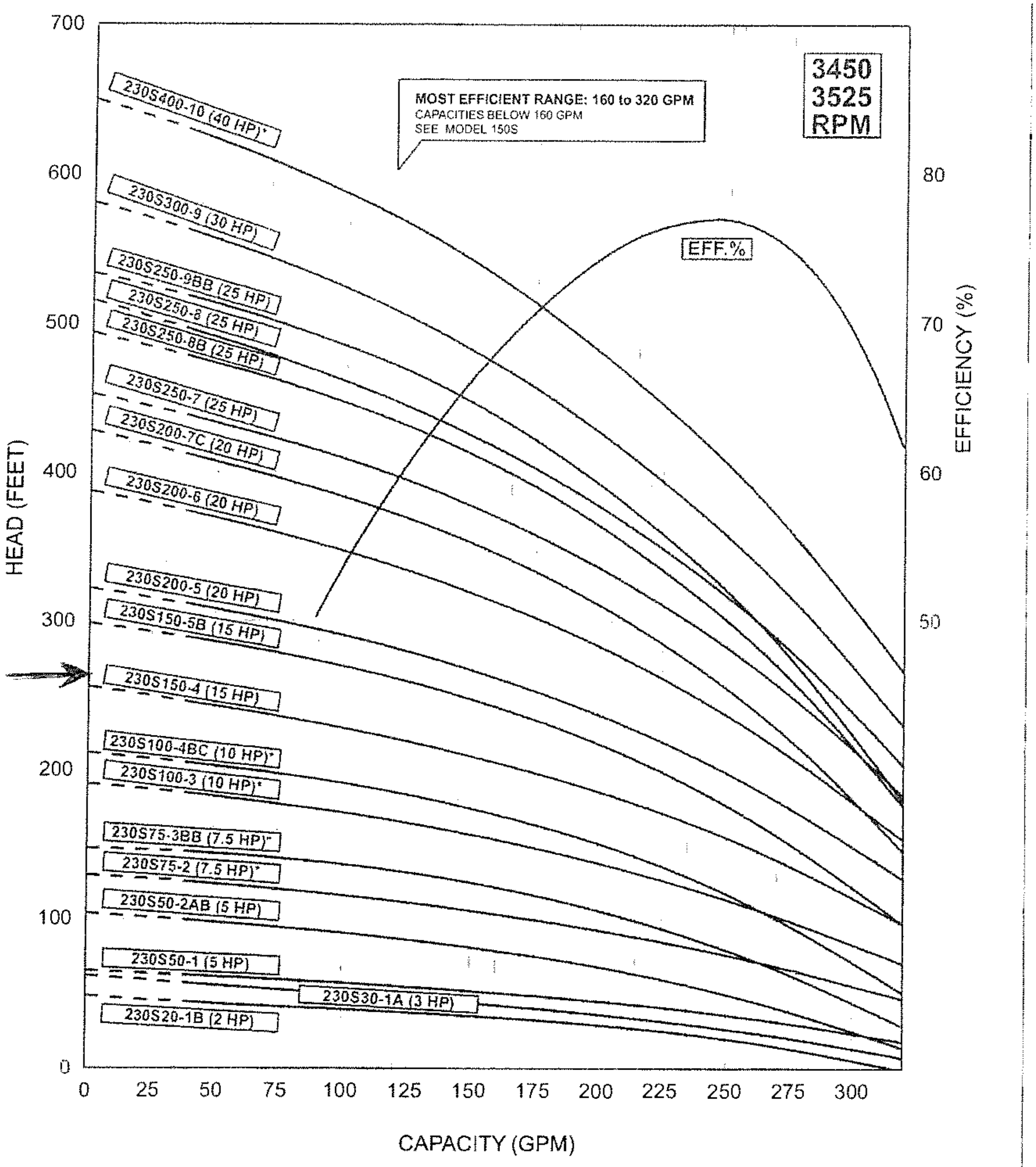


Performance Curves



Materials of Construction

FLOW RANGE: 160 -320 GPM **OUTLET SIZE: 3" NPT** **NOMINAL DIA. 6"**



SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE
4" MOTOR STANDARD, 7.5 HP/3450 RPM
6" MOTOR STANDARD, 10-60 HP/3450 RPM
8" MOTOR STANDARD, 75 HP/3525 RPM
* Alternate motor sizes available

Performance conforms to ISO 9906 1999 (E) Annex A
Minimum submergance is 8 feet

DIMENSIONS AND WEIGHTS

MODEL NO.	FIG	HP	MOTOR SIZE	DISCH. SIZE	DIMENSIONS IN INCHES A	B	C	D	E	APPROX. SHIP WT.
230S20-1B	A	2	4"	3" NPT	29.7	15.1	14.6	3.8	5.7	44
230S30-1A	A	3	4"	3" NPT	38.2	23.6	14.6	3.8	5.7	55
230S50-1	A	5	4"	3" NPT	44.2	29.6	14.6	3.8	5.7	65
230S50-2AB	A	5	4"	3" NPT	48.5	29.6	18.9	3.8	5.7	71
230S75-2	A	7.5	4"	3" NPT	48.5	29.6	18.9	3.8	5.7	88
230S75-2	A	7.5	6"	3" NPT	43.0	24.2	18.9	5.4	5.7	124
230S75-3BB	A	7.5	4"	3" NPT	53.5	29.6	23.9	3.8	5.7	96
230S75-3BB	A	7.5	6"	3" NPT	48.1	24.2	23.9	5.4	5.7	96
230S100-3	A	10	4"	3" NPT	67.8	43.9	23.9	3.8	5.7	146
230S100-3	A	10	6"	3" NPT	49.3	25.4	23.9	5.4	5.7	140
230S100-4BC	A	10	4"	3" NPT	72.3	43.9	28.4	3.8	5.7	147
230S100-4BC	A	10	6"	3" NPT	53.8	25.4	28.4	5.4	5.7	147
230S150-4	A	15	6"	3" NPT	56.4	28.0	28.4	5.4	5.7	161
230S150-5B	A	15	6"	3" NPT	60.8	28.0	32.8	5.4	5.7	165
230S200-5	A	20	6"	3" NPT	63.4	30.6	32.8	5.4	5.7	167
230S200-6	A	20	6"	3" NPT	67.8	30.6	37.3	5.4	5.7	186
230S200-7C	A	20	6"	3" NPT	67.8	30.6	37.3	5.4	5.7	202
230S250-7	A	25	6"	3" NPT	74.9	33.1	41.7	5.4	5.7	202
230S250-8B	A	25	6"	3" NPT	79.3	33.1	46.2	5.4	5.7	209
230S250-8	A	25	6"	3" NPT	79.3	33.1	46.2	5.4	5.7	209
230S250-9BB	A	25	6"	3" NPT	83.8	33.1	50.6	5.4	5.7	228
230S300-9	A	30	6"	3" NPT	86.3	35.7	50.6	5.4	5.7	228
230S400-10*	A	40	6"	3" NPT	95.9	40.81	55.1	5.4	5.7	234
230S400-11*	A	40	6"	3" NPT	100.3	40.81	59.5	5.4	5.7	273
230S400-12*	A	40	6"	3" NPT	104.8	40.81	64.0	5.4	5.7	279
230S400-13*	A	40	6"	3" NPT	109.2	40.81	68.4	5.4	5.7	284
230S500-14*	A	50	6"	3" NPT	130.7	57.83	72.9	5.4	5.7	388
230S500-15*	A	50	6"	3" NPT	135.2	57.83	77.3	5.4	5.7	393
230S500-16*	A	50	6"	3" NPT	139.6	57.83	81.8	5.4	5.7	399
230S600-17*	A	60	6"	3" NPT	151.2	63.83	87.4	5.4	5.7	438
230S600-18*	A	60	6"	3" NPT	155.6	63.83	91.8	5.4	5.7	445
230S600-19*	A	60	6"	3" NPT	160.1	63.83	96.3	5.4	5.7	449
230S600-17	A	60	8"	3" NPT	129.2	41.79	87.4	7.5	7.6	544
230S600-18	A	60	8"	3" NPT	133.6	41.79	91.8	7.5	7.6	551
230S600-19	A	60	8"	3" NPT	138.0	41.79	96.3	7.5	7.6	555
230S750-20**	B	75	8"	4" M-NPT	154.7	47.41	107.3	7.5	7.6	634
230S750-22**	B	75	8"	4" M-NPT	163.6	47.41	116.2	7.5	7.6	681

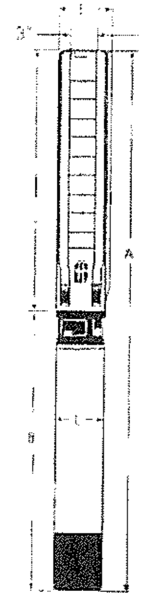


Fig. A

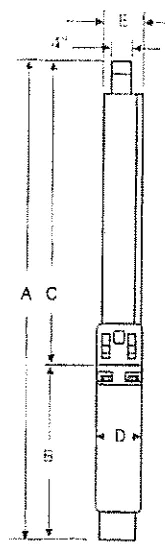


Fig. B

NOTES: All models suitable for use in 6" wells, unless equipped with 8" motor.
Weights include pump end with motor in lbs.
* Alternate motor sizes available.
** Built into sleeve, 4" NPT, 8" motor required.

6", 8" & 10" STAINLESS STEEL SUBMERSIBLE PUMPS

Installation and Operating Instructions

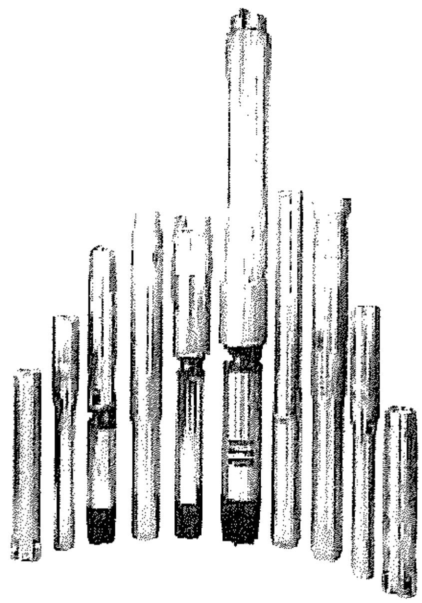


TABLE OF CONTENTS

Please leave these instructions with the pump for future reference.

GRUNDFOS
Leaders in Pump Technology

SAFETY WARNING

Grundfos Stainless Steel Submersible Pumps

Your Grundfos Submersible Pump is of the utmost quality. Combined with proper installation, your Grundfos pump will give you many years of reliable service.

To ensure the proper installation of the pump, carefully read the complete manual before attempting to install the pump.

Shipment Inspection

Examine the components carefully to make sure no damage has occurred to the pump-end, motor, cable or control box during shipment.

This Grundfos Submersible Pump should remain in its shipping carton until it is ready to be installed. The carton is specially designed to protect it from damage. During unpacking and prior to installation, **make sure that the pump is not dropped or mishandled.**

The motor is equipped with an electrical cable. Under no circumstance should the cable be used to support the weight of the pump.

You will find a loose data plate with an adhesive backing with the pump. The nameplate should be completed in pen and attached to the control box.

Pre-Installation Checklist

Before beginning installation, the following checks should be made. They are all critical for the proper installation of this submersible pump.

A. Condition of the Well

If the pump is to be installed in a new well, the well should be fully developed and bailed or blown free of cuttings and sand. The stainless steel construction of the Grundfos submersible make it resistant to abrasion; however, no pump, made of any material, can forever withstand the destructive wear that occurs when constantly pumping sandy water.

If this pump is used to replace an oil-filled submersible or oil-lubricated line-shaft turbine in an existing well, the **well must be blown or bailed clear of oil.**

Determine the maximum depth of the well, and the draw-down level at the pump's maximum capacity. Pump selection and setting depth should be based on this data.

The inside diameter of the well casing should be checked to ensure that it is not smaller than the size of the pump and motor.

B. Condition of the Water

Submersible pumps are designed for pumping clear and cold water that is free of air and gases. Decreased pump performance and life expectancy can occur if the water is not cold and clear or contains air and gasses.

Maximum water temperature should not exceed 102°F. Special consideration must be given to the pump and motor if it is to be used to pump water above 102°F.

The Grundfos stainless steel submersible is highly resistant to the normal corrosive environment found in some water wells. If water well tests determine the water has an excessive or unusual corrosive quality, or exceeds 102°F, contact your Grundfos representative for information concerning specially designed pumps for these applications.

C. Installation Depth

A check should be made to ensure that the installation depth of the pump will always be at least (5) five to (10) ten feet below the maximum draw-down level of the well. For flow rates exceeding 100 gpm, refer to performance curves for recommended minimum submergence.

The bottom of the motor should never be installed lower than the top of the well screen or within five feet of the well bottom.

If the pump is to be installed in a lake, pond, tank or large diameter well, the water velocity passing over the motor must be sufficient to ensure proper motor cooling. The minimum recommended water flow rates which ensure proper cooling are listed in Table A.

D. Electrical Supply

The motor voltage, phase and frequency indicated on the motor nameplate should be checked against the actual electrical supply.

Wire Cable Type

The wire cable used between the pump and control box or panel should be approved for submersible pump applications. The conductor may be solid or stranded. The cable may consist of individually insulated conductors twisted together, insulated conductors molded side by side in one flat cable or insulated conductors with a round overall jacket.

The conductor insulation should be type RW, RUW, TW, TWU or equivalent and must be suitable for use with submersible pumps. An equivalent Canadian Standards Association certified wire may also be used. See Table D for recommended sizes of cable lengths.

Splicing the Motor Cable

A good cable splice is critical to proper operation of the submersible pump and must be done with extreme care.

If the splice is carefully made, it will work as well as any other portion of the cable, and will be completely watertight.

Grundfos recommends using a heat shrink splice kit. The splice should be made in accordance with the kit manufacture's instructions. Typically a heat shrink splice can be made as follows:

1. Examine the motor cable and the drop cable carefully for damage.

2. Cut the motor leads off in a staggered manner. Cut the ends of the drop cable so that the ends match up with the motor leads (See Figure 4-A). On single-phase motors, be sure to match the colors.

3. Strip back and trim off 1/2 inch of insulation from each lead, making sure to scrape the wire bare to obtain a good connection. Be careful not to damage the copper conductor when stripping off the insulation.

4. Slide the heat shrink tubing on to each lead. Insert a properly sized "Sta-kon" type connector on each lead, making sure that lead colors are matched. Using a "Sta-kon" crimping pliers, indent the lugs (Figure 4-B). Be sure to squeeze hard on the pliers, particularly when using large cable.

5. Center the heat shrink tubing over the connector. Using a propane torch, lighter, or electric heat gun, uniformly heat the tubing starting first in the center working towards the ends (Figure 4-C).

6. Continue to apply the heat to the tubing using care not to let the flame directly contact the tubing. When the tubing shrinks and the sealant flows from the ends of the tubing, the splice is complete (Figure 4-D).

FIGURE 4-A

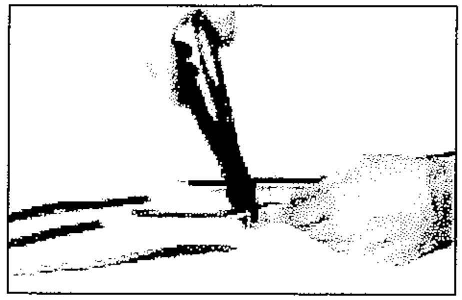


FIGURE 4-B

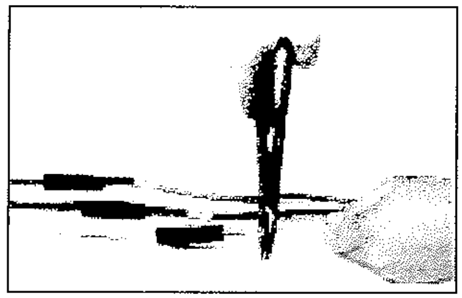


FIGURE 4-C

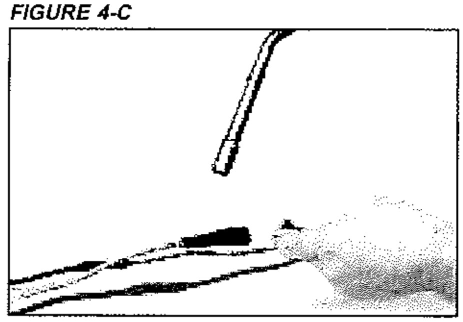
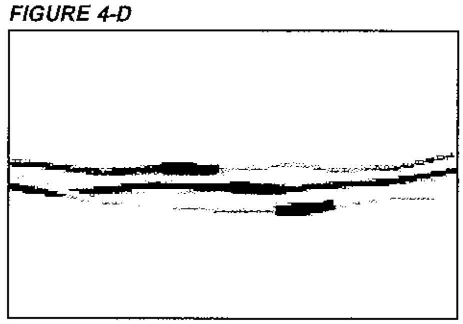
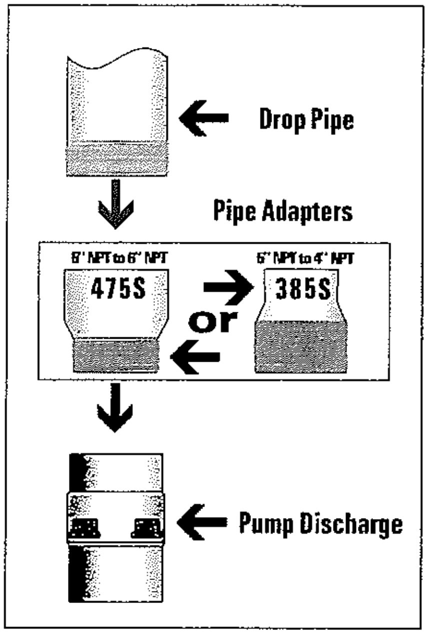


FIGURE 4-D



The riser pipe or hose should be properly sized and selected based on estimated flow rates and friction-loss factors.



If An Adapter Needs To Be Installed:

It is recommended to first install the drop pipe to the pipe adapter. Then install the drop pipe with the adapter to the pump discharge.

A back-up wrench should be used when the riser pipe is attached to the pump. The pump should be gripped only by the flats on the top of the discharge chamber. The body of the pump, cable guard or motor should not be gripped under any circumstance.

If Steel Riser Pipe Is Used:

We recommend that steel riser pipes always be used with the larger submersibles. An approved pipe thread compound should be used on all joints. Make sure the joints are adequately tightened in order to resist the tendency of the motor to loosen the joins when stopping and starting.

When tightened, the first section of the riser pipe must not come in contact with the check valve retainer in the discharge chamber of the pump.

After the first section of the riser pipe has been attached to the pump, the lifting cable or elevator should be clamped to the pipe. **Do not clamp the pump.** When raising the pump and riser section, be careful not to place bending stress on the pump by picking it up by the pump-end only.

Make sure that the electrical cables are not cut or damaged in any way when the pump is being lowered in the well.

The drop cable should be secured to the riser pipe at frequent intervals to prevent sagging, looping or possible cable damage. Nylon cable clips or waterproof tape may be used. The cable splice should be protected by securing it with clips or tape just above and below the splice.

If Plastic or Flexible Riser Pipe Is Used:

It is recommended that plastic type riser pipe be used only with the smaller domestic submersibles. The pipe manufacturer or representative should be contacted to insure the pipe type and physical characteristics are suitable for this use. Use the correct joint compound recommended by the pipe manufacturer. In addition to making sure that joints are securely fastened, the use of a torque arrester is recommended when using plastic pipe.

Installation

Do not connect the first plastic or flexible riser section directly to the pump. Always attached a metallic nipple or adapter into the discharge chamber of the pump. When tightened, the threaded end of the nipple or adapter must not come in contact with the check valve retainer in the discharge chamber of the pump.

The drop cable should be secured to the riser pipe at frequent intervals to prevent sagging, looping and possible cable damage. Nylon cable clips or waterproof tape may be used. The cable splice should be protected by securing it with clips or tape just above each joint.

IMPORTANT – Plastic and flexible pipe tend to stretch under load. This stretching must be taken into account when securing the cable to the riser pipe. Leave 3 to 4 inches of slack between clips or teped points to allow for this stretching. This tendency for plestic and flexible pipe to stretch will also affect the calculation of the pump setting depth. As a general rule, you can estimate that plastic pipe will stretch to approximately 2% of its length. For example, if you installed 200 feet of plastic riser pipe, the pump may actually be down 204 feet. If the depth setting is critical, check with the manufacturer of the pipe to determine who to compensate for pipe stretch.

When plastic riser pipe is used, it is recommended that a safety cable be attached to the pump to lower and raise it.

Check valves:
A check valve should always be installed at the surface of the well. In addition, for installations deeper than 200 feet, check valves should be installed at no more then 200 foot intervals.

Protect the well from contamination:
To protect against surface water entering the well and contaminating the water source, the well should be finished off above grade, and a locally approved well seal or pitless adapter unit utilized.

Electrical

WARNING: To reduce the risk of electrical shock during operation of this pump requires the provision of acceptable grounding. If the meens of connection to the supply connected box is other than grounded metal conduit, ground the pump back to the service by connecting a copper conductor, at least the size of the circuit supplying the pump, to the grounding screw provided within the wiring compartment.

All electrical work should be performed by a qualified electrician in accordance with the latest edition of the National Electrical Code, local codes and regulations.

Verification of the electrical supply should be made to ensure the voltage, phase and frequency match that of the motor. Motor voltage, phase, frequency and full-load current information can be found on the nameplate attached to the motor. Motor electrical data can be found in Table E.

If voltage variations are larger than ± 10%, do not operate the pump.

Direct on-line starting is used due to the extremely fast run-up time of the motor (0.1 second maximum), and the low moment of inertia of the pump and motor. Direct on-line starting current (locked rotor amp) is between 4 and 6.5 times the full-load current. If direct on-line starting is not acceptable and reduced starting current is required, an auto-transformer or resistant starters should be used for 5 to 30 HP motors (depending on cable length). For motors over 30 HP, use auto-transformer starters.

Engine-Driven Generators

If the submersible pump is going to be operated using an engine driven generator, we suggest the manufacturer of the generator be contracted to ensure the proper generator is selected and used. See Table B for generator sizing guide.

If power is going to be supplied through transformers, Table C outlines the minimum KVA rating and capacity required for satisfactory pump operation.

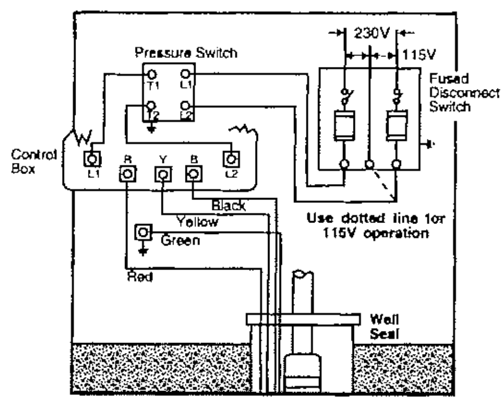
Control Box/Panel Wiring

1. Single-Phase Motors:
Single-phase motors must be connected as indicated in the motor control box. A typical single-phase wiring diagram using a Grundfos control box is shown (Figure 6-A).

2. Three-Phase Motors:
Three-phase motors must be used with the proper size and type of motor starter to ensure the motor is protected against damage from low voltage, phase failure, current unbalance and overload current. A properly sized starter with ambient-compensated extra quick-trip overloads must be used to give the best possible motor winding protection. ***Each of the three motor legs must be protected with overloads.*** The thermal overloads must trip in less than 10 seconds at locked rotor (starting) current. For starter and overload protection guide, see Table H. A three-phase motor wiring diagram is illustrated below (See Figure 6-B).

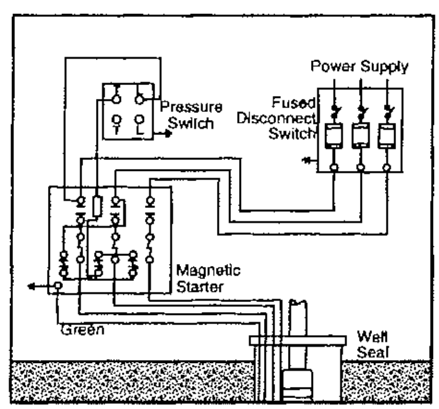
Pumps should NEVER be started to check rotation unless the pump is totally submerged. Severe damage may be caused to the pump and motor if they are run dry.

FIGURE 6-A



Single-Phase Wiring Diagram for GRUNDFOS Control Boxes

FIGURE 6-B



Three-Phase Wiring Diagram for GRUNDFOS and FRANKLIN Motors

High Voltage Surge Arresters

A high voltage surge arrester should be used to protect the motor against lightning and switching surges. Lightning voltage surges in power lines are caused when lightning strikes somewhere in the area. Switching surges are caused by the opening and closing of switches on the main high-voltage distribution power lines.

The correct voltage-rated surge arrester should be installed on the supply (line) side of the control box (Figure 6-C and 6-D). The arrester must be grounded in accordance with the National Electrical Code and local codes and regulations

FIGURE 6-C

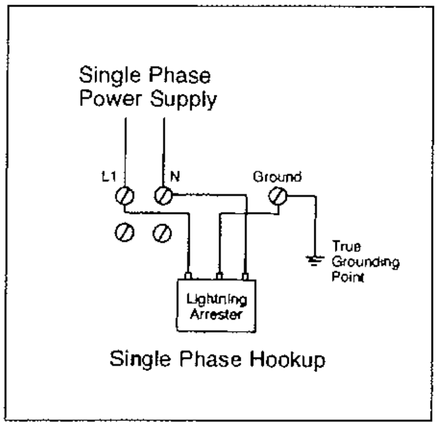
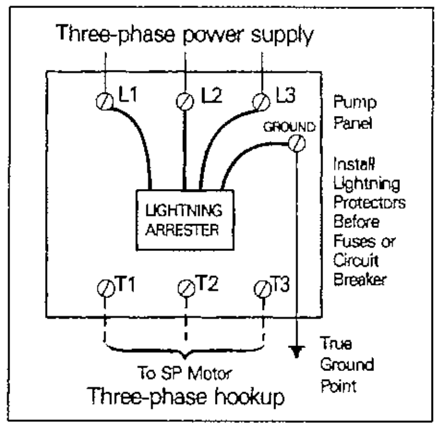


FIGURE 6-D



The warranty on all three-phase submersible motors is VOID if:

1. **The motor is operated with single-phase power through a phase converter.**
2. **Three-leg ambient compensated extra quick-trip overload protectors are not used.**
3. **Three-phase current unbalance is not checked and recorded. (See START-UP Section 7 for instructions.)**
4. **High voltage surge arresters are not installed.**

Control Box/Panel Grounding

The control box or panel shall be permanently grounded in accordance with the National Electrical Code and local codes or regulations. The ground wire should be a bare copper conductor at least the same size as the drop cable wire size. The ground wire should be run as short a distance as possible and be securely fastened to a true grounding point.

True grounding points are considered to be: a grounding rod driven into the water strata, steel well casing submerged into the water lower than the pump setting level, and steel discharge pipes without insulating couplings. If plastic discharge pipe and well casing are used or if a grounding wire is required by local codes, a properly sized bare copper wire should be connected to a stud on the motor and run to the control panel. Do not ground to a gas supply line. Connect the grounding wire to the ground point first and then to the terminal in the control box or panel.

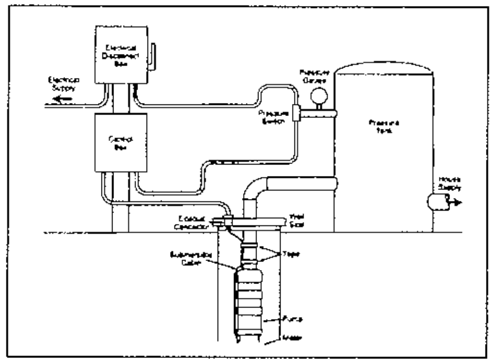
Operating Procedures

Wiring Checks and Installation

Before making the final surface wiring connection of the drop cable to the control box or panel, it is a good practice to check the insulation resistance to ensure that the cable and splice are good. Measurements for a new installation must be at least 2,000,000 ohm. Do not start the pump if the measurement is less than this.

If it is higher than 2,000,000 ohm, the drop cable should then be run through the well seal by means of a conduit connector in such a way as to eliminate any possibility of foreign matter entering the well casing. Condult should always be used from the pump to the control box or panel to protect the drop cable (See Figure 6-E). Finish wiring and verify that all electrical connections are made in accordance with the wiring diagram. Check to ensure the control box or panel and high voltage surge arrester have been grounded.

FIGURE 6-E



Start-Up

After the pump has been set into the well and the wiring connections have been made, the following procedures should be performed:

A. Attach a temporary horizontal length of pipe with installed gate valve to the riser pipe.
B. Adjust the gate valve one-third of the way open.
C. On three-phase units, check direction of rotation and current unbalance according to the instructions below. For single-phase units proceed directly to "Developing the Well."
D. Under no circumstances should the pump be operated for any prolonged period of time with the discharge valve closed. This can result in motor and pump damage due to overheating. A properly sized relief valve should be installed at the well head to prevent the pump from running against a closed valve.

Three-Phase Motors

1. Check the direction of rotation

Three-phase motors can run in either direction depending on how they are connected to the power supply. When the three cable leads are first connected to the power supply, there is a 50% chance that the motor will run in the proper direction. To make sure the motor is running in the proper direction, carefully follow the procedures below:

A. Start the pump and check the water quantity and pressure developed.
B. Stop the pump and interchange any two leads.
C. Start the pump and again check the water quantity and pressure.
D. Compare the results observed. The wire connection which gave the highest pressure and largest water quantity is the correct connection.

2. Check for current unbalance

Current unbalance causes the motor to have reduced starting torque, overload tripping, excessive vibration and poor performance which can result in early motor fellure. It is very important that current unbalance be checked In all three-phase systems. **Current unbalance between the legs should not exceed 5% under normal operating conditions.**

The supply power service should be verified to see if it is a two or three transformer system. If two transformers are present, the system is an "open" delta or wye. If three transformers are present, the system Is true three-phase.

Make sure the transformer ratings in kilovolt amps (KVA) is sufficient for the motor load. See Table C.

The percentage of current unbalance can be calculated by using the following formulas and procedures:

$$\text{Average current} = \frac{\text{Total of current values measured on each leg}}{3}$$

$$\text{\% Current unbalance} = \frac{\text{Greatest amp difference from the average}}{\text{average current}} \times 100$$

To determine the percentage of current unbalance:

A. Measure and record current readings in amps for each leg (hookup 1). Disconnect power.
B. Shift or roll the motor leads from left to right so the drop cable lead that was on terminal 1 is now on 2, lead on 2 is now on 3, and lead on 3 is now on 1 (hookup 2). Rolling the motor leads in this manner will not reverse the motor rotation. Start the pump, measure and record current reading on each leg. Disconnect power.
C. Again shift drop cable leads from left to right so the lead on terminal 1 goes to 2, 2 to 3 and 3 to 1 (hookup 3). Start pump, measure and record current reading on each leg. Disconnect power.
D. Add the values for each hookup.
E. Divide the total by 3 to obtain the average.
F. Compare each single leg reading from the average to obtain the greatest amp difference from the average.
G. Divide this difference by the average to obtain the percentage of unbalance.

Use the wiring hookup which provides the lowest percentage of unbalance. (See Table F for a specific example of correcting for three-phase power unbalance.)

Developing the Well

After proper rotation and current unbalance have been checked, start the pump and let it operate until the water runs clear of sand, silt and other impurities.

Slowly open the valve in small Increments as the water clears until the dseired flow rate is reached. Do not operate the pump beyond its maximum flow rating. **The pump should not be stopped until the water runs clear.**

Start-Up

If the water is clean and clear when the pump is first started, the valve should still be **slowly opened until the desired flow rate is reached.** As the valve is being opened, the drawdown should be checked to ensure the pump is always submerged. **The dynamic water level should always be more than 3 feet above the inlet strainer of the pump.**

Disconnect the temporary piping arrangements and complete the final piping connections.

Under no circumstances should the pump be operated for any prolonged period of time with the discharge valve closed. This can result in motor and pump damage due to overheating. A properly sized relief valve should be installed at the well head to prevent the pump from running against a closed valve.

Start the pump and test the system. Check and record the voltage and current draw on each motor lead.

Operation

1. The pump and system should be periodically checked for water quantity, pressure, drawdown, periods of cycling and operation of controls.

2. If the pump fails to operate, or there is a loss of performance, refer to Troubleshooting, Section 8.

Troubleshooting

The majority of problems that develop with submersible pumps are electrical, and most of these problems can be corrected without pulling the pump from the well. The following chart covers most of the submersible service work. As with any troubleshooting procedure, start with the simplest solution first; always make all the above-ground checks before pulling the pump from the well.

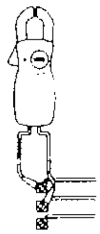
Usually only two instruments are needed – a combination voltmeter/ammeter, and an ohmmeter. These are relatively inexpensive and can be obtained from most water systems suppliers.

WHEN WORKING WITH ELECTRICAL CIRCUITS, USE CAUTION TO AVOID ELECTRICAL SHOCK. It is recommended that rubber gloves and boots be worn and that care is taken to have metal control boxes and motors grounded to power supply ground or steel drop pipe or casing extending into the well. WARNING: Submersible motors are intended for operation in a well. When not operated in a well, failure to connect motor frame to power supply ground may result in serious electrical shock.

Troubleshooting

Preliminary Tests

SUPPLY VOLTAGE



How to Measure

By means of a voltmeter, which has been set to the proper scale, measure the voltage at the control box or starter.

On single-phase units, measure between line and neutral.

On three-phase units, measure between the legs (phasas).

What it Means

When the motor is under load, the voltage should be within ± 10% of the nameplate voltage. Larger voltage varietion may cause winding damage.

Large variations in the voltage indicate a poor electrical supply and the pump should not be operated until these variations have been corrected.

If the voltage constantly remains high or low, the motor should be chenged to the correct supply voltage.

CURRENT MEASUREMENT

How to Measure

By use of an ammeter, set on the proper scale, measure the current on each power lead at the control box or starter. See Electrical Data, Table E, for motor amp draw information.

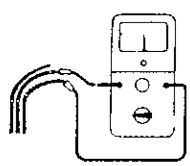
Current should be measured when the pump is operating at a constant discharge pressure with the motor fully loaded.

What it Means

If the amp draw exceeds the listed service factor amps (SFA) or if the current unbalance is greater than 5% between each leg on three-phase units, check for the following:

1. Bumt contacts on motor starter.
2. Loose terminals in starter or control box or possible cable defect. Check winding and insulation resistances.
3. Supply voltage too high or low.
4. Motor windings are shorted.
5. Pump is damaged, causing a motor overload.

WINDING RESISTANCE



How to Measure

Turn off power and disconnect the drop cable leads in the control box or starter. Using an ohmmeter, set the scale selectors to Rx1 for values under 10 ohms and Rx10 for values over 10 ohms.

Zero-adjust the meter and measure the resistance between leads. Record the values.

Motor resistance values can be found in Electrical Data, Table E. Cable resistance values are in Table G.

What it Means

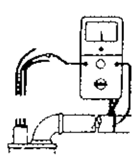
If all the ohm values are normal, and the cable colors correct, the windings are not damaged.

If any one ohm value is less than normal, the motor may be shorted.

If any one ohm velue is greater than normal, there is a poor cable connection or joint. The windings or cable may also be open.

If some of the ohm values are greater than normal and some less, the drop cable leads are mixed. To verify lead colors, see resistance values in Electrical Data, Table E.

INSULATION RESISTANCE



How to Measura

Turn off power and disconnect the drop cable leads in the control box or starter. Using an ohm or mega ohmmeter, set the scale selector to Rx 100K and zero-adjust the meter.

Measure the resistance between the lead and ground (discharge pipe or well casing, if steel).

What it Means

For ohm values, refer to table below. Motors of all HP, voltage, phase and cycle duties have the same value of insulation resistance.

Troubleshooting Chart

OHM VALUE	MEGAOHM VALUE	CONDITION OF MOTOR AND LEADS
		Motor not yet installed:
2,000,000 (or more)	2.0	New Motor.
1,000,000 (or more)	1.0	Used motor which can be reinstalled in the well.
		Motor in well (Ohm readings are for drop cable plus motor):
500,000 - 1,000,000	0.5 - 1.0	A motor in reasonably good condition.
20,000 - 500,000	0.02 - 0.5	A motor which may have been damaged by lightning or with damaged leads. Do not pull the pump for this reason.
10,000 - 20,000	0.01 - 0.02	A motor which definitely has been damaged or with damaged cable. The pump should be pulled and repairs made to the cable or the motor replaced. The motor will still operate, but probably not for long.
less than 10,000	0 - 0.01	A motor which has failed or with completely destroyed cable insulation. The pump must be pulled and the cable repaired or the motor replaced. The motor will not run in this condition.

A. Pump Does Not Run

POSSIBLE CAUSES	HOW TO CHECK	HOW TO CORRECT
1. No power at pump panel.	Check for voltage at panel.	If no voltage at panel, check feeder panel for tripped circuits.
2. Fuses are blown or circuit breakers are tripped.	Remove fuses and check for continuity with ohmmeter.	Replace blown fuses or reset circuit breaker. If new fuses blow or circuit breaker trips, the electrical installation and motor must be checked.
3. Motor starter overloads are burnt or have tripped out (three-phase only).	Check for voltage on line or load side of starter.	Replace burnt heaters or reset. Inspect starter for other damage. If heater trips again, check the supply voltage and starter holding coil.
4. Starter does not energize (three-phase only).	Energize control circuit and check for voltage at the holding coil.	If no voltage, check control circuit. If voltage, check holding coil for shorts. Replace bad coil.
5. Defective controls.	Check all safety and pressure switches for operation. Inspect contacts in control devices.	Replace worn or defective parts.
6. Motor and/or cable are defective.	Turn off power. Disconnect motor leads from control box. Measure the lead-to-lead resistances with the ohmmeter (Rx1). Measure lead-to-ground values with ohmmeter (Rx100K). Record measured values.	If open motor winding or ground is found, remove pump and recheck values at the surface. Repair or replace motor or cable.
7. Defective capacitor (single-phase only).	Turn off the power, then discharge capacitor. Check with an ohmmeter (Rx100K). When meter is connected, the needle should jump forward and slowly drift back.	If there is no needle movement, replace the capacitor.

Troubleshooting Chart

B. Pump Runs But Does Not Deliver Water

POSSIBLE CAUSES	HOW TO CHECK	HOW TO CORRECT
1. Groundwater level in well is too low or well is collapsed.	Check well draw-down. Water level should be at least 3 ft. above pump inlet during operation.	If not, lower pump if possible, or throttle discharge valve and install water level control.
2. Integral pump check valve is blocked.	Install pressure gauge, start pump, gradually close the discharge valve and read pressure at shut-off. After taking reading, open valve to its previous position. Convert PSI to feet. (For water: PSI x 2.31 ft/PSI = ____ ft.), and add this to the total vertical distance from the pressure gauge to the water level in the well while the pump is running. Refer to the specific pump curve for the shut-off head for that pump model. If the measured head is close to the curve, pump is probably OK.	If not close to the pump curve, remove pump and inspect discharge section. Remove blockage, repair valve and valve seat if necessary. Check for other damage. Rinse out pump and re-install.
3. Inlet strainer is clogged.	Same as B.2 above.	If not close to the pump curve, remove pump and inspect. Clean strainer, inspect integral check valve for blockage, rinse out pump and re-install.
4. Pump is damaged.	Same as B.2 above.	If damaged, repair as necessary. Rinse out pump and re-install.

C. Pump Runs But at Reduced Capacity

POSSIBLE CAUSES	HOW TO CHECK	HOW TO CORRECT
1. Wrong rotation (three-phase only).	Check for proper electrical connection in control panel.	Correct wiring and change leads as required.
2. Draw-down is larger than anticipated.	Check draw-down during pump operation.	Lower pump if possible. If not, throttle discharge valve and install water level control.
3. Discharge piping or valve leaking.	Examine system for leaks.	Repair leaks.
4. Pump strainer or check valve are clogged.	Same as B.2 above.	If not close to the pump curve, remove pump and inspect. Clean strainer, inspect integral check valve for blockage, rinse out pump and re-install.
5. Pump worn.	Same as B.2 above.	If not close to pump curve, remove pump and inspect.

D. Pump Cycles Too Much

POSSIBLE CAUSES	HOW TO CHECK	HOW TO CORRECT
1. Pressure switch is not properly adjusted or is defective.	Check pressure setting on switch and operation. Check voltage across closed contacts.	Re-adjust switch or replace if defective.
2. Level control is not properly set or is defective.	Check setting and operation.	Re-adjust setting (refer to manufacturer data.) Replace if defective.
3. Insufficient air charging or leaking tank or piping.	Pump air into tank or diaphram chamber. Check diaphram for leak. Check tank and piping for leaks with soap and water solution. Check air to water volume.	Repair or replace damaged component.
4. Plugged snifter valve or bleed orifice.	Examine valve and orifice for dirt or corrosion.	Clean and/or replace if defective.
5. Tank is too small.	Check tank size. Tank volume should be approximately 10 gallons for each gpm or pump capacity.	If tank is too small, replace with proper size tank.

E. Fuses Blow or Circuit Breakers Trip

POSSIBLE CAUSES	HOW TO CHECK	HOW TO CORRECT
1. High or low voltage.	Check voltage at pump panel. If not within ± 10%, check wire size and length of run to pump panel.	If wire size is correct, contact power company. If not, correct and/or replace as necessary.
2. Three-phase current unbalance.	Check current draw on each lead. Unbalance must be within ± 5%.	If current unbalance is not within ± 5%, contact power company.
3. Control box wiring and components (single-phase only).	Check that control box parts match the parts list. Check to see that wiring matches wiring diagram. Check for loose or broken wires or terminals.	Correct as required.
4. Defective capacitor (single-phase only).	Turn off power and discharge capacitor. Check using an ohmmeter (Rx100K). When the meter is connected, the needle should jump forward and slowly drift back.	If no meter movement, replace the capacitor.
5. Starting relay (Franklin single-phase motors only).	Check resistance of relay coil with an ohmmeter (Rx1000K). Check contacts for wear.	Replace defective relay.

Technical Data

Table A

Minimum Water Flow Requirements for Submersible Pump Motors

MOTOR DIAMETER	CASING OR SLEEVE I.D. IN INCHES	MIN. FLOW PAST THE MOTOR (GPM)
4"	4	1.2
	5	7
	6	13
	7	21
	8	30
6"	6	10
	7	28
	8	45
	10	85
	12	140
	14	198
	16	275
8"	8	10
	10	55
	12	110
	14	180
	16	255
10"	10	30
	12	85
	14	145
	16	220
	18	305

NOTES:

1. A flow inducer or sleeve must be used if the water enters the well above the motor or if there is unsufficient water flow past the motor.
2. The minimum recommended water velocity over 4" motors is 0.25 feet per second.
3. The minimum recommended water velocity over 6, 8, and 10" motors is 0.5 feet per second.

Table B

Guide for Engine-Driven Generators in Submersible Pump Applications

	MINIMUM KILOWATT RATING OF GENERATOR FOR THREE-WIRE SUBMERSIBLE PUMP MOTORS	
MOTOR HP SINGLE OR THREE PHASE UNITS	EXTERNALLY REGULATED GENERATOR	INTERNALLY REGULATED GENERATOR
0.33 HP	1.5 KW	1.2 KW
0.50	2.0	1.5
0.75	3.0	2.0
1.0	4.0	2.5
1.5	5.0	3.0
2.0	7.5	4.0
3.0	10.0	5.0
5.0	15.0	7.5
7.5	20.0	10.0
10.0	30.0	15.0
15.0	40.0	20.0
20.0	60.0	25.0
25.0	75.0	30.0
30.0	100.0	40.0
40.0	100.0	50.0
50.0	150.0	60.0
60.0	175.0	75.0
75.0	250.0	100.0
100.0	300.0	150.0
125.0	375.0	175.0
150.0	450.0	200.0
200.0	600.0	275.0

NOTES:

1. Table is based on typical 80°C rise continuous duty generators with 35% maximum voltage dip during start-up of single-phase and three-phase motors.
2. Contact the manufacturer of the generator to assure the unit has adequate capacity to run the submersible motor.
3. If the generator rating is in KVA instead of kilowatts, multiply the above ratings by 1.25 to obtain KVA.

Table C

Transformer Capacity Required for Three-Phase Submersible Pump Motors

		MINIMUM KVA RATING FOR EACH TRANSFORMER	
THREE-PHASE MOTOR HP	MINIMUM TOTAL KVA REQUIRED*	2 TRANSFORMERS OPEN DELTA OR WYE	3 TRANSFORMERS DELTA OR WYE
1.5	3	2	1
2	4	2	1-1/2
3	5	3	2
5	7-1/2	5	3
7.5	10	7-1/2	5
10	15	10	5
15	20	15	7-1/2
20	25	15	10
25	30	20	10
30	40	25	15
40	50	30	20
50	60	35	20
60	75	40	25
75	90	50	30
100	120	65	40
125	150	85	50
150	175	100	60
200	230	130	75

* Pump motor KVA requirements only, and does not include allowances for other loads.

Table D

Submersible Pump Cable Selection Chart (60 Hz)

The following tables list the recommended copper cable sizes and various cable lengths for submersible pump motors.

These tebles comply with the 1978 edition of the National Electric Table 310-16, Column 2 for 75°C wire. The ampacity (current carrying properties of a conductor) have been divided by 1.25 per the N.E.C., Article 430-22, for motor branch circuits based on motor amps at rated horsepower.

To assure adequate starting torque, the maximum cable lengths are calculated to maintain 95% of the service entrance voltage at the motor when the motor is running at maximum nameplate amps. Cable sizes larger than specified may always be used and will reduce power usage.

The use of cables smaller than the recommended sizes will void the warranty. Smaller cable sizes will cause reduced starting torque and poor motor operation.

Single-Phase Motor Maximum Cable Length

(Motor to service entrance) (2)

VOLTS	HP	14	12	10	8	8	4	2	0	00	000	0000	250	300
115	1/3	130	210	340	540	840	1300	1960	2910					
	1/2	100	160	250	390	820	960	1460	2160					
230	1/3	550	880	1390	2190	3400	5250	7960						
	1/2	400	650	1020	1610	2510	3880	5880						
	3/4	300	480	760	1200	1870	2990	4370	6470					
	1	250	400	630	990	1540	2380	3610	5360	6520				
	1-1/2	190	310	480	770	1200	1870	2850	4280	5240				
	2	150	250	390	620	970	1530	2360	3620	4480				
	3	120	190	300	470	750	1190	1850	2990	3610				
	5			180	280	450	710	1110	1740	2170				
	7-1/2				200	310	490	750	1140	1410				
	10					250	390	600	930	1160				

CAUTION: Use of wire size smeller than listed will void warrenty.

FOOTNOTES:

1. If aluminum conductor is used, multiply lengths by 0.5. Maximum allowable length of aluminum is considerably shorter than copper wire of same size.
2. The portion of the total cable which is between the service entrance end a 3Ø motor starter should not exceed 25% of the total maximum length of aesure reliable starter operation. Single-phase control boxes may be connected at any point of tha total cable length.
3. Cables #14 to #0000 ere AWG sizes, and 250 to 300 are MCM sizes.

Three-Phase Motor Maximum Cable Length

(Motor to service entrance) (2)

VOLTS	HP	14	12	10	8	6	4	2	0	00	000	0000	250	300
208	1-1/2	310	500	790	1260									
	2	240	390	610	970	1520								
	3	180	290	470	740	1160	1810							
	5		170	280	440	690	1080	1660						
	7-1/2			200	310	490	770	1180	1770					
	10				230	370	570	880	1330	1640				
	15					250	390	600	810	1110	1340			
	20						300	460	700	860	1050	1270		
	25							370	570	700	840	1030	1170	
	30							310	470	580	700	850	970	1110
230	1-1/2	360	580	920	1450									
	2	280	450	700	1110	1740								
	3	210	340	540	860	1340	2080							
	5		200	320	510	800	1240	1900						
	7-1/2			230	360	570	890	1350	2030					
	10				270	420	660	1010	1520	1870				
	15					290	450	690	1040	1280	1540			
	20						350	530	810	990	1200	1450		
	25						280	430	650	800	970	1170	1340	
	30							350	540	660	800	970	1110	1270
460	1-1/2	1700												
	2	1300	2070											
	3	1000	1600	2520										
	5	590	950	1500	2360									
	7-1/2	420	680	1070	1690	2640								
	10	310	500	790	1250	1960	3050							
	15			540	850	1340	2090	3200						
	20			410	650	1030	1610	2470	3730					
	25				530	830	1300	1990	3010	3700				
	30				430	680	1070	1640	2490	3060	3700			
	40						790	1210	1830	2250	2710	3290		
	50						640	980	1480	1810	2190	2650	3010	
	60							830	1250	1540	1850	2240	2540	2890
	75								1030	1260	1520	1850	2100	2400
	100									940	1130	1380	1560	1790
	125											1080	1220	1390
	150												1050	1190
	200												1080	1300
	250													1080
575	1-1/2	2620												
	2	2030												
	3	1580	2530											
	5	920	1480	2330										
	7-1/2	660	1060	1680	2650									
	10	490	780	1240	1950									
	15		530	850	1340	2090								
	20			650	1030	1610	2520							
	25			520	830	1300	2030	3110						
	30				680	1070	1670	2560	3880					
	40					790	1240	1900	2860	3510				
	50						1000	1540	2310	2840	3420			
	60						850	1300	1960	2400	2890	3500		
	75							1060	1600	1970	2380	2890	3290	
	100								1190	1460	1770	2150	2440	2790

CAUTION: Use of wire size smaller than listed will void warranty. FOOTNOTES: 1. If aluminum conductor is used, multiply lengths by 0.5. Maximum allowable length of aluminum is considerably shorter than copper wire of same size. 2. The portion of the total cable which is between the service entrance and a 3Ø motor starter should not exceed 25% of the total maximum length of assure reliable starter operation. Single-phase control boxes may be connected at any point of the total cable length. 3. Cables #14 to #0000 are AWG sizes, and 250 to 300 are MCM sizes.

Electrical Data

Submersible Pump Motors - 60Hz

GRUNDFOS MOTORS

HP	PH	VOLT	S.F.	CIR. BRKR OR FUSES STD.	DELAY	AMPERAGE START	MAX.	FULL LOAD EFF. (%)	PWR FACT.	MAX. THRUST (LBS)	NAMEPLATE NO.	GRUNDFOS PRODUCT NO.
4-Inch, Single Phase, 2-Wire Motors (control box not required)												
1/3	1	230	1.75	15	5	25.7	4.6	59	77	750	79952101	791595016
1/2	1	230	1.60	15	7	34.5	6.0	62	76	750	79952102	791595026
3/4	1	230	1.50	20	9	40.5	8.4	62	75	750	79952103	791595036
1	1	230	1.40	25	12	48.4	9.8	63	82	750	79952104	791595046
1-1/2	1	230	1.30	35	15	62.0	13.1	64	85	750	79952105	791595056
4-Inch, Single Phase, 3-Wire Motors												
1/3	1	230	1.75	15	5	14.0	4.6	59	77	750	79453101	791545016
1/2	1	230	1.60	15	7	21.5	6.0	62	76	750	79453102	791545026
3/4	1	230	1.50	20	9	31.4	8.4	62	75	750	79453103	791545036
1	1	230	1.40	25	12	37.0	9.8	63	82	750	79453104	791545046
1-1/2	1	230	1.30	35	15	45.9	11.6	69	89	750	79453105	791545056
4-Inch, Three Phase, 3-Wire Motors												
1-1/2	3	230	1.30	15	8	40.3	7.3	75	72	750	79302005	791530056
		460	1.30	10	4	20.1	3.7	75	72	750	79362005	791536056
		575	1.30	10	4	16.1	2.9	75	72	750	79392005	791539056
2	3	230	1.25	20	10	48	8.7	76	75	750	79302006	791530066
		460	1.25	10	5	24	4.4	76	75	750	79362006	791536066
		575	1.25	10	4	19.2	3.5	76	75	750	79392006	791539066
3	3	230	1.15	30	15	56	12.2	77	75	1000	79304507	96405801
		460	1.15	15	7	28	6.1	77	75	1000	79354507	96405810
		575	1.15	15	6	22	4.8	77	75	1000	79394507	96405815
5	3	230	1.15	40	25	108	19.8	80	82	1000	79304509	96405802
		460	1.15	20	12	54	9.9	80	82	1000	79354509	96405811
		575	1.15	15	9	54	7.9	80	82	1000	79394509	96405816
7-1/2	3	230	1.15	60	30	130	25.0	81	82	1000	79305511	96405805
		460	1.15	35	15	67	13.2	81	82	1000	79355511	96405814
		575	1.15	30	15	67	10.6	81	82	1000	79395511	96405819
6-Inch, Three Phase, 3-Wire Motors												
7-1/2	3	230	1.15	60	35	119	26.4	80.5	76	1000	78305511	96405781
		480	1.15	30	15	59	13.2	80.5	76	1000	78355511	96405794
10	3	230	1.15	80	45	156	34.0	82.5	79	1000	78305512	96405782
		460	1.15	40	20	78	17.0	82	79	1000	78355512	96405795
15	3	230	1.15	150	80	343	66.0	84	81	4400	78305516	96405784
		460	1.15	60	30	115	24.5	82.5	82	440	78355514	96405796
20	3	230	1.15	150	80	343	66.0	84	81	4400	78305516	96405784
		460	1.15	80	40	172	33.0	84	82	4400	78355516	96405797
25	3	460	1.15	100	50	217	41.0	84.5	80	4400	78355517	96405798
30	3	460	1.15	110	60	237	46.5	85	83	4400	78355518	96405799
40	3	460	1.15	150	80	320	64.0	85	82	4400	78355520	96405800

HITACHI MOTORS

6 Inch (Three Wire) Motors

60 HZ

HP	PH	Volts	Service Factor	Circuit Breaker or Standard Fuse	Dual Element Fuse	AMPERAGE Full Load	AMPERAGE Locked Rotor	AMPERAGE S.F. Amps	FULL LOAD Eff.	FULL LOAD Power Factor	Line-to-Line Resistance (Ohms) Blk-Yel	Line-to-Line Resistance (Ohms) Red-Yel	Line-to-Line Resistance (Ohms) Delta	KVA Code ***	Three-Phase Overload Protection Starter Size	Three-Phase Overload Protection Fumes Amb.Comp	Maximum Thrust (lbs.)	GRUNDFOS PART NO.
5	1	230	1.15	80	35	23.8	124	27.1	74.8	91.2	0.61	2.2		G	-	-	1500	82.4119H
	3	230	1.15	45	20	14.8	110	16.4	78.8	82.5			0.81	K	1	K58	1500	82.9915H3
	3	460	1.15	25	10	7.4	55	8.2	78.8	82.5			3.05	K	1	K43	1500	82.9915H6
7-1/2	1	230	1.15	125	45	35.2	167	40.9	72.9	94.9	0.40	1.40		F	-	-	1500	82.4121H
	3	230	1.15	70	30	21.8	144	24.4	78.5	91.8			0.65	J	1	K64	1500	82.9116H3
	3	460	1.15	36	15	10.9	72	12.2	78.5	81.8			2.43	J	1	K54	1500	82.9916H65
10	1	230	1.15	175	80	48.0	202	54.0	73.6	93.2	0.32	1.05		#	-	-	3500	82.4123H
	3	230	1.15	80	40	28.2	208	32.0	79.3	82.8			0.45	K	1.75	K68	3500	82.9117H3
	3	460	1.15	40	20	14.3	104	16.0	79.3	82.8			1.82	K	1	K58	3500	82.9117H6
15	1	230	1.15	250	100	70.8	275	84.9	73.7	83.2	0.23	0.88		O	-	-	3500	82.9118H3
	3	230	1.15	125	80	41.4	320	46.2	81.7	83.2			0.31	K	2	K74	3500	82.9118H3
	3	460	1.15	80	30	20.7	180	23.1	91.7	83.2			1.07	K	1.75	K63	3500	82.9118H6
20	3	230	1.15	175	70	53.0	392	63.0	83.2	84.9			0.28	K	2.5	K77	3500	82.9119H3
	3	460	1.15	90	35	26.5	198	30.0	83.2	84.9			0.86	K	2	K67	3500	82.9119H6
25	3	230	1.15	200	90	67.2	530	75.4	83.0	83.9			0.21	K	3	K83	3500	82.9120H3
	3	460	1.15	100	45	33.8	265	37.7	83.0	83.9			0.67	K	2	K72	3500	82.9120H6
33	3	230	1.15	250	110	80.9	610	80.6	82.5	84.3			0.18	K	3	K86	3500	82.9121H3
	3	460	1.15	125	50	40.4	305	45.3	82.5	84.3			0.55	K	2.5	K74	3500	82.9121H6
40	3	460	1.15	150	70	61.7	340	58.8	84.0	88.3			0.48	H	3	K78	5000	82.3228H
50	3	460	1.15	200	90	69.7	465	78.8	82.5	91.4			0.39	J	3	K83	5000	82.3229H
60	3	460	1.15	225	100	80.8	465	92.8	82.4	84.4			0.39	G	3.5	K86	5000	82.3230H

8 Inch Motors

40	3	460	1.15	150	70	54.3	380	80.9	83.9	82.1	0.37	J	3	K78	10,000	82.3270H
50	3	460	1.15	200	90	64.9	435	73.6	84.1	85.7	0.33	H	3	K78	10,000	82.3271H
60	3	460	1.15	225	100	77.8	510	88.5	84.7	85.3	0.28	H	3.5	K86	10,000	82.3272H
75	3	460	1.15	350	150	96.7	650	110	84.9	85.8	0.22	H	3.5	K88	10,000	82.3274H
100	3	460	1.15	400	175	127	795	145	85.2	86.8	0.18	H	4	K89	10,000	82.3275H
125	3	460	1.15	500	225	172.0	980	192	84.2	80.9	0.14	G	4.5	K28	10,000	82.36H042
150	3	460	1.15	600	250	187.0	1080	218	85.8	87.9	0.13	G	4.5	K29	10,000	82.36H043

10 Inch Motors

200	3	460	1.15	800	350	233.0	1280	270	87.2	92.2	0.09	F	5	K33	10,000	82.36H064
250	3	460	1.15	900	450	294.0	1500	344	86.5	92.1	0.08	E	6	K27	10,000	82.36H066

FRANKLIN MOTORS

(refer to the Franklin Submersible Motors Application Maintenance Manual)

Table F

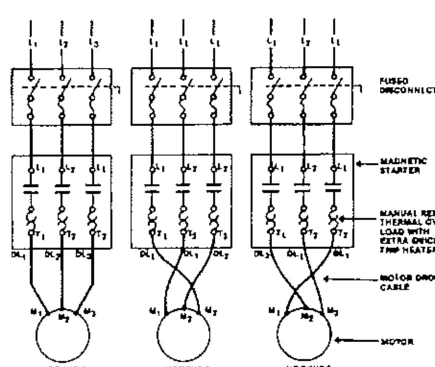
Example: Correcting for Three-Phase Power Unbalance

Example: Check for current unbalance for a 230 volt, 3 phase, 60 Hz submersible pump motor, 18.6 full load amps.

Solution: Steps 1 to 3 measure and record amps on each motor drop lead for Hookups 1, 2 and 3.

	Step 1 (Hookup 1)	**Step** 2 (Hookup 2)	**Step 3** (Hookup 3)
(T_1)	Dl_1 = 25.5 amps	DL_3 = 25 amps	DL_2 = 25.0 amps
(T_2)	DL_2 = 23.0 amps	DL_1 = 24 amps	DL_3 = 24.5 amps
(T_3)	DL_3 = 26.5 amps	DL_2 = 26 amps	DL_1 = 25.5 amps
Step 4	Total = 75 amps	Total = 75 amps	Total = 75 amps
Step 5	Average Current =	total current = / 3 readings	$\frac{75}{3}$ = 25 amps
Step 6	Greatest amp difference from the average:	(Hookup 1) = 25-23 = 2 (Hookup 2) = 26-25 = 1 (Hookup 3) = 25.5-25 = .5	
Step 7	% Unbalance	(HOOKUP 1) = 2/25 X 100 = 8 (HOOKUP 2) = 1/25 X 100 = 4 (HOOKUP 3) = .5/25 X 100 = 2	

As can be seen, Hookup 3 should be used since it shows the least amount of current unbalance. Therefore, the motor will operate at maximum efficiency and reliability.



By comparing the current values recorded on each leg, you will note the highest value was always on the same leg, L_3. This indicates the unbalance is in the power source. If the high current values were on a different leg each time the leads were changed, the unbalance would be caused by the motor or a poor connection.

If the current is greater than 5%, contact your power company for help.

*For a detailed explanation of three-phase balance procedures, see Three-Phase Motor, section 2, page 6.

Technical Data

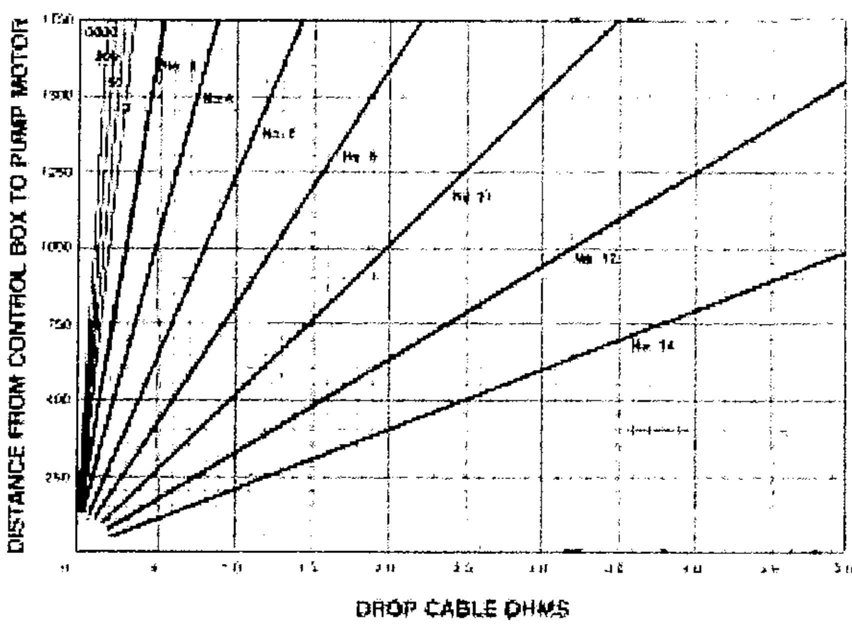
Table G

Total Resistance of Drop Cable (OHMS)

The values shown in this table are for copper conductors. Values are for the total resistance of drop cable from the control box to the motor and back.

To determine the resistance:

1. Disconnect the drop cable leads from the control box or panel.
2. Record the size and length of drop cable.
3. Determine the cable resistance from the table.
4. Add drop cable resistance to motor resistance. Motor resistances can be found in the Electrical Data Chart, Table E.
5. Measure the resistance between each drop cable lead using an ohmmeter. Meter should be set on Rx1 and zero-balanced for this measurement.
6. The measured values should be approximately equal to the calculated values.



Notes

LIMITED WARRANTY

Products manufactured by GRUNDFOS PUMPS CORPORATION (GRUNDFOS) are warranted to the original user only to be free of defects in material and workmanship for a period of 18 months from date of installation, but not more than 24 months from date of manufacture. GRUNDFOS' liability under this warranty shall be limited to repairing or replacing at GRUNDFOS' option, without charge, F.O.B. GRUNDFOS' factory or authorized service station, any product of GRUNDFOS' manufacture. GRUNDFOS will not be liable for any costs of removal, installation, transportation, or any other charges which may arise in connection with a warranty claim. Products which are sold but not manufactured by GRUNDFOS are subject to the warranty provided by the manufacturer of said products and not by GRUNDFOS' warranty. GRUNDFOS will not be liable for damage or wear to products caused by abnormal operating conditions, accident, abuse, misuse, unauthorized alteration or repair, or if the product was not installed in accordance with GRUNDFOS' printed installation and operating instructions.

To obtain service under this warranty, the defective product must be returned to the distributor or dealer of GRUNDFOS' products from which it was purchased together with proof of purchase and installation date, failure date, and supporting installation data. Unless otherwise provided, the distributor or dealer will contact GRUNDFOS or an authorized service station for instructions. Any defective product to be returned to GRUNDFOS or a service station must be sent freight prepaid; documentation supporting the warranty claim and/or a Return Material Authorization must be included if so instructed.

GRUNDFOS WILL NOT BE LIABLE FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES, LOSSES, OR EXPENSES ARISING FROM INSTALLATION, USE, OR ANY OTHER CAUSES. THERE ARE NO EXPRESS OR IMPLIED WARRANTIES, INCLUDING MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, WHICH EXTEND BEYOND THOSE WARRANTIES DESCRIBED OR REFERRED TO ABOVE.

Some jurisdictions do not allow the exclusion or limitation of incidental or consequential damages and some jurisdictions do not allow limitations on how long implied warranties may last. Therefore, the above limitations or exclusions may not apply to you. This warranty gives you specific legal rights and you may also have other rights which vary from jurisdiction to jurisdiction.

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Bulletin 150 — Smart Motor Controllers — SMC™-3 Smart Motor Controller

The SMC-3 is a compact, simple to use, solid-state motor controller designed to operate 3-phase motors. It features a built-in overload relay and a built-in SCR bypass contactor on all three phases, allowing a smaller footprint than other soft starters on the market. This product is designed for many applications, including compressors, chillers, pumps, conveyors, and crushers. Modes of operation for the controller are as follows:

- Soft Start
- Current Limit Start
- Soft Stop
- Kick Start

The controllers offer two voltage ranges: 200...480V AC and 200...600V AC. All voltage ranges will operate at either 50 or 60 Hz.

- 1...480 A Range
- Built-In Electronic Motor Overload Protection
- Built-In SCR/Run Bypass
- Delta Compatibility

Table of Contents

4

Standards Compliance

UL 508
CSA C22.2 No.14
EN/IEC 60947-1
EN/IEC 60947-4-2

Certifications

cULus Listed (Open Type) (File No. E96956, Guides NMFT, NMFT7)
CSA Certified (File No. LR 1234)
CE Marked (Open Type) per EMC and Low Voltage Directive
CCC Certified

PARTS # 150C60NBD

PROTECT BY EXISTING PANEL ENCLOSURE

Modes of Operation

- Soft Start
- Current Limit Start
- Selectable Kickstart
- Soft Stop

Note: For detailed information about the different modes of operation, see page 4-73

Description of Features

Electronic Motor Overload Protection

The SMC-3 controller incorporates, as standard, electronic motor overload protection. This motor overload protection is accomplished electronically with the use of current transformers on each of the three phases. The controller's overload protection is programmable, providing the user with flexibility. The overload trip class selection consists of either OFF, 10, 15, or 20. The trip current is easily selected by adjusting the rotary potentiometer to the motor full-load current rating. Trip reset is selectable to either automatic or manual mode.

Note: Trip rating is 120% of dial setting.

Over-temperature

The SMC-3 monitors the SCR temperature by means of internal thermistors. When the power poles maximum rated temperature is reached, the microcomputer switches off the SMC, a TEMP fault is indicated via LED, and the 97/98 fault contact closes.

Phase Reversal Protection

When enabled via a DIP switch, 3-phase input power will be verified before starting. If input power phasing is detected to be incorrect, the start will be aborted and a fault indicated.

Phase Loss/Open Load

The unit will not attempt a start if there is a single-phase condition on the line. This protects from motor burnout during single-phase starting.

Phase Imbalance

The unit monitors for imbalance between phase currents. To prevent motor damage, the unit will trip if the difference between the minimum phase current and the maximum phase current exceeds 65% for 3 s, and a fault will be indicated.

Shorted SCR

Prior to every start and during starting, the unit will check all SCRs for shorts and unit load connections to the motor. If there is a shorted SCR in the SMC-3 and/or open load, the start will be aborted and a shorted SCR or open load fault will be indicated. This prevents damage from phase imbalance.

Push to Test

The unit with control wiring can be tested for fault conditions by using the Push to Test function. Hold down the Reset button for 7 s to activate the fault Aux (97, 98) and shut down the SMC-3. To clear, either push the Reset button or cycle control power to the device.

LED Description (Number of Flashes)

1. Overload
2. Overtemperature
3. Phase Reversal
4. Phase Loss/Open Load
5. Phase Imbalance
6. Shorted SCR
7. Test

Open Type and Non-Combination Enclosed (IP65, NEMA 4/12) Controllers — For use with Line-Connected Motors

Rated Voltage [V AC]	Motor Current (A)※	Max. kW, 50Hz	Max. Hp, 60 Hz	Control Power	Open Type — Line-Connected Motors Cat. No.	IP65 (Type 4/12) Enclosed Non-Combination Controllers§ Cat. No.
200/208	1...3	—	0.5	100...240V AC, 50/60 Hz	**150-C3NBD**	150-C3FHD
		—		24V AC/DC	**150-C3NBR**	—
	3...9	—	0.75...2	100...240V AC, 50/60 Hz	**150-C9NBD**	150-C9FHD
		—		24V AC/DC	**150-C9NBR**	—
	5.3...16	—	1.5...3	100...240V AC, 50/60 Hz	**150-C16NBD**	150-C16FHD
		—		24V AC/DC	**150-C16NBR**	—
	6.3...19	—	1.5...3	100...240V AC, 50/60 Hz	**150-C19NBD**	150-C23FHD
		—		24V AC/DC	**150-C19NBR**	—
	9.2...27.7	—	3...7.5	100...240V AC, 50/60 Hz	**150-C25NBD**	150-C25FHD
		—		24V AC/DC	**150-C25NBR**	—
	10...30	—	3...7.5	100...240V AC, 50/60 Hz	**150-C30NBD**	150-C30FHD
		—		24V AC/DC	**150-C30NBR**	—
	12.3...37	—	5...10	100...240V AC, 50/60 Hz	**150-C37NBD**	150-C37FHD
		—		24V AC/DC	**150-C37NBR**	—
	14.3...43	—	5...10	100...240V AC, 50/60 Hz	**150-C43NBD**	150-C43FHD
		—		24V AC/DC	**150-C43NBR**	—
	20...60	—	7.5...15	100...240V AC, 50/60 Hz	**150-C60NBD**	150-C60FHD
		—		24V AC/DC	**150-C60NBR**	—
	28.3...85	—	10...25	100...240V AC, 50/60 Hz	**150-C85NBD**	150-C85FHD
		—		24V AC/DC	**150-C85NBR**	—
	27...108	—	20...30	100...240V AC, 50/60 Hz	**150-C108NBD**	150-C108FHD
		—		24V AC/DC✚	150-C108NBR	—
	34...135	—	25...40	100...240V AC, 50/60 Hz	**150-C135NBD**	150-C135FHD
		—		24V AC/DC✚	150-C135NBR	—
	67...201	—	40...60	100...240V AC, 50/60 Hz	**150-C201NBD**	150-C201FHD
		—		24V AC/DC✚	150-C201NBR	—
	84...251	—	50...75	100...240V AC, 50/60 Hz	**150-C251NBD**	150-C251FHD
		—		24V AC/DC✚	150-C251NBR	—
	106...317	—	60...100	100...240V AC, 50/60 Hz	**150-C317NBD**	150-C317FHD
		—		24V AC/DC✚	150-C317NBR	—
	120...361	—	75...125	100...240V AC, 50/60 Hz	**150-C361NBD**	150-C361FHD
		—		24V AC/DC✚	150-C361NBR	—
	160...480	—	100...150	100...240V AC, 50/60 Hz	**150-C480NBD**	150-C480FHD
		—		24V AC/DC✚	150-C480NBR	—

※ Motor FLA rating should fall within specified current range for unit to operate properly.

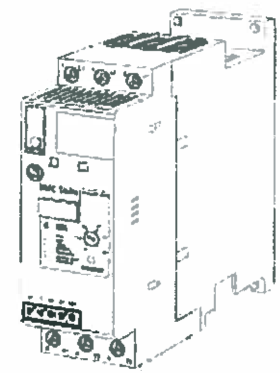
§ These controllers require a separate 100...240V, 50/60 Hz single-phase control source. To add a control circuit transformer to the enclosure, add the appropriate option code to the catalog string.

✚ Separate 120V or 240V single phase is required for fan operation.

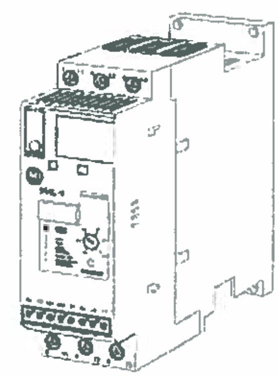
Allen-Bradley

SMC Controllers

Bulletin 150



SMC-Delta



SMC-3

Application and Product Guide

Rockwell Automation

Important User Information

Because of the variety of uses for the products described in this publication, those responsible for the application and use of this control equipment must satisfy themselves that all necessary steps have been taken to assure that each application and use meets all performance and safety requirements, including any applicable laws, regulations, codes and standards.

The illustrations, charts, sample programs and layout examples shown in this guide are intended solely for purposes of example. Since there are many variables and requirements associated with any particular installation, Allen-Bradley does not assume responsibility or liability (to include intellectual property liability) for actual use based upon the examples shown in this publication.

Allen-Bradley publication SGI-1.1, *Safety Guidelines for the Application, Installation and Maintenance of Solid-State Control* (available from your local Allen-Bradley distributor), describes some important differences between solid-state equipment and electromechanical devices that should be taken into consideration when applying products such as those described in this publication.

Throughout this manual we use notes to make you aware of safety considerations:

ATTENTION Identifies information about practices or circumstances that can lead to personal injury or death, property damage or economic loss

---

Attention statements help you to:

- identify a hazard
- avoid a hazard
- recognize the consequences

IMPORTANT Identifies information that is critical for successful application and understanding of the product.

SMC Controllers

The Allen-Bradley SMC™ Controller lines offer a broad range of products for starting or stopping AC induction motors from 1/2 Hp to 25 Hp. The innovative features, compact design, and available enclosed controllers meet world-wide industry requirements for controlling motors. Whether you need to control a single motor or an integrated automation system, our range of controllers meet your required needs.

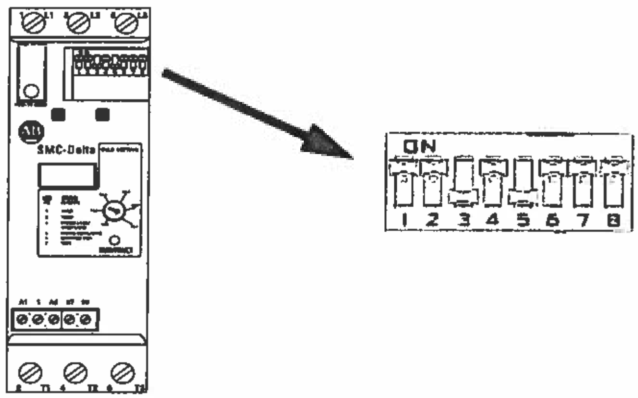
Two of the controllers from the Allen-Bradley SMC Controller line that are covered in this document, are the SMC-Delta™ and SMC-3™. Some of the key features for each of these controllers are highlighted in the table below:

Features	SMC–Delta Controller	SMC-3 Controller
	200…600V 1…64 A	200…600V 1…37 A
Soft start		★
Kickstart		★
Current limit start	★	★
Soft stop		★
Coast-to-rest stop	★	★
Fault aux. - normally open	★	★
Aux. contact		★
Side-mounted aux. contact (optional)	★	★
Fault indication	★	★
Overload protection	★	★
Phase reversal		★
Phase unbalance	★	★
Inside-the-delta control ❶	★	

★ = Available

❶ SMC-Delta requires star-delta (wye-delta) motor

DIP Switch Configuration



Position Number	Description
1	Start time
2	Start time
3	Current limit start setting
4	Current limit start setting
5	Overload class selection
6	Overload class selection
7	Overload reset
8	Optional auxiliary relay #1

The following tables describe the SMC-Delta DIP switch programming details:

Table 1.B Start Time

DIP Switch Number		
1	2	Time (seconds)
OFF	OFF	2
ON	OFF	5
OFF	ON	10
ON	ON	15

Table 1.D Current Limit Start Setting

DIP Switch Number		
3	4	Current Limit Setting
OFF	OFF	150%
ON	OFF	250%
OFF	ON	300%
ON	ON	350%

Table 1.F Overload Class Selection

DIP Switch Number		
5	6	Trip Class
OFF	OFF	OFF
ON	OFF	10
OFF	ON	15
ON	ON	20

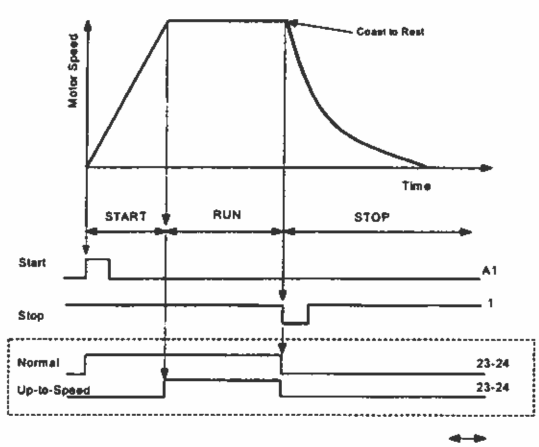
Table 1.C Overload Reset

DIP Switch Number	
7	Reset
OFF	Manual
ON	Automatic

Table 1.E Optional Auxiliary Relay #1

DIP Switch Number	
8	Setting
OFF	Normal
ON	Up-to-speed

Figure 1.3 SMC-Delta Sequence of Operation



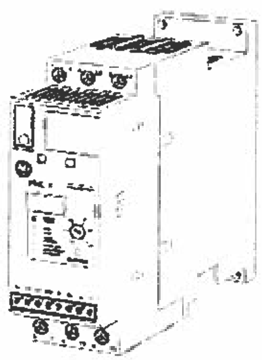
SMC-3™ Smart Motor Controller

Description

The SMC-3 Smart Motor controller is a compact, multi-functional solid-state controller used in reduced voltage motor starting standard three-phase squirrel cage induction motors, and controlling resistive loads. It replaces typical competitive solutions.

The SMC-3 product line includes current ranges: 1…37 A, 200…600V, 50/60 Hz., meets UL, EN, and IEC standards, and is cULus Listed and CE marked. Control voltage ratings include 24V AC/DC and 100…240V AC. This covers applications up to 25 Hp.

Figure 2.1 SMC-3™ Controller



Modes of Operation

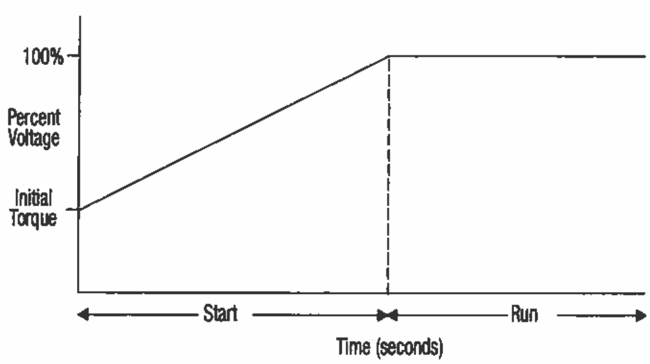
The following modes of operation are standard within a single controller:

- Soft start
- Current limit start
- Kickstart
- Soft stop

Soft Start

Soft start is the most common method of starting. The initial torque setting is DIP switch selectable as a percentage of the locked rotor torque (LRT), ranging from 15…65% of full value. The starting time is customer set, ranging from 2…15 seconds.

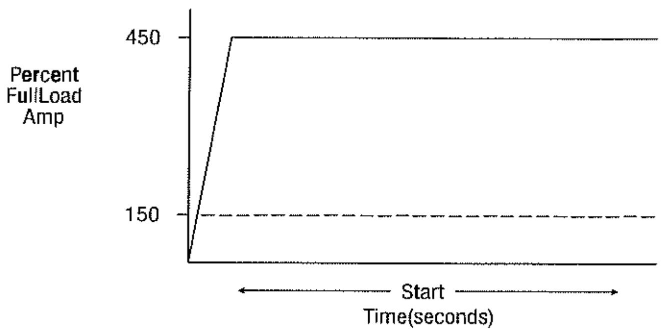
Figure 2.2 Soft Start



Current Limit Start

This starting mode is used when it is necessary to limit the maximum starting current. This is DIP switch selectable and can be adjusted from 150...450% of full load amps. The current limit starting time is customer set, ranging from 2...15 seconds.

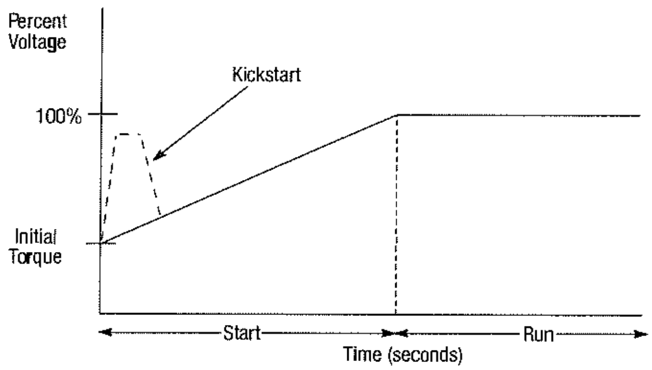
Figure 2.3 Current Limit Start



Selectable Kickstart

The kickstart feature provides a boost at startup to break away loads that may require a pulse of high torque to get started. It is intended to provide a current pulse of 450% of full load current and is user adjustable from 0.0...1.5 seconds.

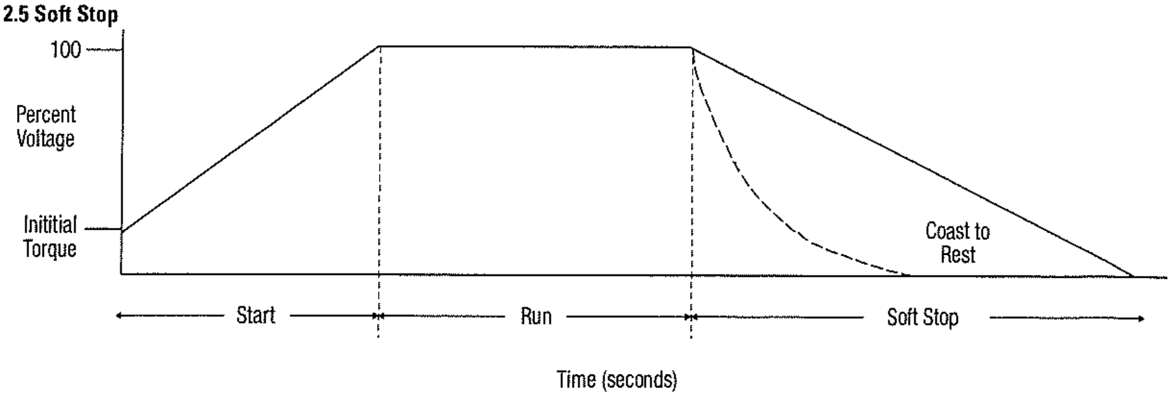
Figure 2.4 Soft Start with Selectable Kickstart



Soft Stop

This function can be used in applications that require an extended coast to rest. When selected, the stop time is either 100, 200, or 300% of the start time. The starting and stopping times are dependently adjusted. The load will stop when the voltage drops to a point where the load torque is greater than the motor torque.

Figure 2.5 Soft Stop



Features

Electronic Overload

The SMC-3 controller meets applicable requirements as a motor overload protective device. Overload protection is accomplished electronically through an I^2t algorithm.

The overload is DIP switch selectable, providing the user with flexibility. The overload trip class is selectable for OFF or a 10, 15, or 20 protection. A CT monitors each phase. The motor's full load current rating is set by a potentiometer. The overload reset option can be operated either manually or automatically. A remote Cat. no. 193-ER1 reset device can be mechanically attached.

Fault Indication

The SMC-3 controller monitors both the pre-start and running modes. A single LED is used to display both RUN/ON and FAULT indication. If the controller senses a fault, the SMC-3 controller shuts down the motor and the LED displays the appropriate fault condition.

The controller monitors the following conditions:

- Overload
- Over-temperature
- Phase reversal
- Phase loss/Open load
- Phase imbalance
- Shorted SCR

Any fault condition will cause the auxiliary contacts to change state and the hold-in circuit to release. All faults can be cleared by either pressing the reset button or by removing control power. Overload and over-temperature are time-based conditions that may require waiting for some additional cooling time, before reset is possible.

Control Terminal Description

The SMC-3 contains eight (8) control terminals on the front of the controller. These control terminals are described below.

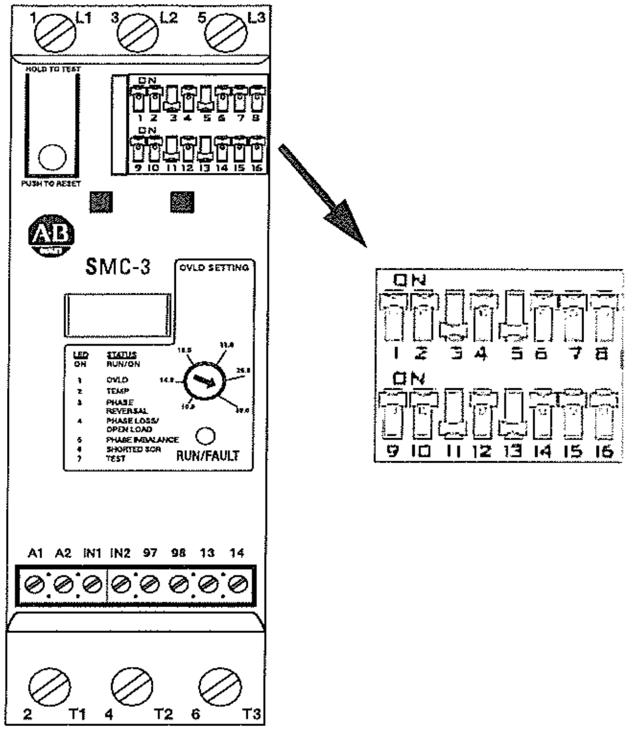
Table 2.A SMC-3 Control Terminal Description

Terminal Number	Description	Terminal Number	Description
A1	Control power input	97	N.O. relay - aux. contact for fault indication
A2	Control power common	98	N.O. relay - aux. contact for fault indication
IN1	Start input	13	N.O. auxiliary relay #1 (normal/up-to-speed)
IN2	Stop input	14	N.O. auxiliary relay #1 (normal/up-to-speed)

Auxiliary Contacts

Two (2) hard contacts are provided as standard with the SMC-3 controller. These contacts are finger safe. The first contact is for fault indication. The auxiliary relay #1 is programmable via dipswitch #14, for normal/up-to-speed indication. A side-mounted additional auxiliary relay #2 can be added as an accessory and programmed via dipswitch #15 for normal/up-to-speed indication.

DIP Switch Configuration



Position Number	Description
1	Start time
2	Start time
3	Start mode (current limit or soft start)
4	Current limit start setting (when selected) or Soft start initial torque setting (when selected)
5	Current limit start setting (when selected) or Soft start initial torque setting (when selected)
6	Soft stop
7	Soft stop
8	Not used
9	Kick start
10	Kick start
11	Overload class selection
12	Overload class selection
13	Overload reset
14	Auxiliary relay #1 (normal or up-to-speed)
15	Optional auxiliary relay #2 (normal or up-to-speed)
16	Phase rotation check

The following tables describe the SMC-3 DIP Switch programming details:

Table 2.B Start Time

DIP Switch Number		
1	2	Time (seconds)
OFF	OFF	2
ON	OFF	5
OFF	ON	10
ON	ON	15

Table 2.C Start Mode (Current Limit or Soft Start)

DIP Switch Number	
3	Setting
OFF	Current limit
ON	Soft start

Table 2.D Current Limit Start Setting (when selected)

DIP Switch Number		
4	5	Current Limit % FLA
OFF	OFF	150%
ON	OFF	250%
OFF	ON	350%
ON	ON	450%

Table 2.E Soft Start Initial Torque Setting (when selected)

DIP Switch Number		
4	5	Initial Torque % LRT
OFF	OFF	15%
ON	OFF	25%
OFF	ON	35%
ON	ON	65%

Table 2.F Soft Stop

DIP Switch Number		
6	7	Setting
OFF	OFF	Coast-to-rest
ON	OFF	100% of start time
OFF	ON	200% of start time
ON	ON	300% of start time

Table 2.G Kick Start

DIP Switch Number		
9	10	Time (seconds)
OFF	OFF	OFF
ON	OFF	0.5
OFF	ON	1.0
ON	ON	1.5

Table 2.H Overload Class Selection

DIP Switch Number		
11	12	Trip Class
OFF	OFF	OFF
ON	OFF	10
OFF	ON	15
ON	ON	20

Table 2.I Overload Reset

DIP Switch Number	
13	Reset
OFF	Manual
ON	Automatic

Table 2.J Auxiliary Relay #1

DIP Switch Number	
14	Setting
OFF	Normal
ON	Up-to-speed

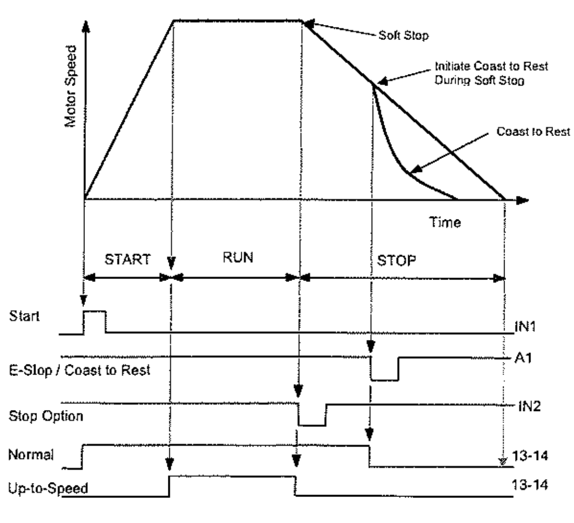
Table 2.K Optional Auxiliary Relay #2

DIP Switch Number	
15	Setting
OFF	Normal
ON	Up-to-speed

Table 2.L Phase Rotation Check

DIP Switch Number	
16	Setting
OFF	Enabled
ON	Disabled

Figure 2.6 SMC-3 Sequence of Operation



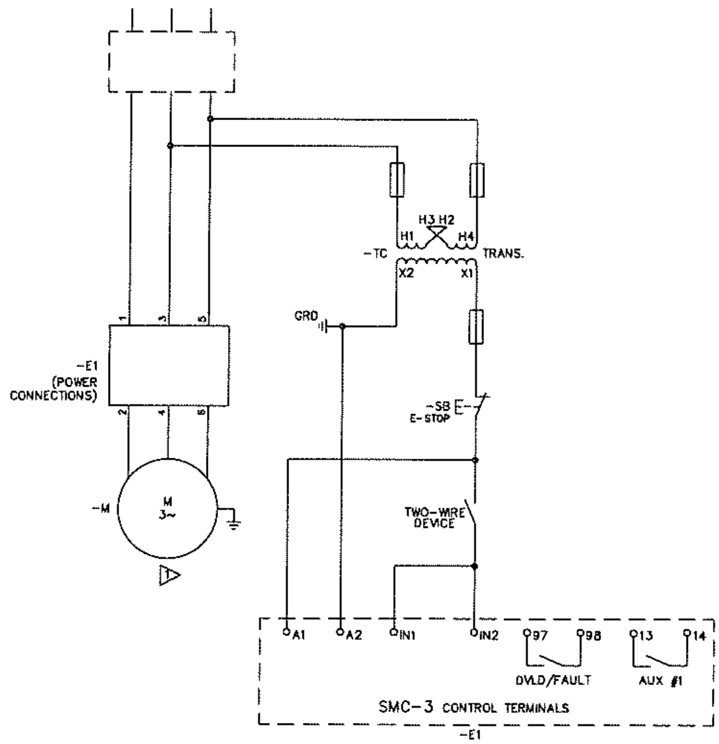
ATTENTION

The user has the ultimate responsibility to determine which stopping mode is best suited to the application and will meet applicable standards for operator safety on a particular machine.

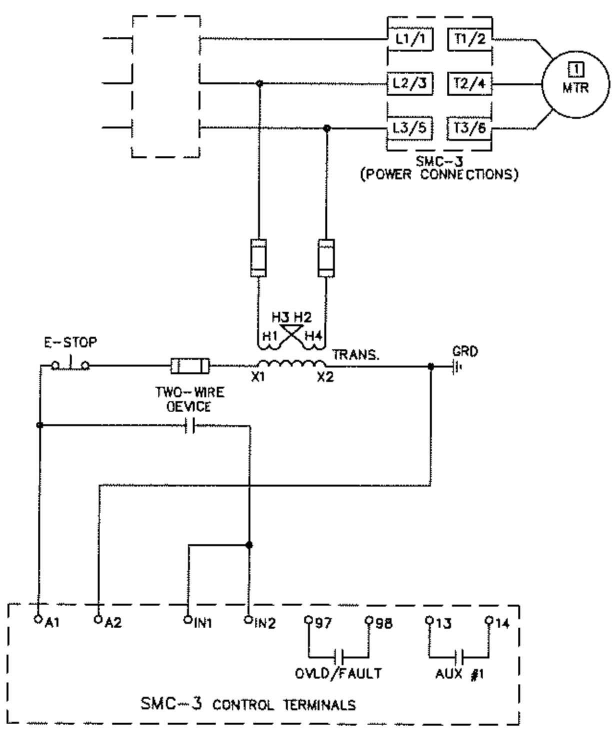
Typical Wiring Diagrams

Two-Wire Configuration

IEC



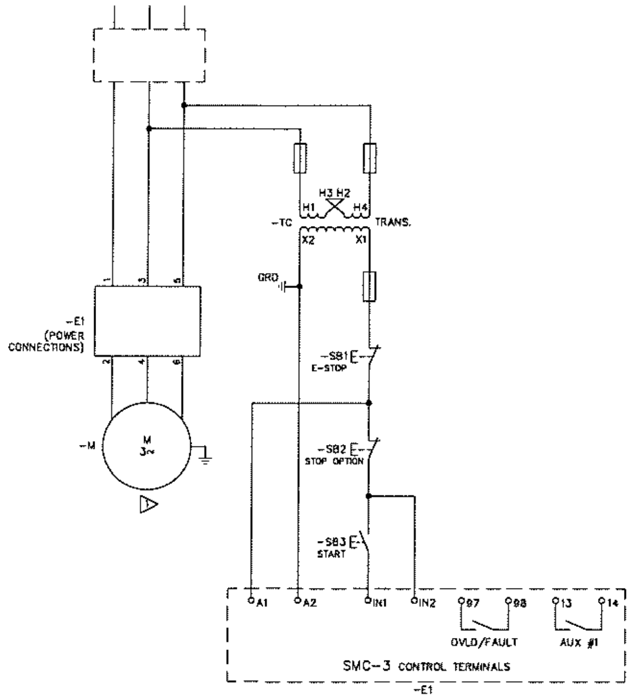
NEMA



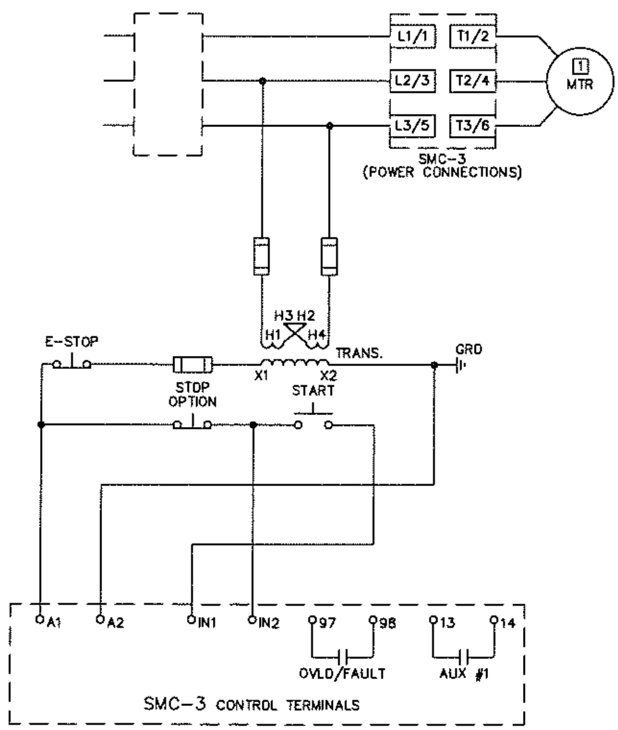
Typical Wiring Diagrams, Continued

Three-Wire Configuration

IEC



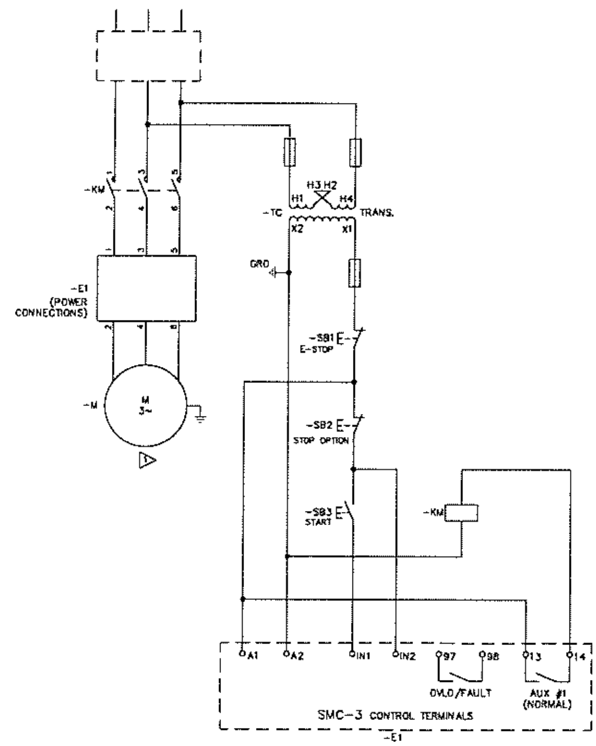
NEMA



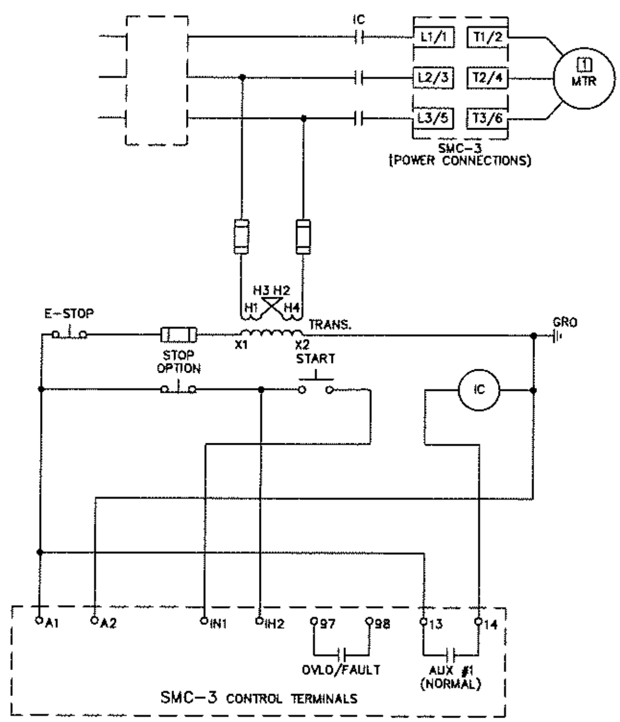
Typical Wiring Diagrams, Continued

Isolation Contactor Configuration

IEC



NEMA

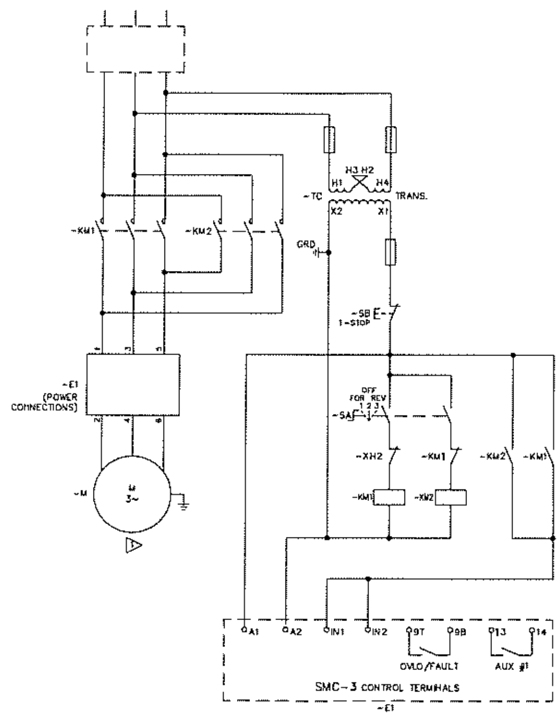


Typical Wiring Diagrams, Continued

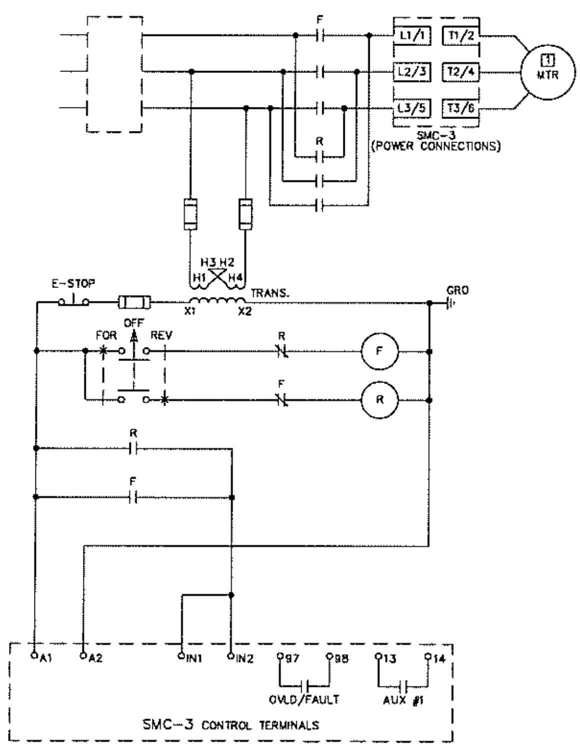
Reversing Configuration

Note: Minimum Off time equals 1.0 second

IEC



NEMA



Applications

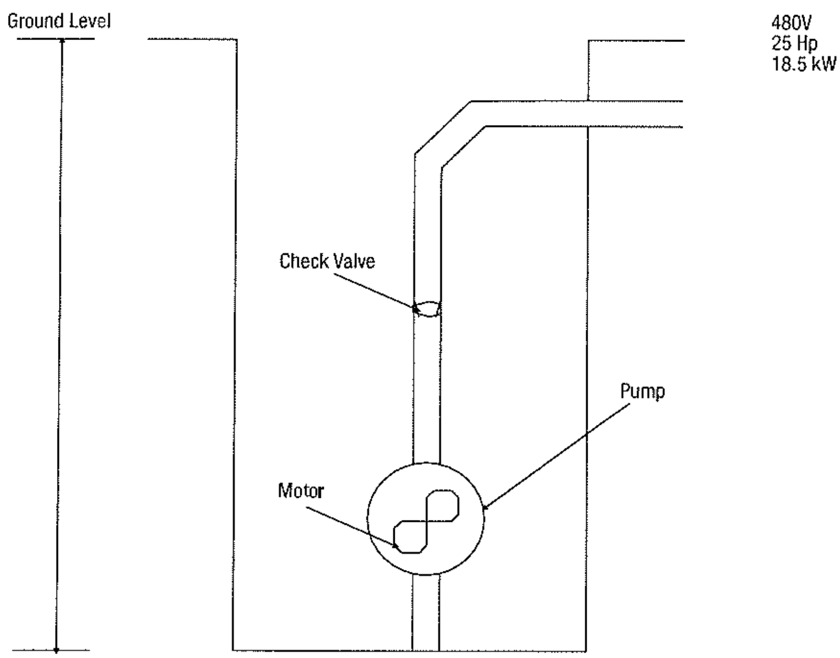
This section describes a few of the many SMC-3 controller applications.

Illustrations are included to help identify the particular application. Motor ratings are specified but this may vary in other typical applications.

Typical applications include:

- Bridge cranes
- Trolleys
- Monorails
- Shrink wrap machines
- Overhead doors
- Conveyors
- Material handling equipment
- Compressors
- Fans and pumps
- Lifts
- Elevators

Figure 2.7 Pump with Soft Start



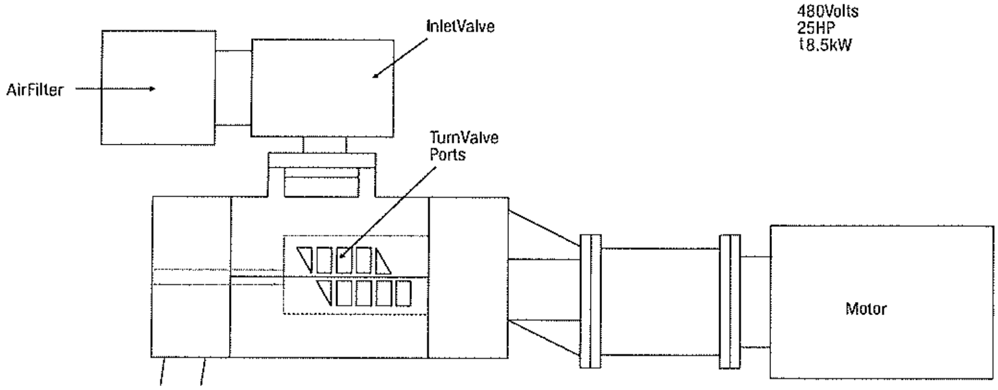
Problem

A municipal water company was experiencing problems with pump impellers being damaged. The damage occurred during an across-the-line start and was caused by the heavy shock to the impeller. The pumping station motor was over 100 feet below ground, making repair costly. An additional concern was frequent line failures, which resulted in single-phasing the motor.

Solution

The SMC-3 controller was installed, providing a controlled acceleration of the motor. The shock to the impeller was reduced by decreasing the torque during startup. The built-in overload saved panel space. The SMC-3 controller's line diagnostics shut off the motor after it detected the pre-start and running single-phase condition. This protected the pump from motor damage.

Figure 2.8 Compressor with Soft Start



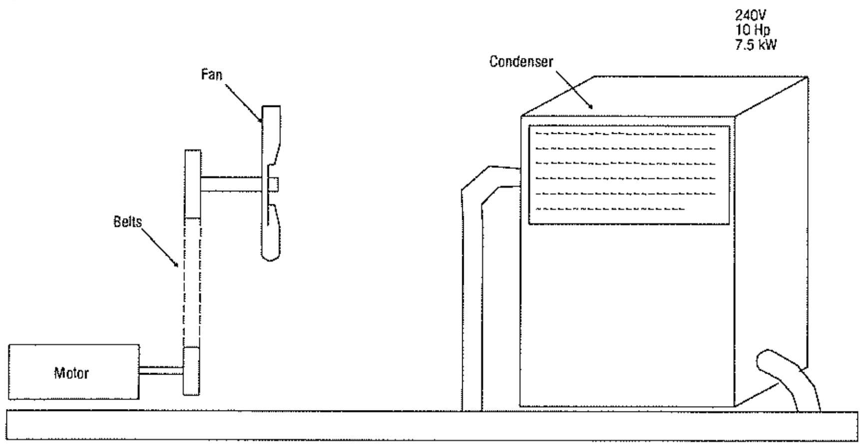
Problem

A compressor OEM shipped its equipment into overseas markets. There were many different voltage and frequency requirements to meet because of the compressor's final destination. Due to power company requirements and mechanical stress on the compressor, a reduced voltage starter was required. This made ordering and stocking spare parts difficult.

Solution

The SMC-3 controller was installed and set for a 15-second soft start, which reduced the voltage to the motor during starting and met the power company requirements. Reducing the voltage, also reduced the starting torque, which minimized the shock to the compressor. The SMC-3 controller has a built-in overload feature which saved panel space.

Figure 2.9 Chiller with Soft Start



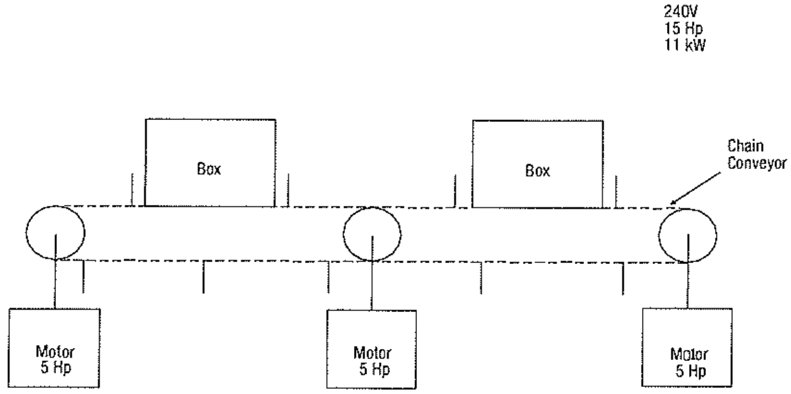
Problem

A belt-driven fan on a chiller was frequently breaking the belt because of high starting torque. Excessive downtime was incurred because the housing had to be removed to replace the belt. A combination across-the-line starter was being used to control the motor. Control panel space was limited. A device that used the same control and line voltages as the starter was required because there was no room in the panel for a control circuit transformer.

Solution

The SMC-3 controller was installed as a retrofit to the chiller. It was set for an 10-second soft start to reduce the snap to the belts as a result of the high starting torque. It also reduced belt "squealing" previously experienced during startup. Because the SMC-3 controller can operate with 240V control and line voltage, a control circuit transformer was not required. The built-in overload protection on the SMC-3 controller further reduced the panel space required. The customer was able to retrofit the controller into the existing panel space.

Figure 2.10 Towline Conveyor with Soft Start



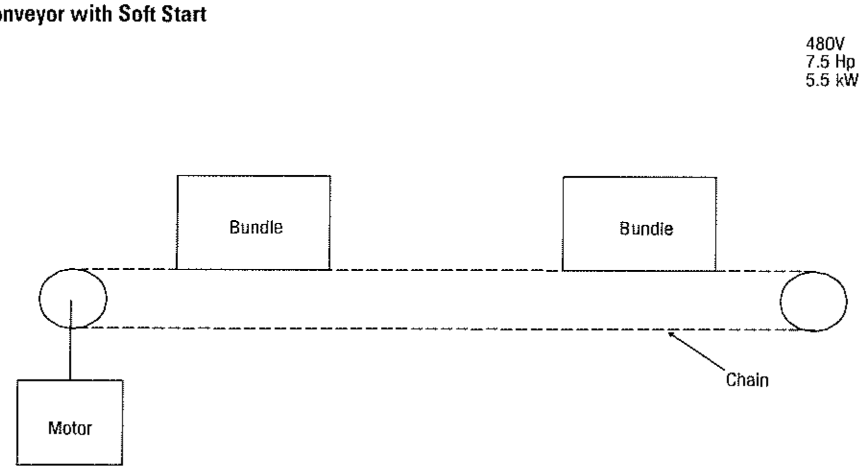
Problem

A towline conveyor in a freight house had three motors, that were effectively "common shaft", to drive the conveying system. Across-the-line starts caused damage to the conveyor and spilled freight on the conveyor.

Solution

The conveyor OEM installed a single SMC-3 controller to provide a smooth acceleration to all three motors, reducing the starting torque of the motors and the mechanical shock to the conveyor and load. The OEM liked the SMC-3 controller because of its ability to control three motors as if they were a single motor, eliminating the need for multiple soft starters.

Figure 2.11 Chain Conveyor with Soft Start



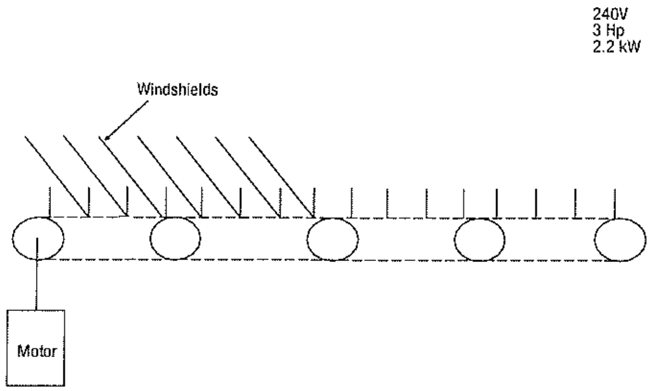
Problem

A chain conveyor was used to transport bundles of paper. The chain was breaking once per day because of high starting torque. Maintenance of the conveyor caused interruptions in the production schedule and lost productivity. Line surges were also a frequent problem.

Solution

The SMC-3 controller was installed. A 10-second soft start was programmed, reducing the starting torque and the mechanical shock to the chain. It was estimated that the SMC-3 controller paid for itself in one week, due to the reduced downtime. A line side protective module (MOV) was installed to suppress the voltage transients.

Figure 2.12 Chain Conveyor with Soft Start and Soft Stop Option



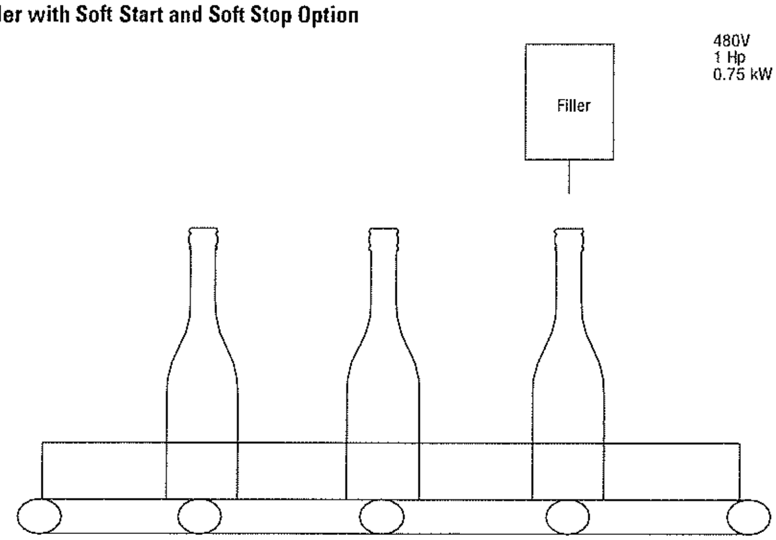
Problem

A chain conveyor was used to transport automobile windshields to a packaging area. The high starting torque would cause the load to shift, damaging the windshields. The stopping of the conveyor also caused shifting problems when the load decelerated quickly. An across-the-line starter was used in this application. Because the cost of downtime was high, a modular controller was required for ease of maintenance.

Solution

The SMC-3 controller with enabled soft stop was installed, reducing the starting torque and decreasing the product shift on startup. The soft stop extended the stopping time, bringing the conveyor to a smooth stop.

Figure 2.13 Bottle Filler with Soft Start and Soft Stop Option



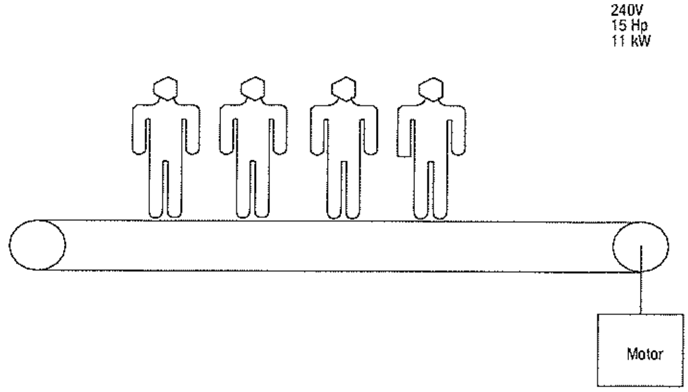
Problem

A bottle filler line had product spillage during starting and stopping. An across-the-line starter was used to start the motor. In addition, the application required an auxiliary contact that would energize when the motor was up to speed.

Solution

The SMC-3 controller was installed and programmed for a 10-second soft start with an 20-second soft stop. The controlled start reduced the starting torque and consequently, the product spillage. The Soft Stop option extended the stopping time, smoothing load shift while stopping. The auxiliary contacts were configured to change state when the motor was up to speed.

Figure 2.14 Power Walk with Soft Start and Soft Stop Option



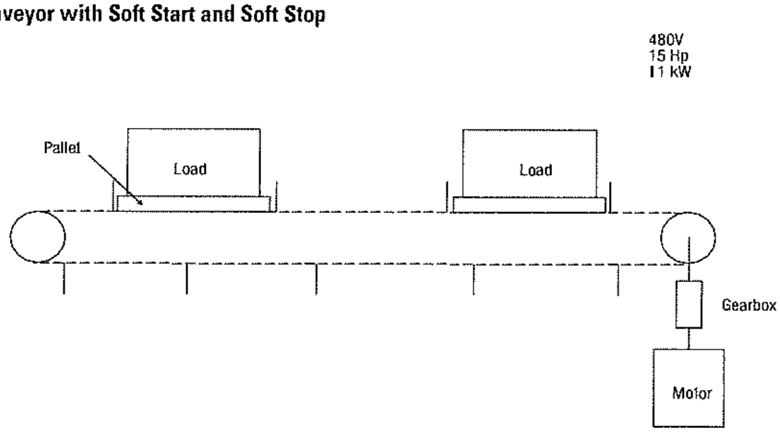
Problem

A power walk in an airport required a soft start to prevent damage to the drive chain gearbox on startup. A soft stop was also required in case the power walk would be shut off while people were on the belt. Several power walks were installed in the airport, and each required its own soft starter. A controller that could be quickly replaced and adjusted was required. Also, panel space was limited.

Solution

The SMC-3 controller with soft stop was installed. An 10-second soft start and a 10-second soft stop were programmed into the controller, facilitating a controlled start and stop. The built-in overload protection eliminated the need for a separate overload relay, thereby saving panel space. In the event that a unit needed replacement, one could be quickly plugged in.

Figure 2.15 Towline Conveyor with Soft Start and Soft Stop



Problem

A towline conveyor at the end of a production line had frequent damage to the gearbox caused by the starting torque from across-the-line starting of the motor. There were also frequent spills during starting and stopping. This towline application had a variety of starting requirements that other soft starters could not satisfy. Investing in a variable speed drive was not cost effective.

Solution

The SMC-3 controller was installed as a retrofit to the existing across-the-line starter. The starting and stopping times were programmed for 10 seconds. The reduced starting torque decreased the shock to the gearbox and kept the load from shifting on startup. The soft stop protected against loads shifting while stopping. The SMC-3 controller met the starting requirements and was a cost-effective solution.

SMC-Delta and SMC-3 Controller Special Application Considerations

Motor Overload Protection

When coordinated with the proper short circuit protection, overload protection is intended to protect the motor, motor controller, and power wiring against overheating caused by excessive overcurrent. The SMC-Delta and SMC-3 controllers meet applicable requirements as a motor overload protective device.

The SMC-Delta and SMC-3 controllers incorporate, as standard, electronic motor overload protection. This overload protection is accomplished via CT monitoring all three phases.

The controller's overload protection is programmable, providing the user with flexibility. The overload trip class is selectable for OFF or a 10, 15, or 20 protection. The trip current can be set to the motor full load current rating.

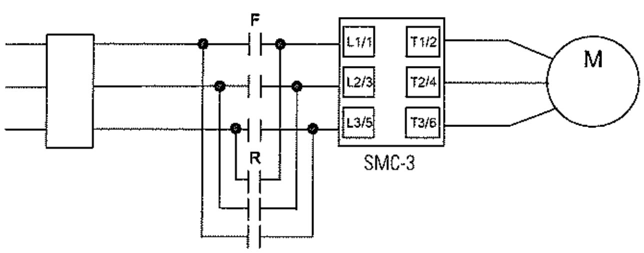
Thermal memory is included to accurately model motor operating temperature. Ambient insensitivity is inherent in the electronic design of the overload.

Reversing Contactors

By using the controller as shown in Figure 3.1, the motor accelerates under a controlled start mode in either forward or reverse.

Notes:	• Minimum transition time for reversing is 1 second.
	• Phase Reversal must be OFF.

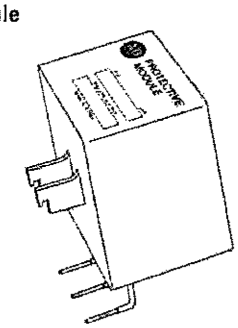
Figure 3.1 Typical SMC-3 Application with a Single-speed Reversing Starter



Use of Protective Modules

A protective module (see Figure 3.2) containing metal oxide varistors (MOVs) and capacitors can be installed to protect the power components from electrical transients and/or electrical noise. The protective modules clip transients generated on the lines and prevent such surges from damaging the SCRs. The capacitors in the protective modules are used to shunt noise energy away from the SMC controller electronics.

Figure 3.2 Protective Module



Use of Protective Modules, Continued

There are two general situations that may occur which would indicate the need for utilizing the protective modules.

1. Transient spikes may occur on the lines feeding the SMC controllers (or feeding the load from the SMC controllers). Lightning can cause spikes. Spikes are also created on the line when devices are attached with current-carrying inductances that are open circuited. The energy stored in the magnetic field is released when the contacts open the circuit. Examples of these are lightly loaded motors, transformers, solenoids, and electromechanical brakes.

2. The second situation arises when the SMC controllers are installed on a system which has fast-rising wavefronts present, although not necessarily high peak voltages. Lightning strikes can cause this type of response. Additionally, if the SMC controllers are on the same bus as other SCR devices, (AC/DC drives, induction heating equipment, or welding equipment) the firing of the SCRs in those devices can cause noise. This high frequency noise can penetrate the SMC controllers through stray capacitance.

ATTENTION

When installing or inspecting the protective module, disconnect the controller from the power source. The protective module should be checked periodically. Inspect for damage or discoloration. Replace if necessary.

Altitude De-rating

Because of the decreased efficiency of fans and heatsinks, it is necessary to de-rate the SMC-Delta and SMC-3 controllers above 2000 meters (6,560 ft). When using the controller above 2000 meters (6,560 ft), the controller amperage value will need to be de-rated.

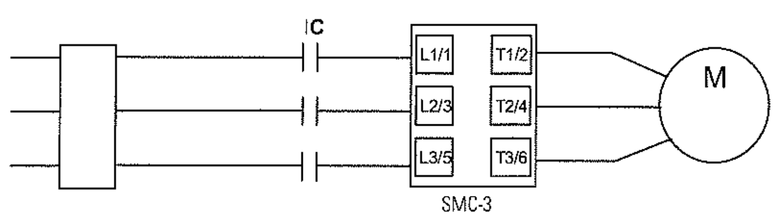
Isolation Contactor

When installed with branch circuit protection, SMC-Delta and SMC-3 controllers are compatible with the National Electric Code (NEC). When an isolation contactor is not used, hazardous voltages are present at the load terminals of the power module even when the controller is turned off. Warning labels must be attached to the motor terminal box, the controller enclosure, and the control station to indicate this hazard.

The isolation contactor is used to provide automatic electrical isolation of the controller and motor circuit when the controller is shut down. Shut down can occur in either of two ways: either manually, by pressing the stop button, or automatically, by the presence of abnormal conditions (such as a motor overload relay trip).

Under normal conditions the isolation contactor carries only the load current. During start, the isolation contactor is energized before the SCRs are gated "on." While stopping, the SCRs are gated "off" before the isolation contactor is de-energized. The isolation contactor is not making or breaking the load current.

Figure 3.3 Typical SMC-3 Connection Diagram with Isolation Contactor



SMC Product Line Applications Matrix

Description

Use this chapter to identify possible SMC-Delta and SMC-3 controller applications. This chapter contains an application matrix which will identify starting and stopping characteristics that may be used in various applications.

Mining and Metals

Applications	SMC-Delta and SMC-3	SMC-3 Only	
	Current Limit	Soft Start	Soft Stop
Roller conveyors		X	X
Centrifugal pumps	X	X	
Fans	X	X	
Dust collector	X	X	
Chillers	X	X	
Compressor	X	X	
Belt conveyors	X	X	X
Slicer	X	X	

Petrochemical

Applications	SMC-Delta and SMC-3	SMC-3 Only	
	Current Limit	Soft Start	Soft Stop
Centrifugal pumps	X	X	
Screw conveyors	X	X	
Mixers	X	X	
Agitators	X	X	
Compressors	X	X	
Fans	X	X	

Water/Wastewater Treatment and Municipalities

Applications	SMC-Delta and SMC-3	SMC-3 Only	
	Current Limit	Soft Start	Soft Stop
Centrifugal pumps	X	X	
Fans	X	X	
Compressors	X	X	

Lumber and Wood Products

Applications	SMC-Delta and SMC-3	SMC-3 Only	
	Current Limit	Soft Start	Soft Stop
Circular saw	X	X	
Edger	X	X	
Conveyors	X	X	X
Centrifugal pumps	X	X	
Compressors	X	X	
Fans	X	X	
Planers	X	X	
Sander	X	X	

Food Processing

Applications	SMC-Delta and SMC-3	SMC-3 Only	
	Current Limit	Soft Start	Soft Stop
Centrifugal Pumps	X	X	
Pallitizers		X	X
Agitators		X	
Conveyors		X	X
Fans	X	X	
Bottle Washers		X	X
Compressors	X	X	
Dryers	X	X	
Slicers	X	X	

Pulp and Paper

Applications	SMC-Delta and SMC-3	SMC-3 Only	
	Current Limit	Soft Start	Soft Stop
Compressors	X	X	
Conveyors	X	X	X
Trolleys		X	X
Dryers	X	X	
Agitators	X	X	
Centrifugal Pumps	X	X	
Mixers	X	X	
Fans	X	X	
Re-Pulper	X	X	

OEM Specialty Machine

Applications	SMC-Delta and SMC-3	SMC-3 Only	
	Current Limit	Soft Start	Soft Stop
Centrifugal Pumps	X	X	
Washers	X	X	
Conveyors	X	X	X
Power Walks	X	X	X
Fans	X	X	
Twisting/Spinning Machine	X	X	

Transportation and Machine Tool

Applications	SMC-Delta and SMC-3	SMC-3 Only	
	Current Limit	Soft Start	Soft Stop
Material Handling Conveyors	X	X	X
Grinders	X	X	
Centrifugal Pumps	X	X	
Trolleys		X	X
Fans	X	X	
Palletizers	X	X	X
Compressors	X	X	
Die Charger		X	
Rotary Table		X	

Design Philosophy

Philosophy

Allen-Bradley SMC controllers are designed to operate in today's industrial environments. Our controllers are manufactured to provide consistent and reliable operation. Rockwell Automation has more than just an adequate solution to meet your needs; we have the *right* solution. With a broad offering of power device products and application services, Rockwell Automation can effectively address the productivity issues most important to you.

Line Voltage Conditions

Voltage transients, disturbances, harmonics, and noise exist in any industrial supply line. A solid-state controller must be able to withstand these noises and should not be an unnecessary source of generating noise back into the line.

- Ease of selection for the required line voltage is achieved with a design that provides operation over a wide voltage range, at 50/60 Hz, within a given controller rating.
- The controller can withstand 3000V surges at a rate of 100 bursts per second for 10 seconds (IEEE Std. 472). Further, the controller can withstand the showering arc test of 350…1500V (NEMA Std. ICS2-230) for higher resistance to malfunction in a noisy environment.
- An optional MOV module is available to protect SCRs from voltage transients.

Current and Thermal Ratings

Solid-state controller ratings must ensure reliability under the wide range of current levels and starting times needed in various applications.

- SCR packaging keeps junction temperatures below 125°C (257°F) when running at full-rated current to reduce thermal stress and provide longer, more reliable operation.
- The thermal capacity of the SMC-3 and SMC-Delta controllers meet NEMA standards MG-1 and IEC34 (S1).
- Open type operating temperature is 0…50°C (32…122°F) and a de-rating chart is required for 60°C (140°F). Storage temperature is –25…+85°C (–13…185°F). Relative humidity is 5… 95% (non-condensing).

Mechanical Shock and Vibration

Solid-state controllers must withstand the shock and vibration generated by the machinery that they control.

- SMC-Delta and SMC-3 controllers meet the same shock and vibration specifications as electromechanical starters.
- Both products attain the desired requirements of 1.0 G vibration operational and 2.5 G vibration non-operational.
- Both products attain the desired requirements of 15 G shock operational and 30 G shock non-operational.

Noise and RF Immunity

Both products meet Class A requirements for EMC emission levels.

Altitude

Altitudes up to 2000 meters (6560 ft) are permitted without de-rating. The products' allowable ambient temperature must be de-rated for altitudes in excess of 2000 meters (6560 ft). The allowable ambient temperature must be de-rated by –3°C (27°F) per 1000 meters (3280 ft), up to a maximum of 7000 meters (23000 ft). Current ratings of the devices do not change for altitudes that require a lower maximum ambient temperature.

Pollution

Both products are intended for a Pollution Degree 2 environment.

Set-up

Simple, easily understood settings provide identifiable, consistent results.

- For ease of installation, the controllers include compact design and feed-through wiring.
- SMC-Delta and SMC-3 controllers are global products rated at 50/60 Hz.
- All parameter adjustments are made via DIP switches.
- A full line of enclosures is available.

Reduced Voltage Starting

Introduction to Reduced Voltage Starting

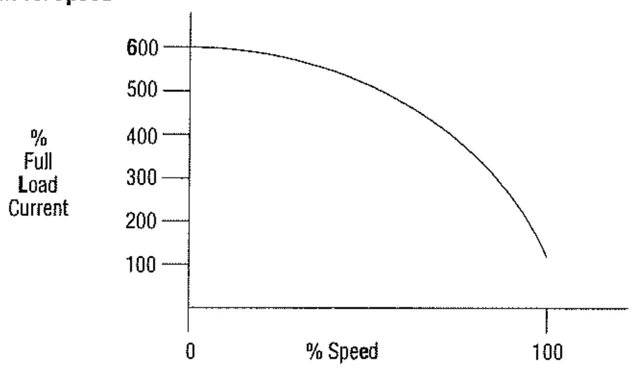
There are two primary reasons for using reduced voltage when starting a motor:

- Limit line disturbances
- Reduce excessive torque to the driven equipment

The reasons for avoiding these problems will not be described. However, different methods of reduced voltage starting of motors will be explored.

When starting a motor at full voltage, the current drawn from the power line is typically 600% of normal full load current. This high current flows until the motor is almost up to speed and then decreases, as shown in Figure 6.1. This could cause line voltage dips and brown-outs.

Figure 6.1 Full Load Current vs. Speed



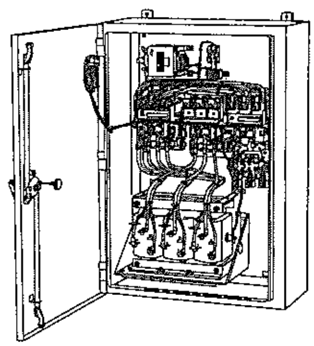
In addition to high starting currents, the motor also produces starting torques that are higher than full load torque. The magnitude of the starting torque depends on the motor design. NEMA publishes standards for torques and currents for motor manufacturers to follow. Typically, a NEMA Design B motor will have a locked rotor or starting torque in the area of 180% of full load torque.

In many applications, this starting torque can cause excessive mechanical damage such as belt, chain, or coupling breakage.

Reduced Voltage

The most widely used method of electromechanical reduced voltage starting is the autotransformer. Wye-delta (Y-Δ), also referred to as star-delta, is the next most popular method.

Figure 6.2 Bulletin 570 Autotransformer



All forms of reduced voltage starting affect the motor current and torque characteristics. When a reduced voltage is applied to a motor at rest, the current drawn by the motor is reduced. In addition, the torque produced by the motor is a factor of approximately the square of the percentage of voltage applied.

For example, if 50% voltage is applied to the motor, a starting torque of approximately 25% of the normal starting torque would be produced. In the previous full voltage example, the NEMA Design B motor had a starting torque of 180% of full load torque. With only 50% voltage applied, this would equate to approximately 45% of full load torque. See Table 6.A for the typical relationship of voltage, current, and torque for a NEMA Design B motor.

Table 6.A Typical Voltage, Current and Torque Characteristics for NEMA Design B Motors

Starting Method	% Voltage at Motor Terminals	Motor Starting Current as a % of:		Line Current as a % of:		Motor Starting Torque as a % of:	
		Locked Rotor Current	Full Load Current	Locked Rotor Current	Full Load Current	Locked Rotor Torque	Full Load Torque
Full Voltage	100	100	600	100	600	100	180
Autotrans. 80% tap 65% tap 50% tap	 80 65 50	 80 65 50	 480 390 300	 64 42 25	 384 252 150	 64 42 25	 115 76 45
Part winding	100	65	390	65	390	50	90
Wye-delta	100	33	198	33	198	33	60
Solid-state	0...100	0...100	0...600	0...100	0...600	0...100	0...180

With the wide range of torque characteristics for the various starting methods, selecting an electromechanical reduced voltage starter becomes more application dependent. In many instances, available torque becomes the factor in the selection processes.

Limiting line current has been a prime reason in the past for using electromechanical reduced voltage starting. Utility current restrictions, as well as in-plant bus capacity, may require motors above a certain horsepower to be started with reduced voltage. Some areas of the world require that any motor above 7-1/2 Hp be started with reduced voltage.

Using reduced voltage motor starting also enables torque control. High inertia loads are a good example of an application in which electromechanical reduced voltage starting has been used to control the acceleration of the motor and load.

Electromechanical reduced voltage starters must make a transition from reduced voltage to full voltage at some point in the starting cycle. At this point, there is normally a line current surge. The amount of surge depends upon the type of transition being used and the speed of the motor at the transition point.

There are two methods of transition: open circuit transition and closed circuit transition. Open circuit transition means that the motor is actually disconnected from the line for a brief period of time when the transition takes place. With closed transition, the motor remains connected to the line during transition. Open circuit transition will produce a higher surge of current because the motor is momentarily disconnected from the line. Examples of open and closed circuit transition currents are shown in Figure 6.3 and Figure 6.4.

Figure 6.3 Open Circuit Transition

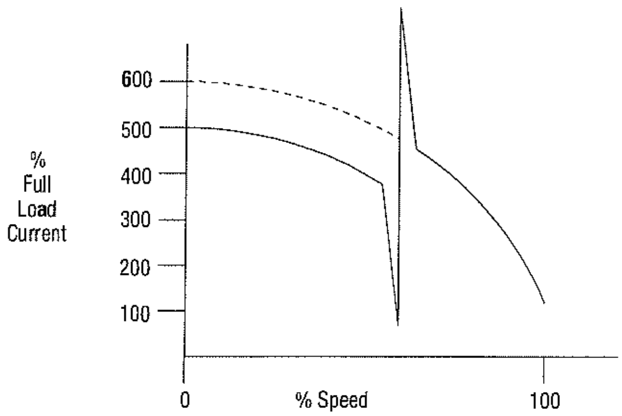
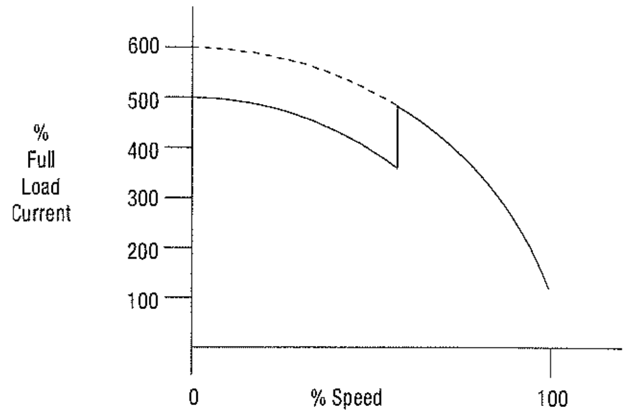


Figure 6.4 Closed Circuit Transition



The motor speed can determine the amount of current surge that occurs at transition. Transfer from reduced voltage to full voltage should occur at as close to full speed as possible. This also minimizes the amount of surge on the line.

The following figures illustrate transition at low motor speed and near full speed. The transition at low speed shows the current surge as transition occurs at 550%, which is greater than the starting current of 400%. The transition near full speed shows that the current surge is 300%, which is below the starting current.

Figure 6.5 Transition at Low Speed

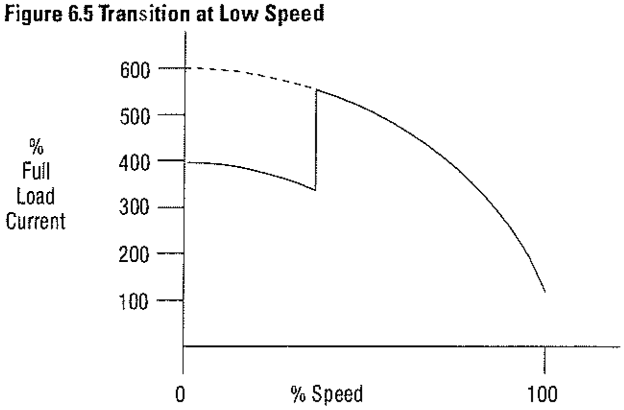
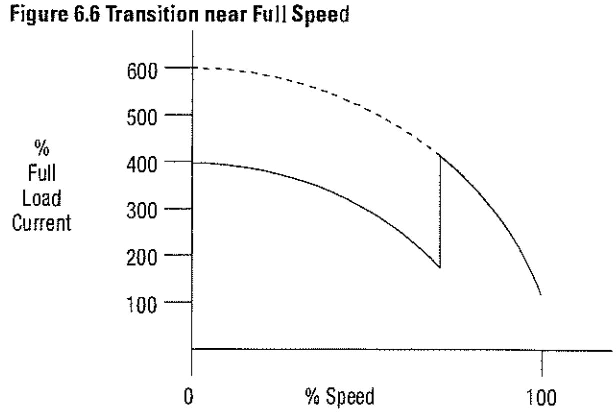


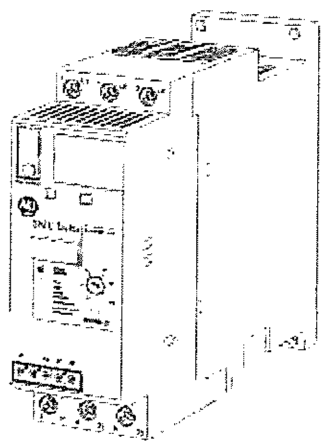
Figure 6.6 Transition near Full Speed



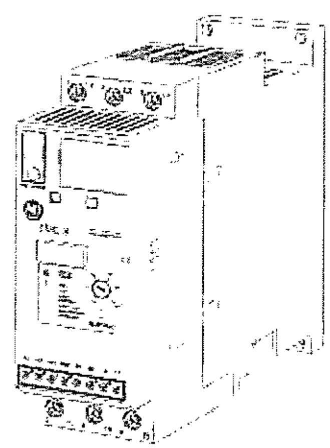
Solid-state

The main function of solid-state controllers is their ability to provide a soft start or stepless reduced voltage start of AC motors. The same principles of current and torque apply to both electromechanical reduced voltage starters and solid-state controllers. Many solid-state controllers offer the choice of four starting modes: soft start, current limit start, dual ramp start, or full voltage start in the same device.

Figure 6.7 SMC-Delta and SMC-3 Controllers



SMC-Delta

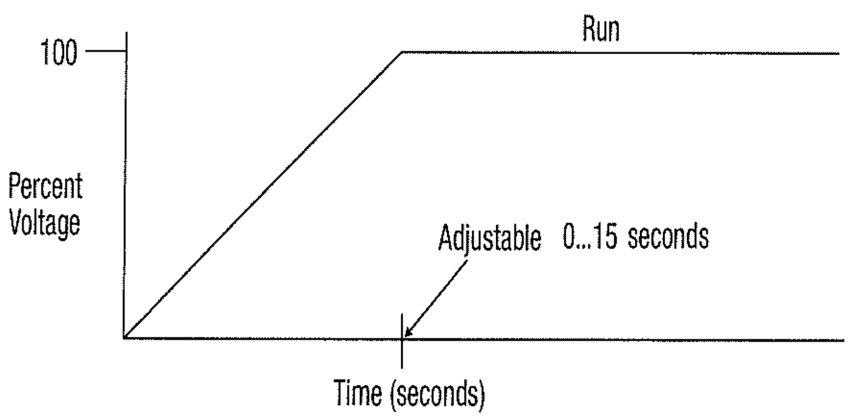


SMC-3

In addition to selecting the starting modes, the solid-state controller allows adjustment of the time for the soft start ramp, or the current limit maximum value, which enables selection of the starting characteristic to meet the application. The most widely used version is the soft start. This method provides a smooth start for most applications.

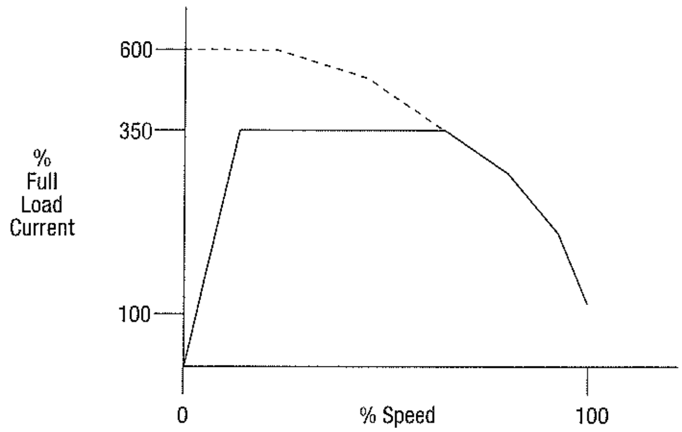
The major advantages of solid-state controllers are the elimination of the current transition point and the capability of adjusting the time to reach full voltage. The result is no large current surge when the solid-state controller is set up and correctly matched to the load, as illustrated in Figure 6.8.

Figure 6.8 Soft Start



Current limit starting can be used in situations in which power line limitations or restrictions require a specific current load. The next illustration shows a 350% current limit curve. Other values may be selected, such as 150%, 250%, or 350%, depending on the particular application. Current limit starting is also used in applications where higher starting torque is required compared to a soft start, which typically starts at less than 300% current. Current limit starting is typically used on high inertia loads, such as ball mills.

Figure 6.9 Current Limit Start



Features available with solid-state controllers include additional protection to the motor and controller, and diagnostics to aid in set-up and troubleshooting. Protection typically provided includes shorted SCR, phase loss, open load, SCR over-temperature, and jammed motor. Appropriate fault messages are displayed to aid in troubleshooting when one of these faults trip out the solid-state reduced voltage controller.

Notes:

Solid-state Starters Using SCRs

Solid-state Starters Using SCRs

In solid-state starters, silicon controlled rectifiers (SCRs - See Figure 7.1) are used to control the voltage output to the motor. A SCR allows current to flow in one direction only. The amount of conduction of a SCR is controlled by the pulses received at the gate of the SCR. When two SCRs are connected back to back (See Figure 7.2), the AC power to a load can be controlled by changing the firing angle of the line voltage (See Figure 7.3) during each half cycle. By changing the angle, it is possible to increase or decrease the voltage and current to the motor. The SMC controllers incorporate a microprocessor to control the firing of the SCRs. Six SCRs are used in the power section to provide full cycle control of the voltage and current. The voltage and current can be slowly and steplessly increased to the motor.

ATTENTION

This chapter uses NEMA design B motors as a basis for the information that it describes.

High efficiency motors with a locked rotor torque between 8…10 and initial surge of 16…24x are more than NEMA Design B motors. Use caution when applying motors other than NEMA design B types.

Figure 7.1 Silicon Controlled Rectifier (SCR)

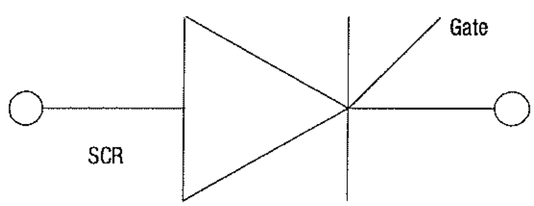


Figure 7.2 Typical Wiring Diagram of SCRs

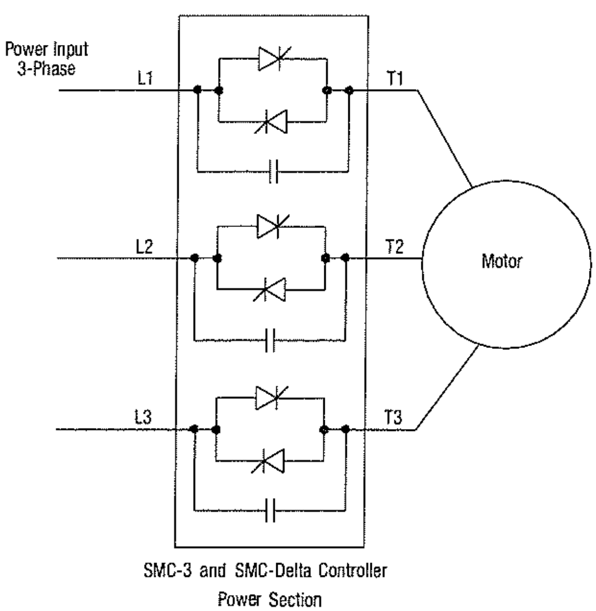
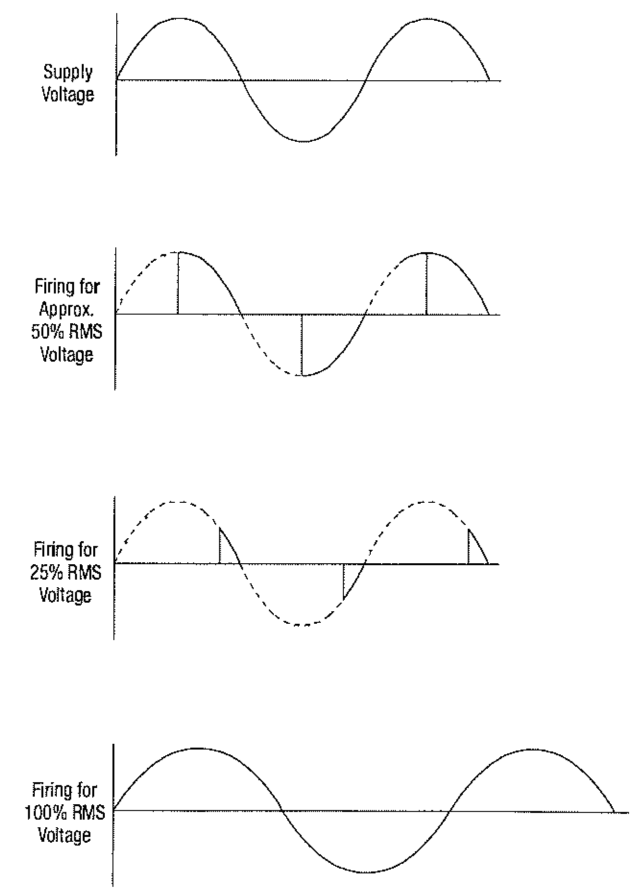


Figure 7.3 Different Firing Angles (Single-phase Simplification)



Notes:

Reference

Introduction

Certain mechanical parameters must be taken into consideration when applying motor controllers. The following section explains these parameters and how to calculate or measure them.

Motor Output Speed/Torque/Horsepower

The speed at which an induction motor operates depends on the input power frequency and the number of poles for which the motor is wound. The higher the frequency, the faster the motor runs. The more poles the motor has, the slower it runs. To determine the synchronous speed of an induction motor, use the following equation:

$$\text{Synchronous Speed} = \frac{60 \times 2 \times \text{Frequency}}{\text{Number of Poles}}$$

Actual full-load speed (the speed at which the motor will operate at nameplate rated load) will be less than synchronous speed. This difference between synchronous speed and full-load speed is called slip. Percent slip is defined as follows:

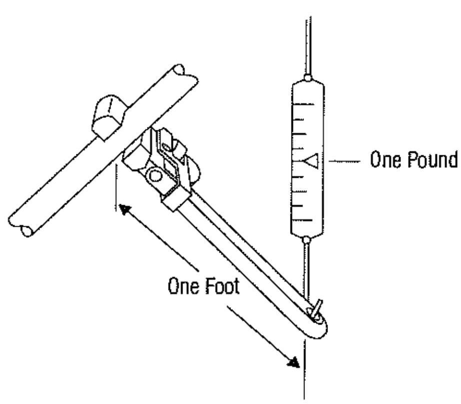
$$\text{Percent Slip} = \frac{\text{Synchronous Speed} - \text{Full Load Speed}}{\text{Synchronous Speed}} \times 100$$

Induction motors are built with slip ranging from less than 5% to as much as 20%. A motor with a slip of less than 5% is called a normal slip motor. Motors with a slip of 5% or more are used for applications requiring high starting torque.

Torque and Horsepower

Torque and horsepower, two important motor characteristics, determine the size of the motor required for a given application. The difference between the two can be explained using a simple illustration of a shaft and wrench.

Figure 8.1 Shaft and Wrench



Torque is merely a turning effort. In the previous illustration, it takes one pound at the end of the one foot wrench to turn the shaft at a steady rate. Therefore, the torque required is one pound × one foot, or one ft-lb. If the wrench were turned twice as fast, the torque required would remain the same, provided it is turned at a steady rate.

Horsepower, on the other hand, takes into account how fast the shaft is turned. Turning the shaft rapidly requires more horsepower than turning it slowly. Thus, horsepower is a measure of the rate at which work is done. By definition, the relationship between torque and horsepower is as follows:

$$1 \text{ horsepower} = 33{,}000 \text{ ft-lbs/min}$$

In the above example, the one pound of force moves a distance of:

$$2 \text{ ft} \times \pi \times 1 \text{ lb} \quad \text{or} \quad 6.68 \text{ ft-lbs}$$

To produce one horsepower, the shaft would have to be turned at a rate of:

$$\frac{1 \text{ Hp} \times 33{,}000 \text{ ft-lbs/min}}{6.28 \text{ ft-lbs/revolution}} = 5{,}250 \text{ rpm}$$

For this relationship, an equation can be derived for determining horsepower output from speed and torque.

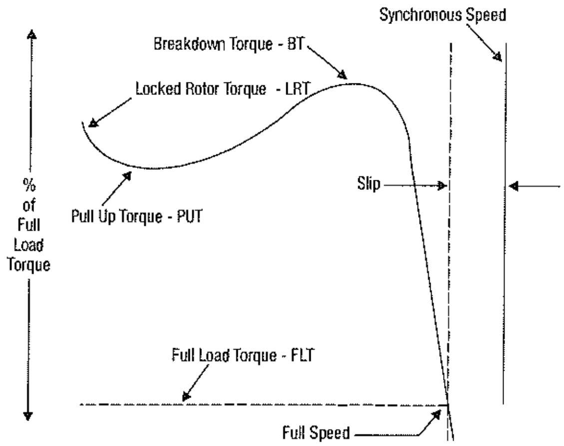
$$\text{Hp} = \frac{\text{rpm} \times 2 \times \text{Torque}}{30{,}000} \quad \text{or} \quad \frac{\text{rpm} \times \text{Torque}}{5{,}250}$$

For this relationship, full-load torque is:

$$\text{Full-load Torque in ft-lbs} = \frac{\text{Hp} \times 5{,}250}{\text{Full-load rpm}}$$

The following graph illustrates a typical speed-torque curve for a NEMA Design B induction motor. An understanding of several points on this curve will aid in properly applying motors.

Figure 8.2 Speed Torque Curve



Locked-Rotor Torque (LRT)

Locked-rotor torque is the torque which the motor will develop at rest for all angular positions of the rotor, with rated voltage at rated frequency applied. It is sometimes known as "starting torque" and is usually measured as a percentage of full-load torque.

Pull-Up Torque (PUT)

Pull-up torque of an induction motor is the minimum torque developed during the period of acceleration from locked rotor to the speed at which breakdown torque occurs. For motors that do not have definite breakdown torque (such as NEMA Design D), pull-up torque is the minimum torque developed, up to rated full-load speed, and is usually expressed as a percentage of full-load torque.

Breakdown Torque (BT)

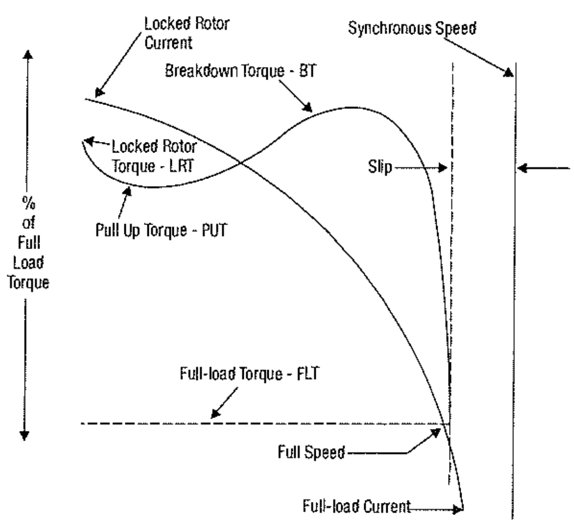
The breakdown torque of an induction motor is the maximum torque the motor will develop with rated voltage applied, at rated frequency, without an abrupt drop in speed. Breakdown torque is usually expressed as a percentage of full-load torque.

Full-load Torque (FLT)

The full-load torque of a motor is the torque necessary to produce its rated horsepower at full-load speed. In foot-lbs, it is equal to the rated horsepower, multiplied by 5250, divided by the full-load speed in rpm.

In addition to the relationship between speed and torque, the relationship of current draw to these two values is an important application consideration. The speed/torque curve is repeated below, with the current curve added, to demonstrate a typical relationship.

Figure 8.3 Speed Torque Curve with Current Curve



Two important points on this current curve require explanation.

Full-load Current

The full-load current of an induction motor is the steady-state current taken from the power line when the motor is operating at full-load torque with rated voltage and rated frequency applied.

Locked-rotor Current

Locked-rotor current is the steady state current of a motor with the rotor locked and with rated voltage applied at rated frequency. NEMA has designed a set of code letters to define locked-rotor: kilovolt-amperes-per-horsepower (kVA/Hp). This code letter appears on the nameplate of all AC squirrel-cage induction motors.

kVA per Horsepower is Calculated as Follows:

For three-phase motors:

$$kVA/Hp = \frac{1.73 \times \text{Current (in amps)} \times \text{Volts}}{1{,}000 \times Hp}$$

For single phase motors:

$$kVA/Hp = \frac{\text{Current (in amps)} \times \text{Volts}}{1{,}000 \times Hp}$$

Table 8.A NEMA Locked-Rotor Current Code Letters

Letter Designator	kVA/Hp❶	Letter Designator	kVA/Hp❶	Letter Designator	kVA/Hp❶	Letter Designator	kVA/Hp❶	Letter Designator	kVA/Hp❶
A	0...3.15	E	4.5...5.0	J	7.1...8.0	N	11.2...12.5	T	18.0...20.0
B	3.15...3.55	F	5.0...5.6	K	8.0...9.0	P	12.5...14.0	U	20.0...22.4
C	3.55...4.0	G	5.6...6.3	L	9.0...10.0	R	14.0...16.0	V	22.4 and up
D	4.0...4.5	H	6.3...7.1	M	10.0...11.2	S	16.0...18.0		

❶ Locked-rotor kVA/Hp range includes the lower figure up to, but not including, the higher figure [i.e., 3.14 is letter "A" and 3.15 is letter "B"].

By manipulating the preceding equation for kVA/Hp for three-phase motors, the following equation can be used for calculating locked-rotor current:

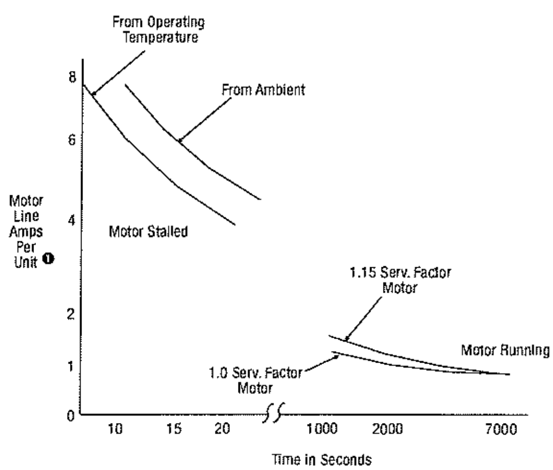
$$LRA = \frac{1{,}000 \times Hp \times kVA/Hp}{1.73 \times \text{Volts}}$$

This equation can then be used to determine the approximate starting current of any particular motor. For instance, the approximate starting current for 7-1/2 Hp, 230 volt motor with a locked-rotor kVA code letter of G would be:

$$LRA = \frac{1{,}000 \times 7.5 \times 6.0}{1.73 \times 230} = 113\text{ A}$$

Operating a motor in a locked-rotor condition for an extended period of time will result in insulation failure because of the excessive heat generated in the stator. The following graph illustrates the maximum time a motor may be operated at locked-rotor without incurring damage caused by heating. This graph assumes a NEMA Design B motor with Class B temperature rise.

Figure 8.4 Motor Safe Time vs. Line Current - Standard Induction Motors



Motor protection, either inherent or in the motor control, should be selected to limit the stall time of the motor.

❶ Base Amps and Nameplate Amps.

Calculating Torque (Acceleration Torque Required for Rotating Motion)

Some machines must be accelerated to a given speed in a certain period of time. The torque rating of the drive may have to be increased to accomplish this objective. The following equation may be used to calculate the average torque required to accelerate a known inertia (WK2). This torque must be added to all the other torque requirements of the machine when determining the drive and motor's required peak torque output.

$$T = \frac{WK^2 \times (\Delta N)}{308 \times t}$$

Where:
T = Acceleration Torque (ft-lb)
WK^2 = total system inertia (ft-lb^2) that the motor must accelerate.
(This value includes motor armature, reducer, and load.)
ΔN = Change in speed required (rpm)
t = time to accelerate total system load (seconds).

Consult the conversion tables located at the end of this chapter, if required.

The same formula can be used to determine the minimum acceleration time of a given drive, or it can be used to establish whether a drive can accomplish the desired change in speed within the required time period. The transposed formula is:

$$T = \frac{WK^2 \times (\Delta N)}{308 \times t}$$

General Rule:

If the running torque is greater than the accelerating torque, use the running torque as the full-load torque required to determine the motor horsepower.

Calculating Horsepower

The following equations for calculating horsepower are meant to be used for estimating purposes only. These equations do not include any allowance for machine friction, winding or other factors that must be considered when selecting a device for a machine application.

After the machine torque is determined, the required horsepower is calculated using the formula:

$$Hp = \frac{T \times N}{5{,}250}$$

Where:
Hp = Horsepower
T = Torque (ft-lb)
N = Speed of motor at rated load (rpm)

If the calculated horsepower falls between standard available motor ratings, select the higher available horsepower rating. It is good practice to allow some margin when selecting the motor horsepower.

Inertia

Inertia is a measure of the body's resistance to changes in velocity, whether the body is at rest or moving at a constant velocity. The velocity can be either linear or rotational.

The moment of inertia (WK^2) is the product of the weight (W) of an object and the square of the radius of gyration (K^2). The radius of gyration is a measure of how the mass of the object is distributed about the axis of rotation. Because of this distribution of mass, a small diameter cylindrical part has a much lower inertia than a large diameter part.

Inertia, Continued

$$WK^2 \text{ or } WR^2$$

Where:

WR^2 refers to the inertia of a rotating member that was calculated by assuming the weight of the object was concentrated around its rim at a distance R (radius) from the center (e.g., flywheel).

WK^2 refers to the inertia of a rotating member that was calculated by assuming the weight of the object was concentrated at some smaller radius, K (termed the radius of gyration). To determine the WK^2 of a part, the weight is normally required (e.g., cylinder, pulley, gear).

Torque Formulas

$$T = \frac{Hp \times 5250}{N}$$

Where:
T = Torque (ft-lb)
Hp = Horsepower
N = Speed of motor at rated load (rpm)

$$T = F \times R$$

Where:
T = Torque (ft-lb)
F = Force (lbs)
R = Radius (ft)

$$T\ (\text{Accelerating}) = \frac{WK^2 \times (\Delta rpm)}{308 \times t}$$

Where:
T = Torque (ft-lb)
WK^2 = Inertia reflected to the Motor Shaft (ft-lb^2)
Δ rpm = Change in speed
t = Time to accelerate (seconds)
Note: To change ft-lb^2 to in.-lb-s^2: Divide by 2.68 To change in.-lb-s^2 to ft-lb^2: Multiply by 2.68

AC Motor Formulas

$$\text{Sync Speed} = \frac{\text{Freq} \times 120}{\text{Number of Poles}}$$

Where:
Sync Speed = Synchronous Speed (rpm)
Freq = Frequency (Hz)

$$\%\ \text{Slip} = \frac{\text{Sync Speed} - \text{FL Speed}}{\text{Sync Speed}} \times 100$$

Where:
FL Speed = Full Load Speed (rpm)
Sync Speed = Synchronous Speed (rpm)

$$\text{Reflected } WK^2 = \frac{(WK^2 \text{ of Load})}{(\text{Reduction Ratio})^2}$$

Where:
WK^2 = Inertia (ft-lb^2)

Torque Characteristics on Common Applications

This chart offers a quick guideline on the torque required to breakaway, start and run many common applications.

Table 8.B Torque Characteristics

Application	Load Torque as Percent of Full Load Drive Torque		
	Break-away	Accel-erating	Peak Run
Agitators:			
Liquid	100	100	100
Slurry	150	100	100
Blowers, centrifugal:			
Valve closed	30	50	40
Valve open	40	110	100
Blowers, positive-displacement, rotary, bypassed	40	40	100
Card machines, textile	100	110	100
Centrifuges (extractors)	40	60	125
Chippers, wood, starting empty	50	40	200
Compressors, axial-vane, loaded	40	100	100
Compressors, reciprocating, start unloaded	100	50	100
Conveyors, belt (loaded)	150	130	100
Conveyors, drag (or apron)	175	150	100
Conveyors, screw (loaded)	175	100	100
Conveyors, shaker-type (vibrating)	150	150	75
Draw presses (flywheel)	50	50	200
Drill presses	25	50	150
Escalators, stairways (starting unloaded)	50	75	100
Fans, centrifugal, ambient:			
Valve closed	25	60	50
Valve open	25	110	100
Fans, centrifugal, hot:			
Valve closed	25	60	100
Valve open	25	200	175
Fans, propeller, axial-flow	40	110	100
Feeders, (belt) loaded	100	120	100
Feeders, distributing, oscillating drive	150	150	100
Feeders, screw, compacting rolls	150	100	100
Feeders, screw, filter-cake	150	100	100
Feeders, screw, dry	175	100	100
Feeders, vibrating, motor-driven	150	150	100
Frames, spinning, textile	50	125	100
Grinders, metal	25	50	100
Ironers, laundry (mangles)	50	50	125

Application	Load Torque as Percent of Full Load Drive Torque		
	Break-away	Accel-erating	Peak Run
Jointers, woodworking	50	125	125
Machines, bottling	150	50	100
Machines, buffing, automatic	50	75	100
Machines, cinder-block, vibrating	150	150	70
Machines, keyseating	25	50	100
Machines, polishing	50	75	100
Mills, flour, grinding	50	75	100
Mills, saw, band	50	75	200
Mixers, chemical	175	75	100
Mixers, concrete	40	50	100
Mixers, dough	175	125	100
Mixers, liquid	100	100	100
Mixers, sand, centrifugal	50	100	100
Mixers, sand, screw	175	100	100
Mixers, slurry	150	125	100
Mixers, solids	175	125	175
Planers, woodworking	50	125	150
Presses, pellet (flywheel)	150	75	150
Presses, punch (flywheel)	150	75	100
Pumps, adjustable-blade, vertical	50	40	125
Pumps, centrifugal, discharge open	40	100	100
Pumps, oil-field, flywheel	150	200	200
Pumps, oil, lubricating	40	150	150
Pumps, oil fuel	40	150	150
Pumps, propeller	40	100	100
Pumps, reciprocating, positive displacement	175	30	175
Pumps, screw-type, primed, discharge open	150	100	100
Pumps, Slurry-handling, discharge open	150	100	100
Pumps, turbine, centrifugal, deep-well	50	100	100
Pumps, vacuum (paper mill service)	60	100	150
Pumps, vacuum (other applications)	40	60	100

Table 8.B Torque Characteristics, Continued

Application	Load Torque as Percent of Full Load Drive Torque		
	Break-away	Accel-erating	Peak Run
Pumps, vane-type, positive displacement	150	150	175
Rolls, crushing (sugar cane)	30	50	100
Rolls, flaking	30	50	100
Sanders, woodworking, disk or belt	30	50	100
Saws, band, metalworking	30	50	100
Saws, circular, metal, cutoff	25	50	150
Saws, circular, wood, production	50	30	150
Saws, edger (see edgers)			
Saws, gang	60	30	150
Screens, centrifugal (centrifuges)	40	60	125
Screens, vibrating	50	150	70
Separators, air (fan-type)	40	100	100
Shears, flywheel-type	50	50	120
Textile machinery	150	100	90
Walkways, mechanized	50	50	100
Washers, laundry	25	75	100

Notes:

THIS INFORMATION NEEDS TO BE ADDED TO THE OPERATION AND MAINTENANCE MANUAL, QIKIQTARJUAQ WATER PUMPING UPGRADE, OCTOBER 2009

GSE Lining Technology, Inc

Roll Test Data Report

Sales Order No.	Project Number	Customer Name	Project Location	Product Name	Report Date
47539	520721	Nilex	Canada	HDE080A000	7/8/2009

GSE QC APPROVED

Roll No.	ASTM D 5199 Average Thickness (mils) every roll	ASTM D 5199 Minimum Thickness (mils) every roll	ASTM D638, Type IV / D6693 TD Strength @ Yield (ppi) every 5th	MD Strength @ Yield (ppi) every 5th	TD Strength @ Break (ppi) every 5th	MD Strength @ Break (ppi) every 5th	TD Elongation @ Yield (%) every 5th	MD Elongation @ Yield (%) every 5th	TD Elongation @ Break (%) every 5th	MD Elongation @ Break (%) every 5th	ASTM D 1004 TD Tear Resistance (lbs) every 5th	ASTM D 1004 MD Tear Resistance (lbs) every 5th	ASTM D 4833 Puncture Resistance (lbs) every 5th	ASTM D 1505 Density (g/cc) every 5th	ASTM D 4218/1603 Carbon Black Content (%) every 5th	ASTM D 5596 Carbon Black Dispersion Views in Cat1 - Cat2 every 5th
101119380	81	75	215	198	422	419	18	20	904	885	64	63	171	0.946	2.61	10
101119381	81	77	217	211	416	430	17	19	902	868	65	68	177	0.945	2.50	10
101119382	81	76	217	211	416	430	17	19	902	868	65	68	177	0.945	2.50	10
101119383	81	77	217	211	416	430	17	19	902	868	65	68	177	0.945	2.50	10
101119384	81	77	217	211	416	430	17	19	902	868	65	68	177	0.945	2.50	10
101119385	81	78	217	211	416	430	17	19	902	868	65	68	177	0.945	2.50	10
101119386	81	77	219	209	421	404	17	19	887	819	64	67	179	0.944	2.71	10
101119387	81	76	219	209	421	404	17	19	887	819	64	67	179	0.944	2.71	10
101119388	81	80	219	209	421	404	17	19	887	819	64	67	179	0.944	2.71	10
101119389	81	77	219	209	421	404	17	19	887	819	64	67	179	0.944	2.71	10
101119390	81	80	219	209	421	404	17	19	887	819	64	67	179	0.944	2.71	10
101119391	82	81	211	203	415	390	21	19	897	819	62	64	177	0.945	2.58	10
101119392	81	79	211	203	415	390	21	19	897	819	62	64	177	0.945	2.58	10
101119393	81	79	211	203	415	390	21	19	897	819	62	64	177	0.945	2.58	10
101119394	81	81	211	203	415	390	21	19	897	819	62	64	177	0.945	2.58	10
101119395	82	79	211	203	415	390	21	19	897	819	62	64	177	0.945	2.58	10
101119396	81	78	220	206	414	421	17	20	855	848	64	68	173	0.945	2.66	10
101119397	82	77	220	206	414	421	17	20	855	848	64	68	173	0.945	2.66	10
101119398	82	79	220	206	414	421	17	20	855	848	64	68	173	0.945	2.66	10
101119399	82	80	220	206	414	421	17	20	855	848	64	68	173	0.945	2.66	10
101119400	81	79	220	206	414	421	17	20	855	848	64	68	173	0.945	2.66	10
101119401	81	79	209	194	397	394	18	21	857	813	64	68	177	0.944	2.40	10

Laboratory Manager: [signature]

GSE-8.2.4-029 Rev – 0

19103 Gundle Road - Houston, Texas 77073

GSE Lining Technology, Inc

Roll Test Data Report

Sales Order No.	Project Number	Customer Name	Project Location	Product Name		Report Date
48519	521208	Layfield Environmental Systems	NT, Canada	HDE080A000	GSE QC APPROVED	7/8/2009

	ASTM D 5199		ASTM D638, Type IV / D6693								ASTM D 1004		ASTM D 4833	ASTM D 1505	ASTM D 4218/1603	ASTM D 5596
	Average Thickness (mils)	Minimum Thickness (mils)	TD Strength @ Yield (ppi)	MD Strength @ Yield (ppi)	TD Strength @ Break (ppi)	MD Strength @ Break (ppi)	TD Elongation @ Yield (%)	MD Elongation @ Yield (%)	TD Elongation @ Break (%)	MD Elongation @ Break (%)	TD Tear Resistance (lbs)	MD Tear Resistance (lbs)	Puncture Resistance (lbs)	Density (g/cc)	Carbon Black Content (%)	Carbon Black Dispersion Views in Cat1 - Cat2
Roll No.	every roll		every 4th								every 4th		every 4th	every 4th	every 4th	every 4th
101120157	83	78	208	194	404	366	17	18	866	764	65	71	173	0.945	2.78	10
101120159	82	78	208	194	404	366	17	18	866	764	65	71	173	0.945	2.41	10

Laboratory Manager: Jane Allen

GSE-8.2.4-029 Rev – 0

19103 Gundle Road - Houston, Texas 77073

GSE *Lining Technology, Inc*

Roll Test Data Report

Sales Order No.	*Project Number*	*Customer Name*	*Project Location*	*Product Name*	*Report Date*
46429	520174	Newmont	Battle Mountain, NV	LLD080A000	7/8/2009

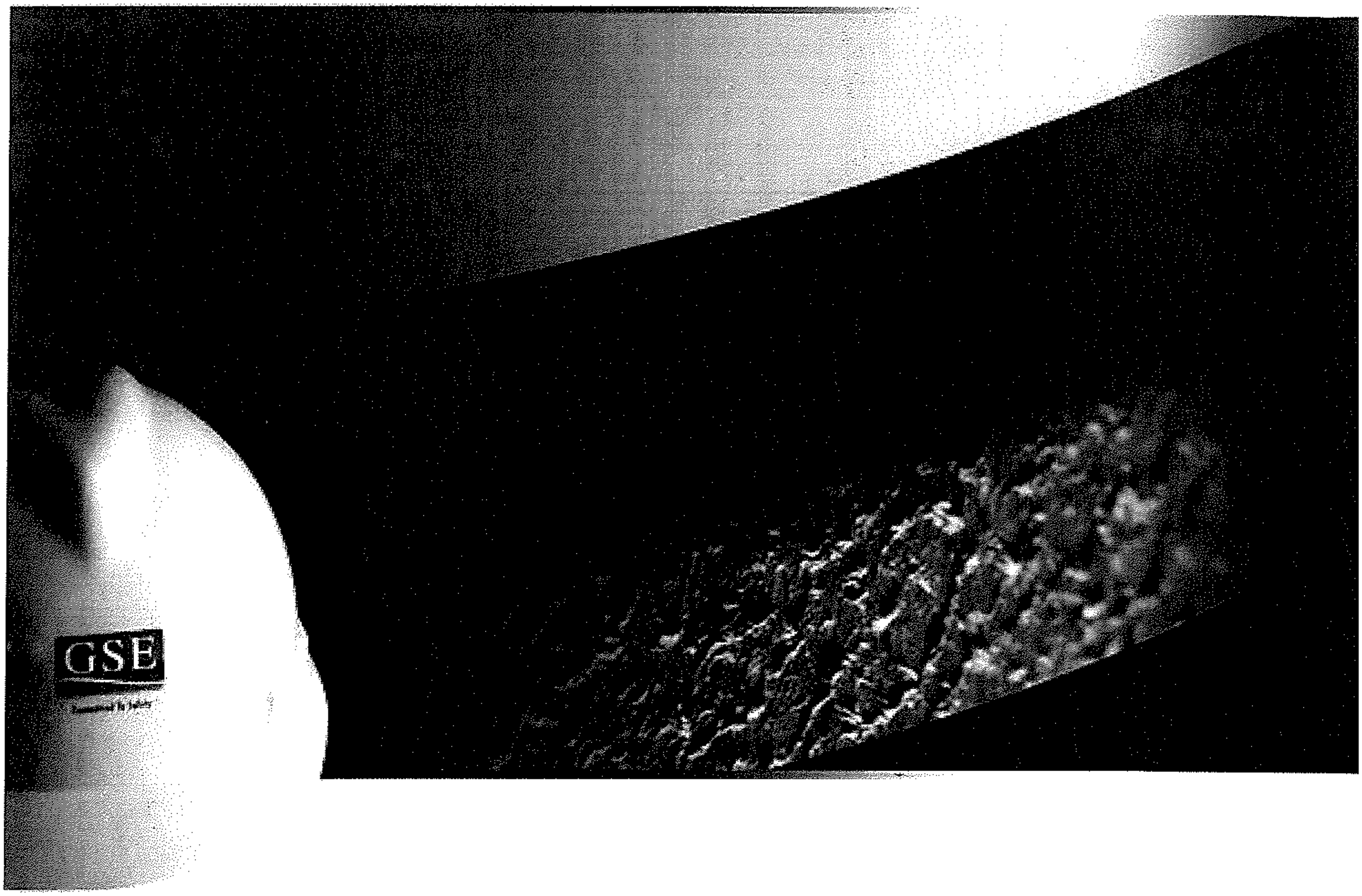
GSE QC APPROVED

	ASTM D 5199		ASTM D638, Type IV / D6693				ASTM D 1004		ASTM D 4833	ASTM D 1505	ASTM D 4218/1603	ASTM D 5596
	Average Thickness (mils)	Minimum Thickness (mils)	TD Strength @ Break (ppi)	MD Strength @ Break (ppi)	TD Elongation @ Break (%)	MD Elongation @ Break (%)	TD Tear Resistance (lbs)	MD Tear Resistance (lbs)	Puncture Resistance (lbs)	Density (g/cc)	Carbon Black Content (%)	Carbon Black Dispersion Views in Cat1 - Cat2
Roll No	every roll		every 5th				every 5th		every 5th	every 5th	every 5th	every 5th
101119368	81	77	460	425	1100	1125	50	48	145	0.93	2.55	10

Laboratory Manager: [signature] GSE-8.2.4-029 Rev – (

19103 Gundle Road - Houston, Texas 77073

Installation Quality Assurance Manual



Geomembrane Products

Table of Contents

1.0 INTRODUCTION

This manual provides an overview of the GSE Installation Quality Assurance procedures consistent with industry accepted practices to ensure that the geomembrane products installed will perform for its intended purpose. In addition, all installation work will be performed in strict accordance per the customer's specifications. Please read the procedures below completely before you begin. If you need further clarification, contact the GSE Installation Department for assistance. Remember safety first and use safe practices always on every project.

2.0 STANDARD TEST METHODS

ASTM D 6392: Standard Test Methods For Determining The Integrity Of Non-Reinforced Geomembrane Seams Produced Using Thermo Fusion Methods

ASTM D 5820: Standard Practice For Pressurized Air Channel Evaluation of Dual Seamed Geomembranes

ASTM D 5641: Standard Practice For Geomembrane Seam Evaluation By Vacuum Chamber

ASTM D 6497: Standard Guide For Mechanical Attachment of Geomembrane to Penetrations or Structures

ASTM D 7240: Standard Practice for Leak Location using Geomembranes with an Insulating Layer in Intimate Contact with a Conductive Layer via Electrical Capacitance Technique (Conductive Geomembrane Spark Test)

GRI Standard GM13: Test Properties, Testing Frequency and Recommended Warranty for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes

GRI Standard GM14: Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes

GRI Standard GM17: Test Properties, Testing Frequency and Recommended Warranty for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes

GRI Standard GM19: Standard Specification for Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes

3.0 MATERIAL DELIVERY

A. Upon arrival on site, the GSE QA personnel will inventory all materials on the job site.

B. Roll numbers of geomembrane will be logged on the Inventory Check List (Appendix A) and cross-referenced with the Bill of Lading for materials supplied by GSE.

C. Copies of the Inventory Check List and signed Bill of Lading should be sent to the GSE's corporate headquarters while the QA personnel retains the original copies.

IQA GEO R02/09/10

D. Any visible damage to roll materials should be noted on the roll and Inventory Check List.

4.0 EARTHWORK

A. The general contractor is responsible for preparing and maintaining the subgrade. The subgrade should be prepared and maintained per the job specifications.

B. The GSE site manager shall be responsible for assuring that the subgrade surface has been properly prepared for deployment of geosynthetics. After each day's deployment the Subgrade Surface Acceptance form (Appendix B) will be signed by all parties.

5.0 PANEL PLACEMENT

A. Each panel will be assigned a number as described below.
   1. When there is one layer, panels may be designated with only a number, i.e...1, 2, 3, 4 etc.

   2. When two or more layers are required, use a letter and number, i.e....
      Primary Liner P1, P2, P3, P4 etc...
      Secondary Liner S1, S2, S3, S4 etc...
      Tertiary Liner T1, T2, T3, T4 etc...

B. This numbering system should be used whenever possible. Agreement to a panel numbering system should be made at the pre-construction meeting. However, it is essential that GSE and the owner representative and third party QA inspector agree.

C. Panel numbers shall be written in large block letters in the center of each deployed panel. The roll number, date of deployment and length (gross) should be noted below the panel number. All notes should be made, so that they are easily visible from a distance. On long panels it is beneficial to write information on both ends.

D. Panel numbers shall be logged on the GSE Panel Placement Log (Appendix C) along with the roll number and other information neccessary to complete the form.

E. If there is a partial roll left after deployment, it is important to write the last four digits of the roll number in several locations on the roll along with the estimated length for future identification.

F. Deployment of geomembrane panels shall be performed in a manner that will comply with the following guidelines:

   1. Unroll geomembrane using methods that will not damage geomembrane and will protect underlying surface from damage. GSE Conductive should be installed with Conductive layer facing down.

   2. Place temporary ballast, such as sangbags, on geomembrane that will not damage the geomembrane and to prevent wind uplift.

   3. Personnel walking on geomembrane shall not engage in activities or wear shoes that could

damage it. Smoking is not permitted on the geomembrane.

4. Do not allow heavy vehicular traffic directly on geomembrane. Rubber tired and tracked ATV's and equipment are acceptable if contact pressure is less than 8 psi.

   a. Protect geomembrane in areas of heavy traffic by placing protective cover over the geomembrane.

   b. Prior to driving on any geomembrane layer, please check for sharp edges, embedded rocks, or other foreign objects that may protrude in the tires and tracks.

   c. Path driven on geomembranes shall be as straight as possible with no sharp turns, sudden stops or quick starts.

   d. Areas where driving occurs shall be continuously and thoroughly inspected throughout the deployment process by the contractor and the third party CQA.

6.0 TRIAL WELDS

A. Seaming apparatus shall be allowed to warm up a minimum of 10 minutes before performing trial welds.

B. Each seaming apparatus along with GSE welding technician will pass a trial weld prior to use. Trial welds to be performed in the morning and afternoon, as a minimum, as well as whenever there is a power shutdown.

C. Fusion or wedge welds will always be performed or conducted on samples at least 6.0 ft long. Extrusion welds will be done on samples at least 3.0 ft long.

Note: Always perform trial welds in the same conditions that exist on the job. Run the trial welds on the ground, not the installed liner. Do not use a wind break unless you are using one on the job.

D. Operating temperatures should be monitored while welding. The welding technician should verify that the equipment is capable of maintaining temperature while welding.

E. Sampling Procedure

   1. Cut five 1.0 in wide specimens from the trial weld sample. Specimens will always be cut using a 1.0 in die cutter, so the peel values may be used for qualitative analysis.

   2. When cutting coupons from the trial weld samples, the inside and outside tracks on the coupon should be identified to assist in troubleshooting problems in case the weld fails. The outside track will be defined as the track, which would be peeled if pulling the overlap exposed in a typical installation, or the seam that is closest to the edge of the top sheet. The inside track is the seam closest to the edge of the bottom sheet.

F. Cutter
   1. Only cut one sample at a time to avoid damaging the die cutter.
   2. Samples should be free of sand and grit prior to cutting sample.
   3. Inspect the die edge weekly for nicks, dents or signs of dullness. Dullness of the cutting edge may damage the units.
   4. Remove die when edge has been dulled and lightly reshape it with a medium hand file. When wear is excessive return it for a replacement die.
   5. When the cutting board becomes deeply scored and/or interferes with coupon cutting it should be replaced.
   6. To adjust the depth of the die cut into the cutting board, after replacing the cutting board or sharpening the die, 0.015 in washer shims can be added or removed between the cutting ram and the ram extension. Only add shims when cutting is difficult due to lack of depth of cut.

G. Trial Weld Testing
   1. Allow coupons to cool prior to testing. Avoid separating the coupons while hot as failure of the sheet may be initiated and false readings indicated.
   2. In extreme heat the coupons may need to be cooled, using water or an insulated cooler prior to peel testing. Lab conditions specify 70 degrees (plus or minus 4 degrees) Fahrenheit. Coupon temperatures greater than 70 degrees may result in lowered strengths.
   3. Visually inspect the coupons for squeeze-out, footprint, pressure and general appearance.
   4. Each of the five coupons will be tested in peel on the field tensiometer at a separation rate of 2 in per minute (for HDPE). Shear tests, in addition to the peel tests, will be performed.

H. Pass/Fail Criteria
   1. Criteria for passing trial welds will be as follows:
      a. Seam must exhibit film tear bond (FTB). Trial welds should have no incursion into the weld.
      b. Peel and shear values shall meet or exceed the values as listed in Appendix D, Table 1 for HDPE smooth or textured sheet (@ 2 in/min).
      c. Peel and shear values shall meet or exceed the values as listed in Appendix D, Table 2 for LLDPE smooth or textured sheet (@ 20 in/min).
      d. Both tracks of fusion welded samples must pass for the trial weld to be considered acceptable. If any of the five coupons fail due to seam incursion (no FTB) or low strength values, the trial weld must be performed again.

10A GEO R07/09/10

e. The GSE QA personnel will give approval to proceed with welding after observing and recording all trial welds.

2. All trial weld data will be logged on the GSE Trial Weld Log (Appendix E).

3. When logging fusion welded peel values on the GSE Trial Weld Log indicate the values. for the outside track first, followed by the inside track.

4. Speed and temperature settings will be recorded for each machine trial weld as appropriate.

7.0 GEOMEMBRANE FIELD SEAMING

A. The seam number takes the identity of the panels on each side. The seam between panels 1 & 2 becomes seam 1/2.

B. Welding technicians will record their initials, machine number, date and time at the start of every seam and on the GSE Seam Log (Appendix F). The technician should also periodically mark temperatures along the seam and at the end of the seam.

C. Approved processes for field seaming and repairing are fusion welding and extrusion welding. All welding equipment shall have accurate temperature monitoring devices installed and working to ensure proper measurement.

D. Fusion welding shall be used for seaming panels together and is not used for patching or detail work. The GSE site manager shall verify that:

1. The equipment used is functioning properly.

2. All work is performed on clean surfaces and done in a professional manner. No seaming will be performed in adverse weather conditions.

E. Extrusion welding shall be used primarily for repairs, patching and special detail fabricating and may be used for seaming. The GSE site manager shall verify that:

1. Equipment used is functioning properly.

2. Welding personnel are purging the extrusion welders of heat degraded extrudate prior to actual use.

3. All work is performed on clean surfaces and done in a professional manner. No seaming will be performed in adverse weather conditions.

F. For seam preparation, the welding technician shall verify that:

1. Prior to seaming, the seaming area is free of moisture, dust, dirt, sand or debris of any nature.

2. The seam is overlapped properly for fusion welding.

3. The seam is overlapped or extended beyond damaged areas at least 4.0 in when extrusion welding.

4. The seam is properly heat tacked and abraded prior to extrusion welding.

5. Seams are welded with fewest number of unmatched wrinkles or "fishmouths".

G. No seaming will be performed in ambient air temperatures or adverse weather conditions that would jeopardize the integrity of the liner installation.

8.0 FIELD DESTRUCTIVE TESTING

A. Destructive seam tests shall be performed to evaluate bonded seam strength. The frequency of sample removal shall be one sample per 500 ft of seam, unless site specifications differ. Location of the destructive samples will be selected and marked by the QA technician or third party QA inspector. Field testing should take place as soon as possible after seam is completed.

B. Samples should be labeled in numerical order, i.e. DS-1, DS-2 etc....This should carry thru any layer and or multiple ponds, do not start numbering from 1 again. The size of samples and distribution should be approximately 12 in x 39 in (Size may vary depending on job requirements) and distributed as follows:

1. 12 in x 12 in piece given to QA technician for field testing.

2. 12 in x 12 in piece sent to the GSE's corporate headquarters for testing, if required.

3. 12 in x 12 in piece given to third party for independent testing or to archive.

NOTE: All samples will be labeled showing test number, seam number, machine number, job number, date welded and welding tech number.

C. The sample given to the QA technician in the field shall have ten coupons cut and be tested with a tensiometer adjusted to a pull rate as shown below. The strength of four out of five specimens should meet or exceed the values below, and the fifth specimen must meet or exceed 80% of the value below.

1. Seam must exhibit film tear bond (FTB). Welds should have ≤ 25% incursion into the weld.

2. Peel and shear values shall meet or exceed the values as listed in Appendix D, Table 1 for HDPE smooth or textured sheet (@ 2 in/min).

3. Peel and shear values shall meet or exceed the values as listed in Appendix D, Table 2 for LLDPE smooth or textured sheet (@ 20 in/min).

D. All weld destructive test data will be logged on the GSE Destructive Test Log (Appendix G).

E. When logging fusion welded peel values on the GSE Destructive Test Log, indicate the values for the outside track first, followed by the inside track.

F. Test results will be noted in the GSE Destructive Test Log as Pass (P) or Fail (F).

G. If a test fails, additional samples will be cut, approximately 10 ft on each side of the failed test, and retested. These will be labeled A (After) & B (Before). This procedure will repeat itself until a sample passes. Then the area of failed seam between the two tests that pass will be capped or reconstructed.

9.0 NON-DESTRUCTIVE TESTING

A. GSE shall non-destructively test all seams their full length using an air pressure or vacuum test. The purpose of this test is to check the continuity of the seam.

B. For air pressure testing, the following procedures are applicable to those seams welded with a double seam fusion welder.

1. The equipment used shall consist of an air tank or pump capable of producing a minimum 35 psi and a sharp needle with a pressure gauge attached to insert into the air chamber.

2. Seal both ends of the seam by heating and squeezing them together. Insert the needle with the gauge into the air channel. Pressurize the air channel to 30 psi. Note time test starts and wait a minimum of 5 minutes to check. If pressure after five minutes has dropped less than 2 psi then the test is successful (Thickness of material may cause variance).

3. Cut opposite seam end and listen for pressure release to verify full seam has been tested.

4. If the test fails, follow these procedures.
   a. While channel is under pressure walk the length of the seam listening for a leak.

   b. While channel is under pressure apply a soapy solution to the seam edge and look for bubbles formed by air escaping.

   c. Re-test the seam in smaller increments until the leak is found.

5. Once the leak is found using one of the proceedures above, cut out the area and retest the portions of the seams between the leak areas per 4a to 4b above. Continue this procedure until all sections of the seam pass the pressure test.

6. Repair the leak with a patch and vacuum test.

C. For vacuum testing, the following procedures are applicable to those seams welded with an extrusion welder.

1. The equipment used shall consist of a vacuum pumping device, a vacuum box and a foaming agent in solution.

2. Wet a section with the foaming agent, place vacuum box over wetted area. Evacuate air from the vacuum box to a pressure suitable to affect a seal between the box and geomembrane. Observe the seam through the viewing window for the presence of soap bubbles emitting from the seam.

3. If no bubbles are observed, move box to the next area for testing. If bubbles are observed, mark the area of the leak for repair per section 11.0 and re-test per section 9.0.

Note: If vacuum testing fusion welded seams, the overlap flap must be cut off to perform the tests

4. All non-destructive tests will be noted in the GSE Non-Destructive Logs (Appendixes H-I).

D. For spark testing GSE Conductive geomembranes, ASTM D 7240 will be the procedure, unless otherwise instructed by the engineer client.

10.0 DEFECTS & REPAIRS

A. All seams and non-seam areas of the geomembrane lining system shall be examined for defects.

B. Identification of the defect should be made using the following procedures:

1. For any defect in the seam or sheet that is an actual breach (hole) in the liner, installation personnel shall circle the defect and mark with the letter P along side the circle. The letter P indicates a patch is required.

2. For any defect that is not an actual hole, installation personnel shall circle the defect indicating that the repair method may be only an extruded bead and that a patch is not required.

3. Each suspect area that has been identified as repair shall be repaired in accordance with section 11.0 and in the non-destructively testing per section 9.0. After all work is completed, the GSE site manager will conduct a final walk-through to confirm all repairs have been completed and debris removed. Only after this final evaluation by the GSE site manager, the owner, and the agent shall any material be placed over the installed liner.

11.0 REPAIR PROCEDURES

A. Any portion of the geomembrane lining system exhibiting a defect that has been marked for repair may be repaired with any one or combination of the following procedures:

1. Patching - used to repair holes, tears, undispersed raw materials in the sheet.

2. Grind and Reweld - used to repair small sections of extrusion welded seams.

3. Spot Welding - Used to repair small minor, localized flaws.

4. Flap Welding - Used to extrusion weld the flap of a fusion weld in lieu of a full cap.

5. Capping - Used to repair failed seams.

B. The following conditions shall apply to the above methods:

1. Surfaces of the geomembrane which are to be repaired shall be prepared according to this section.

2. All surfaces must be clean and dry at the time of the repair.

3. All seaming equipment used in repairing procedures shall be qualified.

4. All patches and caps shall extend at least 4 in beyond the edge of the defect, and all patches must have rounded corners.

5. All cut out holes in liner must have rounded corners of 3.0 in minimum radius.

C. Patches should be labeled in numerical order, i.e. RP-1, RP-2, etc... This should carry through any layer and/or multiple ponds, and do not start with the number 1 again.

12.0 AS-BUILT DRAWINGS

As-built drawings are available per these items:

A. As-built drawings will be provided at the completion of the project.

B. AutoCad as-built drawings will be provided in either a printed version or by email in a PDF file.

C. As-built drawings will include geomembrane panels and panel numbers with the last four digits of the roll number.

D. Panel numbers and the full roll numbers will correspond with the GSE Panel Placement Log.

E. All destructive testing and repair locations will be placed on the as-built drawings.

If you require further information, please contact the GSE Installation Department directly.

IQA GEO 802/09/10

Appendix A: Inventory Checklist

GSE Inventory Check List

Project: ______________ QA Tech: ______________ Site Mgr.: ______________ Date: ______________

Project #: ______________ Page: ______ of ______

Material	Roll #	Used	Material	Roll #	Used	Material	Roll #	Used	Material	Roll #	Used

IQA GEO R02/09/10

Appendix B: Subgrade Surface Acceptance

Subgrade Surface Acceptance

Date: ____________

Project: ______________________ **Site Manager:** ________________

Project #: ______________________

Location: ______________________ **Partial:** ____________ **Final:** ____________

This document only applies to the acceptablity of surface conditions for installation of geosynthetic products. GSE does not accept responsibility for compection, elevetion or moisture content, nor for the surface maintenance during deployment. Structural integrity of the subgrade and maintenance of these conditions are the responsibility of the owner or earthwork contrator.

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For GSE Lining Technology, LLC: ____________________ ____________________

For Owner / Contractor: ____________________ ____________________

Acceptance Number: ____________ Area Accepted: ____________ s.f. Total Area Accepted to date: ____________ s.f.

IQA GEO R02/09/10

Appendix C: Panel Placement Log

GSE Panel Placement Log

Project Name: ____________________

Location: ____________________ Site Supervisor: ____________________

Job Number: ____________________ Type of Material: ____________________

Q.A. Tech.: ____________________ Sheet Thickness: ____________________

Panel Number	Roll Number	Deployment Date	Width (Feet)	Length (Feet)	Square Feet	Square Feet (Cumulative)	A/T 1	A/T 2

IQA GEO R03/09/10

Appendix D: HDPE & LLDPE Seam Strength Properties

Table 1. HDPE Seam Strength Properties

Material (Mil)	Shear Strength (PPI)	Fusion Peel (PPI)	Extrusion Peel (PPI)
40	81	65	52
60	121	98	78
80	162	130	104
100	203	162	130

Table 2. LLDPE Seam Strength Properties

Material (Mil)	Shear Strength (PPI)	Fusion Peel (PPI)	Extrusion Peel (PPI)
40	60	50	48
60	90	75	72
80	120	100	96
100	150	125	120

Appendix E: Trial Weld Log

GSE Trial Weld Log

Project Name: ____________________
Location: ____________________
Job Number: ____________________
Q.A. Tech.: ____________________

Site Supervisor: ____________________
Type of Material: ____________________
Sheet Thickness: ____________________

Fusion (ppi)
Min. Peel ______
Min. Shear ______

Extrusion (ppi)
Min. Peel ______
Min. Shear ______

Trial No.	Date of Trial	Time of Trial	Technicians ID Number	Ambient Temp.	WELDER TYPE	Wedge Mass	Speed Preheat	Peel ppi	Peel ppi	Peel ppi	Peel ppi	Peel ppi	Shear ppi	Shear ppi	Shear ppi	Shear ppi	Shear ppi	Pass Fail

Appendix F: Seam Log

GSE Seam Log

Project Name: ______________________________

Location: ____________________ Site Supervisor: ____________

Job Number: ____________________ Type of Material: ____________

Q.A. Tech.: ____________________ Sheet Thickness: ____________

Seam Number	Time of Weld	Date of Weld	Type of Weld	Length of Seam	Machine Number	Technician ID Number

IQA GEO R02/09/10

Appendix G: Destructive Test Log

GSE Destructive Test Log

Project Name: ______________________
Location: ______________________
Job Number: ______________________
Q.A. Tech.: ______________________

Site Supervisor: ______________________
Type of Material: ______________________
Sheet Thickness: ______________________

	Fusion (ppi)	Extrusion (ppi)
Min. Peel	____	____
Min. Shear	____	____

Sample Number	Date Welded	Seam Number	Technician ID Number	Machine Type & No.	Location	Peel ppi	Peel ppi	Peel ppi	Peel ppi	Peel ppi	Shear ppi	Shear ppi	Shear ppi	Shear ppi	Shear ppi	Pass/ Fail

IQA GEO R02/09/10

Appendix H: Repair Log - Vacuum Test

GSE Repair Log - Vacuum Test

Project Name: ______________________________

Location: ____________________ Site Supervisor: ____________________

Job Number: ____________________ Type of Material: ____________________

Q.A. Tech.: ____________________ Sheet Thickness: ____________________

Repair Number	Weld Date	Machine Number	Tech ID	Location	Test Date	Tech ID	Pass/Fail

IQA GEO R02/09/10

Appendix I: Non-Destructive Log - Air Test

GSE Non-Destructive Log - Air Test

Project Name: ______________________________

Location: ____________________ Site Supervisor: ____________

Job Number: ____________________ Type of Material: ____________

Q.A. Tech.: ____________________ Sheet Thickness: ____________

Seam Number	Test Dete	Technician ID Number	Air Pressure Test		Test Result (P or F)	Location
			psi start	psi finish		

IQA GEO R02/09/10