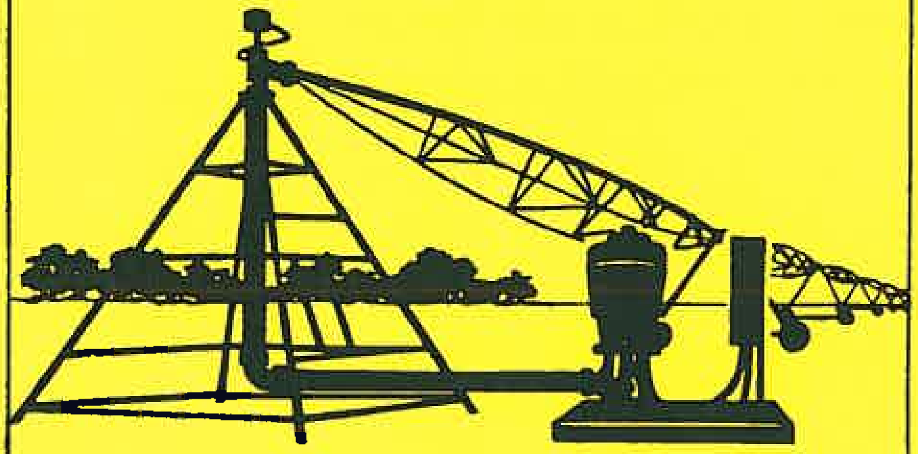
TECHNICAL IRRIGATION PUMPING PLANT TEST

PROCEDURE MANUAL



TECHNICAL IRRIGATION PUMPING PLANT TEST PROCEDURE MANUAL

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FOREWORD

The Technical Irrigation Pumping Plant Test provides the means to properly analyze the energy efficiency of an irrigation pumping plant. This manual gives the procedures necessary to gather important information such as pumping lift, discharge pressure, water flow rate, and the energy consumption of any particular pumping unit.

The Simplified Irrigation Pumping Plant Test also outlined procedures to find the above items. However, the test equipment and procedures were relaxed for economy and ease of use. The simplified test should only be used to determine an approximate energy efficiency level. The test only provides an indicator of the excess energy being used. It does not provide all the information, nor accuracy, needed to diagnose why the pumping plant may not be performing at recommended energy efficiency levels.

The Technical Irrigation Pumping Plant Test differs in this respect. The equipment and procedures given in the manual provide the best possible accuracy that can be practically obtained in the field with equipment presently available.

The Technical Manual also gives additional procedures to find such items as pump and engine rpm, and measurement voltage and amperage of electrical equipment. These are diagnostic tools necessary to properly analyze pumping plant operations and provide information for adjustments or possible changes in equipment to improve performance.

The Technical Irrigation Pumping Plant Test Procedure Manual was designed to complement the "Irrigation Pumping Plant Performance Handbook". While the procedure manual shows "how to", the Pump Handbook provides the technical information to analyze the information acquired from the technical test.

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ACKNOWLEDGEMENTS

The author is indebted to many individuals for their guidance, suggestions, and comments in the preparation of this manual. Many test procedures are adapted from past work done by the professional staff of the Agricultural Enginnering Department, University of Nebraska.

Irrigation pumping plant test programs have been conducted by the University of Nebraska for the past 30 years. This manual attempts to pass on the knowledge and experience of those who have contributed to the improvement of pumping plant performance. They include John Sulek, Paul Schleusner, Deon Axthlem, Paul Fischbach, John Schrunk, H.R. Mulliner, G.G. "Jud" Morin, Walter Trimmer, Dean Eisenhauer, Dale Rolofson, Neil Sullivan, Tom Dorn, Layne Rolofson, Wally Leander, LaVerne Stetson, DeLynn Hay, Norman Klocke and Dean Yonts.

Many irrigation equipment manufacturers and representatives have committed their time and products to help with the test programs. Their efforts are appreciated.

Thanks also to Donna DeLair for her suggestions on editing and layout, typing and her patience in preparing the manual; to Bruce Sandhorst for photographs of the test equipment; and to Shelia Smith, Linda McCaugherty and staff for the drawings and artwork in the manual.

DISCLAIMER

The technical irrigation pumping plant test was developed through staff experience at the University of Nebraska with consideration given to common problems and hazards that may be encountered while performing a pumping plant test. However, it is impossible to foresee all problems and hazards which may be encountered in the field. Care on the part of the person performing the test is a must to provide a safe and successful test.

The University of Nebraska, its agents and employees, and the State of Nebraska accept no liability resulting from the use of the test equipment or procedures as given in the manual.

Mention of trade names, or commercial products in this manual does not infer endorsement of the product.

INTRODUCTION

This manual is designed to instruct how to conduct an accurate pumping plant performance test. The test determines four important items which indicate the performance of a pumping plant, namely:

1) Discharge pressure (psi)

2) Lift (ft)

3) Water pumping rate (gpm)

and 4) Fuel consumption rate

Diesel, Propane - gal/hr
Electric - kW
Natural Gas - mcf/hr.

The pressure, lift, and flow rate are combined to determine the horsepower output of the pump. The horsepower output is compared to the pumping plants' fuel consumption required to produce the horsepower. This value is compared to the expected fuel consumption to produce the same horsepower if the pumping plant is efficient. Fuel consumption exceeding the expected rate results in a performance rating below 100%. A fuel consumption rate below the expected rate results in a rating above 100%.

This manual addresses itself primarily to test procedures used in the field. Reference should be made to the Irrigation Pumping Plant Performance Handbook for additional information regarding reasons for a test, technical information, how to calculate the performance rating, and analysis procedures. The chapter entitled, "List of Equipment for a Pumping Plant Testing Laboratory", lists recommended equipment required for an accurate test. It outlines the accuracy required from the testing equipment.

Proper test procedures are very important to obtain accurate measurements. The most accurate equipment can be used, but if operator error occurs, the errors in the test can far exceed the inaccuracy caused by the testing equipment.

The accuracy of each variable of the test, namely, pressure, lift, gpm and fuel consumption is dependent on both equipment accuracy and the procedure used. The overall accuracy of the test is dependent on the accuracy of each variable. Each variable inaccuracy will either add or subtract to the overall accuracy. Consider this example of a diesel pumping plant test:

	Actual	Observed	Error
Pressure	78.4 psi	80 psi	2% high
Lift	147.0 ft	150 ft	2% high
Output	980 gpm	1000 gpm	2% high
Fuel Consumption	6.83 g/h	6.70 g/h	2% low

The observed performance rating of the pumping plant is 101%. The actual performance rating is 95%.

Note that the highest error of any measurement was 2%. However, since the errors of measurement are accumulative, the overall error is 6%. Because the pressure head and lift are added together, they form one component of error. In the example, the total error for both is 2%. Fuel consumption error is subtracted.

[(+)2% head + (+)2% gpm - ( )2% fuel = 6%]

The pumping plant test must be performed in the same time frame with all conditions constant throughout the test. The test should not begin until the pumping water level in the well is stabilized. Stabilized can be considered as a less than one foot change in pumping water level over the time of the test. To minimize the effect of a change of pumping water level during a test, the discharge pressure should be taken at the same time the pumping water level measurement is made. On closed systems such as a center pivot irrigation system, a drop in pumping water level will also show a change of discharge pressure head.

The engine rpm (throttle setting) should not be changed during the test. A change in engine speed will affect the operating characteristics of the engine which would change the fuel consumption of the engine over the period of the test. More importantly, the gpm, psi, and lift would change and the horsepower required would change, which in turn changes fuel consumption.

The pumping plant must also be operated long enough to allow proper warm-up of mechanical parts. Engines and gearheads should be at their normal operating temperature before the test begins.

Care must also be taken to account for loads drawn from an engine or power line which are not applied to the pump. This situation occurs when a center pivot is powered from an engine driven alternator or hydraulic pump, or from electricity drawn through the watt-hour meter common to the electric motor for the pumping plant. Ideally, the pivot should not be operated during the test. Consult the Pump Handbook for further information.

Special consideration must be given to low pressure pivots using a booster pump for the end gun. Consult the section in this Manual on Alternator and Hydraulic Pumps Fuel Consumption Correction."

Finally, overall accuracy of the test can be enhanced if certain measurements are taken during a specific time interval. For example, water output and fuel measurement should be taken in the same time interval when using a propeller water meter. A small change in water output during the test would reflect a corresponding change in fuel consumption. If the measurements are taken during the same time interval, the average flow rate and the average fuel consumption during the test time interval would correspond. This same idea applies to the discharge pressure and lift measurement. They should be taken at the same time as indicated previously.

The ideal test procedure sequence during the test is as follows:

- Start pumping plant and bring the system to normal operating conditions.
- Check and note the pumping water level.
- Check to see if the pressure and/or water flow rate is set at their normal condition. Make changes if necessary.
- Check and note pumping water level.
- Repeat these steps until the pumping water level has stabilized.
- Make sure the engine and gearhead are at their normal operating conditions.
- Begin test by recording engine and pump rpm.
- Begin fuel measurement for diesel or propane
- Begin water flow rate measurement if using water meter.
- Check and record pumping water level.
- Run flow rate measurement using Collins Flow Gage if not using water meter.
- Run electric or natural gas measurement, if appropriate.
- Make voltage and current measurements, if necessary.
- End fuel measurement test for diesel or propane.
- End water meter flow test.
- Check and note rpm.
- Check and note pumping water level.
- Test is valid if pump rpm did not change ± 1/2% rpm during the test (10 rpm at 1760 rpm) and if pumping water level did not change ± 1% during the test (1 foot at 100 ft; 2 feet at 200 ft.)
- If not valid, repeat test.
- Calculate performance and analyze pumping plant.

The performance rating is calculated as follows:

1) Determine water horsepower (whp)

$$\text{whp} = \text{gpm} \times \text{head}/3960$$

$$\text{head} = \text{lift (ft)} + \text{pressure (psi)} \times 2.31 + \text{column friction (ft)}$$

2) Determining energy performance (whp•h/e)

where;

e = energy unit

= gallon for diesel, propane or gasoline

= kW (kWh/hr) for electric

= mcf/hr (thousand cubic feet per hour) for natural gas

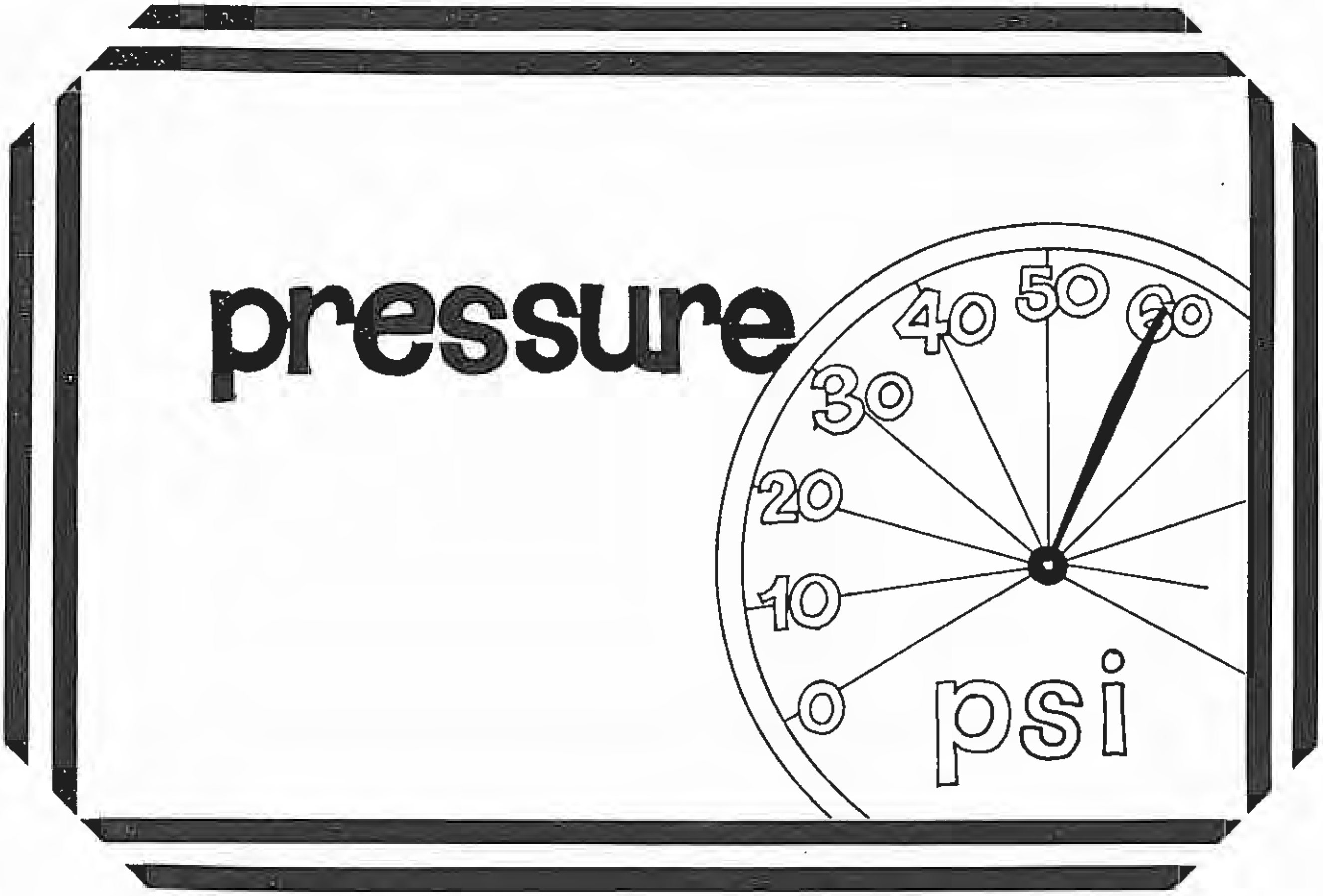
$$\text{whp.h/e} = \frac{\text{whp}}{\text{energy consumption}}$$

3) Calculate performance rating

$$\%\ \text{Rating} = \frac{\text{whp.h/e}}{\text{criteria}} \times 100$$

where criteria = 12.5 for diesel
6.9 for propane
0.885 for electricity
61.7 for natural gas (925 Btu/ft^3)
8.7 for gasoline

Several articles in the Handbook are useful for analysis of the pumping plant. The Handbook also provides information on how to improve the performance of the pumping plant.


pressure
0
10
20
30
40
50
60
psi

DISCHARGE PRESSURE

Equipment:

Presssure gauge
10' hose (optional for 3 psi or less)

Description:

A 4 1/2" dial, liquid filled pressure gauge is recommended for use. It should be calibrated occasionally to verify accuracy and provide a correction curve to adjust for discrepancies. The discharge pressure (psi) is converted to equivalent feet of water head by multiplying by 2.31. The discharge head (feet) is a component of total pumping head, as is lift.

Discharge Head (ft) = psi x 2.31.

For very low pressures (< 3 psi), a 1/4" hose provides the best accuracy. The hose is installed instead of the pressure gauge. The open end of the hose is raised above the pipe until water stops flowing through the hose. The vertical distance between the hose end and the center line of the discharge pipe is the discharge head (ft) (Figure 3). Pressure (psi) can be determined by dividing by 2.31.

Equipment Use:

1) Selection of proper gauge (Figure 1).

Select a pressure gauge which has a range which exceeds the anticipated system pressure, yet is matched closely.

Note: Installation of a 1/4" cock valve before the pressure gauge will protect the gauge if a water hammer condition occurs in the system. Open the valve when system is up to pressure. The valve also makes it easy to change gauges, if necessary while the system is operating.

Generally for:

Gated pipe	- use 0 - 15 psi	(use hose for 3 psi or less)
Sprinklers	- use 0 - 100 psi or 0 - 60 psi	
Volume Guns	- use 0 - 160 psi	

2) Location of gauge (Figure 2).

The pressure gauge must be installed near the pump discharge base before (upstream of) any valve or other obstruction. The pressure at the gauge will then indicate the true pressure head at that point regardless of elevation changes or friction head loss downstream of the gauge.

Often the existing pressure gauge port on the system can be used. If a suitable port is not available, a 7/16" hole can be drilled at the desired location and tapped for a 1/4" National pipe thread. The pipe section to be drilled must have adequate wall thickness (1/16") to be tapped.

3) Installation of gauge

Most pressure gauges will have 1/4" tapered pipe thread. If the port on the system to be used is larger, a reducing bushing will be required. If possible, install a pipe tee to allow use of the existing system pressure gauge to verify its accuracy.

Be careful not to over tighten the gauge, as damage may result to the threads. Use a wrench, not your hand, to tighten the gauge snuggly. A pipe sealing compound is recommended to eliminate leakage and provide lubrication for the gauge threads.

4) The pumping plant must be stabilized before a pressure reading is obtained.

5) Record the pressure reading immediately after recording the pumping water level.

Read between the division lines to maintain reading accuracy, if necessary.

Note: If the gauge was installed above the discharge pipe, the distance between the center line of the gauge and the center line of the discharge pipe must be added to the discharge head. If the gauge is below the pipe, subtract the distance.

6) Multiply by 2.31 to obtain the pressure head.

7) Note pressure reading of existing system gauge, if installed, for comparison purposes.

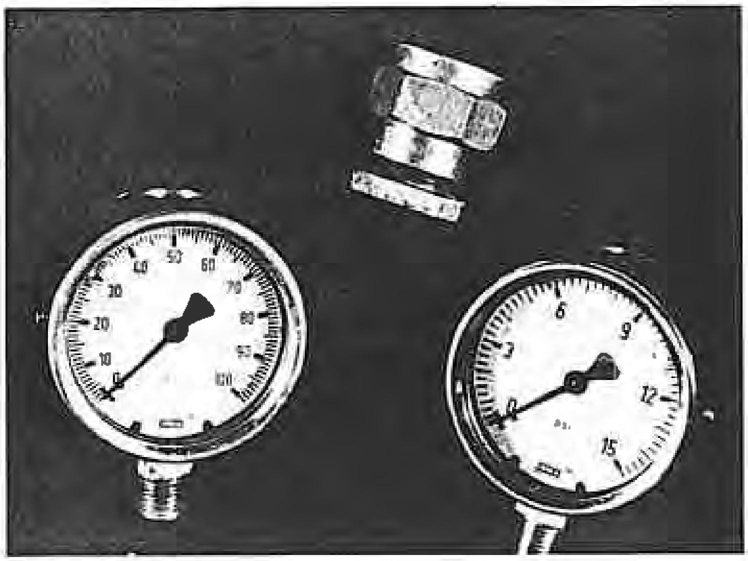
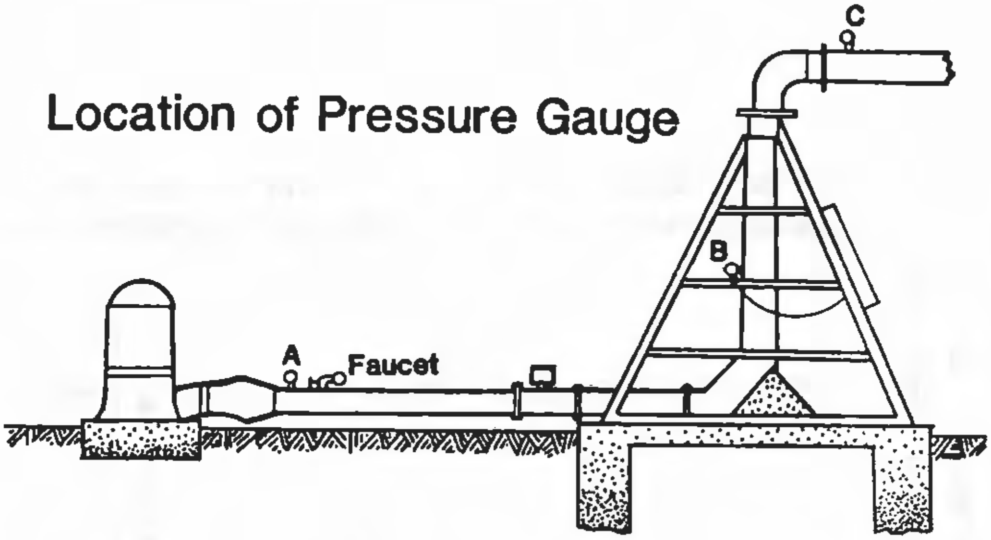


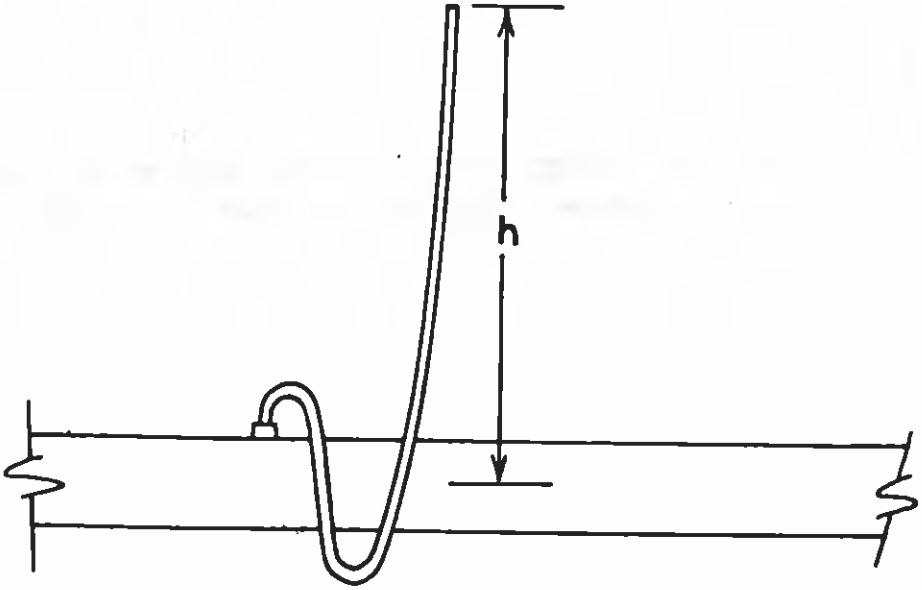
Figure 1. Pressure gauges and faucet adapter.

Figure 2.

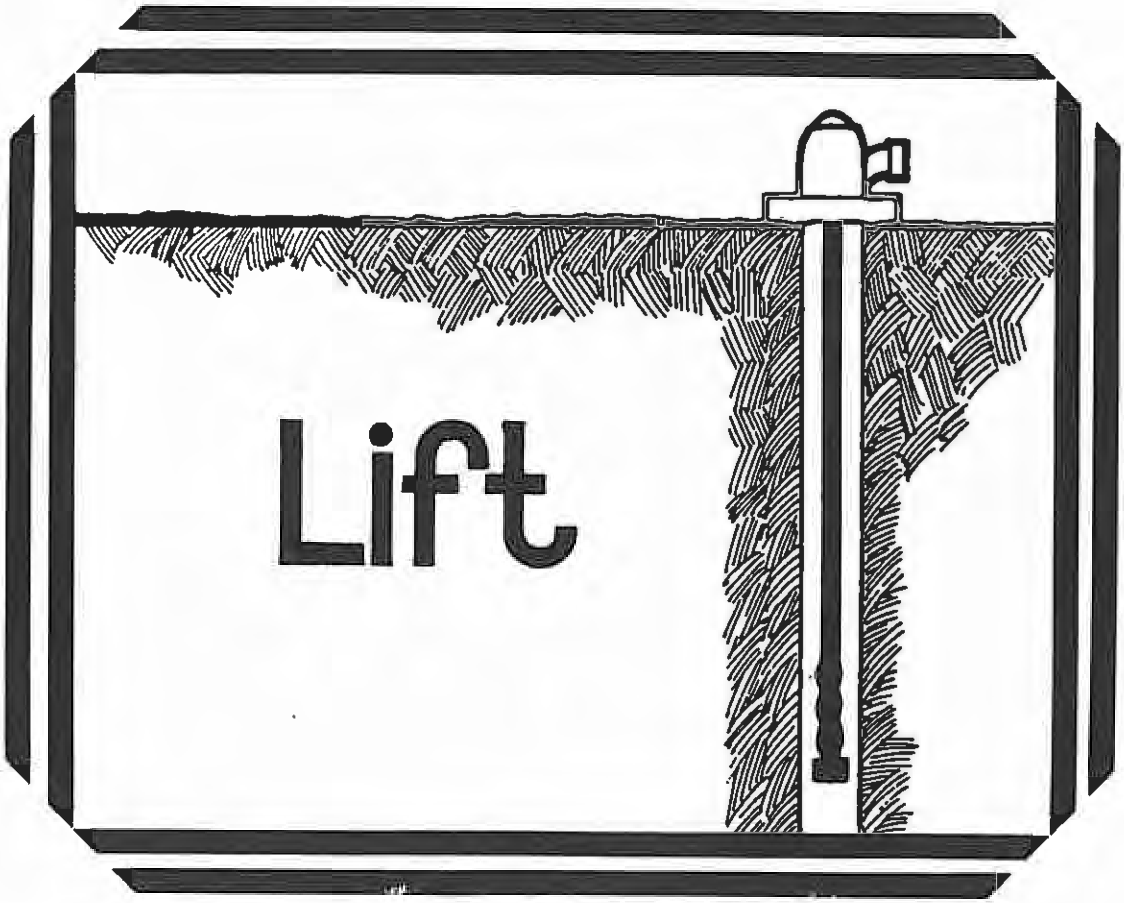


Position "A" - acceptable
Position "B" or "C" - not acceptable

Figure 3. Low discharge pressure measurement.



The hose end is raised until water stops flowing from the hose at height "h". The discharge head is "h" in feet.


Lift

PUMPING WATER LEVEL
Deep Well Turbine
(Without Air Line)

Equipment:

Electric water level indicator
Tape measure

Description:

The water level indicator is used to find the water level in the well — either static or pumping. The indicator, also known as an "electric sounder", works on the principle of electrical conductivity of water. A weighted electrode, attached to a two-conductor cable, is lowered into the well. When the electrode is immersed in the water, a circuit is completed and is indicated by a millivolt meter. The cable is marked with brass brads every five feet which indicates the distance to the water level. For accuracy, it is necessary to measure the cable from the nearest brad with a tape measure to get the exact water level.

Equipment use:

Note: Instructions pertain to a Fisher Research brand meter. The general procedure applies to other units also.

1) An access hole is needed to lower the electrode and cable into the well, (Figure 2).

   This hole is located in the base of the discharge head on many applications. Removal of a cover plate or plug is all that is needed to use the hole.

   Where no hole is located, a 7/16" hole can be drilled through the pump base. This hole can be tapped for a 1/4" pipe plug to plug the hole after use. Care must be taken not to drill into the water carrying section of the pump base.

2) Check the battery condition by switching to the "Batt" position. The meter reading should be in the "OK" region. (Figure 3). If not, a new standard 9 volt transistor battery should be installed by removing the two black knobs which hold the control panel in place.

3) Turn the unit to the "ON" position.

4) Familiarize yourself with the unit by placing the electrode into a jar of water. Contact with the water will cause the needle on the meter to move to the right. This demonstrates what happens when the electrode reaches the pumping water level in the well.

5) Lower the electrode and cable into the well. An upward jerk of the cable every 5-10 feet will verify if the cable is going down the well. The weight of the lead electrode should be felt after the jerk if the cable is proceeding down the well casing.

Warning: Never let out more cable than the pump setting (column length). If more cable is reeled out than the depth of the pump setting, the cable and/or electrode could be drawn into the pump. If this occurs the cable will become stuck and the pump will usually stop pumping water. The pump assembly would have to be pulled to remove the cable.

6) Continue lowering until the needle on the meter moves towards the right and remains there (Figure 4). Once the needle movement has stabilized, raise the cable until the needle begins moving towards zero. This point is the water level in the well.

Abnormal Conditions:

In some wells where the lineshaft has been excessively lubricated, a layer of oil will be floating on top of the water. When the electrode reaches the oil level, the meter needle will only move partially to the right (Figure 5). At this point, the "water level" has been located, even though water is not present.

Some wells have water from the aquifer falling down into the well casing to the pumping water level. This condition is known as cascading water. The meter needle movement will be irratic if this condition is present due to intermittent contact with the electrode from the falling water. Continue lowering the cable until the meter needle stabilizes. At this point the pumping water level is located. Severe cascading water may prevent a reading. Special electrode tips are available for many meters for cascading water.

7) Read the amount of cable in the well. You will find a brass brad located every five feet on the cable. Every 10 feet, the brad is marked with a number corresponding the length of the cable.

Example: A brad with the number 21 on it means 210 feet. (Figure 6). The next brad would be blank and would indicate 215 feet. The next brad would have number 22 on it which would be 220 feet. Measure from the closest brad and record the pumping water level.

8) Reel the cable up to at least the static water level after recording the pumping water level or before shutting down the pumping plant. If this is not done, the cable could wrap around the pump column as the water level rises in the well when pumping stops. If this happens, the cable will be stuck and cannot be removed easily.

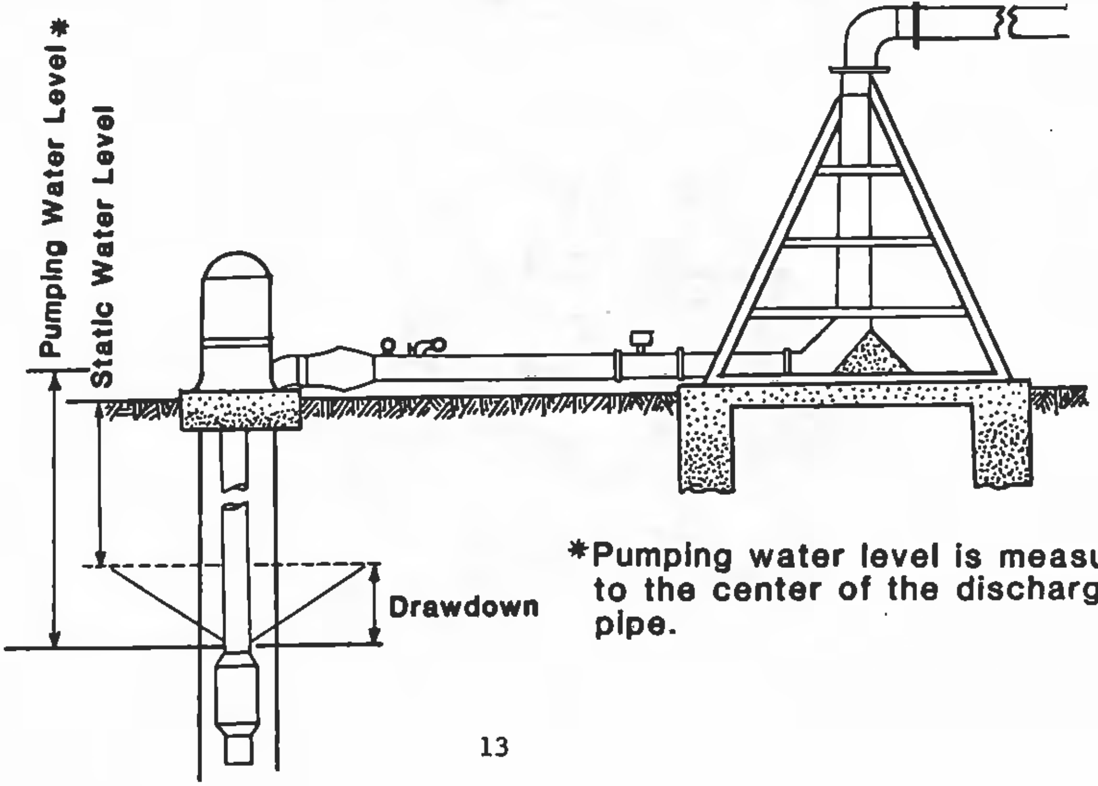
Note: If the cable should become lodged around the column or between the column and casing, do not apply enough excessive pull on the cable to break it. If the cable should break, it could fall into the well where it would be drawn into the pump.

One method to free the cable is to allow slack (10-20 ft) in the cable and apply a jerking movement to the cable. This may have to be done several times.

If the cable remains lodged, have a helper start and stop the pump in succession a few times. This often sways the pump column enough to free the cable. This procedure is not recommended on electric systems due to the strain on the motor.

Another method sometimes used if all else fails, is to "tilt" the pump column away from the casing where the cable is suspected to be lodged. A hydraulic jack can be positioned between the pump base and the foundation and pressure applied. A small movement of the pump base will cause a large movement of the column further down the well. This will often free the cable.

When these methods fail, the cable can be cut well above the ground level and tied to the pump base. The cable must not be allowed to fall into the well. In time the cable may free itself.



***Pumping water level is measured to the center of the discharge pipe.**

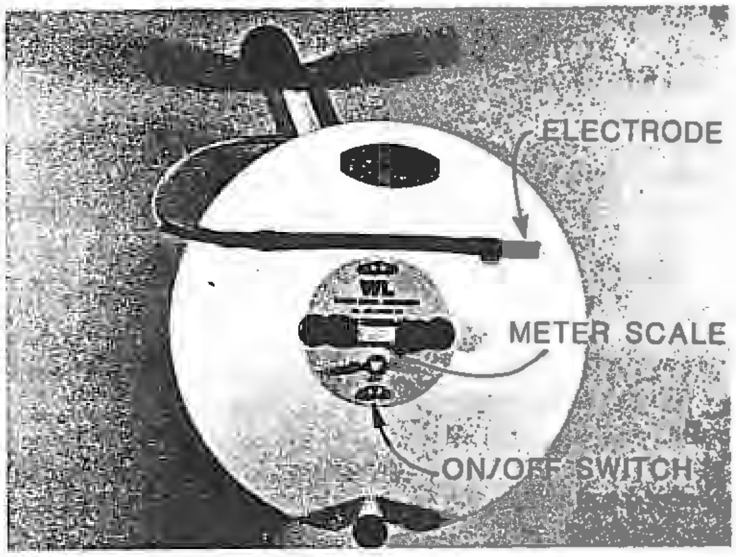


Figure 1.

Water level indicator.

Figure 2.

Access hole to well.

Figure 3.

Checking battery condition.

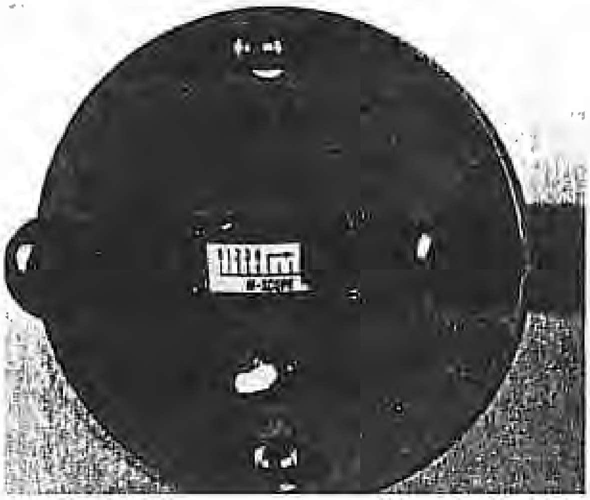


Figure 4.

View of meter after electrode has reached the pumping water level.

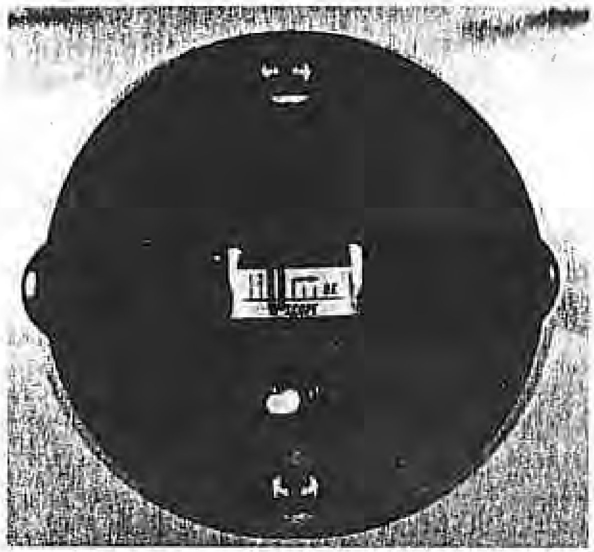


Figure 5.

View of meter when electrode has reached an oil layer in the well. This is the pumping water level.

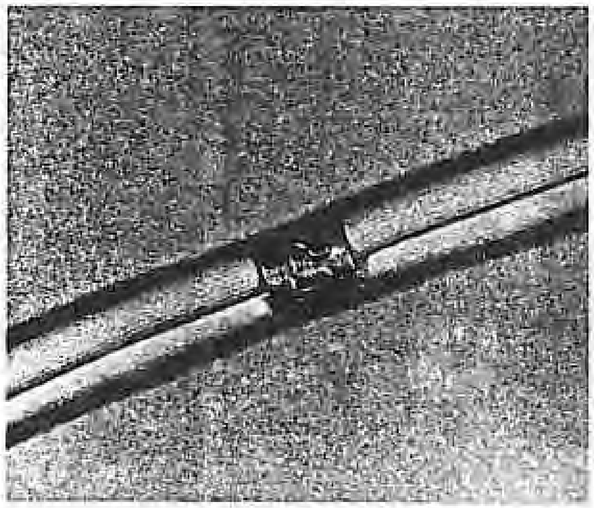


Figure 6.

Brass marking brad indicating 210 feet.

PUMPING WATER LEVEL
Deep Well Turbine
(Air Line Method)

Equipment

The air line method is a simple and accurate method for determining both static and pumping water levels. The air line can be made of copper, galvanized steel, nylon, or plastic pipe. The diameter must be small enough for clearance into the well (see Figure 1) and is usually 1/4 or 5/16 inch. If flexible plastic or nylon is used, a weight on the end is necessary so it will hang vertically. Also, the weighted end will help prevent the pipe from swirling and wrapping around the pump column.

The length of the pipe must be known. Check records to determine length of previously installed air line. For accurate measurement, the minimum required submergence or depth of water above the end of the pipe is 15-20 feet. The end of the pipe should be at least two feet above the inlet to the pump.

At the base of the pump, the upper end of the air line is fitted with a pressure gauge and an air snifter valve (Figure 1). The air snifter valve is similar to the valve stem of a tire. The pressure gauge should be selected to match the anticipated water level conditions. For accurate measurement, the full scale reading of the pressure gauge should not be more than four times the minimum submergence. For example, if the expected minimum submergence is about 25 feet or 11 psi, a pressure gauge with a 40 psi maximum range would be necessary. The nearest gauge sold in this instance is 0-30 psi, since a 0-60 psi range gauge would exceed the recommended maximum. Pump testers should use a calibrated gauge to verify accuracy of the original gauge.

The addition of a manual valve as shown in Figure 1 is optional. The manual valve can be used to regulate air flow so that pressure surges do not damage the pressure gauge.

All fittings must be air tight. Use sealing compounds during assembly.

A bicycle tire pump or other source of compressed air is necessary for operation.

The equipment necessary for the air line system is available in a complete kit from commercial companies, or can be easily constructed from parts from local plumbing suppliers.

Operation

As air is pumped into the submerged air line, via the snifter valve, the pressure rises until all water has been forced out of the pipe. At this point the pressure in the air line is in equilibrium with the column of water above the end of the pipe. The pressure reading will no longer increase as air is pumped into the system. Once the pressure has stabilized the pressure reading is taken.

The water level in the well is equal to the length of the pipe (L) minus the depth of submergence (D) (See Figure 1). If the pressure gauge is calibrated in psi (pounds per square inch), the depth of submergence is obtained by multiplying the gauge reading by 2.31, i.e. 1 psi equals 2.31 feet of water. Thus, if the gauge reads 11 psi, the depth of submergence of the end of the air line is 25.4 feet (11 x 2.31 = 25.4). If the length of the air line is 140 feet, then the water level is 114.6 feet (140 - 25.4 = 114.6).

Some pressure gauges are calibrated in feet of water head. In that case, the water level is obtained directly by subtracting the gauge reading from the length of the air line. Also, there are special gauges available with adjustable dials that will indicate water levels directly. They must be set to indicate the appropriate air line length before use.

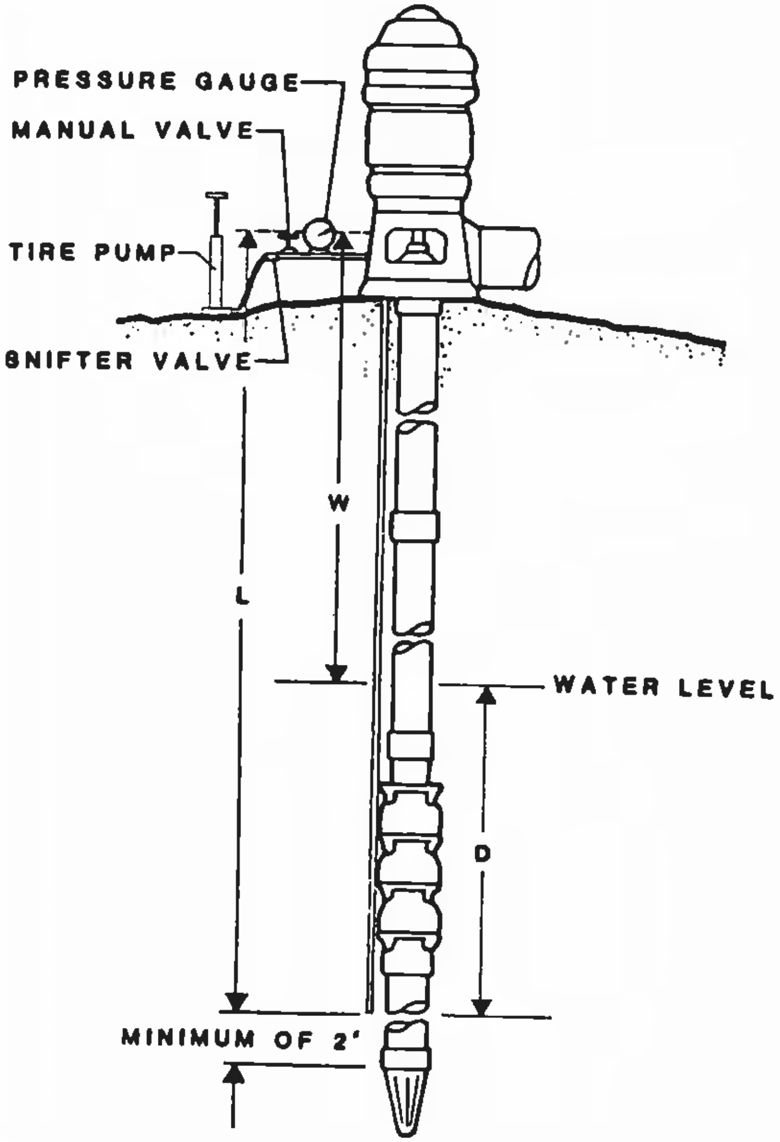
The worksheet below can be used for recording the data and doing calculations.

WATER LEVEL WORKSHEET

	Example Well	Your Well
1. Length of air line (L)	140 feet	______ feet
2. Pressure gauge reading	11 psi	______ psi
3. Depth of submergence of the air line equals psi x 2.31 (D)	25.4 feet	______ feet
4. Water level in well equals the length of the air line minus the depth of submergence (W)	114.6 feet	______ feet

NOTE: Some pressure gauges may be calibrated in feet of water. Therefore, Item 2 can be omitted and the gauge reading be entered directly as Item 3.

Air Line Installation



PUMPING WATER LEVEL
Centrifugal Pump
(Suction Head)

Equipment: Vacuum gauge (in. Hg)

Description:

The vacuum gauge can be used to determine the suction head or "pumping water level" of pumps operating above a free surface of water such as a lake, river, or canal. This method accounts for the elevation of the pump from the water surface (lift) and also the friction, suction and velocity losses due to the suction pipe. The resulting suction head can indicate whether the suction conditions are exceeding the required NPSH of the pump. This would cause cavitation in the pump. (See Pump Handbook). The vacuum gauge, installed at the suction entrance of the pump, is usually graduated in inches of mercury. One inch of mercury is equivalent to 1.13 feet of water head.

Procedure:

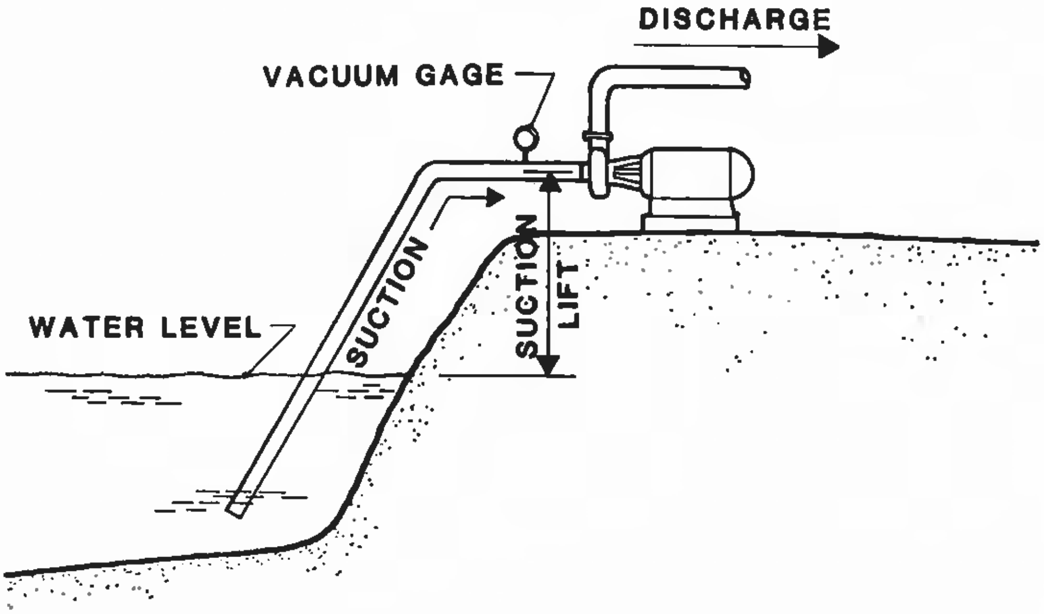
1) Install a vacuum gauge at the suction entrance of the pump (Figure 1).

2) When the system is operating and stabilized, take the reading.

3) Convert the reading of in. Hg to feet of water by multiplying by 1.13 and record as "pumping water level." Column friction loss (suction pipe friction) is included.

Note: There is no correction for elevation of the gauge above or below the suction entrance. The true reading is at the point of attachment to the pipe.

Figure 1. Typical horizontal centrifugal pump.



COLUMN FRICTION HEAD

Equipment: None

Description:

Friction occurs when water flows through pump column pipe as in any other type of pipe. The pressure gauge at the discharge measures the friction head loss downstream. However, the friction head loss in the column cannot be measured in the field. Therefore, the head loss must be obtained from Table 1. The head loss through the pump column must be added to the discharge head and lift to determine the total pumping head. The pump must produce the column friction head loss as well as lift and discharge head.

The head loss is greater in pump column than for regular pipe. This is because the pump column also houses the lineshaft and oil tube which create more friction in less cross section area.

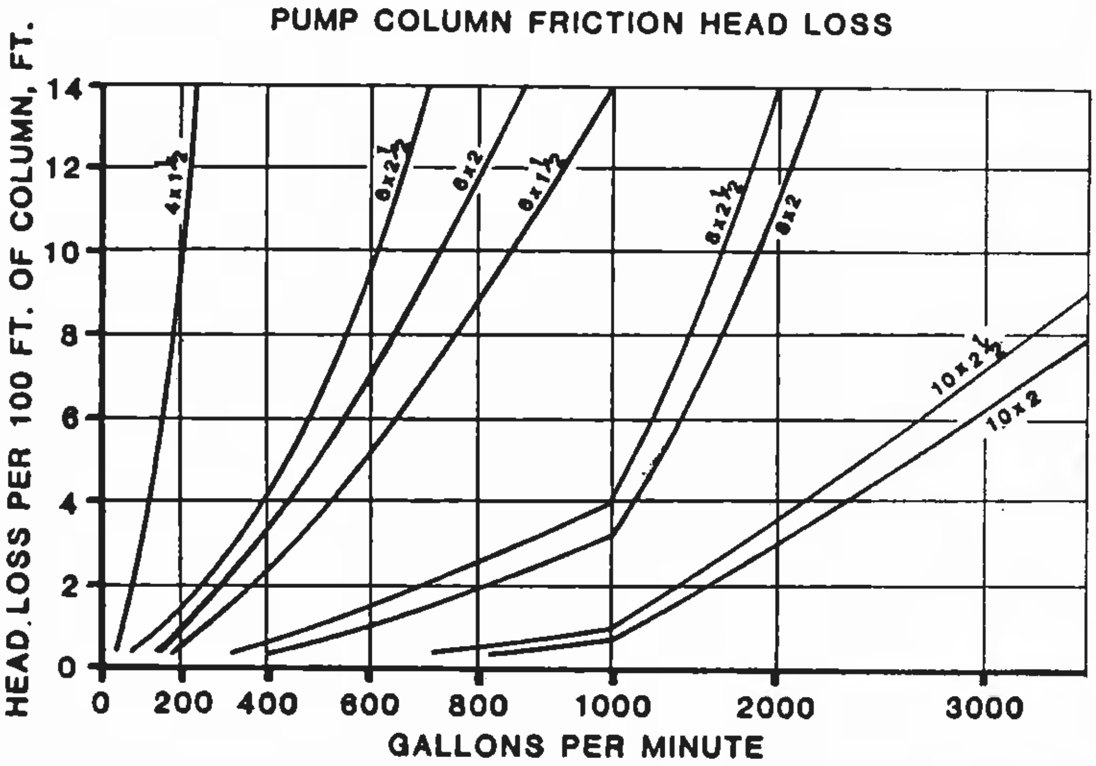
Figure 1 gives the expected water head loss per 100 feet of pump column given the column size, oil tube size, and flow rate (gpm). To determine the head loss for water lubricated pumps (no oil tube), use the 2" oil tube size for open lineshaft sizes to 1 1/2". For open lineshaft sizes over 1 1/2", use the 2 1/2" oil tube size.

Example: A pump is producing 1000 gpm at 55 psi discharge pressure from a 100' pumping water level. The pump column consists of 8 5/8" (8" nominal size) pipe, 150 feet in length (pump setting - 150'), and the lineshaft size is 1 1/2" with a 2 1/2" oil tube (8 x 2 1/2).

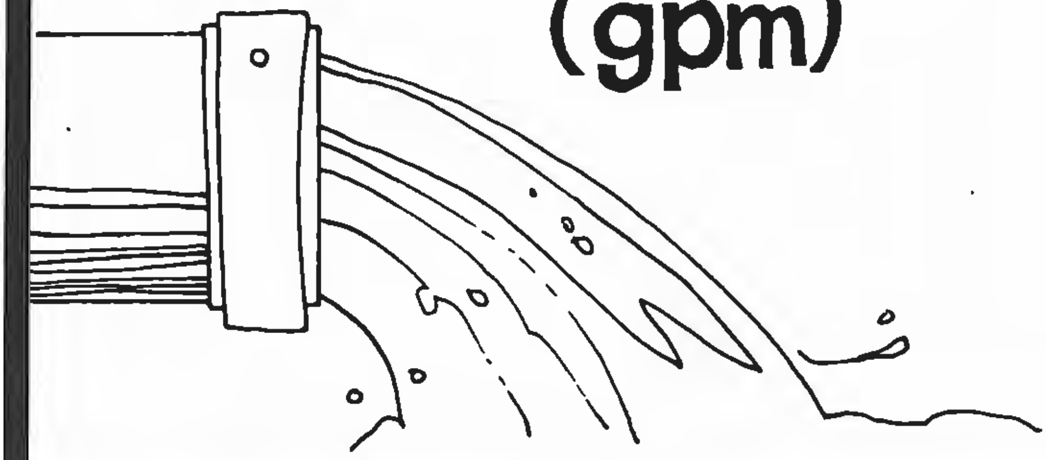
From Table 1 the friction head loss is:
4' for 100' of column or
6' for 150' of column (4' x 150/100)

The total pumping head is:
= [Pressure (psi) x 2.31] + lift + column loss

= (55 psi x 2.31) + (100' lift) + (6' column loss)
= 233' Total Pumping Head


PUMP COLUMN FRICTION HEAD LOSS
HEAD LOSS PER 100 FT. OF COLUMN, FT.
0
2
4
6
8
10
12
14
GALLONS PER MINUTE
0
200
400
600
800
1000
2000
3000
4x1½
6x2½
6x2
6x1½
8x2½
8x2
10x2½
10x2

Water Flow Rate
(gpm)



FLOW RATE
(gpm)
PROPELLER WATER METER

Equipment:

Propeller flow meter (Figure 1)
Stopwatch
Adapters (optional) (pipe reducer, increaser, collapsible pipe section)

Description:

The propeller flow meter is used to determine the quanity of water being pumped. By clocking the water flow over a time interval, the flow rate (gpm) can be found. The water meter is the most accurate and fastest device for field testing. When set up in a portable tube section with bell coupler, it is conveniently installed in gated pipe or open discharge irrigation systems. The test meter should have straightening vanes to reduce spiral and turbulent flow which reduces the accuracy of the meter. The meter should be certified for accuracy once a year. Typical accuracy of a water meter is 1-2%. An eight inch meter will handle most systems with a flow range of 100-1500 gpm. Intermittent flow is allowed to 2000 gpm.

The test meter should also have an index or test dial to provide for clocking. Many meters will have an instantaneous flow rate indicator which gives gpm directly. However, the indicator is not accurate enough for testing purposes (Figure 2).

Location and installation of test meter:

1) The meter should be placed a minimum of 3 1/2 feet downstream from any obstruction such as an elbow, tee, or valve. The meter must be placed ahead of any point where water is lost from the pipe line. The meter can be installed at any angle but must have full water flow through it (Figure 3).

2) Adapters will be needed to install the meter if the meter pipe size is different from the pipe size of the system.

3) The meter must be installed with the male end upstream (water flow in direction of arrow on meter).

4) The meter will need to be clamped or chained into place if the water pressure of the system exceeds 3 psi.

Determining flow rate:

1) The pumping plant must be stabilized before taking any readings.

2) The meter must have full water flow through it. This can be checked on many test meters by removing the pressure port plug. If not flowing full, artificial head, downstream of the meter, needs to be applied to "backup" the water. A pipe section can be elevated downstream or a valve installed after the meter to accomplish this.

3) Watch the test dial on the meter face. Notice that when it is at the "0" position, all the numbers in the totalizer are centered.

4) Start the stopwatch when this hand reaches the "0" position and immediately record the number from the totalizer (Figure 4).

5) Wait at least five minutes.

6) Stop the stopwatch when the hand reaches the "0" position and immediately record the numbers from the totalizer (Figure 5).

7) Record the time on the data worksheet.

8) Calculate the flow rate in gpm.

$$\frac{\text{Gallons stop} - \text{Gallons start}}{\text{time (minutes)}} = \text{gpm.}$$

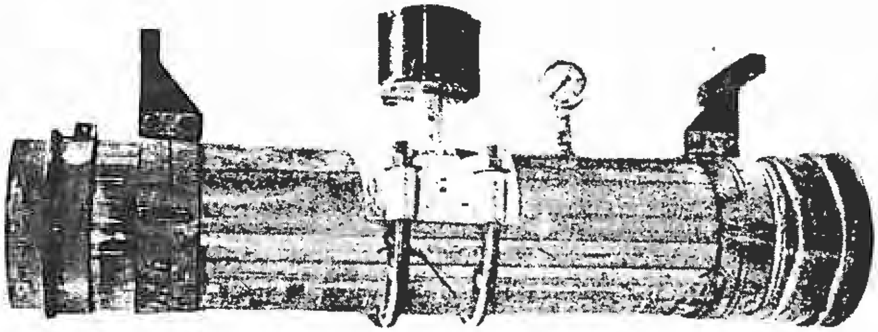


Figure 1. 8" test propeller water meter.

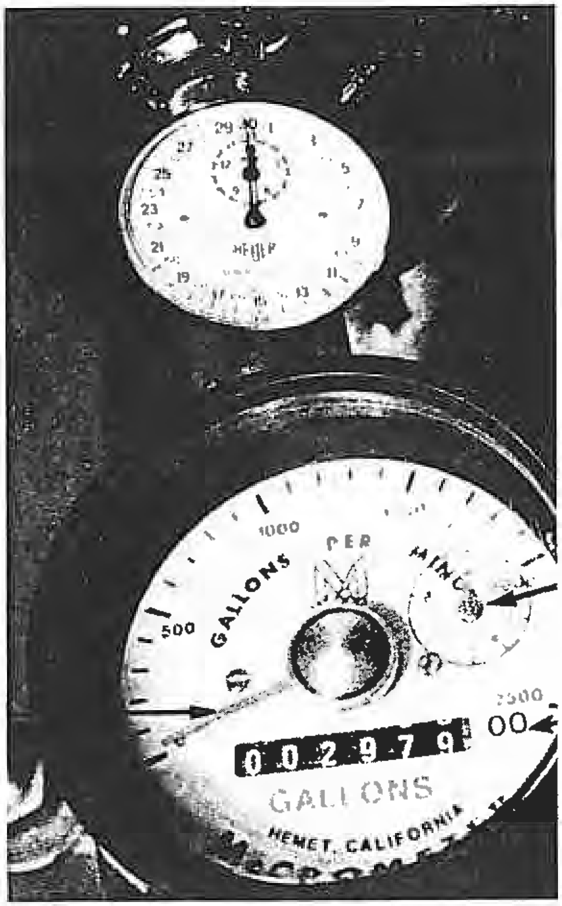


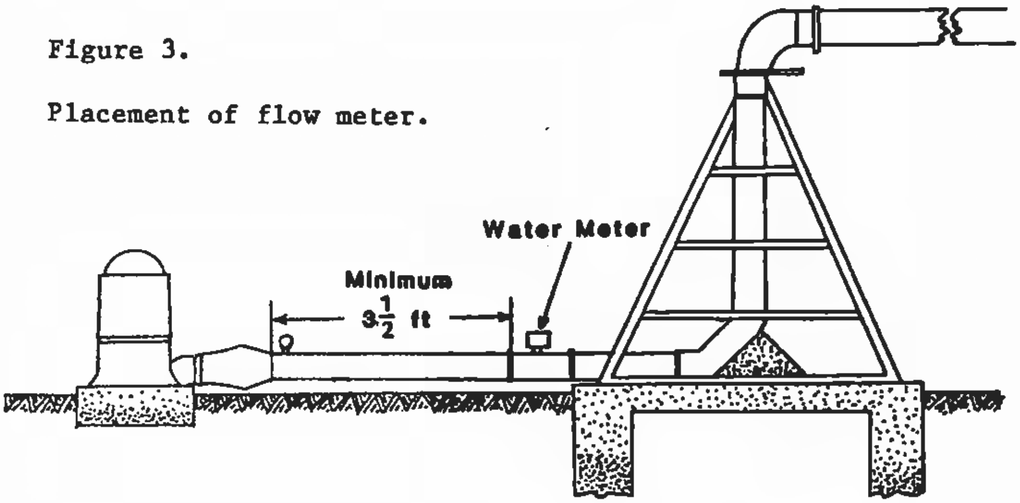
Figure 2.

Water meter face and stopwatch

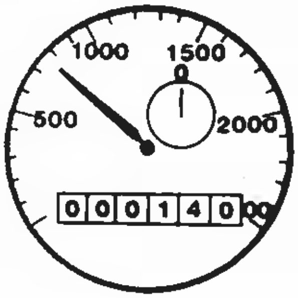
The totalizer reading is 297,900

Figure 3.

Placement of flow meter.



Example Start Position



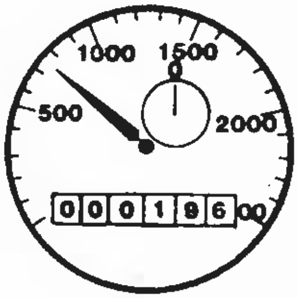
TIME: 0 MINUTES-0 SECONDS

Figure 4.

Example start position.

The totalizer reading is 14,000.

Example Stop Position



TIME: 6 MINUTES-20 SECONDS

Figure 5.

Example stop position.

The totalizer reading is 19,600.

Data Worksheet Example

Head

Flow Test
☑ Propeller Flow Meter Time: 6 min. 20 sec. = 380 seconds
Gallons stop 19600 - Gallons start 14000
= 5600 Total Gallons ÷ 380 seconds x 60 = 884 gpm

FLOW RATE
(gpm)
COLLINS FLOW GAGE

Equipment:

Collins Flow Gage
Support equipment:

Electric drill	
1/4" drill bit	Optional drill and tap jig
7/16" drill bit	will substitute. Available
1/4" NPT pipe tap	from R.W. Collins.
1/4" pipe plugs	
Center punch	
Dry wall seam tape	
Tools - knife, screwdriver, adjustable wrench	
Ruler	

Description:

The Collins Flow Gage, (a pitot flow device) is one method of determining the flow rate in gallons per minute (gpm) of the water being pumped. This method measures the average flow velocity in the pipe. Given the pipe size and velocity, flow rate can be computed (A x V = Q).

The Collins Flow Gage is very versatile. It can be installed in any size pipe having a wall thickness of at least 1/16". Dismantling the pipe system is not necessary as is required with a propeller flow meter.

Two 7/16" holes must be drilled and tapped across from each other into the irrigation pipe. The pitot tube is installed using these holes. The pitot tube has two opposed orifices built in. The forward orifice (facing the water flow) measures the pressure in the pipe and the impact force due to the water movement. The higher the velocity the greater the impact. The trailing orifice (facing downstream) measures only the pressure in the pipe. A manometer indicates the pressure differential between the two orifices. The pressure differential is converted directly on the measuring scale into velocity (feet/second).

Water flow does not have constant velocity throughout the cross-section of the pipe. Flow velocity will tend to be higher near the center and lower at the side wall. Therefore, to find the <u>average</u> velocity, the orifices in the tube must be placed a certain distance from the center line of the pipe. This value is calculated as 0.353 x the inside pipe diameter. Two velocity measuring points are therefore necessary - one on each side of the center line of the pipe. This is known as the two-point test (Figure 1).

The pitot tube must be reversed (rotated 1/2 turn) and two more measurements taken at the same measuring points. This is necessary because of a slight misalignment of the orifices in the tube. Four velocities result. These four velocities are averaged to determine the average velocity.

The two-point test provides a quick and accurate test in most conditions. When water flow is turbulent or inverted, a ten-point test provides better accuracy. This test requires ten velocity measuring points transversed across the pipe section. The measuring points are: 0.158 x ID, 0.275 x ID, 0.354 x ID, 0.420 x ID, and 0.475 x ID from the pipe center line. There are five points on each side of the center line (Figure 2).

The tube must be reversed as in the two-point test. Twenty readings are therefore obtained and averaged to determine the average velocity.

In Nebraska field tests, the two-point test has shown an average gpm deviation of 1.5% from the ten-point test. In most cases the two-point test is adequate. A ten-point test should be run when the pitot tube is placed closer than three feet from a valve, tee, elbow, or check valve; or when more than 1/2 ft/sec deviation is noticed from one side of the pipe to the other side.

The following instructions are for the two-point test. Equipment installation and operation are the same for both the two-and ten-point test. Additional ten-point test instructions follow the two-point instructions.

Equipment setup:

Locating and drilling the holes:

1) Locate a section of pipe near the pump which has few obstructions such as check valves, cooling coils, or elbows. Two small holes will be drilled in this pipe section. This location should be at least three feet downstream from any obstructions if possible. Select the longest possible distance from any of the above.

Note: The pipe wall thickness must be at least 1/16" thick in order to tap the holes. Aluminum pipe is not adequate. The steel discharge pipe downstream from the pump is usually the best location for the holes.

The Collins impact tube can be installed in the dogleg or stand pipe of many pivot systems. Check to make sure the pivot design does not contain a conduit running inside the stand pipe. Other pivots may also use the stand pipe as a bearing assembly for the pivot and the Collins cannot be installed.

2) The two holes must be placed directly across from each other. To find the correct position of these holes, follow this procedure.

   a) Tear off a length of tape long enough to wrap around the pipe so it will have an overlap of at least 2 inches, (Figure 3).

   b) Wrap the tape around the pipe at the location where the holes are to be drilled. The tape ends should overlap each other at the top of the pipe and line up with each other along the edges (Figure 4).

   c) Using a sharp knife, cut across the overlap in the direction of the pipe (Figure 5).

   d) Remove the tape. The tape should now be the length of the circumference of the pipe.

   e) Place the two ends of the tape together and fold the tape in half. Fold the tape in half one more time. The tape should now be divided into fourths, (Figures 6 and 7).

   f) Again wrap the tape around the pipe so that the ends meet at the top of the pipe. The ends should line up perfectly, (Figure 8).

   g) Use a piece of adhesive tape to secure the paper tape ends together.

   h) Locate the two folds of the tape on the sides of the pipe (one on each side).

   i) Using a center punch, mark the pipe at the point where the folds cross the center line of the tape. (Both sides of the pipe), (Figure 9).

   j) These two marks must be directly across from each other.

3) Use a 1/4" drill bit to drill through the pipe at the two center punch marks (Figure 10).

4) Use a 7/16" drill bit to enlarge the 1/4" holes to the proper size for the tap. Be sure to drill squarely into the pipe (Figure 11).

5) Tap these two holes using a 1/4"-18 National pipe thread size tap. Use a lubricant on the tap. A 7/16" 8-point socket can be used with a 3/8" drive ratchet to drive the tap. If the tap begins to turn hard, reverse direction 1 turn, and then continue. Be sure to tap squarely (Figure 12).

Important: Only tap into the pipe about halfway on the tap. Tapping too deeply may make the threads too large to use a pipe plug to seal the holes after the test (Figure 13, 13a, 13b).

6) The inside pipe diameter of the pipe must be determined. A special ruler can be constructed similar to the one pictured in Figure 18.

Insert the ruler into the pipe through one of the tapped holes (roll pin end first). Position the ruler so that the roll pin end of the ruler enters the opposite hole. With the roll pin against the inside of the pipe, read the inside diameter of the pipe. This reading is found by looking at the inner edge of the pipe. Record the inside diameter on the data worksheet.

Caution: Don't push too hard on the ruler when taking the measurement. It may bend slightly and an error may result.

An alternative to the ruler is a length of stiff wire with a hook bent at one end. Insert the wire until the hook stops at the inner edge of the pipe and mark the other end with a pencil. Use a common ruler to determine the length.

Installation of the tube:

1) Locate the tube in the kit. It will consist of a tube with two threaded packing glands and two "stop clamps" (split brass bars with two screws). On one end of the tube is an alignment bar. Never loosen or remove this bar (Figure 14).

2) Remove one of the stop clamps and one packing gland.

3) Insert the tube into the pipe so that the tube protrudes through both holes (Figure 15).

4) Screw the packing gland (on the tube) into the pipe and tighten by hand (Figure 16).

5) Slip the remaining packing gland on the tube and screw into the remaining hole. Tighten by hand (Figure 17).

Note: If the holes were drilled and tapped properly, steps 4 and 5 should not be difficult. If not, you may need to drill another set of holes.

6) The tube ends must be located an equal distance from each side of the pipe. Notice that there is a mark near both ends of the tube. Using the ruler, move the tube until the mark on each end of the tube is the same distance to the side of the pipe (Figure 18). The tube is now centered within the pipe.

7) Position the tube so that the alignment bar is parallel with the pipe (Figure 19).

8) From the chart included with the Collins or Table 1, determine the "stop-clamp" setting and the gpm factor, using the inside pipe diameter found earlier.

9) Position the stop clamp on the tube using the stop-clamp setting distance. This distance is measured from the outermost portion of the packing gland to the edge of the stop clamp facing the pipe. Repeat for the opposite side of the pipe using the remaining stop-clamp. Tighten both clamps, Figure 20 and 21).

Setting up the meter (manometer): (Figure 22).

1) Remove the manometer from the box. Close all valves on the manometer.

2) Set the manometer in a vertical position and secure the meter.

3) Connect one hose from the manometer to one end of the tube in the pipe. Connect the other hose to the other end of the tube. Hose clamps may be necessary to secure the hose.

Running the test:

1) The engine and pump should be allowed to run long enough to warm up and stabilize the irrigation system.

2) Open the four bottom cock valves on the manometer and allow water to flow out for a few moments to remove all air in the hoses. Close the two bottom valves. (Figures 23 and 24).

3) Water should rise in both glass tubes. If not, open the top valve on the left side of the manometer and allow the water to rise into both tubes (Figure 25). Close the valve when both water levels can be seen.

4) If the water rises to the top in any one of the glass tubes so it cannot be seen, follow this procedure, (Figures 26 and 26a).

   - Make sure both upper valves on the manometer are closed.

   - Connect the tire pump found in the kit to the top of the manometer on the right side.

   - Open the right valve.

   - Pump air into the manometer until the water level in both tubes move about half way down.

   - Close valve and remove tire pump.

(5) At this point, notice that the water level is not the same in both glass tubes. This is normal and indicates that the Collins Flow Gage is working properly.

6) Move the tube, installed in the pipe, until the stop-clamp butts against the packing gland. Be sure the alignment bar is still parallel with the pipe, (Figure 27).

7) Notice that the center section of the manometer has a numbered scale. It also slides up and down.

8) Slide the center section up until the "0.0" line is at the same level of the lowest water level in one of the glass tubes.

9) The higher water level in the other tube will correspond with some number on the scale. Record this number on the data worksheet for the first velocity reading. (Figure 28).

10) Rotate the alignment bar and tube 180° or 1/2 turn. The stop-clamp should still be in the same position. Notice that the water level in the manometer is changing. Allow it to stabilize and take a reading as in Steps 8 and 9. Record as the second velocity . (Figure 29).

11) Pull the alignment bar and tube to the other side of the pipe. The stop-clamp should butt against the packing gland. Again, make sure the alignment bar is parallel with the pipe.

12) Take a reading as in Steps 8 and 9. Record as the third velocity measurement. (Figure 30).

13) Again, rotate the alignment bar and tube 180° (1/2 turn). The water levels in the glass tubes will switch. Allow the levels to stabilize and record the final velocity reading. (Figure 31.)

14) Calculate the flow rate (gpm) using the data worksheet.

15) Remove tube assembly from the pipe in reverse order. Plug the two pipe holes with 1/4" pipe plugs (Figure 32).

Ten-Point Test

The ten-point test varies in the number of points checked (10 vs 2) and where the stop clamps are positioned. The gpm factor does not change for the same pipe size.

To set the Collins pitot tube up for the ten-point test, calculate the following settings:

1) 0.475 D where: D = inside pipe diameter (inches).
2) 0.055 D
3) 0.121 D
4) 0.200 D
5) 0.317 D

Step 1 After centering the tube, set the stop clamps at 0.475 D and slide to the packing gland stop.

Step 2 Pull tube out the required distance calculated above for the remaining four readings.

Step 3 Repeat for other side of pipe.

Step 4 Reverse tube and repeat above.

Step 5 Add readings and divide by 20 to obtain average velocity. Multiply by gpm factor, Table 1 to determine flow rate (gpm).

Note: A 6-inch steel rule graduated in 1/10" and 1/100" works best for measurements.

Data Worksheet Example

☑ Collins Flow Gage	2-point setting	Pipe I.D. 7.81"		10-point setting		
	0.353D	0.475D 3.71	0.055D 0.43	0.121D 0.94	0.200D 1.56	0.317D 2.48
left (+)		5.40	5.33	5.17	5.00	4.85
left (-)		5.41	5.33	5.20	5.05	4.70
right (+)		5.20	5.05	4.88	4.75	4.20
right (-)		5.15	5.00	4.84	4.77	4.15
Average Velocity	ft/sec	4.98 ft/sec	x 147.8 gpm factor ($2.55D^2 - D$)			
= Flow Rate	gpm	736 gpm				

COLLINS FLOW GAGE
TABLE

Pipe Inside Diameter	Stop-Clamp Setting (2 pt)	GPM Factor	Pipe Inside Diameter	Stop-Clamp Setting (2 pt)	GPM Factor
4	1 7/16	36.8	8 1/8	2 7/8	160.2
4 1/8	1 7/16	39.3	8 3/16	2 7/8	162.8
4 3/16	1 1/2	41.1	8 1/4	2 15/16	165.3
4 1/2	1 9/16	47.3	8 5/16	2 15/16	167.9
4 5/8	1 5/8	49.9	8 3/8	2 15/16	170.5
4 11/16	1 11/16	51.5	8 1/2	3	175.7
4 3/4	1 11/16	52.8	8 5/8	3 1/16	180.0
4 13/16	1 11/16	54.2	8 3/4	3 1/16	186.5
4 7/8	1 3/4	55.7	8 15/16	3 3/16	194.9
5	1 3/4	58.8	9	3 3/16	197.6
5 1/16	1 13/16	59.9	9 1/8	3 3/16	203.2
5 1/8	1 13/16	61.9	9 1/4	3 1/4	208.9
5 3/16	1 13/16	63.4	9 1/2	3 3/8	220.6
5 1/4	1 7/8	65.0	9 9/16	3 3/8	224.5
5 9/16	1 15/16	73.3	9 3/4	3 7/16	232.7
5 11/16	2	76.4	9 7/8	3 1/2	238.8
5 3/4	2	68.6	10	3 9/16	246.0
5 13/16	2 1/16	80.3	10 1/8	3 9/16	251.7
5 7/8	2 1/16	82.1	10 3/16	3 5/8	254.5
6	2 1/8	85.8	10 1/4	3 5/8	257.4
6 1/16	2 1/8	87.7	10 5/16	3 11/16	261.2
6 1/8	2 3/16	89.5	10 1/2	3 11/16	270.1
6 1/4	2 3/16	93.4	10 9/16	3 3/4	273.3
6 3/8	2 1/4	97.3	10 3/4	3 13/16	283.1
6 1/2	2 5/16	101.2	11	3 7/8	296.5
6 5/8	2 3/8	106.2	11 1/4	4	310.1
6 3/4	2 3/8	109.4	11 3/8	4	317.0
6 7/8	2 7/8	113.7	11 1/2	4 1/16	324.0
7	2 1/2	118.7	11 11/16	4 1/8	334.7
7 1/2	2 5/8	135.9	11 3/4	4 1/8	338.3
7 9/16	2 11/16	138.3	11 7/8	4 3/16	345.5
7 5/8	2 11/16	140.7	12	4 1/4	352.8
7 11/16	2 11/16	143.0	12 1/16	4 1/4	358.1
7 3/4	2 3/4	145.4	12 1/8	4 1/4	360.2
7 13/16	2 3/4	147.8	12 1/4	4 5/16	367.7
7 7/8	2 3/4	150.3	12 3/8	4 3/8	375.2
8	2 13/16	155.2	12 1/2	4 7/16	382.8
8 1/16	2 7/8	158.0	12 3/4	4 1/2	398.3

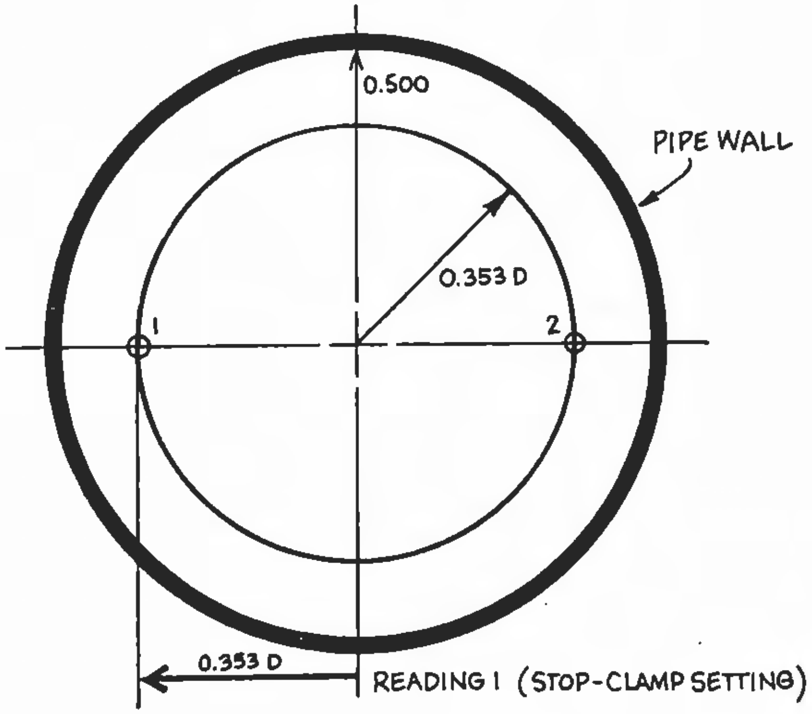


Figure 1. Pipe cross-section showing two-point test settings.

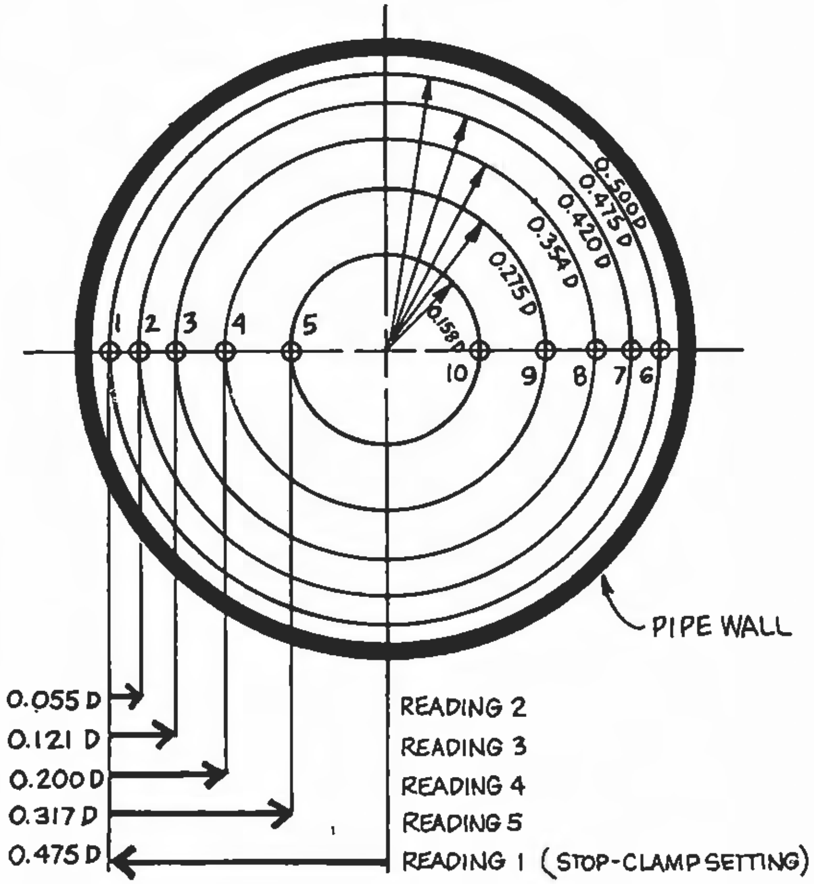


Figure 2. Pipe cross-section showing ten-point test settings.

Figure 3.

Wrapping paper tape around pipe section where holes are to be drilled. Notice overlap.

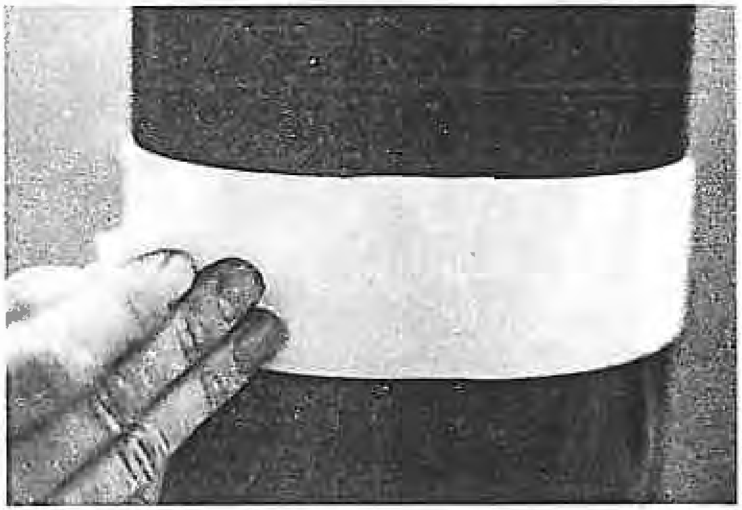


Figure 4.

Positioning the paper tape so the edges line up.

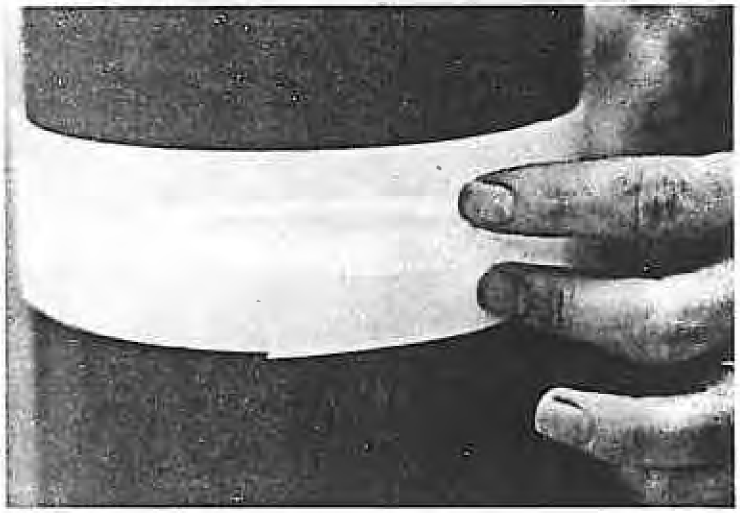


Figure 5.

Cutting the paper tape parallel with the pipe.

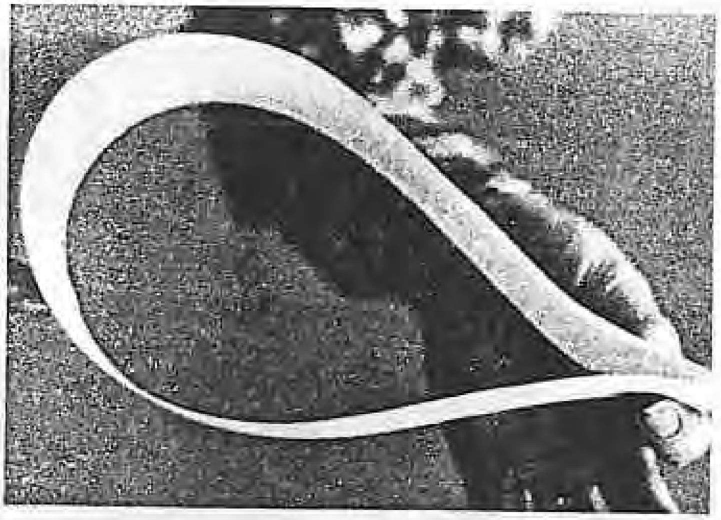


Figure 6.

Placing the ends of the cut paper tape together.

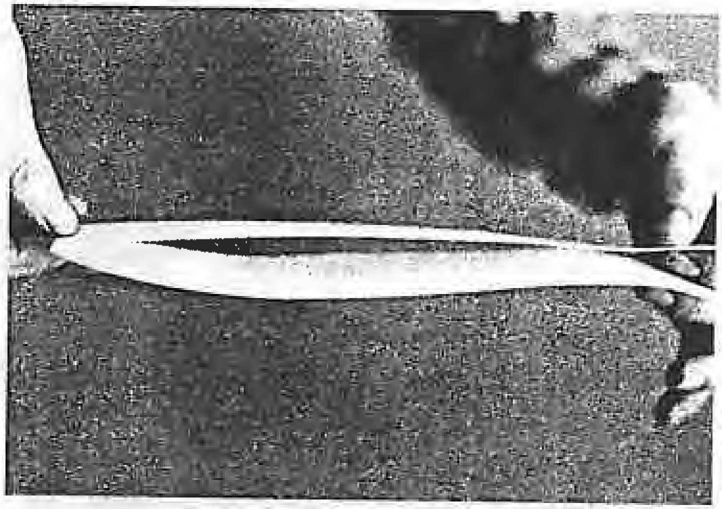


Figure 6a.

The first fold.

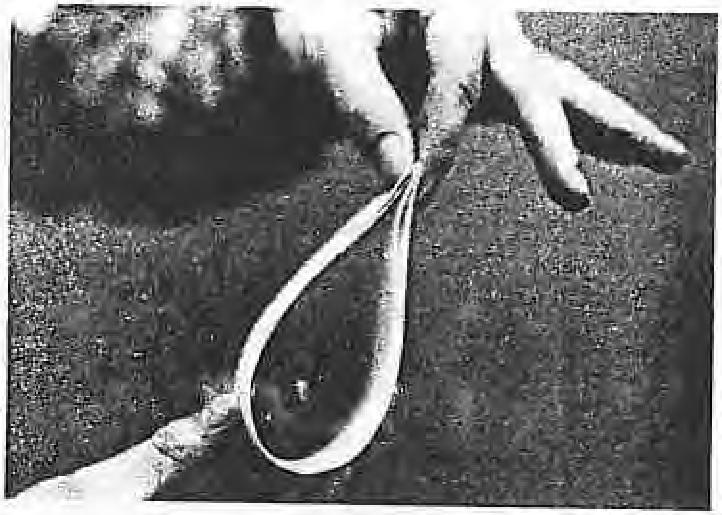


Figure 7.

Folding the paper tape in half again. The final fold.

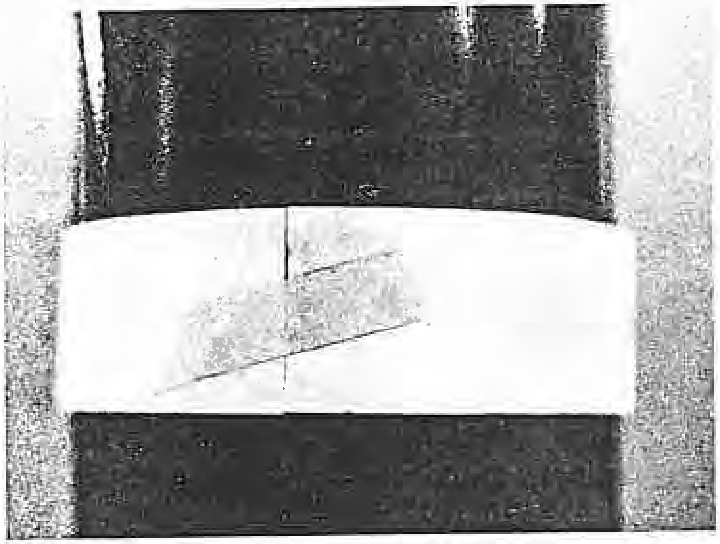


Figure 8.

Paper tape applied around the pipe with the edges lined up and secured with adhesive tape.

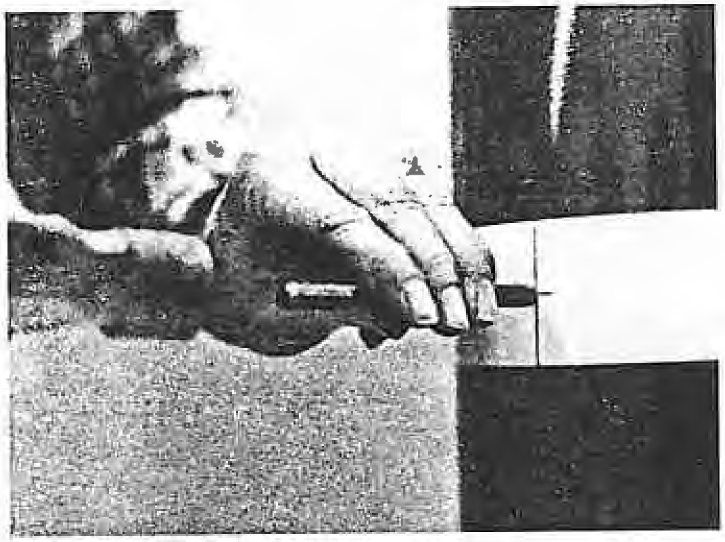


Figure 9.

Making the center punch mark for drilling the holes. Done on both sides of the pipe.

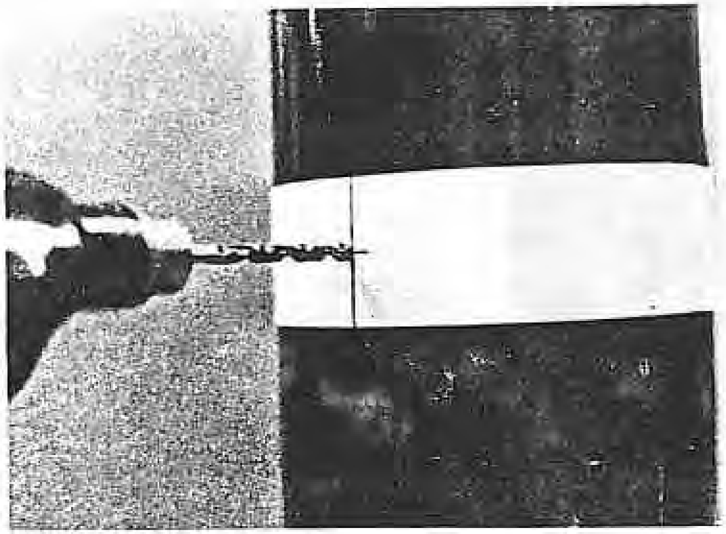


Figure 10.

Drilling the first 1/4" hole at the center mark.

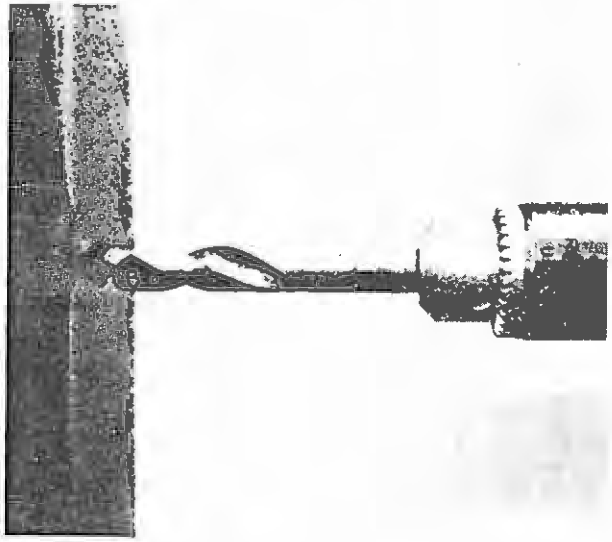


Figure 11.

Enlarging the 1/4" holes to 7/16".

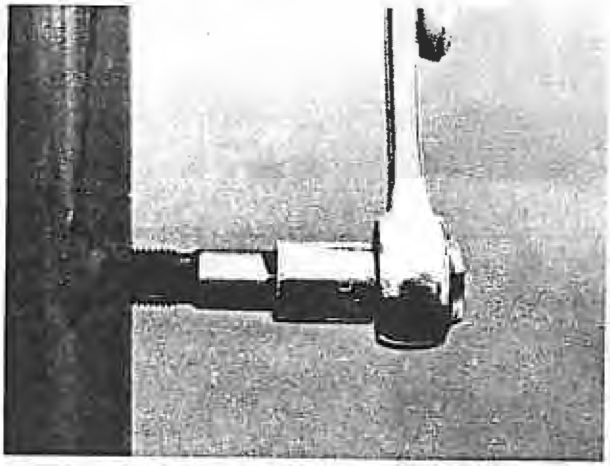


Figure 12.

Tapping the pipe. Take care to tap squarely. Only tap into the pipe about halfway on the tap as shown.

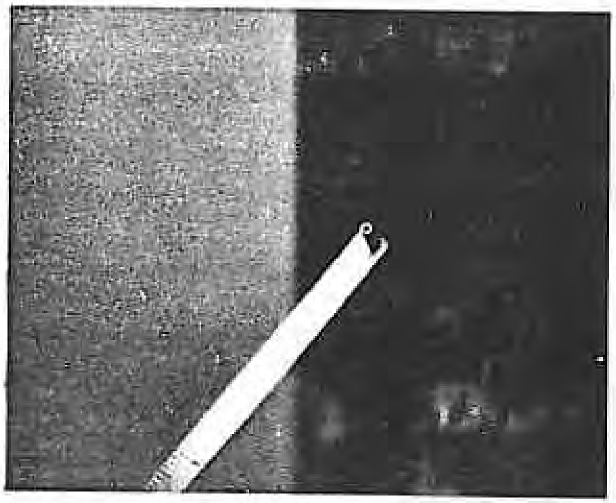


Figure 13.

Inserting steel ruler to find the pipe inside diameter.

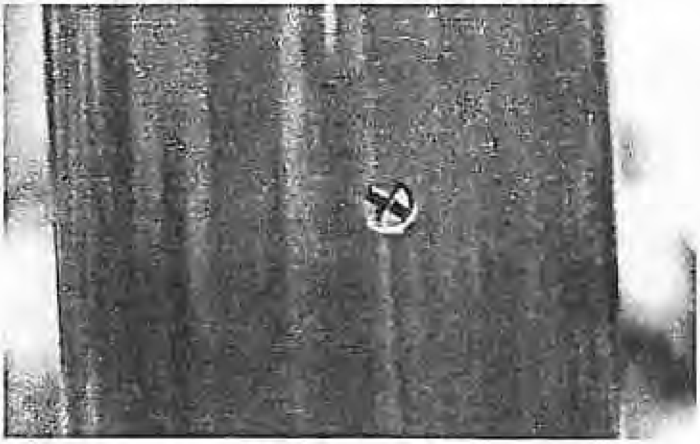


Figure 13a.

Steel ruler inserted in the pipe with the roll pin against the inside edge of the pipe.

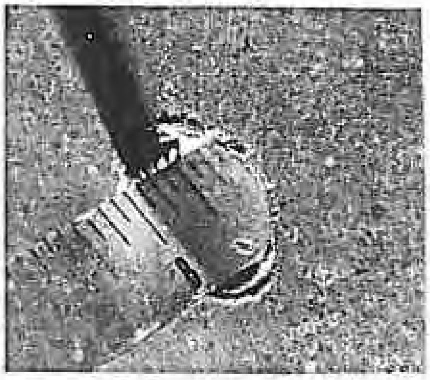


Figure 13b.

Reading the inside diameter (7 13/16").

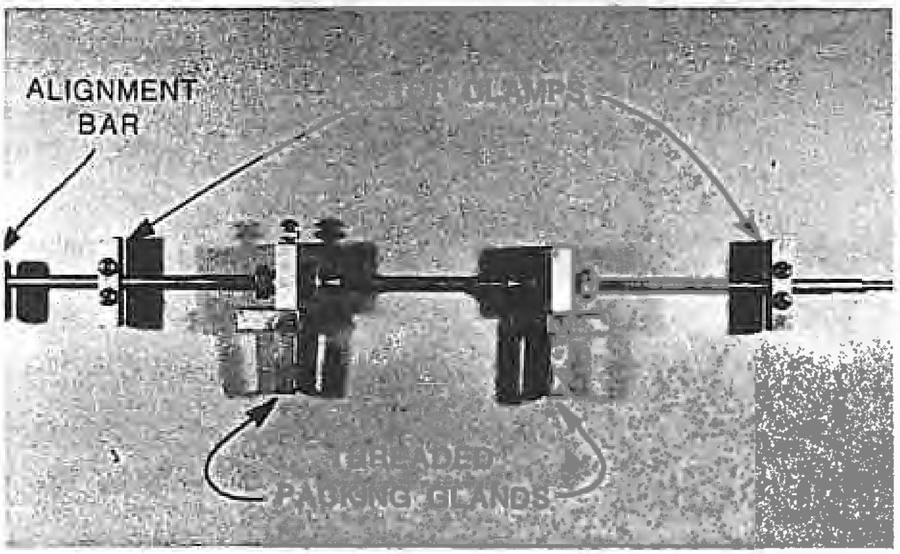


Figure 14.

The Collins tube with packing glands, stop clamps, and alignment bar.

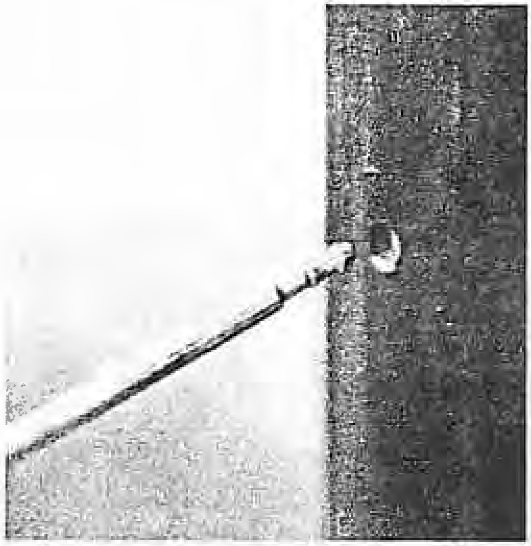


Figure 15.

Inserting the Collins tube into the pipe through the tapped holes.

Figure 16.

Installing the first packing gland.

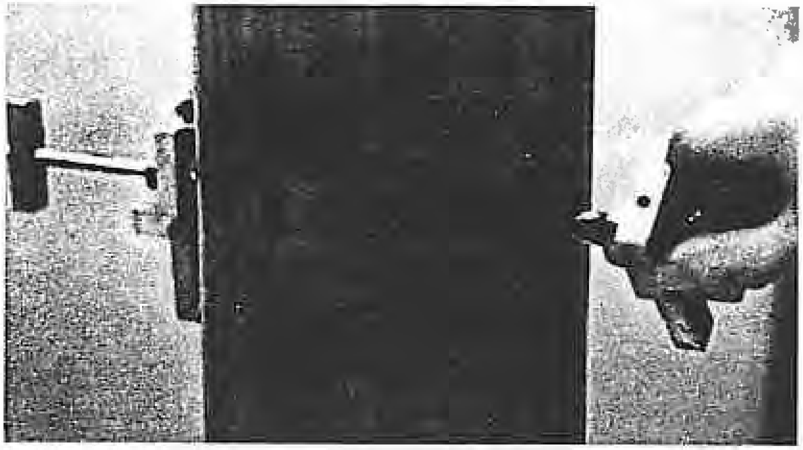


Figure 17.

Installing the remaining packing gland.

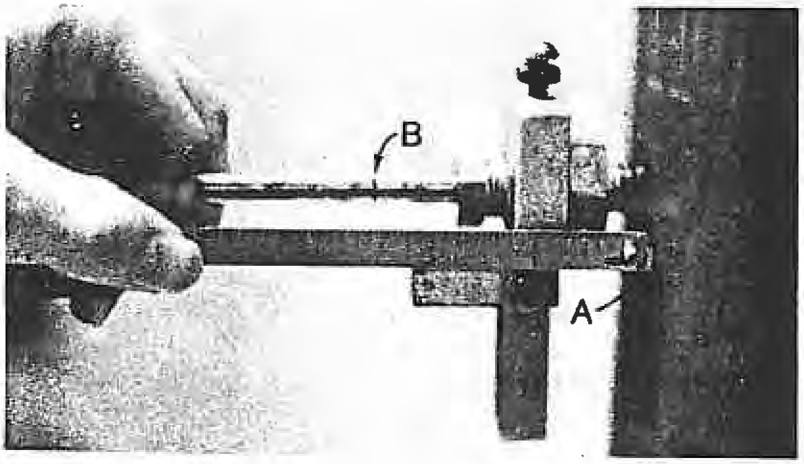


Figure 18.

Centering the Collins tube. Measure from the side of the pipe (point A) to the mark on the tube (point B). This distance should be the same on both sides of the pipe.

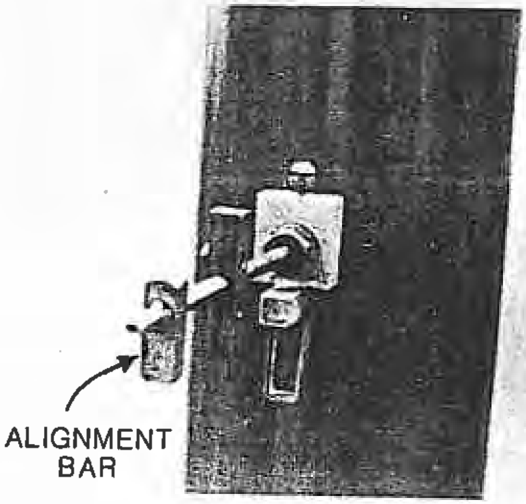


Figure 19.

Alignment bar is positioned parallel with the pipe.

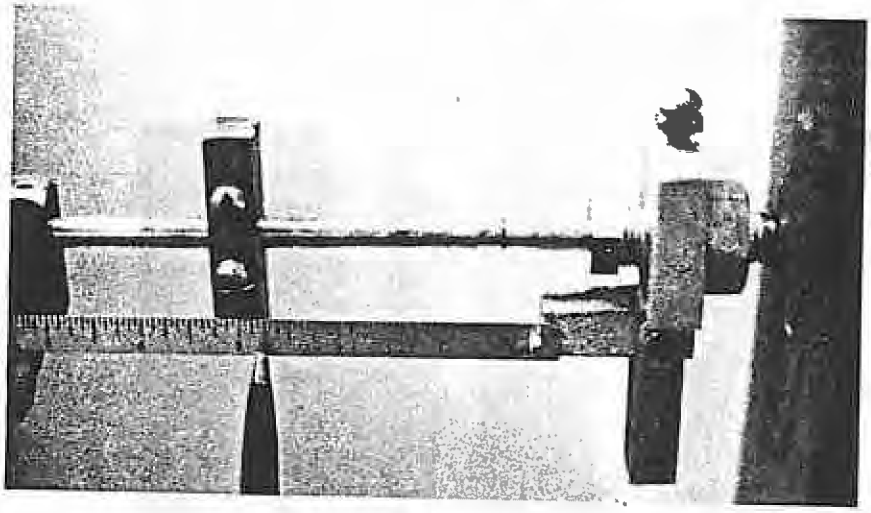


Figure 20.

Setting the stop clamps. For example, if the I.D. pipe size is 7 13/16", the stop clamp setting is 2 3/4" (from table). The stop clamp would be set at 2 3/4" as shown. This procedure is done on both sides of the pipe.

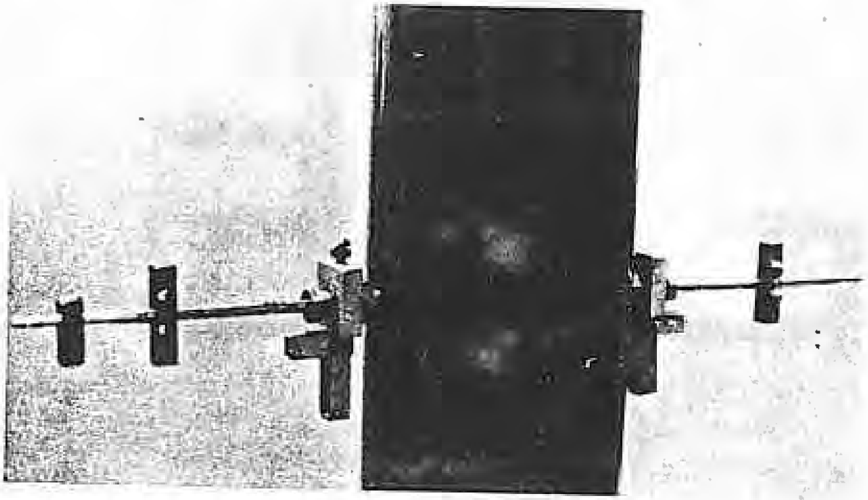


Figure 21.

Collins tube properly installed.

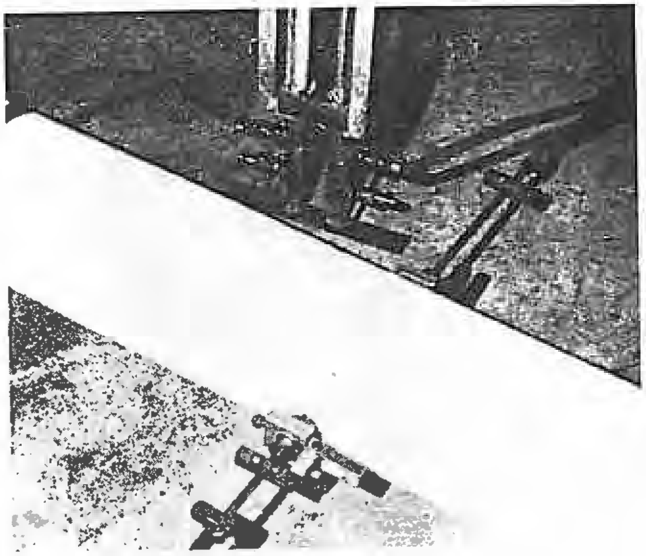


Figure 22.

Manometer connected to Collins tube ends with hoses.

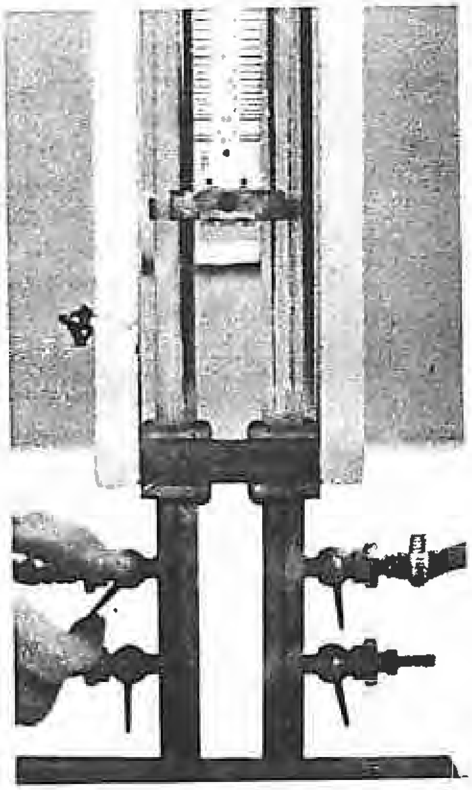


Figure 23.

Open the valves connected to the hoses.

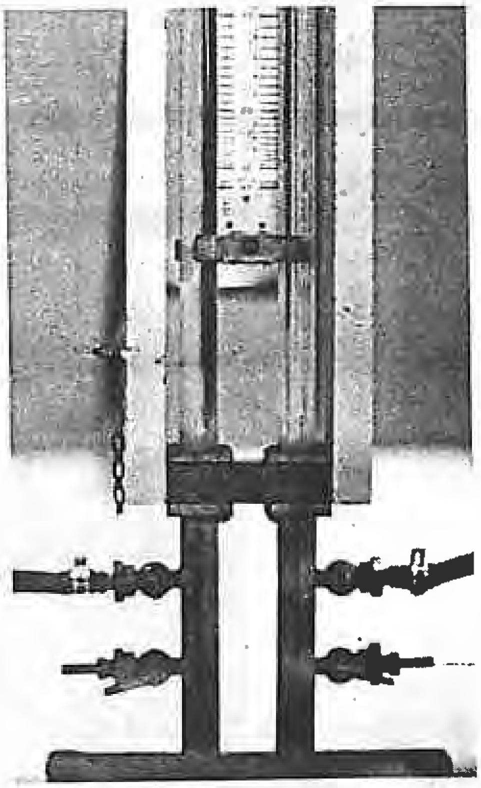


Figure 24.

Bleeding the manometer with the bottom cock valves open.

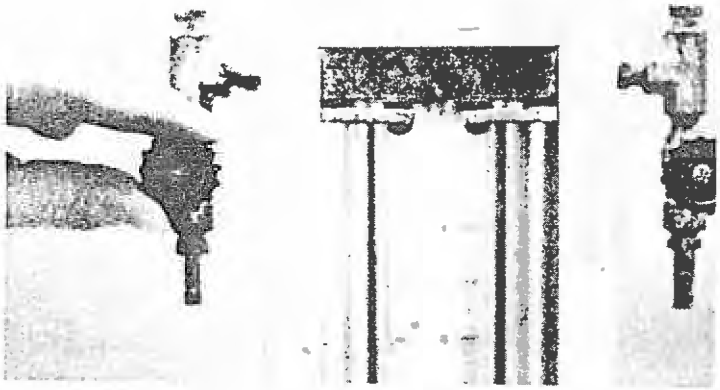


Figure 25.

Opening this valve allows water to rise into the manometer. Close when water levels in both tubes can be seen and are at a convenient measuring level.

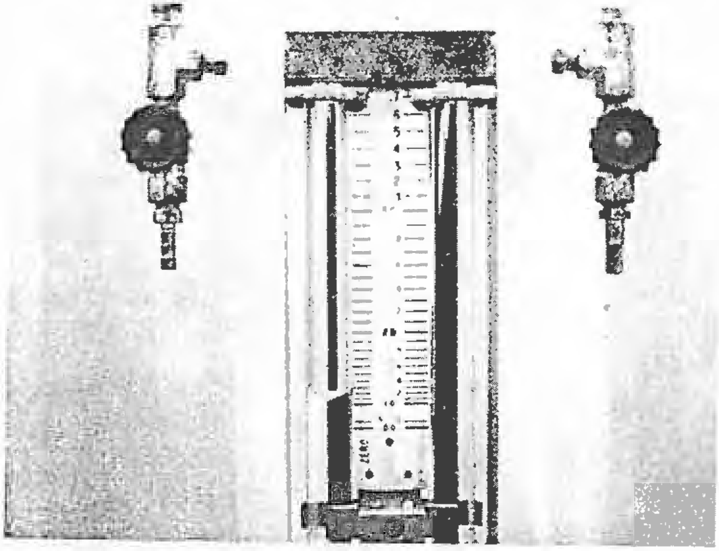


Figure 26.

Water in the right glass tube has risen completely to the top. To lower the water level so it is visible, air is pumped into the manometer.

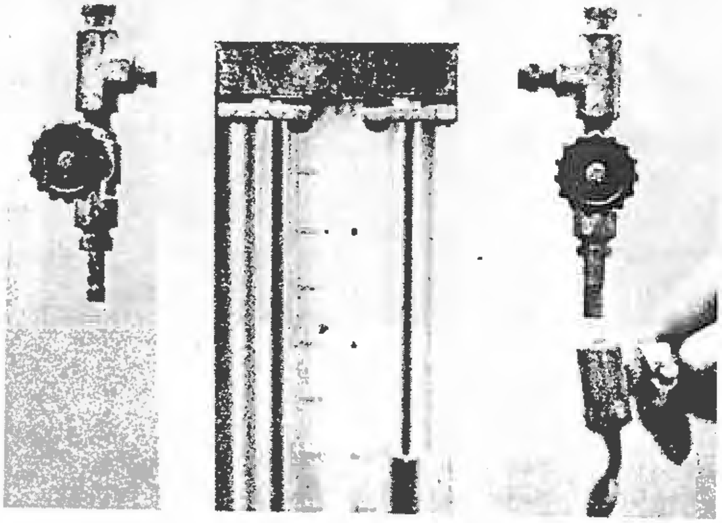


Figure 26a.

Install the tire pump hose on this fitting, open the valve, and apply air pressure until the water level lowers in the manometer.

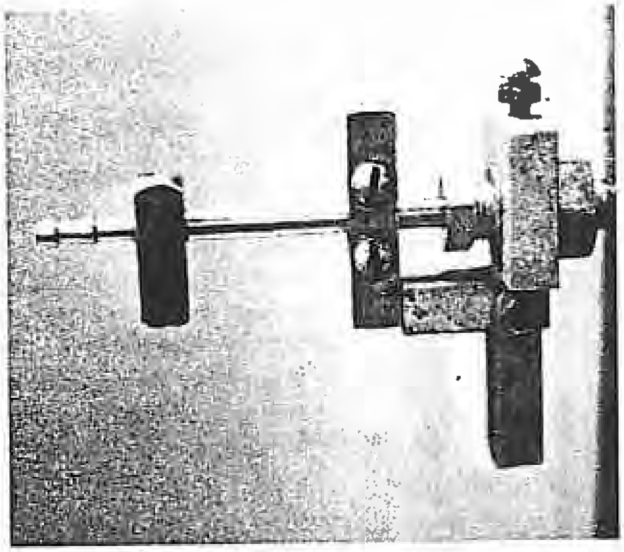


Figure 27.

Move the tube so that the stop clamp butts against the packing gland as shown. This will be the position of the tube for the first reading of the flow velocity.

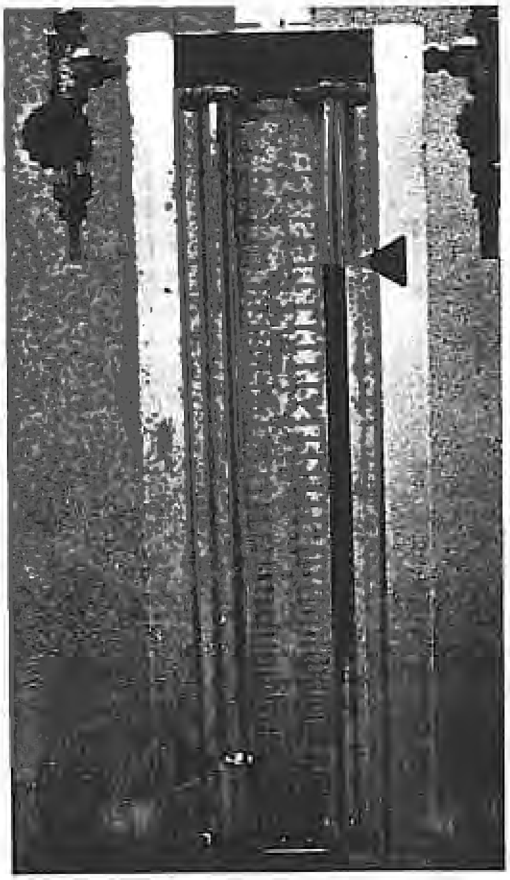


Figure 28.

Example of reading 1 (4.8). Make sure the lower water level is aligned with the "0.0" mark.

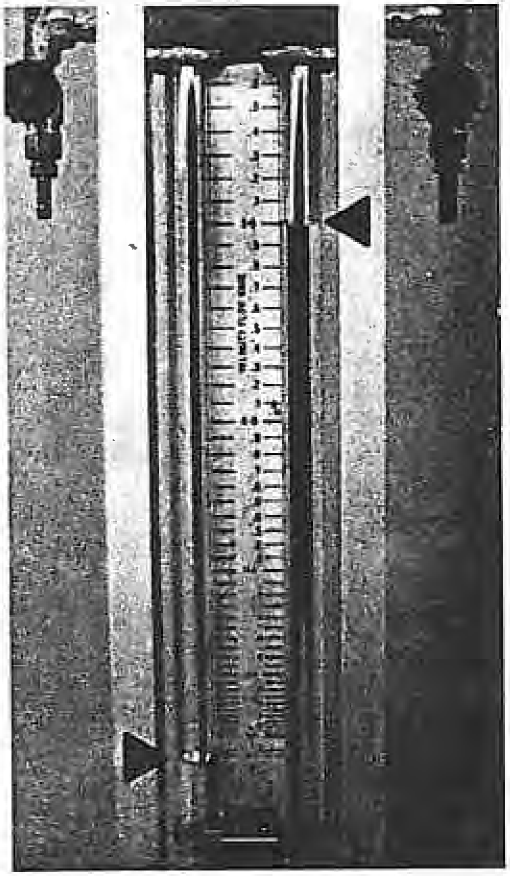


Figure 29.

Example of reading 2 (5.0). Make sure the lower water level is aligned with the "0.0" mark.

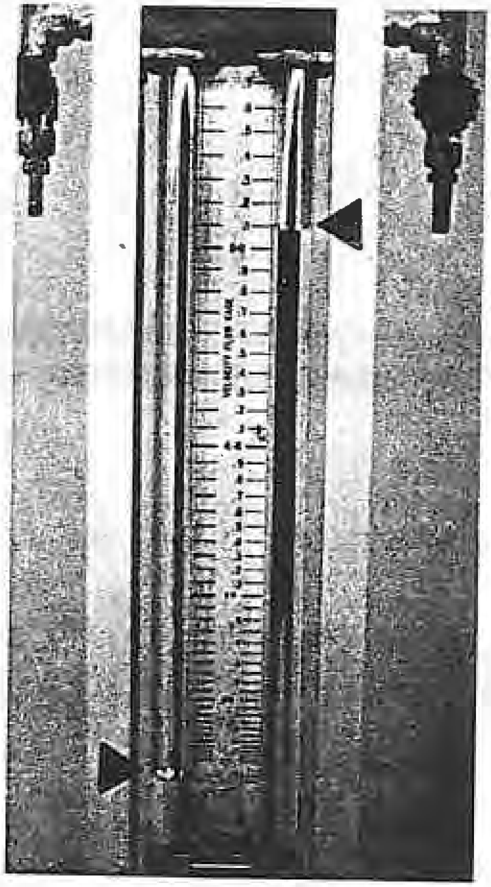


Figure 30.

Example of reading 3 (5.1). Make sure the lower water level is aligned with the "0.0" mark.

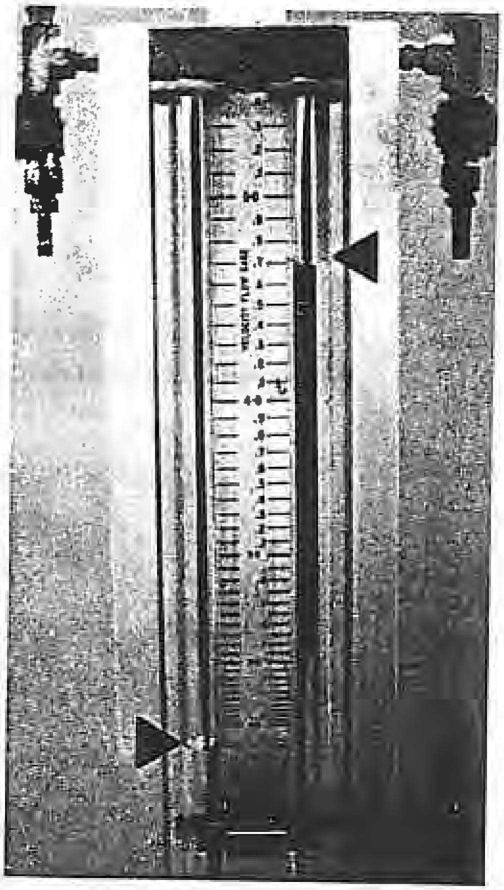


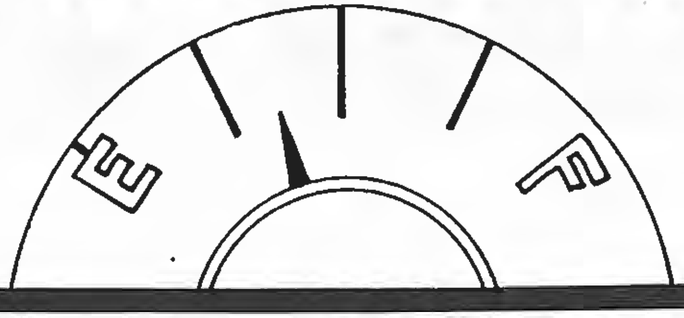
Figure 31.

Example of reading 4 (4.7). Make sure the lower water level is aligned with the "0.0" mark.

Figure 32.

After completion of the test, remove the Collins tube and packing glands. Install 1/4" pipe plugs in the tapped hole. Tighten snugly.

fuel consumption



ENERGY USE RATE
Diesel
Gallons Per Hour

Equipment:

5 gallon fuel can (modified for test)
Platform beam scale
Stopwatch
Fuel hoses
Misc. fittings

Description:

Fuel consumption is determined by weight. The quanity of fuel used over a time interval is weighed. The net weight of fuel used is converted to gallons. The net gallons used per the time interval equals the gallons per hour.

A five-gallon G.I. type fuel can, modified for a supply line near the bottom of the can, works well for test purposes. A return fuel fitting is also necessary which can be placed at the top of the can. Provisions should be made to allow filling of the can between tests if necessary. A platform beam scale is recommended as the weighing device (Figure 1).

Equipment Set-up:

Note: It is important when switching from the diesel supply tank to the fuel can that all air is removed from the hose and fittings. Air in the fuel line can cause the engine to stall and may require repriming of the fuel system. If this happens, consult the engine's owner manual for correct priming procedures.

1) Fill the fuel can with diesel. Keep the fuel can contents from being contaminated with water or dirt.

2) Most diesels will have a fuel supply to the engine and a return fuel to the tank. Both need to be used with the fuel can since the return fuel is not used by the engine.

3) Connect the supply line from the bottom of the fuel can to the engine, or use the existing supply line and connect it to the fuel can. A supply of miscellaneous fittings is helpful since fuel connections are not standardized.

Important: Bleed air from these lines by allowing diesel fuel to run free through the line before making the connections (Figure 2).

Important: The supply line must not bypass the final fuel filter.

4) If the engine has a return line, connect it to the top fitting on the can, or use the hose from the fuel can return and connect it to the return line fitting on the engine (Figure 3).

   Note: The return line may be placed into the fill spout of the fuel can if the can is not modified for return fuel (Figure 4).

5) Loosen fill cap on the can to allow air to enter.

6) Place the scale on a hard level surface. A piece of plywood may be used for this. Protect the scale from wind if possible. Wind will make reading of the sensitive scale difficult.

Determine the fuel use:

1) The engine and pump should be allowed to warm up and stabilize before beginning the test.

2) Set the weight on the scale beam on a division mark slightly less in weight than the weight of the fuel can and contents.

3) When the beam balances, start the stopwatch. Record the weight (Figure 5).

4) Allow the engine and pump to run long enough for a minimum of five pounds of diesel to be used. The more diesel used will result in a more accurate measurement. However, be careful not to allow the fuel can to go empty.

5) Again set the weights on the scale beam on a division mark slightly less in weight than the weight of the fuel can and contents.

6) When the beam balances, stop the stopwatch. Record the weight and time (Figure 6).

7) Calculate the fuel use rate.

   Start Weight - Stop Weight = Net Weight of Fuel

   Net Weight of Fuel / 7.05 lbs/gal* = Net gallons

   Net Gallons/time (hours) = gallon/hour

   * Average weight of No. 2 diesel per gallon. Actual weight may vary between 7.01 and 7.1 pounds per gallon.

8) Reconnect the fuel and return lines after the test. Again, make sure the air in the lines are bled off.

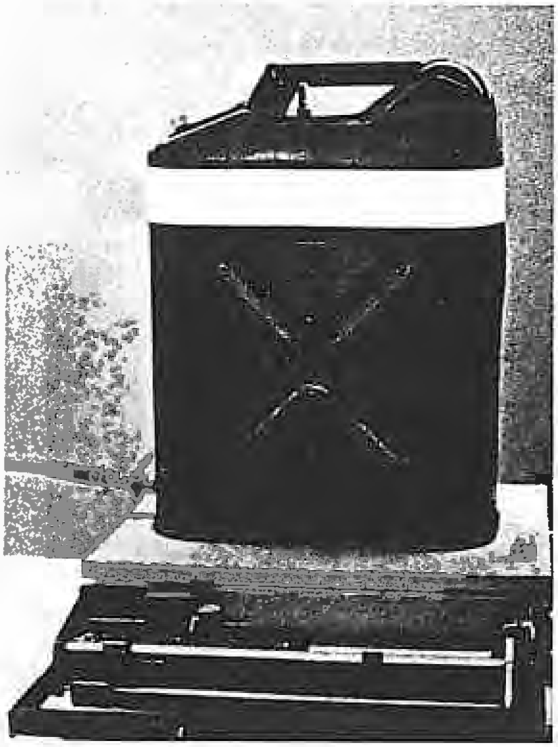


Figure 1.

Platform beam scale and test fuel can.

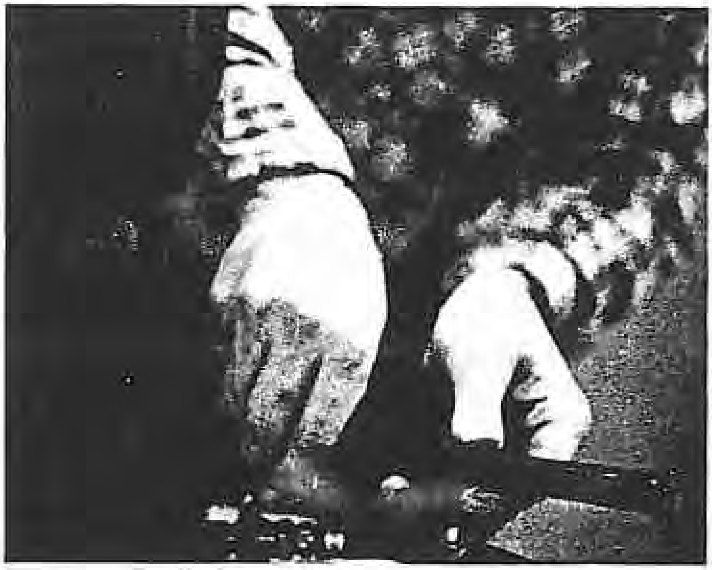


Figure 2.

Bleeding air from diesel supply hose.

Figure 3.

Installing return fuel hose on hose fitting on top of test can.

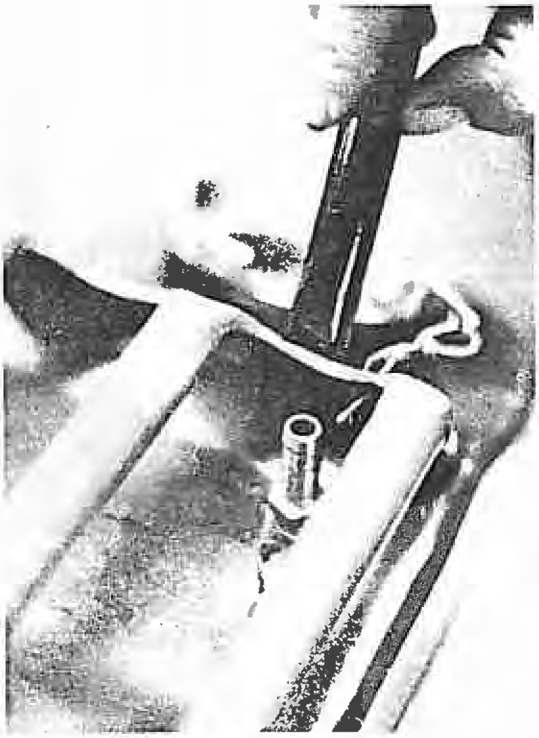
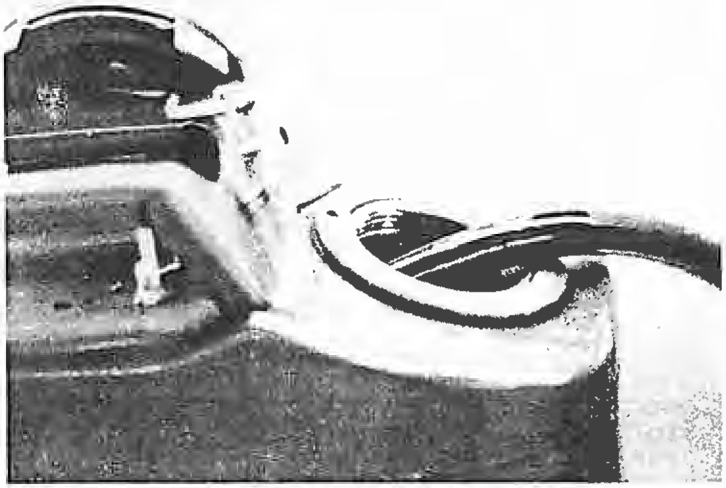


Figure 4.

Alternative method to accomodate the fuel return hose.



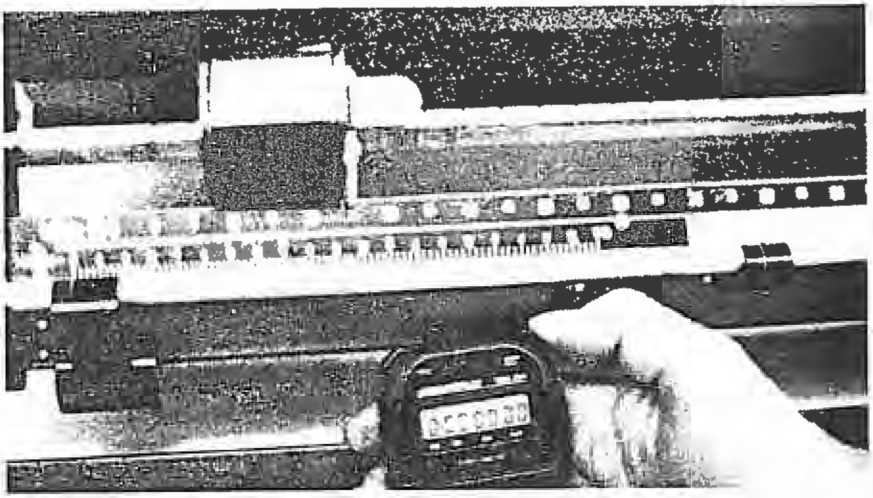


Figure 5.

Example start position.

Scale weight = 25 lbs
Time = 0 minutes
0 seconds

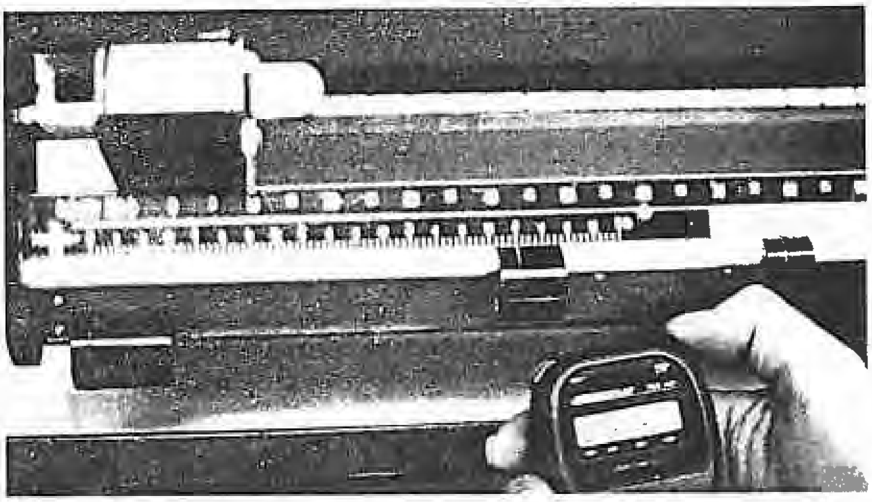


Figure 6.

Example stop position.

Scale weight = 14 lbs.
Time = 12 minutes
28.9 seconds
= 748.9 seconds

Data Worksheet Example

Energy Use Test   Time: 12 min. 28.9 sec.= 748.9 seconds

☑ Diesel   Weight start 25 lbs - Weight Stop 14 lbs
= 11 Net weight used ÷ 7.05 lbs/gal = 1.56 gallons ÷
☐ Propane   748.9 seconds x 3600   = 7.50 gal/hr

ENERGY USE RATE
Propane
Gallons Per Hour

Equipment:

Test propane cylinder (7.5 gal - 30#)
Platform beam scale
Stopwatch
Fuel hose

Description:

Fuel consumption is determined by weight. The quanity of fuel used over a time interval is weighed. The net weight of fuel used is converted to gallons. The net gallons used per the time interval equals the gallons per hour.

A 30 pound (7.5 gallon) propane cylinder is used for the test. A ten foot hose supply is needed to connect the tank to the engine. A platform beam scale is recommended as the weighing device.

Equipment setup:

Note: It must be determined whether the engine is equipped to use propane in the liquid or vapor state. Look for a regulator near the engine and installed just before the carberator. If the system is using liquid propane, the regulator will probably be combined with a liquid converter (vaporizer) which changes the liquid propane to vapor. The converter will have hot water hoses from the engine connected to it if the system is using liquid (Figure 1).

Another method is to close the valve on the propane supply tank and loosen the fuel line. If a white cloud appears, the engine is drawing liquid propane.

1) Place the scale on a hard level surface. A piece of plywood may be used for this. Protect the scale from wind if possible. Wind will make reading of the sensitive scale difficult.

2) Close the valve on the supply tank.

3) If the supply line is constructed of rubber hose, it may be removed from the supply tank and connected to the test fuel tank, (Figure 2). This allows flexibility between the test tank and the engine.

   Otherwise, use a ten-foot hose for the test tank. Connect the downstream end of the hose to the regulator and/or converter at the point where the existing fuel line was. The hose end fittings are usually for 3/8" tubing flare (Figure 3).

   Note: The POL fittings on the supply tank and test tank valves have left-handed threads — turn clockwise to loosen.

   Important: Do not by-pass any pressure regulating device when connecting the test tank.

4) Place the test tank right-side up (valve up) on the scale if the engine was connected to vapor, (Figure 4). Otherwise, place the test tank on the scale bottom-side up (valve down) for liquid applications, (Figure 5).

5) Turn the test tank valve on and listen for leaks. The use of a liquid leak detector is adviseable.

6) Correct if any leaks are detected.

Determine fuel use:

1) The engine and pump should be allowed to warm up and stabilize before beginning the test.

2) Set the weight on the scale beam on a division mark slightly less in weight than the weight of the test tank and contents.

3) When the beam balances, start the stopwatch. Record the weight (Figure 6).

   Important: Do not move the supply hose during the test.

4) Allow the engine and pump to run long enough for a minimum of five pounds of propane to be used. The more propane used will result in a more accurate measurement. However, be careful not to empty the test tank during the test. It only contains 30 pounds of fuel when full.

5) Again set the weight of the scale beam on a division mark slightly less than the weight of the test tank and contents.

6) When the beam balances, stop the stopwatch. Record the weight and time (Figure 7).

7) Calculate the fuel use rate:

Start weight - Stop weight = Net weight of fuel

Net weight of fuel / 4.25 lbs/gal* = Net gallons

Net gallons / time (hours) = Gallons/hour

8) Reconnect the supply line and check for leaks.

* Average weight of pure propane without butane. If propane/butane ratio is known, the average weight per gallon is (Propane % x 4.25) + (Butane % x 4.85).

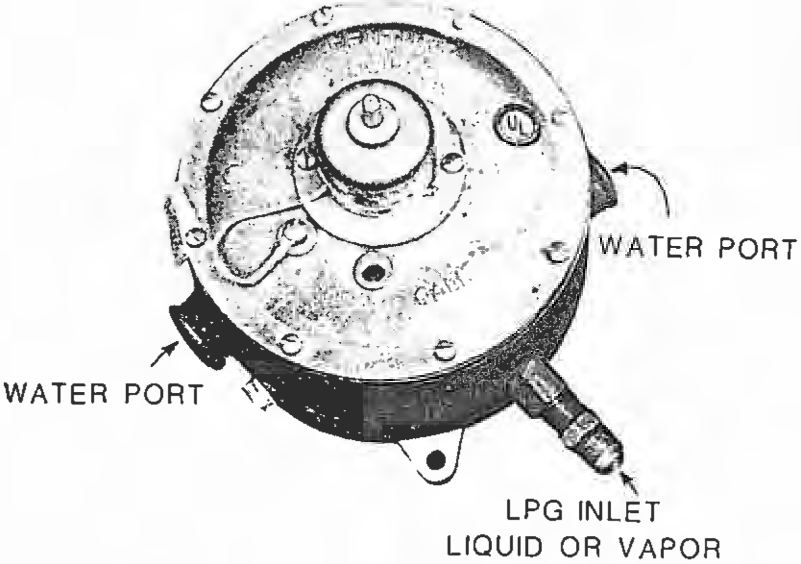


Figure 1.

Typical propane regulator/converter (vaporizer). Hot water hoses will be connected to the water ports if the engine is equipped to use liquid propane.

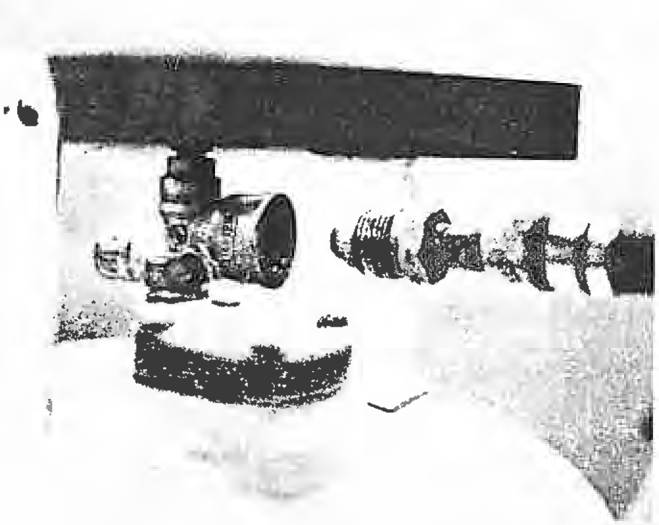


Figure 2.

Connecting the propane supply hose to the test tank. Threads are left-handed, turn clockwise to loosen.

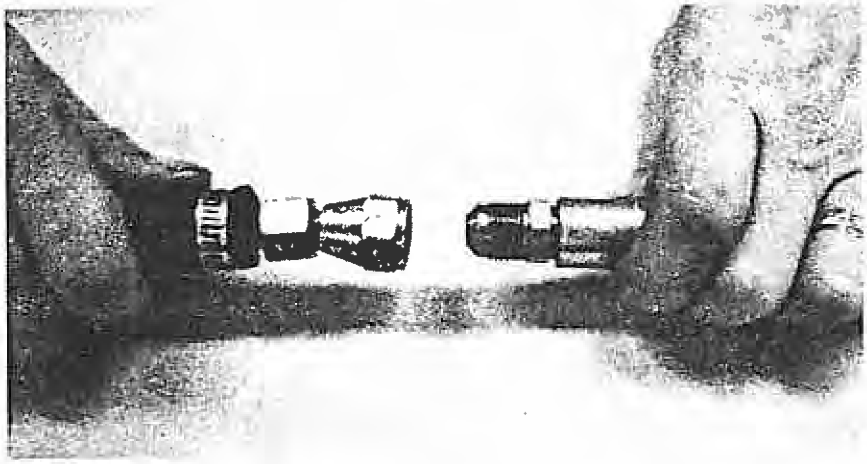


Figure 3.

End of propane supply hose with common 3/8" flare fitting. Threads are right handed; turn counter-clockwise to loosen.

Figure 4.

Tank upright for vapor only application.

Figure 5.

Tank upside down for liquid propane applications.

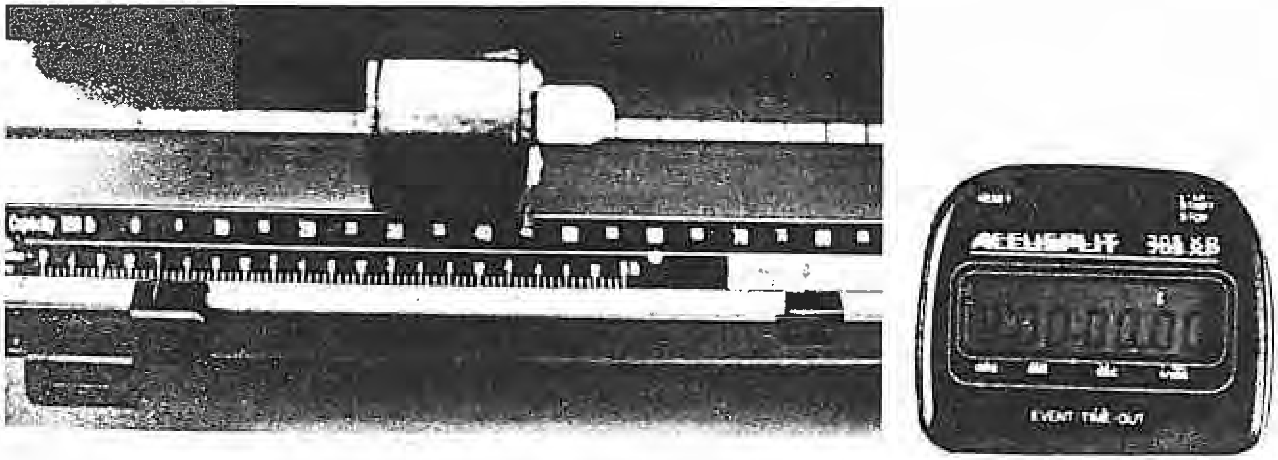


Figure 6.

Example start position. Scale weight = 46 lbs.
Time = 0.0 seconds

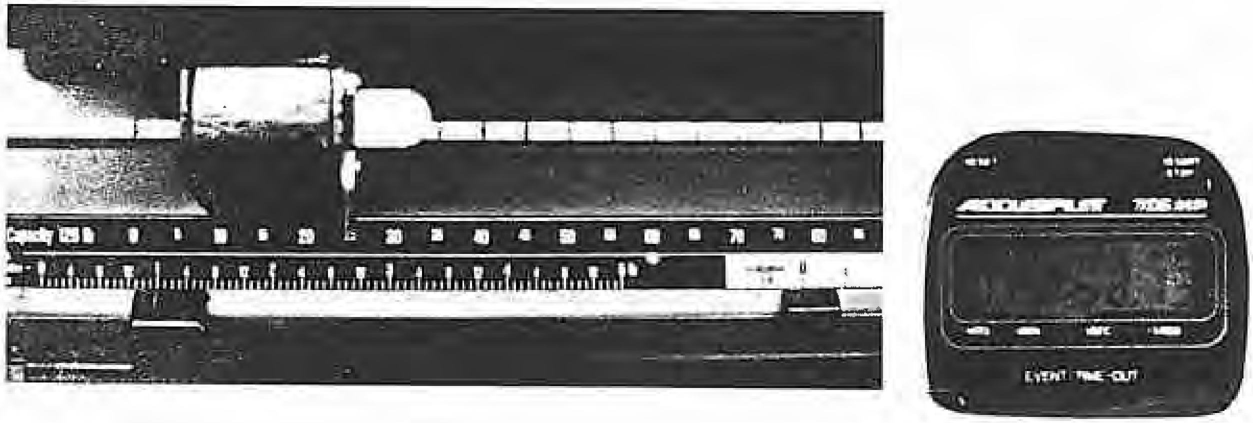


Figure 7. Example stop position. Scale weight = 26 lbs
Time = 20 minutes
38.1 seconds
= 1238.1 seconds

Data Worksheet Example

Energy Use Test Time: 20 min. 38.1 sec. = 1238.1 seconds

☐ Diesel Weight start 46 lbs - Weight Stop 26 lbs

= 20 Net weight used ÷ 4.25 lbs/gal = 4.71 gallons ÷

☑ Propane 1238.1 seconds x 3600

= 13.68 gal/hr

ENERGY USE RATE
Electric
kW or kWh/hr

Equipment:

Existing utility watt-hour meter
Stopwatch

Description:

The energy use rate in kilowatts (kW) can be determined by using the existing watt-hour meter (or electric meter) at the well site (Figure 1). The KW usage is found by counting the disc revolutions over a period of time and doing a simple calculation. In addition, voltage and current measurements should be taken to verify the kW observed.

Taking the measurement:

1) The motor and pump should be allowed to stabilize before beginning the test.

2) Locate the revolving disc in the meter and the black mark on this disc.

3) Start the stopwatch when this black mark is in view and begin counting the revolutions.

4) Continue counting for at least one minute.

5) Stop the stopwatch when the black mark passes the same point where you started.

6) Record the revolutions and time.

7) From the meter dial face, the "Kh" factor must be located. (A typical Kh number may be 28.8 or 57.6) (Figure 1).

8) Calculate the energy use rate in kW and record.

$$\text{kW} = 3.6 \times \text{Disc Revolutions} \times \text{Kh factor} / \text{time (seconds)}$$

Field Problems

Meter ratio

Some electric utility companies have current and/or power transformers installed with their watt-hour meters. This allows less current to flow through the meter. If they are used, observed kW will need to be corrected to compensate for the transformer. If the observed kW from the watt-hour meter seems excessively low, check for the use of these transformers. Often the current transformer ratio (CTR) or the power transformer ratio (PTR) will be indicated on the meter face. If not, the utility should be consulted for the correct ratio. This ratio is multiplied by the observed kW to determine the correct kW.

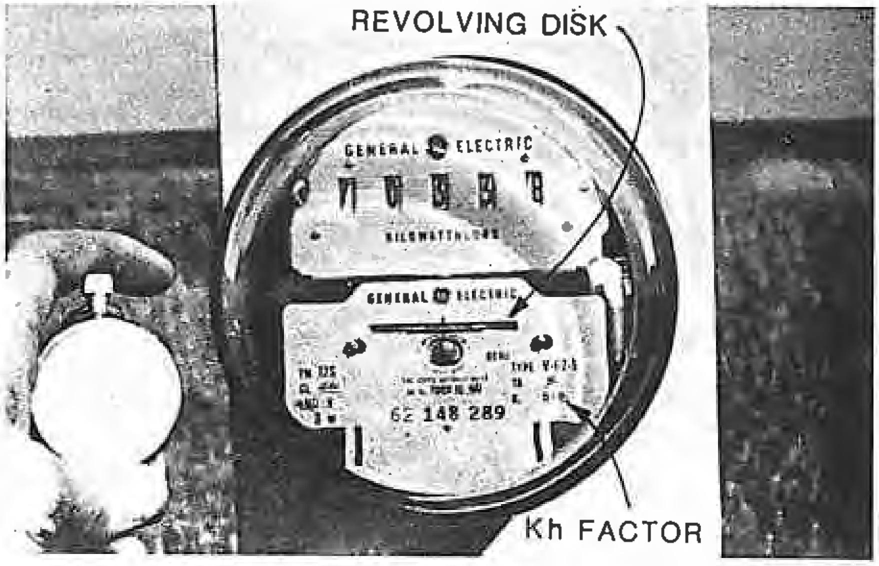
$$\text{kW} = \text{observed kW} \times \text{CTR} \times \text{PTR}$$

Underground Feerder Line Correction

If the watt-hour meter is located an appreciable distance from the pump motor (>100'), the observed kW should be corrected for line loss. Consult the Pump Handbook article "Power Loss in Underground Electrical Feeders".

Defective Meter

Although the utility watt-hour meter is generally within 1/2% accurate, it can give erroneous readings. On electric pumping plants, a performance rating over 125% would indicate an error in measurement. A check on kW using voltage and amperage should be made. Occasionally a wrong Kh factor is listed, or the meter has been damaged by lightening strike. Seldom will a meter read high.



ENERGY USE RATE
Natural Gas
1000 Cubic Feet Per Hour (mcf/hr)

Equipment:

Existing gas meter (calibrated meter, optional)
Stopwatch
15 psi pressure gauge

Description:

The existing natural gas meter* can be used to determine the energy use rate of the engine. The number of revolutions of the fastest moving dial on the meter face is counted over a time interval using the stopwatch. A simple calculation gives the natural gas usage in thousand cubic feet per hour (abbreviated mcf/hr). This value must be corrected for elevation and gas pressure. The correction multiplier is calculated based on elevation and gas pressure.

Taking the measurement:

1) The engine and pump must be warmed up and stabilized before beginning the test.

2) Locate the rotating dial which is moving the fastest, (Figure 2).

3) This dial will have a label on it such as "five cubic feet" or "ten cubic feet." Record the number on the data worksheet as "dial capacity."

4) Start the stopwatch when the dial indicator reaches the top of the dial and begin counting the revolutions.

5) Continue counting for at least 10 revolutions.

6) Stop the stopwatch when the dial indicator reaches the top. Record the number of revolutions and the time on the data worksheet.

7) Calculate the uncorrected fuel use using the worksheet.

* Most meters are checked for accuracy by the local gas company at least every 5 years. A calibrated meter may be available on a loan basis from the gas company. Figure 1 shows a test meter installed using flexible hose.

Determine the correction factor:

1) The gas pressure at the gas meter is necessary to determine the correction multiplier.

2) Locate the second gas pressure regulator in the gas line. This will be the one closest to the engine.

3) If the gas meter is between this regulator and the engine, the gas pressure is less than 1/2 psi and the correction multiplier is 1.0 (Figure 3-2).

4) If the gas meter is located between the first and second gas pressure regulator, the gas pressure will be greater than 1/2 psi and must be measured (Figure 3-1).

5) Check to see if there is a pressure gauge fitting in the gas line between the first and second regulators. If there is none, contact the local gas company to obtain the correction factor for the meter. Do not attempt to make your own fitting by drilling into the gas line.

6) If a suitable fitting was located, install a 15 psi pressure gauge. The gauge must be located at the metering site if the meter is an appreciable distance away from the power unit (Figure 3-3).

7) Take and record the pressure when the engine and pump are operating.

8) Determine the pressure correction multiplier (see following section).

9) Calculate the true corrected natural gas consumption in mcf/hr using the worksheet.

Pressure Correction Multiplier

The correction factor is used whenever the pressure of the gas being metered is different than the base pressure of the gas. For natural gas the base pressure is 4 ounces, or the equivalent to 0.25 psi. All natural gas is sold by the cubic foot based on this pressure of 0.25 psi.

If the pressure of the gas passing through the meter is 4 ounces (0.25 psi), no correction factor is needed. The natural gas which passes through the meter is accurately measured.

In many cases, the pressure of the gas passing through the meter is greater than 0.25 psi. The pressure often ranges between 7 - 12 psi. Gas passing through the meter at this pressure is compressed. When gas is compressed by pressure, its volume decreases. The meter therefore registers the volume of compressed gas flowing through it. If the gas pressure was reduced to 0.25 psi after exiting the meter, the compressed gas would expand into a larger volume. Since the meter only registered the smaller volume, the gas meter reading must be corrected to the larger volume of gas. This would be the true volume of gas which would pass through the meter if at 0.25 psi.

A correction factor can be calculated to determine the actual cubic feet of gas metered when the gas pressure exceeds 0.25 psi. The atmospheric pressure at the metering site must be known before the correction factor can be found.

"Atmospheric pressure" is caused by the weight of air acting downward on the earth's surface. At sea level the atmospheric pressure is 14.7 psi. As altitude (elevation) increases the air becomes thinner and exerts less pressure. At about 18 miles elevation, atmospheric pressure becomes zero.

The atmoshperic pressure has an effect on the volume of gas metered similar to gas pressure. The average atmospheric pressure can be calculated at any elevation. It decreases about 0.5 psi for every 1000 feet of elevation increase from sea level (14.7 psi).

The correction factor must be applied when the metered gas has a pressure exceeding 0.25 psi.

The correction factor is calculated as follows:

$$\text{Correction Factor} = \frac{\text{Gas Pressure} + \text{Atmoshperic Pressure}}{\text{Atmospheric Pressure} + 0.25}$$

where:

Gas Pressure is the gauge pressure of the gas passing through the meter. This is measured at the meter.

Atmospheric Pressure is the average absolute pressure (psi) at the meter site.

Average Atmospheric Pressure
= 14.7 psi - (0.5 psi x Elevation / 1000)

Example One:

Uncorrected metered gas consumption = 0.600 mcf/hr
Gas pressure = 4 oz (0.25 psi)
Elevation = 2500 ft

Atmospheric Pressure = 14.7 psi-(0.5 psi x 2500 ft/1000 ft)
= 13.45 psi

$$\text{Correction Factor} = \frac{0.25 \text{ psi} + 13.45 \text{ psi}}{13.45 \text{ psi} + 0.25 \text{ psi}}$$

$$= 1.00$$

Correction factor is 1.00 because the metered gas pressure is equal to 0.25 psi.

Corrected Gas Consumption

0.600 mcf/hr x 1.00 = 0.600 mcf/hr

Example Two:

Uncorrected metered gas consumption = 0.600 mcf/hr
Gas pressure = 10. psi
Elevation = 2500

Atmospheric Pressure = 14.7 - (0.5 x 2500/1000)
= 13.45 psi

$$\text{Correction Factor} = \frac{10 \text{ psi} + 13.45 \text{ psi}}{13.45 \text{ psi} + 0.25 \text{ psi}}$$

$$= 1.71$$

Corrected Gas Consumption = 0.600 mcf/hr x 1.71
= 1.027 mcf/hr

The gas volume metered at 10 psi was 600 cubic feet.
The volume would increase to 1027 cubic feet
when de-pressurized to 0.25 psi.

Data Worksheet Example

☑ Natural Gas
3.6 x 5 Dial Capacity x 10 Dial Revolutions ÷
201 seconds = .896 x Correction Factor 1.70 =1.522 mcf/hr
Gas Pressure 10.0 psi Elevation 2100

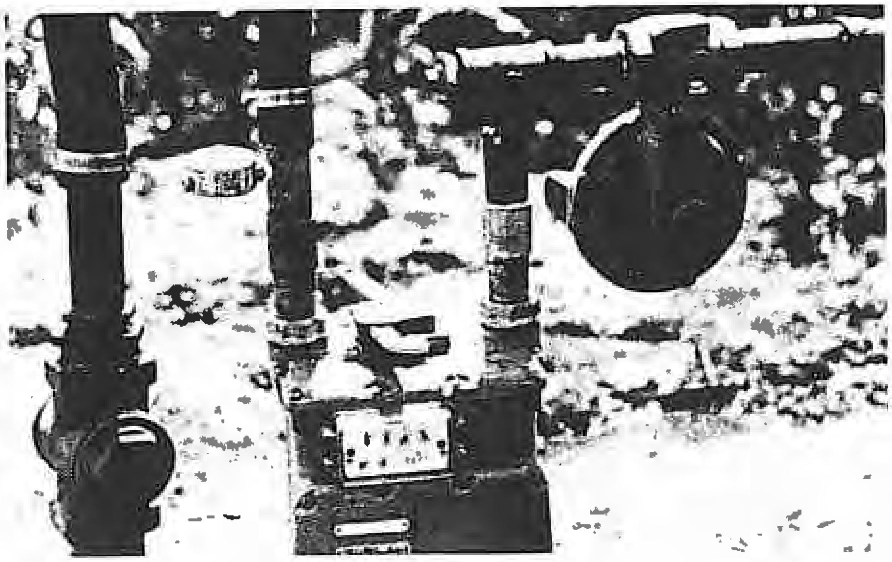


Figure 1. Calibrated gas test meter installed in gas line using flexible hose.

Gas Meter Face

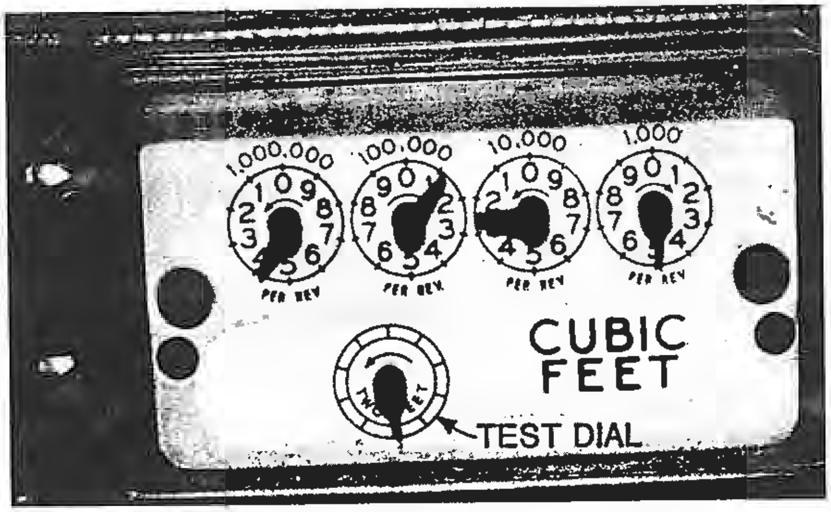


Figure 2. Dial capacity of this meter is two feet.

Gas Pressure at different Locations & Situations

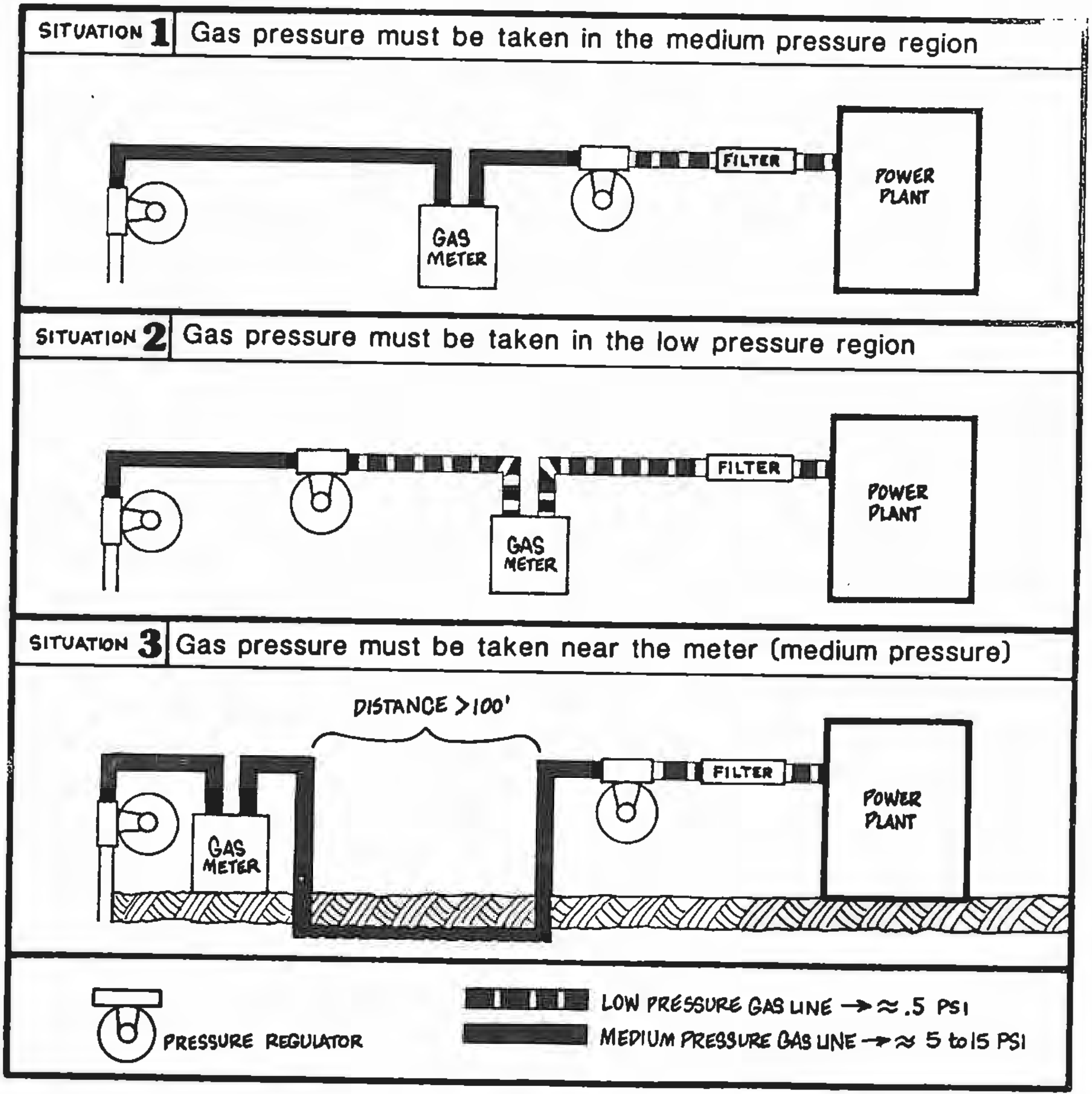


FIGURE 3

ALTERNATORS AND HYDRAULIC PUMPS
FUEL CONSUMPTION CORRECTION

Quite often the pumping plant power unit supplies the power to drive a center-pivot irrigation system. On electric driven center-pivots the engine may drive an electric alternator. Center-pivots driven by oil hydraulics require the use of a hydraulic pump.

The fuel consumption will be higher when these devices are in use, than when just operating the turbine pump. It would be incorrect to allot this extra fuel consumption to the turbine pump performance. If the fuel consumption is not corrected for the alternator or hydraulic pump, the performance level of the pumping plant will be lower — not due to an inefficient pump or engine, but due to a parasite load.

Therefore, during a pumping plant performance test, these devices should be disconnected from the engine or otherwise isolated from the power unit to properly represent the true performance of the pumping plant.

Pump Test, Center Pivot (Method 1)

One method is to physically disconnect the alternator or hydraulic pump from the engine by removing the belts. The center-pivot and its power source therefore, do not contribute to total fuel consumption.

Pump Test, Center Pivot (Method 2)

An easier method is to simply not operate the pivot while taking the fuel measurement. The percentage timer on electric-drive pivots should be set at "0". The flow control valve on hydraulic systems should be closed. Since the pivot motors will not be operating, they will not draw any power and the alternator or pump will essentially run idle. There will be some power loss due to belt drive friction losses and/or bearing losses within the alternator or hydraulic pump*, but are not significant during the fuel measurement.

Generally, allowing the pivot to be at a standstill for up to a half hour should not cause any problems. Some runoff can be expected, however. A quarter section pivot applying 1000 gpm will typically apply less than 1 1/2" of water when operating at a standstill for a half an hour while a test for fuel consumption is being made.

*Even though the pivot may be set not to move, the hydraulic pump typically requires one brake horsepower to operate at no load. Therefore if the hydraulic pump is being driven, the estimated fuel consumption for <u>no load</u> conditions should be subtracted from the total fuel consumption.

Pump Test, Center-Pivot (Method 3)

Some operators may strongly object to allowing the pivot to be at a standstill. If the pivot must be running during the test, fuel consumption for driving the pivot can be estimated and subtracted from the overall fuel consumption of the pumping plant.

For electric driven center-pivots:

Estimated Fuel Used to Drive Pivot

7 or 10 Tower Center-Pivot (1300')

	Timer Setting			
Power Unit	25%	50%	75%	100%
Diesel[1]	0.10	0.20	0.30	0.40
Propane[1]	0.18	0.36	0.54	0.72
Natural Gas[2]	0.020	0.040	0.060	0.080

[1] gallons/hour

[2] mcf/hour

Example: 10 tower system, diesel power; timer setting = 50%
measured fuel consumption = 5 gal/hr
Corrected fuel consumption = 5.0 - .2 = 4.8 gal/hr

For a shorter length pivot, multiply the table value by the pivot length and divide by 1300.

Example: 4 tower system (800'); diesel power; timer setting = 50%
measured fuel consumption = 5 gal/hr
Corrected fuel consumption = 5.0 - (.2 x 800/1300)
= 4.88 gal/hr.

For oil hydraulic motor driven center-pivot:

Estimated Fuel Used to Drive Pivot

24 Hour Rotation Setting

Power Unit	No Load	10 Tower	7 Tower
Diesel	0.06 gal/hr	0.66 gal/hr	0.36 gal/hr
Propane	0.11 gal/hr	1.20 gal/hr	0.65 gal/hr
Natural Gas	0.11 mcf/hr	0.134 mcf/hr	0.073 mcf/hr
Electric	0.9 kW	9.6 kW	5.3 kW

For rotation times other than 24 hours, multiply the table value by 24 and divide by the rotation time.

Estimated electric consumption is listed for comparison purposes only. The electric hydraulic pump should be stopped when measuring the kW of the pumping plant. The pivot would only be stopped for a maximum of 5 minutes.

End Gun Booster Pumps

Several of the new low pressure center-pivots use an electric powered booster pump at the end of the pivot to increase end gun pressure. Since the booster pump will operate most of the time, the pumping plant should be tested with the booster pump on. However, this presents a problem to obtain the fuel consumption of the pumping plant alone, since the booster pump also will contribute to the fuel consumption.

To isolate the end gun booster pump component from the total fuel consumption, the power requirement of the booster pump is needed. To accomplish this, the kW usage of the pump can be determined by measuring the voltage a current supplied to the end gun booster pump.

Measure the voltage and current following the procedure in the section "Voltage and Current". The pivot percentage timer should be set to 0% during the measurement.

Determine the estimated fuel consumption to run the end gun booster by:

$$\frac{V \times A}{C} = \text{fuel to drive booster pump}$$

where:

V = average volts
A = average amps
C = conversion constant*

Diesel	7,660
Propane	4,230
Natural Gas	37,790

* Calculates kW with 75% power factor; converts to hp; assumes 80% generation efficiency; and includes criteria for engine output with 95% drive efficiency.

Subtract the estimated end gun booster pump fuel consumption from the total consumption to calculate the pumping plant performance rating.

For electric pumping plants, calculate the kW consumption with a 75% power factor and subtract from the watt-hour kW.

$$kW = 1.73 \times V \times A \times .75/1000$$

PUMP AND POWER UNIT SPEED

Equipment:

Hand held tachometer

Description:

Although the pump and power unit speed is not necessary for calculation of the pumping plant performance, it is an invaluable aid for analysis of the pump and power unit. Two types of tachometers are commonly used. One requires physical contact with the rotating part. The other, known as a photo tachometer, uses reflected light and need not touch the rotating part. Both count the number of revolutions over a small time interval and read in revolutions per minute (rpm). Digital tachometer types (Figure 1) are the most accurate (± 1 rpm) and are recommended for use.

Use of Equipment:

Caution: Extreme care must be taken when using tachometers due to rotating parts. Loose clothing such as shirt tails, cuffs, and ties can easily be entangled with drastic, even fatal, results. Fingers, arms, and hair must be kept as far away as possible.

Points to remember:

- For vertical electric motor installations, the pump rpm is the same as the power unit rpm.

- For belt-driven or right angle gearbox installations, both pump and power unit rpm should be measured.

- Power unit rpm should be measured immediately after the pump rpm.

  Knowing the gearhead or pully ratios and one of the speeds would allow calculation of the other speed. However, there have been cases where the gears were changed in the right angle gearhead to a different ratio and the name plate reflected only the original ratio. On belt driven equipment, there is some slippage and the pulley ratio will not always reflect the true rpm.

- The pump rpm can be taken from the headshaft or a rotating part of it.

- Engine rpm can be taken from the driveshaft, flywheel, or crankshaft pulley.

Using the Contact Tachometer*

1) Choose the appropriate tip for the tachometer.

   - Use the conical tip for center drilled end shafts (Figure 2).

   - Use the flat tip for shafts which have no center (Figure 3).

2) Place the appropriate tip on the tachometer and apply the tachometer keeping it centered and parallel to the axis of the rotating shaft.

3) Take the reading and record.

4) If the engine crankshaft end is not accessible due to a cooling fan or radiator, the above method will not work to obtain the rpm of an engine.

   Alternative Method for Engine rpm:

   Some tachometers will have a wheel attachment. This wheel is attached to the tachometer and is applied to the circumference of a smooth shaft such as the driveshaft (Figure 5). The circumference of the wheel is usually one foot.

   To calculate the rpm:

   a) Determine the diameter (inches) of the shaft to be measured for rpm.

   b) Determine the circumference of the shaft in feet

$$\frac{3.14 \times \text{diameter (inches)}}{12} = \text{circumference (feet)}$$

   c) Apply tachometer wheel to rotating shaft

   d) Obtain reading from tachometer

   e) Divide the tachometer reading by the circumference of shaft and multiply by the wheel circumference.

$$\frac{\text{tachometer reading} \times \text{circumference of wheel}}{\text{circumference of shaft}} = \text{rpm shaft}$$

Using the Photo Tachometer*

1) This tachometer can be used for almost all situations provided a piece of reflective tape can be attached to the rotating part (Figure 4).

2) Attach a small piece of reflective tape to the rotating parts to be measured. A fast drying solvent may be needed to clean the surface first so the tape will stick. White chalk is an alternative to reflective tape when necessary. However, it is usually not as effective.

3) When the pumping plant is operating, aim the photo tachometer at the rotating marked surface. The tachometer should be perpendicular to the surface.

4) Vary the distance between the tachometer and the rotating surface until a stable reading is obtained and record the reading.

*Consult with the tachometer manufacturer's owner's manual for additional instructions.

Figure 1.

Digital tachometers.
Contact type on left.
Photo type on right.

Figure 2.

Contact tachometer,
using conical tip for
a shaft with a center.

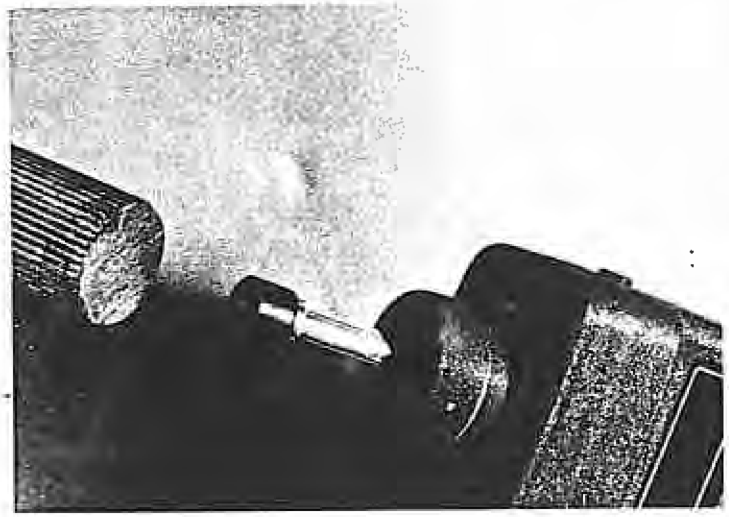


Figure 3.

Contact tachometer with a
flat tip for a shaft without
a center.

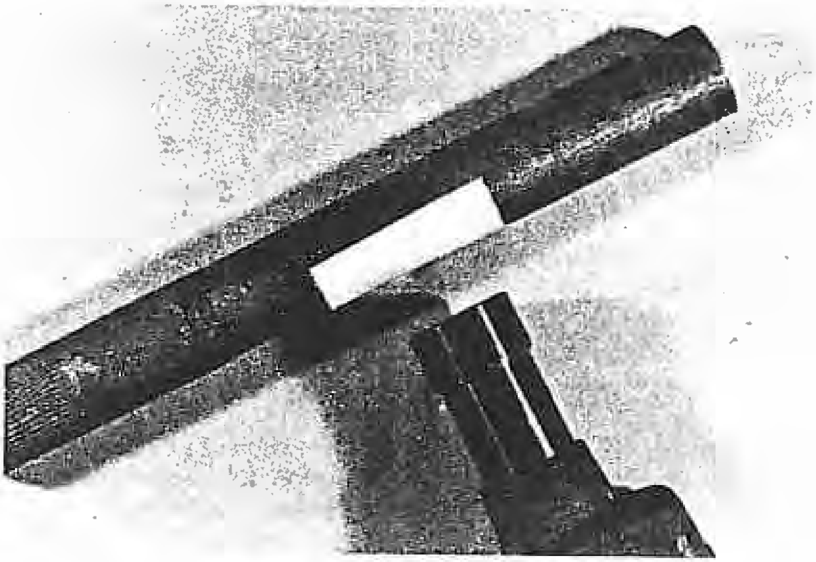


Figure 4.

Photo tachometer (non-contact) aimed at shaft marked with reflective tape.

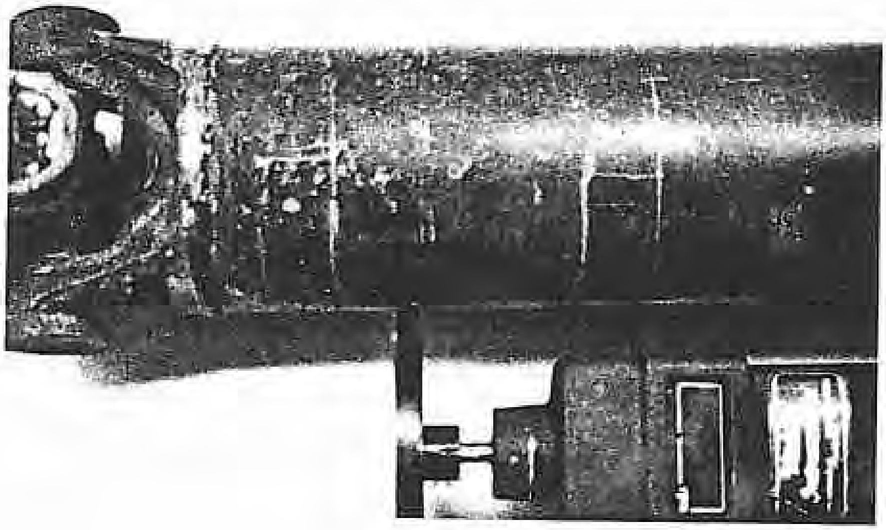


Figure 5.

Contact tachometer with circumference wheel applied to drive shaft.

VOLTAGE AND CURRENT

Equipment:

Volt-Amp Meter (Figure 1)
Linesmen Gloves
Eye Protection (goggles or glasses)

Description:

In most cases, voltage and current (amperage) measurements of electrical equipment is not necessary to determine the performance of a pumping plant. However, these items are important to analyze possible problems of the electrical equipment.

Voltage and current measurements are often used to:

1) verify the operation and accuracy of the watt-hour meter
2) detect voltage inbalance which creates excessive heating in motors
3) determine the loading of the motor
4) check proper conductor size
5) determine power loss in conductors (to correct watt-hour readings)
6) determine individual kW usage for equipment operating on a single watt-hour meter (i.e. well pump motor and booster pump motor)
7) correct fuel consumption measurements of engines driving an alternator to operate a pivot or end gun booster pump.

Two articles in the Pump Handbook, namely "Three Phase Electric Motors" and "Power Loss in Underground Electrical Feeders", address several of the above problems.

Electrical Measurements:

CAUTION: Extreme care must be exercised when taking electrical measurements. High voltage and wet conditions, typical around pumping plants, create a potential for fatal electrocution. Also, any arcing caused by an energized conductor coming into contact with a ground will cause a blinding, white hot flash which can cause serious burns to the entire body.

Caution: Remove rings, neck chains, and watches before working near exposed electrical equipment. These items are excellent conductors and can prevent escape in the event of a short between them and the current.

Caution: Wear approved electric linesmen gloves with leather protectors to reduce a shock potential. Wear a hard hat to protect the head from accidental contact. Wear eye protection.

Caution: Do Not operate the disconnect switch with the control panel door open. Most doors can be opened by activating special releases of the safety interlock without opening the circuit.

Caution: Do Not forceably move wires in the control panel. A wire or connecting lug may break. Contact with you or any ground could cause arcing.

Caution: Keep control panel doors closed when not taking measurements.

Caution: Make sure capacitors are discharged. Improperly wired capacitors can hold a large charge of current even though the equipment disconnect is off.

Point of Measurement:

Consideration must be given to the particular electric equipment for which voltage and current is desired. The current and voltage will the different when taken from the main feeder conductors as opposed to the pump motor conductors if other loads such as a pivot are also on the line. Figure 2 illustrates the proper positions to measure voltage and current for different conditions.

Many electrical systems have capacitors installed to increase the power factor. Voltage and amperage must be measured at some point between the capacitor and the load. Amperage will be lower at any point before current reaches the capacitor because of a lower power factor.

Voltage:

Important: Read and follow the owner's manual for your volt-amp meter.

Three Phase Power (Figure 3).

1) Set meter for voltage measurement and range
2) Measure voltage between legs 1 and 2
3) Measure voltage between legs 1 and 3
4) Measure voltage between legs 2 and 3
5) Average the above 3 readings to determine the average voltage.

Single Phase (115 v). (Figure 4).

1) Set meter for voltage measurement and range
2) Measure voltage between "hot" black conductor and "neutral" white conductor.

Single Phase (230 v.) (Figure 5).

1) Set meter for voltage measurement and range.
2) Measure voltages between the two "hot" black conductors.

Note: Some installations may have one red and one black conductor. Measure voltage between these two for those cases.

Current (Amperage)

Three Phase (Figure 3).

1) Remove meter voltage test leads and set for current measurement.
2) Place meter clamp around leg 1 and record amps.
3) Place meter clamp around leg 2 and record amps.
4) Place meter clamp around leg 3 and record amps.
5) Average the above 3 readings to determine the average current.

Single Phase (115 v.) (Figure 4).

1) Remove meter voltage test leads and set for current measurement.
2) Place meter clamp around "hot" black conductor <u>or</u> "netural" white conductor.
3) Current is as indicated.

Single Phase (230 v) (Figure 5).

1) Remove meter voltage test leads and set for current measurement.
2) Place meter clamp around either "hot" conductor.
3) Current is as indicated.

kW Calculation*

Three Phase (3 ϕ)

$kW = 1.73 \times V \times A \times P.F./1000$

Single Phase (1 ϕ)

$kW = V \times A \times P.F./1000$

where:
kW = kilowatts (kWh/hr)
V = average voltage
A = average amperage
P.F. = power factor** (0.85)

* Due to measuring equipment error and power factor (P.F.) estimation, the calculated kW could vary 10% from actual.

** Power factor is the ratio of current used to produce power, and the total current consisting of the power current and the motor magnetizing currents. Motor magnetizing current is not consumed and not recorded by the watt-hour meter. Measurement requires specialized equipment and accuracy is seldon better than ± 5%. Power factor can best be obtained by tables such as in the Pump Handbook page 77 and 78. An average P.F. value of .85 can be used as a rule of thumb.

Other useful electricl formulas:

Measured kW x 1.341 = horsepower (input) or drawn horsepower.

Horsepower (input) x motor efficiency = horsepower (output)

Horsepower 1 ϕ (output) = V x A x P.F. x eff / 746

Horsepower 3 ϕ (output) = V x A x P.F. x eff / 430

Note: Electric motors are rated by output horsepower as listed on the nameplate.
Full load amps is the rated amps at the specified voltage and nameplate horsepower.

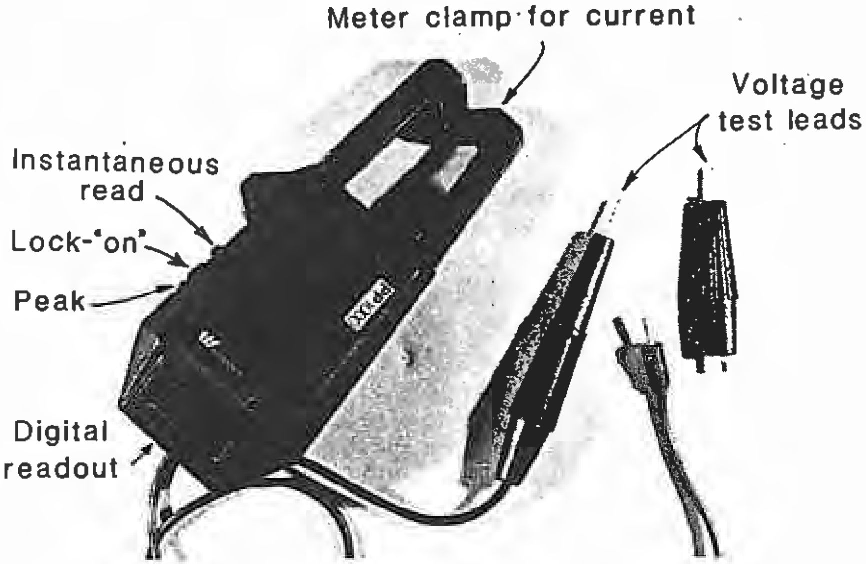
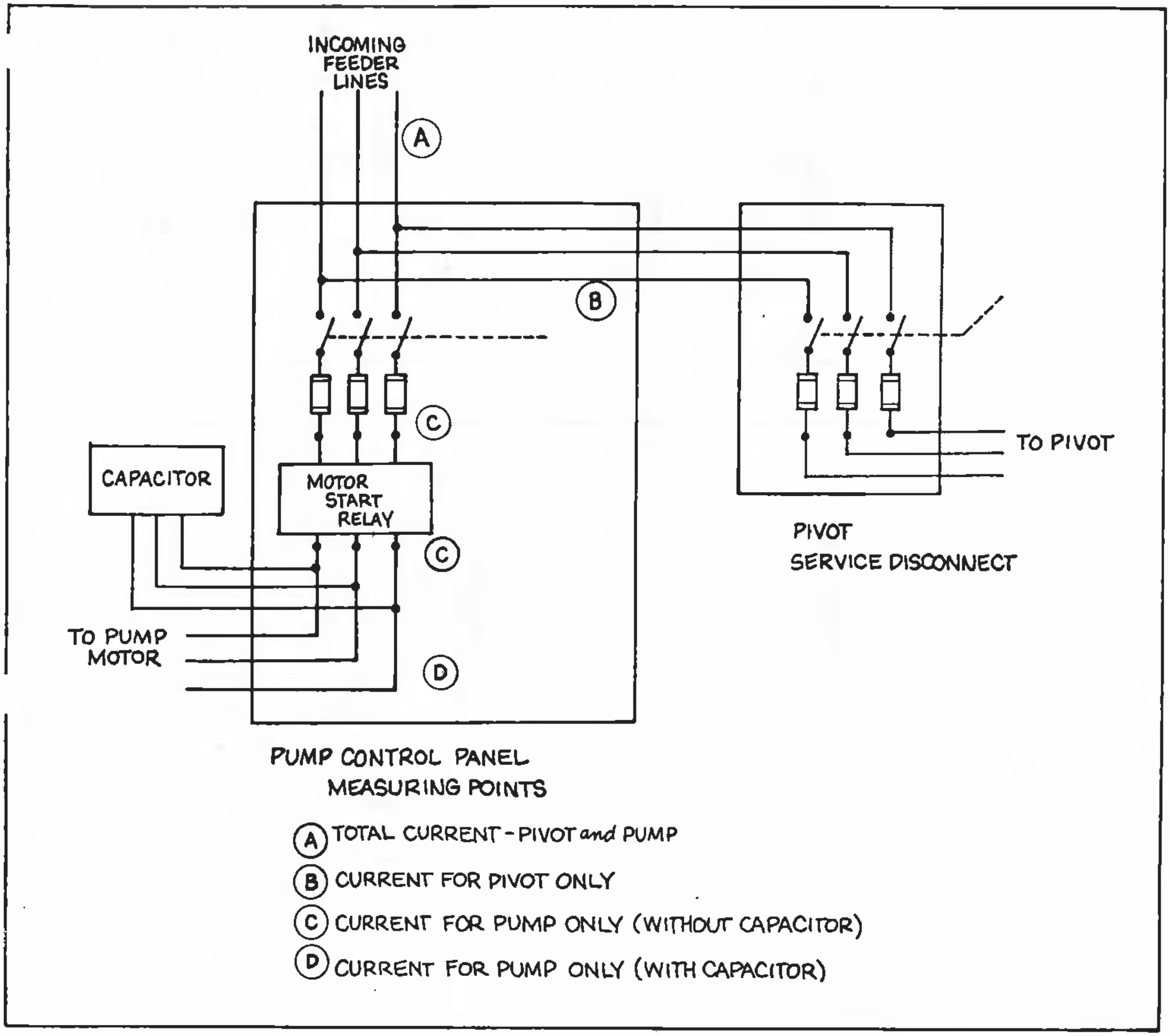


Figure 1. Digital volt-ohm-amp test meter.



MEASURING POINTS

Ⓐ TOTAL CURRENT - PIVOT and PUMP

Ⓑ CURRENT FOR PIVOT ONLY

Ⓒ CURRENT FOR PUMP ONLY (WITHOUT CAPACITOR)

Ⓓ CURRENT FOR PUMP ONLY (WITH CAPACITOR)

FIGURE 2

FIGURE 3

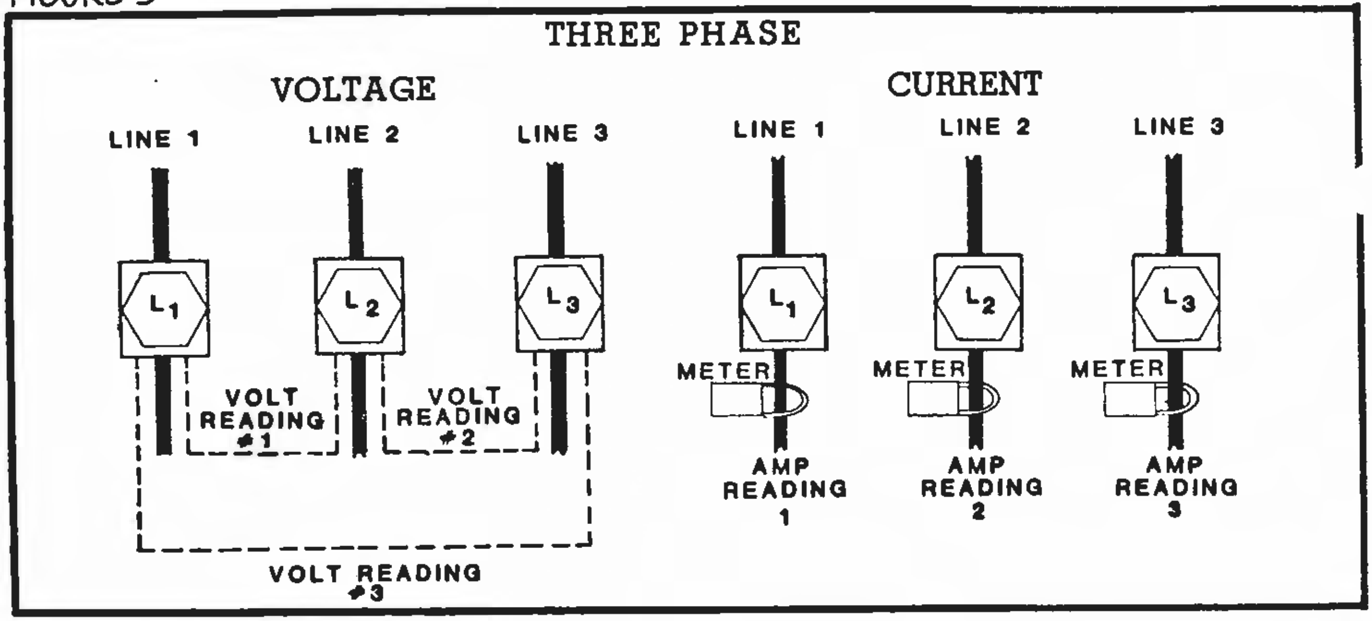
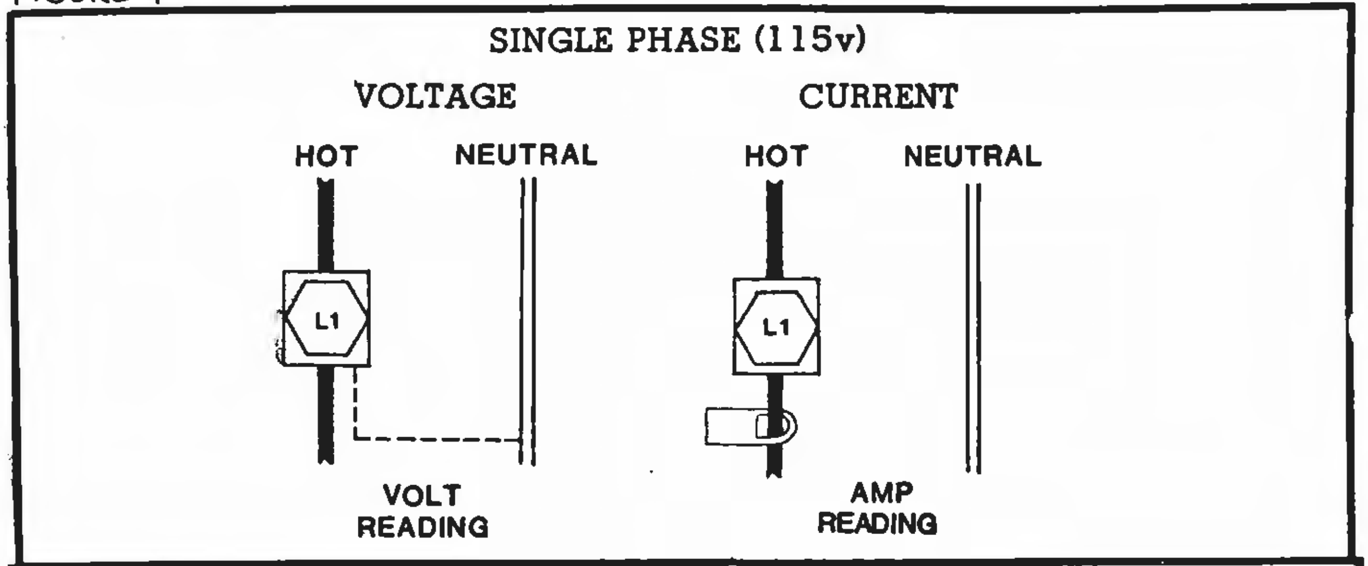


FIGURE 4



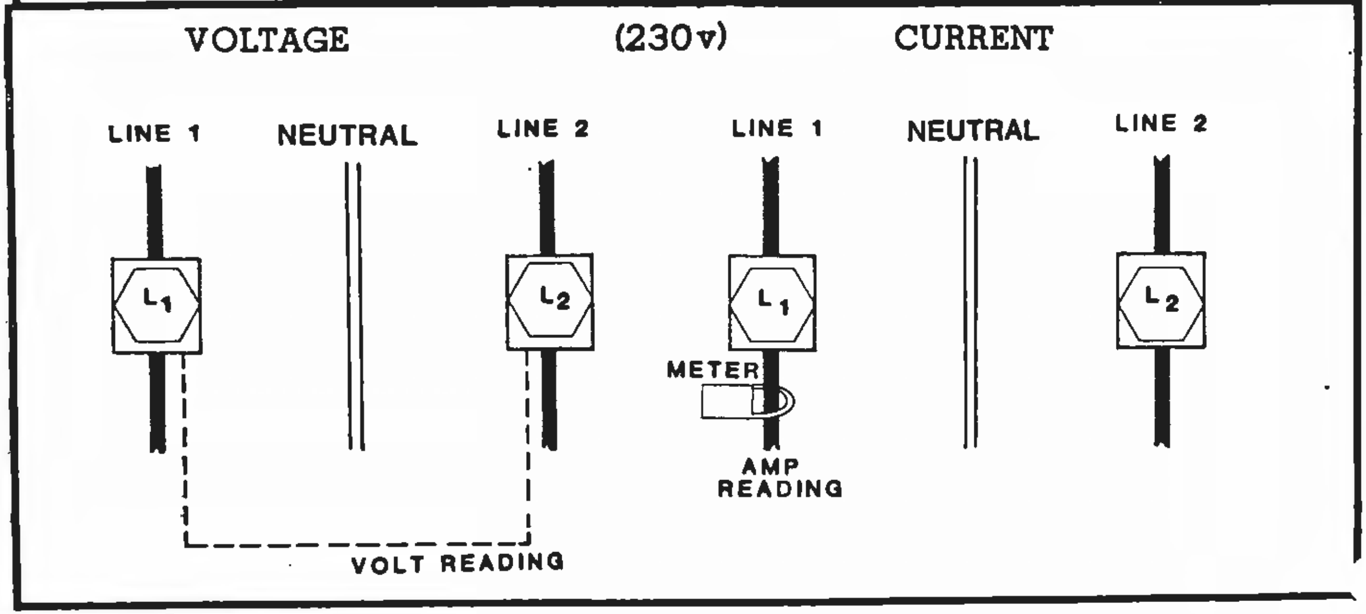


FIGURE 5

FIELD DATA

Name ____________ County ____________ Test No. ______
Pump Co. ____________ Stages ______ Pump No. ______ Run No. ______
Pump Setting ______ Pump Column x Shaft Dia. ______ Airline Length ______
Pump RPM ______ Driver RPM ______ Cascading Water ______ Bhp ______
Test Conditions ____________ Static Water Level ______

Pumping Head

Pressure ____ psi x 2.31= ____ ft. Discharge Head + Gauge Elevation ____
+ ____ ft. Pumping Water Level
+ ____ ft. Column Head Loss = ____ Total Pumping Head

Flow Test

☐ Propeller Flow Meter Time: ____ min. ____ sec. = ____ seconds

Gallons stop ______ - Gallons start ______
= ____ Total Gallons ÷ ____ seconds x 60 = ____ gpm

☐ Collins Flow Gage	2-point setting	Pipe I.D. ____ "		10-point setting		
	0.353D ____	0.475D ____	0.055D ____	0.121D ____	0.200D ____	0.317D ____
left (+)	____	____	____	____	____	____
left (-)	____	____	____	____	____	____
right (+)	____	____	____	____	____	____
right (-)	____	____	____	____	____	____
Average Velocity	____ ft/sec	____ ft/sec	x ____ gpm factor ($2.55D^2 - D$)			
= Flow Rate	____ gpm	____ gpm				

Energy Use Test

Time: ____ min. ____ sec.= ____ seconds

☐ **Diesel** Weight start ____ lbs - Weight Stop ____ lbs
= ____ Net weight used ÷ ____ lbs/gal = ____ gallons ÷

☐ **Propane** ____ seconds x 3600 = ____ gal/hr

☐ **Electric**
3.6 x ____ Disc Revolutions x ____ Kh ÷ ____ seconds = ____ kW
Volts ____ ____ ____ Av. ____ Amps ____ ____ ____ Av. ____

☐ **Natural Gas**
3.6 x ____ Dial Capacity x ____ Dial Revolutions ÷
____ seconds = ____ x Correction Factor ____ = ____ mcf/hr
Gas Pressure ____ psi Elevation ____

Performance Rating

____ Head x ____ GPM ÷ 3960 = ____ Whp ÷
____ Fuel Use = ____ Performance ÷ ____ Criteria = ____ % Rating

Pump Adjustment

(As is: ______ turns)

____ Head x ____ Thrust (k) x ____ Shaft Length ÷
____ shaft diameter^2 ÷ 1,900,000
= ____ shaft stretch x ____ Threads/inch = ____ turns
= ____ turns ____ flats

FIELD DATA (Electric Test Example)

Name John Irrigator County Middle Test No. 17a
Pump Co. High Head, Inc. Stages 7 Pump No. 12M Run No. 1
Pump Setting 220' Pump Column x Shaft Dia. ____ Airline Length ____
Pump RPM 1766 Driver RPM 1760 Cascading Water none Bhp —
Test Conditions Pivot @ 0% Static Water Level 155'

Pumping Head

Pressure 85 psi x 2.31= 196 ft. Discharge Head + Gauge Elevation 0
\+ 206 ft. Pumping Water Level
\+ 4 ft. Column Head Loss = 406 Total Pumping Head

Flow Test

☐ Propeller Flow Meter Time: ____ min. ____ sec. = ____ seconds

Gallons stop ____ - Gallons start ____
= ____ Total Gallons ÷ ____ seconds x 60 = ____ gpm

☑ Collins Flow Gage	2-point setting	Pipe I.D. 7 13/16		10-point setting		
	0.353D 2 3/4	0.475D	0.055D	0.121D	0.200D	0.317D
left (+)	4.8					
left (-)	5.0					
right (+)	5.1					
right (-)	4.7					
Average Velocity	4.9 ft/sec	ft/sec	x 147.8 gpm factor $(2.55D^2 - D)$			
= Flow Rate	724 gpm	gpm				

Energy Use Test Time: ____ min. 59.0 sec. = 59.0 seconds

☐ **Diesel** Weight start ____ lbs - Weight Stop ____ lbs
= ____ Net weight used ÷ ____ lbs/gal = ____ gallons ÷

☐ **Propane** ____ seconds x 3600 = ____ gal/hr

☑ **Electric**
3.6 x 30 Disc Revolutions x 57.6 Kh ÷ 59.0 seconds = 105.4 kW
Volts 490 493 497 Av. 493 Amps 147 145 143 Av. 145

☐ **Natural Gas**
3.6 x ____ Dial Capacity x ____ Dial Revolutions ÷
____ seconds = ____ x Correction Factor ____ = ____ mcf/hr
Gas Pressure ____ psi Elevation ____

Performance Rating

406 Head x 724 GPM ÷ 3960 = 74.2 Whp ÷
105.4 Fuel Use = .704 Performance ÷ .885 Criteria = 80 % Rating

Pump Adjustment (As is: ____ turns)

____ Head x ____ Thrust (k) x ____ Shaft Length ÷
$\_\_\_\_^2$ shaft diameter ÷ 1,900,000
= ____ shaft stretch x ____ Threads/inch = ____ turns
= ____ turns ____ flats

PUMP

IRRIGATION PUMPING PLANT ANALYSIS AND RECOMMENDATIONS

Name ____________ County ____________ Test No. ____________

Well location ____________ Town ____________ Fuel Type ____________

Static Water Level ____________ Date ____________

Pumping Plant Condition	Before Adjustments		After Adjustments	
Pumping water level		Feet		Feet
Operating pressure		psi		psi
Operating flow rate		gpm		gpm
Power requirement		Whp		Whp
Pump RPM		Rev/min		Rev/min
Engine RPM		Rev/min		Rev/min
Performance Rating (NPPPC)*		%		%
Energy Analysis				
Water application capacity		Ac-in/hr		Ac-in/hr
Fuel consumption/hr				
Fuel Unit Cost		$		$
Cost to pump 1 ac-in		$/Ac-in		$/Ac-in
Cost to pump 1 ac-ft		$/Ac-ft		$/Ac-ft

Summary of Fuel Cost for Pumping Plant

	% of NPPPC*	Acres	x	$/ac-in	x	in/yr	=	Annual Cost	Annual Savings
Before adj.			x		x		=		
After adj.			x		x		=		
At criteria	100		x		x		=		

Adjustments, remarks and recommendations

Cooperative Extension Service
Agricultural Engineering Dept.
University of Nebraska-Lincoln

* Nebraska Pumping Plant Performance Criteria

☆ U.S. Government Printing Office 1984 - 776-319/1 Reg. 8

AGRICULTURAL ENGINEERING

Cooperative Extension Service

Institute of Agriculture and Natural Resources
University of Nebraska–Lincoln

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