COLORADO STATE UNIVERSITY

ALLUVIAL RIVER MECHANICS PROJECT

ACOP PUMPING SAMPLER

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The use of specific commercial equipment referred to in this report does not imply endorsement of a particular manufacturer over any other.

INDEX

INDEX (CONT'D)

Page

LIST OF APPENDICES

INTRODUCTION

The Alluvial Channels Observation Project (ACOP) Pumping Sampler is designed for gathering point-integrated suspended sediment samples from sandbed channels, and is specially adapted for use in the Link Canals of West Pakistan. The Sampler is designed to be a robust device that requires a minimum of field maintenance over long operational periods. It is also designed to obtain large volume samples by directly filtering out the sediment from the pumped supply or to obtain periodic one pint samples. These two modes are respectively called herein the Cartridge Sample Mode and the Pint Sample Mode. Each of these modes is suited to some particular investigation and may be used separately or together for reinforcing or augmenting collected sediment data.

As stated above, the Pumping Sampler is a point integrating device. It draws a sediment/water sample through a nozzle directed into the flow which is connected to a positive displacement pump. The pump is powered by two 12 V batteries connected in series. The velocity of water through the nozzle is manually controlled by using different size nozzles and varying the discharge of the pump. This type of operation avoids the use of an automatic velocity and feedback electronic controls in the sampler. A necessary operation in using the Pumping Sampler therefore, is the prior determination of velocity at each point of sampling. The configuration of the pumping sampler appears in Figure 1 and 2.

PRINCIPLE OF OPERATION

The principle for obtaining the local velocities is based on the assumption that in steady and quasi-steady alluvial channel flow an equilibrium velocity distribution pattern exists. Thus the instantaneous velocity at a point may vary in time due to high frequency

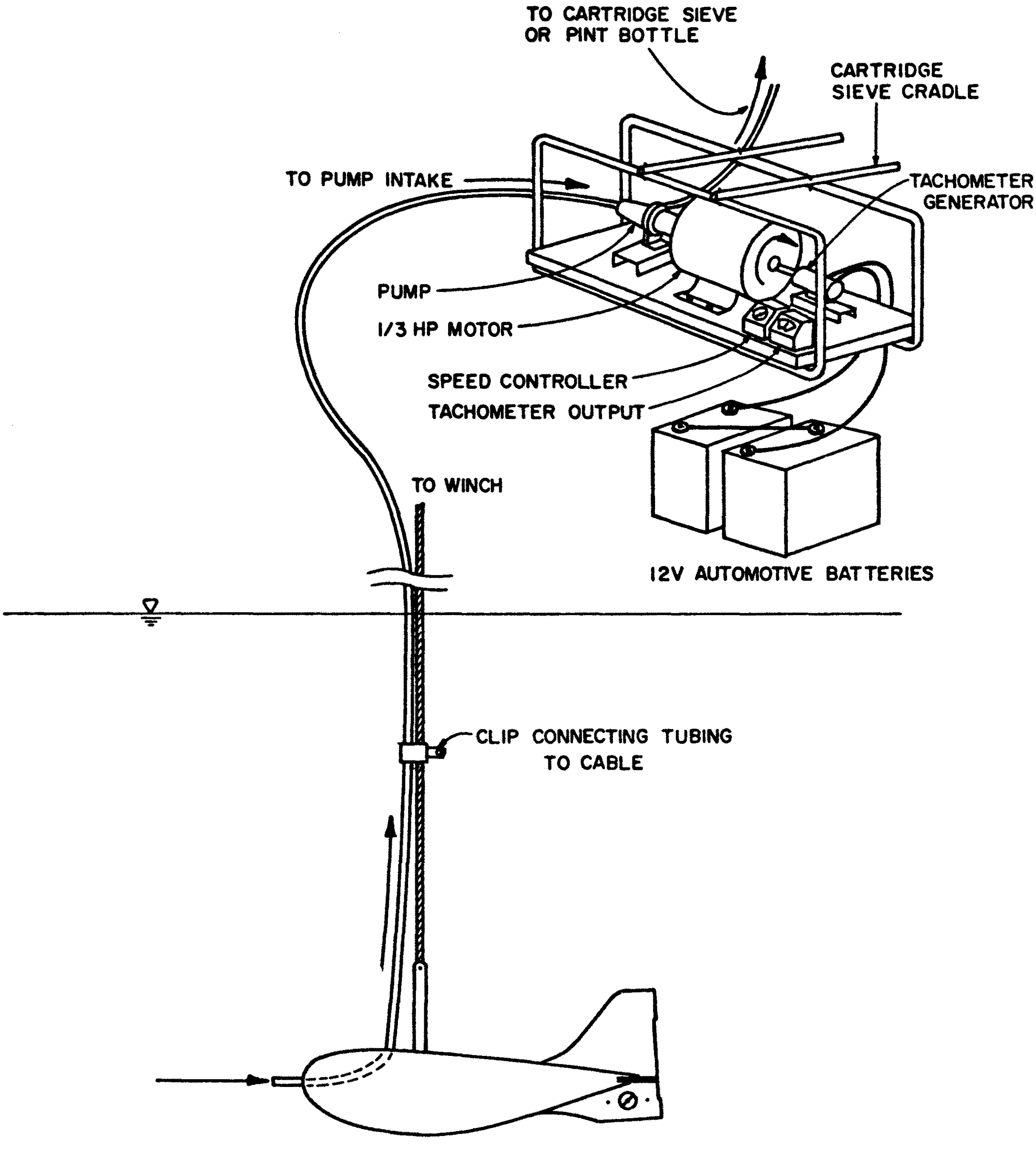


Figure 1. Layout of ACOP Pumping Sampler

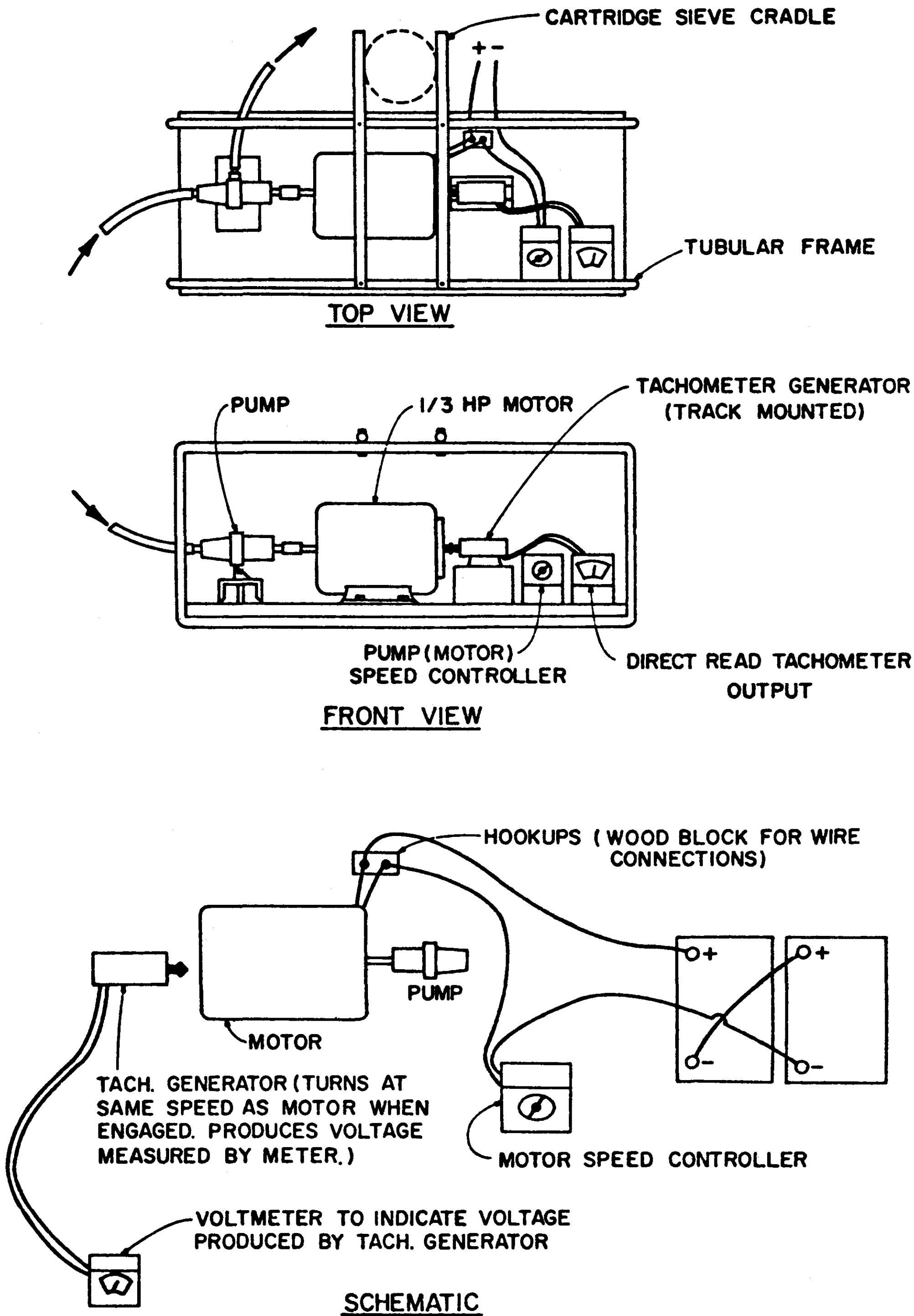


Figure 2. Pump and Motor Assembly for ACOP Pumping Sampler

turbulence or low frequency pulsations but it is assumed the departures from the average are generally not large. It is therefore sufficient to determine the local average velocity and use it as the design intake velocity at the sampler. However, owing to the velocity gradients in the flow, failure to relocate a particular point in the flow field can introduce large errors in the determination of the local velocity. For this reason, it is preferable to determine the velocity distribution in the region of sampling rather than the velocity at a single point. In most cases, the information on velocity distribution will be obtained in the allied observations at the channel section. If the sediment sampling is to be done on a vertical, then a minimum of two traverses of velocity should be made to obtain the average velocity profile on that vertical. One of these may be going up from the bed and the other toward the bed. Note that if the two profiles do not coincide, more detailed velocity distribution investigations should be made to determine the average velocity distribution in the sampling region. Also for the same reason, this sampler can only be used in flows that are at least quasi-steady and are not rapidly changing.

The Pumping Sampler operates on the premise that if an element of the sediment/water mixture flowing past a point can be diverted through a nozzle such that the element is withdrawn at the same velocity as the flow, then the mixture so obtained will contain sediment particles with the same concentration and gradation as they instantaneously occur at that point. If the withdrawal velocity exceeds the stream velocity, the sample obtained will have a low concentration relative to true concentration in the stream. This is owing to the fact that the sediment particles, having greater density and inertia than the water will respond more slowly to changes in velocity vector due to curvature of streamlines induced by an excessive relative pumping rate. Likewise, if a sample is drawn at a rate lower than the stream velocity, the sediment concentration in the sample will be higher than the true concentration of the stream. Research by Federal Interagency Sedimentation Project[1] has shown that for sand size sediments, maintaining the relative velocity within ±5% of stream velocity will result in only negligible error. This principle, along with effects of high, or low relative sampling rates is illustrated in Figures 3, 4, and 5 for sediments up to 0.8 mm.

In using a pump in the sampling system, it is also assumed that the sediment concentration in the sampled fluid does not change during its travel up to, through, and beyond the pump. For this purpose, it is necessary that the flow velocity in the tubes and pump be at least 8 times the fall velocity of the maximum particle size. This objective is achieved by pumping at rates greater than the stipulated minimum and by sealing off large voids inside the pump. In operation the pump stator is fitted with a rubber membrane which prevents sediment and water from traveling around the stator. With the membrane in place no sediment has been found in the pump. The sample design described herein is suitable for the largest particle size of 1 mm.

METHOD OF OPERATION

In order to apply the sampler, it is necessary to know the stream velocity at any point where a suspended sediment sample is desired. Knowing the range of velocities existing in a vertical, the operator may consult the rating curves for the sampler and stator in use (Figure 7). For each individual stator the characteristics of its

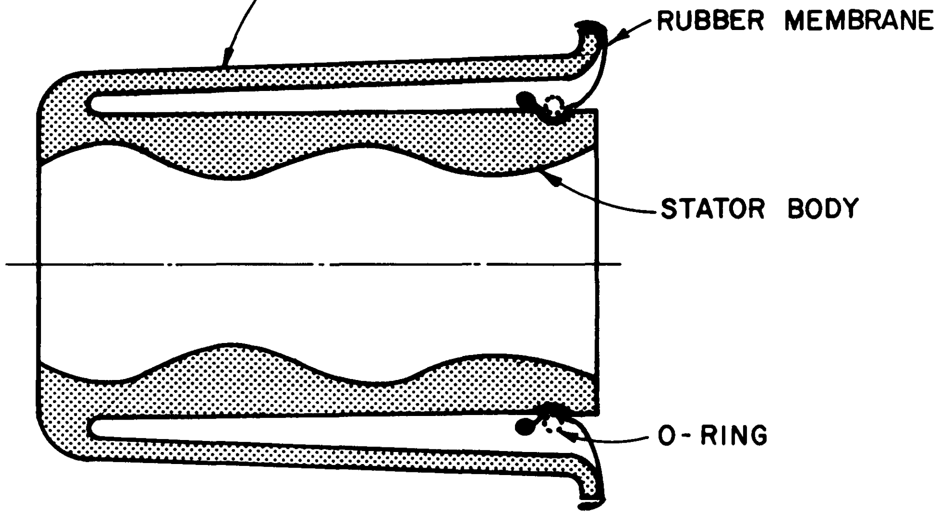
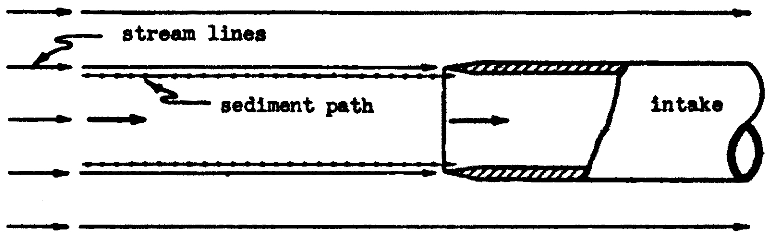
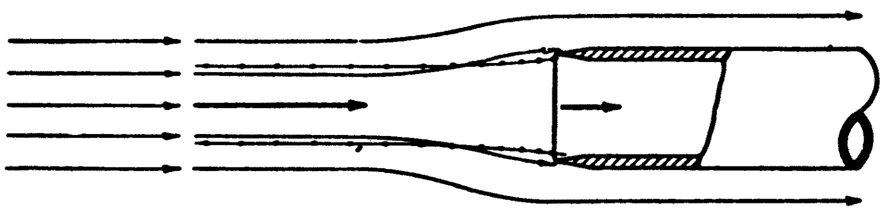


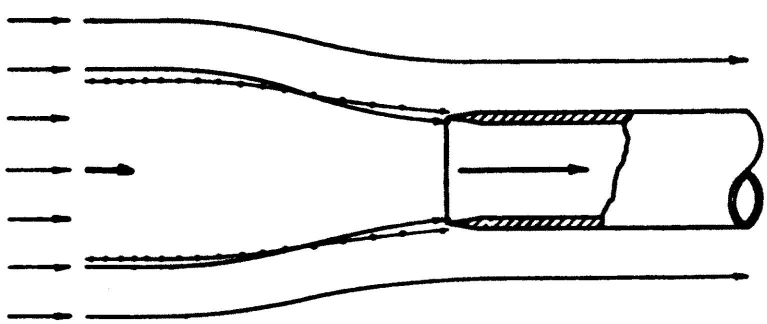
Figure 3. Section View of Stator with Membrane in Place



a. Normal sampling rate -- intake velocity equal to stream velocity.



b. Sampling rate below normal -- as illustrated, ratio of intake velocity to stream velocity approximately 1/3.



c. Sampling rate above normal -- as illustrated, ratio of intake velocity to stream velocity approximately 3 .

Figure 4. Flow and Sediment Inflow Patterns for Sampling Rate at and Different from the Local Stream Velocity (after reference 1)

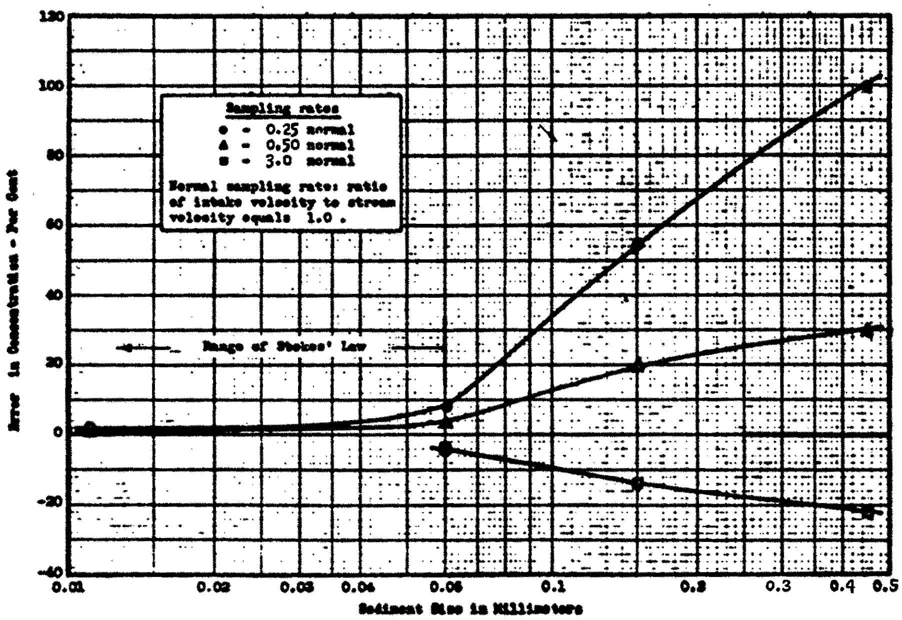


Figure 5. Relation of Sediment Size to Errors in Sediment Concentration (after reference 1)

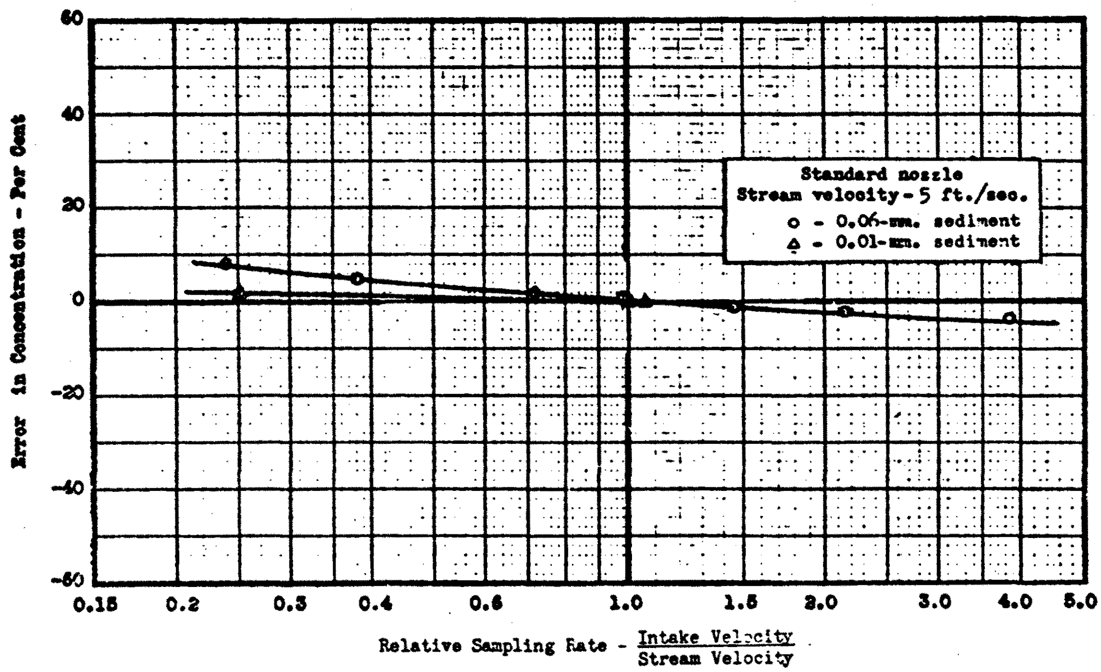


Figure 6a. Effect of Sampling Rate on Sediment Concentration in Withdrawn Samples - 0.06 mm and 0.01 mm sediment (after reference 1)

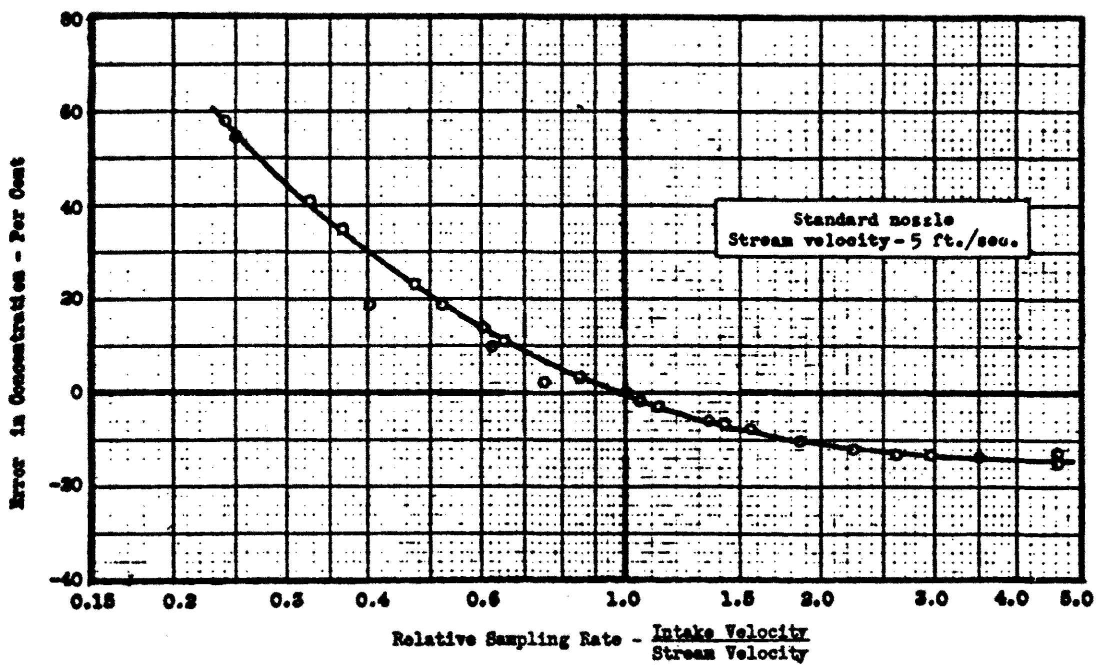


Figure 6b. Effect of Sampling Rate on Sediment Concentration in Withdrawn Samples- 0.15 mm sediment (after reference 1)

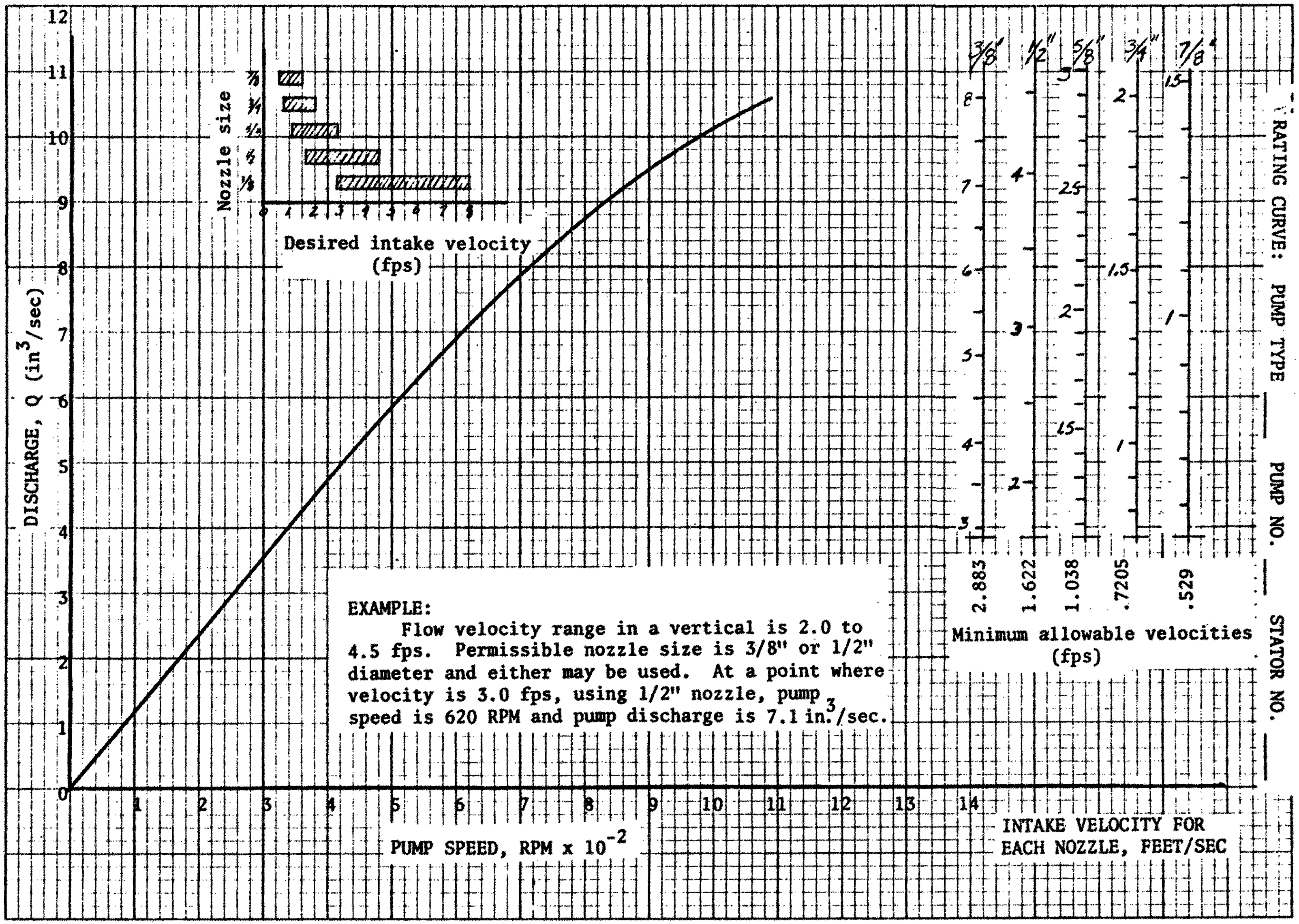


Figure 7. Typical Rating Curve for Pumps and Minimum Withdrawal Velocities for Nozzle

discharge as related to pump speed have been determined by calibration tests in the lab. From the discharge rating curve, it has been computed for each stator that for a given nozzle and pump speed, a certain, unique velocity of the water sediment mixture will exist at the mouth of the nozzle. It is a characteristic of the pump used in this sampler that the discharge rate at a given RPM is rather insensitive to the total head guaranteed by the pump, ΔH, or the water pressure at the discharge end. The rating supplied with the pump-stator units are at ΔH = 5.0 ft and the net variation at ΔH = 3.0 and 7.0 ft is specified. The operator can monitor the pump speed as often as necessary by pressing the tachometer generator up against the motor spindle and observing the RPM on the meter located next to the speed controller. The rating curves will give the ranges of intake velocities obtainable for each nozzle. Upon choosing a nozzle compatible with all points or at least the first points to be sampled in the vertical, the operator then mounts the nozzle by screwing it into the nose of the sampler weight. The tube leading out the top of the weight is connected to the pump intake and the weight/nozzle assembly lowered into position to obtain the first sample.

NOTE: In the use of a nozzle size and pump speed that will produce the necessary velocity at the mouth of the nozzle to match the stream velocity at that point, the skill and attention of the operator are the prime factors in obtaining accurate samples.

Once the sampler weight is positioned at the sampling point the pump is started at its full speed. Immediately thereafter, the speed may be regulated down to the necessary speed for sampling. The Sampler should be allowed to run at this speed for about 20 seconds to achieve equilibrium of flow within the sampler. The operator may then proceed in one of the two operating modes: I. Cartridge Sampling Mode, or II. Pint Bottle Mode.

I. Cartridge Sampling Mode: One of the strong points of the ACOP Pumping Sampler is its ability to draw a large sample of sediment water mixture, remove the sand size particles, and then discard the water back into the canal in a single operation. This is accomplished by directing the flow from the pump discharge outlet into the cartridge sieves. The cartridge sieves retain all particles larger than their mesh size. The cartridges are provided in 2 different mesh sizes: 230 mesh (62μ) and 200 mesh (75μ). All water and smaller particles are then directed through a tube back into the canal. The amount of sediment/water mixture directed through the cartridge sieve is known by observing the length of time that water was pumped into the cartridge, noting the discharge produced by the pump for the speed used from its rating curve and applying the relation: $V = \frac{Qt}{1728}$ where V = the volume of water pumped through the cartridge in time t, ft^3, t = time of pumping in seconds, and Q = discharge of pump for the speed used in gathering the sample, $\frac{in^3}{sec}$. It should be noted that the pump of this sampler is a positive-displacement pump. Therefore, its discharge is a function of its speed only, and is not significantly altered by head losses, velocity of water past the nozzle, or like factors. Rather, the pump speed will vary and its discharge can still be determined by monitoring its speed. The motor used with the pump consumes a current of 11 amperes at a voltage of 24 volts at the maximum discharge. Thus, fully charged auto batteries can be continuously used a full day without affecting the pump speed. In normal applications, an observation of pump speed near the beginning and end of each sample collected is sufficient.

Having collected a volume of sand size particles sufficiently large for laboratory analysis (approx. 0.1 gm.) and having observed the pump speed near the end of the test the operator directs the flow out of the cartridge sieve and notes the sampling time on a stopwatch. He seals the cartridge sieve top and bottom, then records on it the description of sampling point and test number for later reference in the laboratory. Note that the duration of sampling time in this mode will be determined by the time required for a representative average sample or the collection of a suitable size of sample for analysis, whichever is longer. This duration should also be guided by the need to reduce the relative error in measurement of sampling time. In general, the experiment requiring the use of this mode will specify the limits on sampling time duration.

In some cases a gradation of particle sizes less than those retained in the sieve are necessary. Where such a need is specified, just after removing the pump outlet tube from the cartridge sieve and stopping the stopwatch, the operator fills one or more pint bottles with water sediment mixture, then caps the bottle and cartridge and records necessary information. The standard form developed for this purpose appears in Appendix II.

II. <u>Pint Bottle Mode</u>: In addition to the large volume sample, the ACOP Point Sampler can operate in such a manner as to obtain short time samples of one pint volume. The pint samples may be obtained one for each sampling point, or upon demands of an experiment, be collected in short succession of one another. The operation of successive samples requires close cooperation between the operator and an assistant. Having determined the velocity at the desired sampling point, the operator chooses the largest nozzle which can deliver the necessary nozzle mouth velocity. Lowering the weight into position, he starts the motor and regulates the speed to the proper level. Then, in a methodical fashion, the assistant passes the operator one bottle which he fills to not more than 3 inches from the top. The operator directs the pump output into the canal, returns the bottle, receives another bottle, and, having allowed a set time to elapse, fills the second bottle in the same manner and repeats the process the number of times specified for the experiment. In general, the largest practicable nozzle size is used in this sampling mode, so that the sample represents nearly instantaneous concentrations. Note that after starting the pump or after locating the sampler at a new location, it is necessary in this mode also to allow about 20-30 seconds operation of the sampler, to achieve equilibrium before obtaining samples. A data sheet is set up in Appendix II which specifies all information to be recorded in carrying out sampling in the mode.

OPERATIONAL CHECKLIST

I. Cartridge Sampling Mode

1. Erect pumping sampler in boat on middle seat near edge of boat. Connect to 24 V Power Source as shown in the schematic Fig. 2. Clamp on sieve cartridge to the sampler frame. Allow its outlet and pump outlet to discharge back into canal.

2. According to form of experiment data sheet, enter Canal Name, Location, etc., up to point where Velocity Data appears.

3. Rig current meter on weight and connect to winch. At each level specified for sampling, determine the velocity on descent and ascent. Enter Current Meter used, Vertical Number, Depth to Local Bed, and fill in table of velocities. The intention is to obtain the velocity field as accurately as possible.

OPERATIONAL CHECKLIST (CONT'D)

4. Proceed with Sediment Concentration segment. Enter Pump Sampler used, rating curve number (each rating curve refers to one pump and one stator), vertical Depth to Local Bed, and Time Begin.

5. Note the average velocity of each sampling point. Upon viewing the rating curves one nozzle may be found which can service all the velocities in the vertical. If not, choose the nozzle suitable for the shallower point. Install the nozzle in the weight nose. Attach a length of polyflow tubing to the tube leading from the top of the weight which will allow the weight travel to the canal bottom. Lower the weight to point 1. While lowering, clip the polyflow tubing to the wire cable. Note the Point number, Depth below water surface, Nozzle number and size and RPM required on data sheet.

   Note: The requirement of data acquisition and record in paragraphs 2,3,4, and 5 may be superceded by the requirements of the particular experiments being performed.

6. Upon reaching the sampling point, consult the rating curve of the nozzle in use. Referring back to average velocity at that point, determine appropriate pump speed for the point. Turn on the pump at full speed and regulate down to appropriate speed. Occasionally, it will be required to prime the pump from the discharge outlet side. Never run the pump without assuring that the stator and motor are wet. Doing so would damage the stator which is lubricated by water in normal operation.

7. While regulating the speed of the motor (and thus the pump) monitor its speed by pressing the tachometer generator against the rotating motor axle. A stop is installed on the tachometer generator track. By pushing the tachometer generator up against this stop it will be engaged correctly each time. The screw should be adjusted to the point where the generator spindle makes positive contact with the motor axle but not so far that it imposes a load on the motor and slows it down. The RPM of the motor is noted on the tachometer output gage. After regulating the motor speed to the necessary value, allow the tachometer generator to return to the neutral position.

8. Allow the sampler to run at the adjusted speed for about 20 seconds and then simultaneously start the stopwatch and direct pump discharge into sieve. Avoid splattering of water out of sieve. The objective of the test will be to collect a sample suitable for Bottom Withdrawal Analysis ($\geq$ 0.1 gm) and to sample for a duration required to obtain the representative average concentration or to control the relative error in the time measurement. Towards the conclusion of sampling, the pump speed may be checked more frequently at the discretion of the operator.

OPERATIONAL CHECKLIST (CONT'D)

9. When ample sediment lies in the sieve or the time specified by the experiment has elapsed, stop timing and simultaneously direct the pump discharge out of the sieve cartridge and into the canal. If no pint sample is required, turn off the pump and return the pump speed control to FULL SPEED.

10. Optional if called for. After stopping the watch and diverting the pump discharge out of the sieve cartridge, fill a pint bottle with the discharge to not more than 3 inches of the top. Shut off pump and return speed control to FULL SPEED.

11. Record the second RPM observed on data sheet. Record Sample Number, Location, and date on sieve cartridge and (if taken) on pint bottle.

12. Prepare new sieve cartridge, lower weight to next point, observe necessary nozzle, pump speed, and continue.

    Note: To avoid undue wear on batteries, turn off the pump between sample points and always start it at FULL SPEED.

OPERATIONAL CHECKLIST

II. <u>Pint Bottle Mode</u>

1. Erect pumping sampler in boat on middle seat near edge of boat. Connect to 24 V Power Source as shown in the schematic Fig. 2. Clamp on sieve cartridge to the sampler frame. Allow its outlet and pump outlet to discharge back into canal.

2. According to form of experiment data sheet, enter Canal Name, Location, etc., up to point where <u>Velocity Data</u> appears.

3. Rig current meter on weight and connect to winch. At each level specified for sampling, determine the velocity on descent and ascent. Enter Current Meter used, Vertical Number, Depth to Local Bed, and fill in table of velocities. The intention is to obtain the velocity field as accurately as possible.

4. Proceed with <u>Sediment Concentration</u> segment. Enter Pump Sampler used, rating curve number (each rating curve refers to one pump and one stator), vertical Depth to Local Bed, and Time Begin.

OPERATIONAL CHECKLIST (CONT'D)

5. Note the average velocity of each sampling point. Upon viewing the rating curves one nozzle may be found which can service all the velocities in the vertical. If not, choose the nozzle suitable for the shallower points. Install the nozzle in the weight nose. Attach a length of polyflow tubing to the tube leading from the top of the weight which will allow the weight travel to the canal bottom. Lower the weight to point 1. While lowering, clip the polyflow tubing to the wire cable. Note the Point number, Depth below water surface, Nozzle number and size and RPM required on data sheet.

   Note: The requirement of data acquisition and record in paragraphs 2,3,4, and 5 may be superceded by the requirements of the particular experiments being performed.

6. Upon reaching the sampling point, consult the rating curve of the nozzle in use. Referring back to average velocity at the point, determine appropriate pump speed for the point. Turn on the pump at full speed and regulate down to appropriate speed. Occasionally, it will be required to prime the pump from the discharge outlet side. Never run the pump without assuring that the stator and motor are wet. Doing so would damage the stator which is lubricated by water in normal operation.

7. While regulating the speed of the motor (and thus the pump) monitor its speed by pressing the tachometer generator against the rotating motor axle. A stop is installed on the tachometer generator track. By pushing the tachometer generator up against this stop it will be engaged correctly each time. The screw should be adjusted to the point where the generator spindle makes positive contact with the motor axle but not so far that it imposes a load on the motor and slows it down. The RPM of the motor is noted on the tachometer output gage. After regulating the motor speed to the necessary value, allow the tachometer generator to return to the neutral position.

8. Allow the sampler to run at the adjusted speed for about 20 seconds and then divert the pump discharge into a pint bottle. Fill to no more than 3 inches below top. If successive samples are required a system may be used whereby the assistant passes bottles to the operator for filling, then replaces them in the bottle neck for marking immediately afterward. The time between samples is indicated in each experiment.

9. After the experiment, shut off the motor and return its speed controller to FULL SPEED for next run.

OPERATIONAL CHECKLIST (CONT'D)

10. Record the second RPM observed on data sheet. Record Sample Number, Location, and date on the pint bottles.

11. Lower weight to next sampling point if the nozzle in use is best suited for that depth. If not, retrieve the weight and mount the best suited nozzle. Repeat the experiment for all necessary points. The sampling system should be allowed to achieve equilibrium at every new point or sampling rate.

    Note: To avoid undue wear on batteries, turn off the pump between sample points and always start it at FULL SPEED.

PRECAUTIONS

The following precautions are specified for the field use of the equipment:

1. Batteries should be fully charged.

2. Use a stopwatch with at least 1/10 second least count.

3. Subject to stipulations of each particular experiment, in Cartridge Mode the longer duration sample is more desirable.

4. In Pint Bottle Mode avoid overfilling the bottle.

5. All fittings on the pump should be tight enough to avoid leakage and air suction.

6. Motor speed should be frequently checked during each test to assure that it is constant.

7. Start the motor with the speed controller on FULL SPEED.

8. Once every twenty tests, disassemble the pump and assure that the stator membrane is intact and tightly secured to the stator.

9. Do not stress the plastic tubes by loading. Attach the tube between the nozzle and the pump securely to the winch cable every five feet.

10. Operate the pump at a discharge sufficiently high to ensure passage of all sediment particles as indicated on the rating curve.

CONCLUSION

A point integrating pumping sampler has been assembled. This sampler uses a positive displacement pump driven by a D.C. motor. The discharge of the pump is regulated by its speed.

The sampler is designed on the premise that the local velocity in the channel is known and that representative samples can be obtained by maintaining the intake velocity at the same rate. A prior determination of the velocity field at and around the sampling point is therefore needed.

The sampler can be operated in a Cartridge Sampling Mode to obtain long time samples or in a Pint Bottle Mode to obtain nearly instantaneous samples.

This report is based on the experience gained in the laboratory with a sand of median size = 0.20 mm. It is likely that experience in the field will necessitate changes in the sequence of operation.

ACKNOWLEDGEMENT

This report is part of continuing research in Alluvial River Mechanics at Colorado State University under the leadership of the senior author. It is sponsored by National Science Foundation Grant No. ENG 72-00274-A01. Field testing of this sampler will be carried out on the Link Canal in Pakistan under National Science Foundation Special Foreign Currency Grant No. OIP73-002277-A01 to Pakistan Water and Power Development Authority.

APPENDIX I

List of References

1. Federal Interagency Sedimentation Project, A Study of Methods Used in Measurement and Analysis of Sediment Load in Streams, Report no. 5: Laboratory Investigations of Suspended Sediment Samples. Hydraulic Laboratory, University of Iowa, Iowa City, 1941.

APPENDIX II

Typical Data Sheets

I. Cartridge Sample Mode

Velocity Data

Current Meter Used: Sonic Sounder Used:

Vertical No.: Depth to Local Bed:

Point	Depth Below Water Surface	Going Down		Coming Up		Average Velocity
		No. of Revs	Velocity	No. of Revs	Velocity	
1 2 3 4 5						

Sediment Concentration

Pumping Sampler Used: Vertical: Total Depth to Local Bed:

Rating Curve No.: Time Begin: Time End:

Point	Depth Below Water Surface	Nozzle Number	RPM Req'd	RPM Observed		Capsule Data					Pint Bottle Data			
						Capsule No.	Capsule Analysis				Pint Bottle No.	Pint Bottle Analysis		
				Begin	Near End		Duration	Conc	D_{50}	σ		Conc	Dissolved	Clay
1 2 3														

Note 1. Attach Original V.A. Tube or other size analysis record and results including D_{84}, D_{65}, D_{50}, D_{35}, D_{16} and pipet analysis for pint samples.

2. Repeat above table for other verticals.

3. This form will always be used in conjunction with some experiment. For relative information see the experimental record.

II. Pint Bottle Mode

Velocity Data

Current Meter Used: Sonic Sounder Used:

Vertical No.: Depth to Local Bed:

Point	Depth Below Water Surface	Going Down		Coming Up		Average Velocity
		No. of Revs	Velocity	No. of Revs	Velocity	
1						
2						
3						
4						
5						

Sediment Concentration

Pumping Sampler Used: Vertical: Total Depth to Local Bed:

Rating Curve No.: Time Begin: Time End:

Point No.: Depth Below Water Surface:

Nozzle No.: RPM Required:

RPM Observed: (1) (2) (3)

Time Begin	Pint Bottle No.	Volume	DATA ANALYSIS				
			Sampling Time, sec.	Conc. in ppm		Size Distribution for Fraction coarser than 62μ	
				<62μ	Total	D_{50}mm	σ
1							
2							
3							

Note 1. Attach Original V.A. Tube or other size analysis record and results including D_{84}, D_{65}, D_{50}, D_{35}, D_{16} and pipet analysis for pint samples.

2. Repeat above table for other verticals.

3. This form will always be used in conjunction with some experiment. For relative information see the experimental record.

APPENDIX III

Positive Displacement Pump Tested for ACOP Sampler

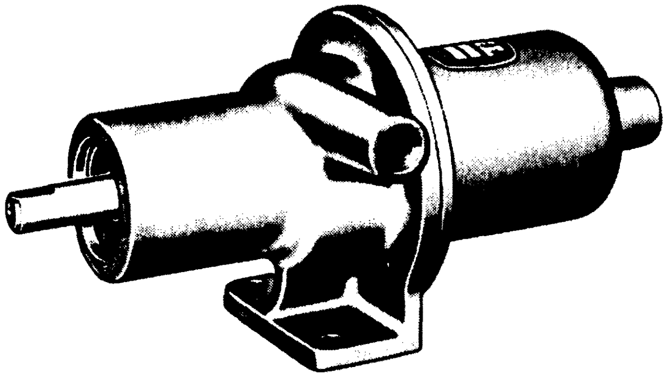
Your Teel rotary-screw pump will give excellent service if given only normal care and maintenance. The pump body is cast aluminum; the rotor and drive shaft are #416 stainless steel and the stator is oil resistant synthetic rubber. Therefore, care should be taken that the material to be pumped will not damage these parts.

Do not run the pump under power until it is filled with the liquid to be pumped. Dry friction is harmful to this pump. Liquid serves as a lubricant rather than a prime since a flow of 10% of pump displacement will satisfy cooling and lubricating requirements.

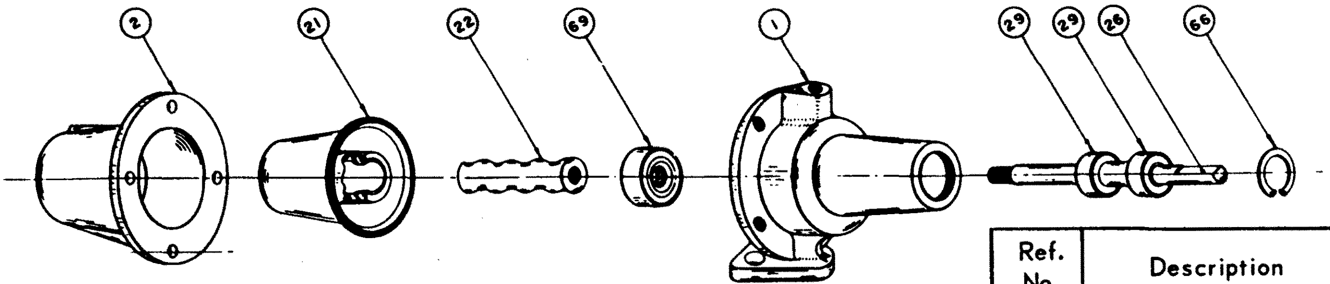
Prelubricated ball bearings are lifetime sealed and require no further lubrication.

Alignment of pump to motor should be carefully checked to avoid excessive operating noise and strain on pump and motor.

Piping to pump should generally be equal in size to the suction port opening. All piping joints should be carefully "doped" before tightening, especially suction line connections. Piping should mate with pump ports free of strain. Make all lines as direct and free of fittings as possible and minimize suction line length by locating the pump near the source of the liquid to be handled.



ROTATION IS CLOCKWISE LOOKING AT SHAFT. PUMP INLET IS AT REAR.



Ref. No.	Description
1	Pump Body
2	Suction Housing
21	Stator
22	Rotor
26	Drive Shaft
29	Ball Bearing
66	Snap Ring
69	Rotary Seal

CAPACITY IN GPH							
MODEL	PRESSURE	850 RPM		1150 RPM		1800 RPM	
		GPH	HP	GPH	HP	GPH	HP
1P610	0	134.7	1/6	187.0	1/4	281.0	1/4
	10	128.5	1/6	179.0	1/4	278.0	1/4
	20	120.0	1/6	168.0	1/4	264.5	1/4
	30	103.8	1/6	148.7	1/4	225.0	1/4
	40	91.6	1/6	135.2	1/4	204.5	1/3