A STUDY OF METHODS USED IN

MEASUREMENT AND ANALYSIS OF SEDIMENT LOADS IN STREAMS

SUBCOMMITTEE ON SEDIMENTATION
INTER-AGENCY COMMITTEE ON WATER RESOURCES

REPORT Q

PROGRESS REPORT

INVESTIGATION OF A PUMPING SAMPLER WITH ALTERNATE SUSPENDED–SEDIMENT HANDLING SYSTEMS

JUNE 1962

A Study of Methods Used in

MEASUREMENT AND ANALYSIS OF SEDIMENT LOADS IN STREAMS

A Cooperative Project
Sponsored by the
Subcommittee on Sedimentation
Inter-Agency Committee on Water Resources

Participating Agencies

Corps of Engineers ** Geological Survey
Soil Conservation Service ** Bureau of Reclamation
Agricultural Research Service ** Coast and Geodetic Survey
Tennessee Valley Authority ** Federal Power Commission
Bureau of Public Roads ** Department of Labor
Forest Service ** Bureau of Mines
Public Health Service

REPORT Q

Progress Report

INVESTIGATION OF A PUMPING SAMPLER WITH ALTERNATE SUSPENDED-SEDIMENT HANDLING SYSTEMS

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ST. ANTHONY FALLS HYDRAULIC LABORATORY

HENNEPIN ISLAND & THIRD AVE., S. E.

MINNEAPOLIS 14, MINNESOTA

PREFACE

This investigation is part of the program of the Federal Inter-Agency Sedimentation Project, which is located at the St. Anthony Falls Hydraulic Laboratory of the University of Minnesota. The project is under the supervision of an Inter-Agency Technical Committee and it is sponsored by the Subcommittee on Sedimentation of the Inter-Agency Committee on Water Resources. The purposes of the project are the development and improvement of equipment and methods for obtaining and analyzing sediment samples.

This report was prepared by H. H. Stevens, Jr., who built and operated the field installation, assisted in the design of the recording samplers, and designed the bottling sampler. T. F. Beckers assisted in operation of the field installation. B. C. Colby, project supervisor, designed the two recording samplers, supervised the operation, and reviewed the report. The cooperation of F. S. Witzigman and R. P. Christensen is gratefully acknowledged.

D. M. Culbertson, District Engineer, Quality Water Branch, U.S. Geological Survey, Lincoln, Nebr., furnished personnel to help in the field construction at the test site and to collect and analyze suspended-sediment samples. A. F. Pendleton, Engineer-in-charge, Surface Water Branch, U.S. Geological Survey, Grand Island, Nebr., and G. G. Jamison, Engineer-in-charge, Surface Water Branch, U.S. Geological Survey, Ord, Nebr., furnished personnel to help in the maintenance of the field installation.

SYNOPSIS

A pumping sampler, consisting of an intake and pumping system, was developed that will intermittently collect suspended-sediment samples from one point in the cross section of a stream. The development of the pumping sampler included design of: circuitry to control the cycle of the pumping system; an intake for extracting a sample from the stream; a protection device in case of pump stoppage; and a fish trap to prevent fish from damaging the pumping system. Field tests showed that the intake efficiency and operational dependability of the pumping sampler were satisfactory at the testing site on the North Loup River near St. Paul, Nebr.

Two recording systems and one bottling system were developed to handle the pumped samples:

1. The accumulative-weight recording system measures the weight of the suspended sediment in the pumped samples as the sediment settles onto a suspended weighing pan. A record of sediment concentration is obtained without laboratory analysis of any samples except those taken separately as a periodic check on sampling efficiency. Good accuracy can be expected for periods of uniform flow at fairly high concentrations of sands and coarse silts.

2. The volume recording system photographically records the quantity of water and accumulated sediment in samples. Every 6 hours a pint sample is bottled for later analysis in the laboratory. If there is not much clay in suspension, good accuracy can be obtained for periods of high concentrations of sands and coarse silts, even though concentration and flow change rapidly.

3. The individual-sample bottling system collects a pint sample at preset times for later analysis in the laboratory. Fine sediments and flashy streams are readily handled. The bottling sampler can be moved from site to site.

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Progress Report

INVESTIGATION OF A PUMPING SAMPLER WITH ALTERNATE SUSPENDED-SEDIMENT HANDLING SYSTEMS

I. INTRODUCTION

1. Purpose of the investigation--Work on the pumping sampler is part of an investigation aimed at development of new devices to measure suspended-sediment loads in streams automatically. Although the investigation is based on a consideration of all factors involved in the discharge of suspended sediment, the scope of the project has been limited primarily to development of a pumping sampler that will collect and handle suspended-sediment samples from one point in the cross section of a stream.

The idea of a pumping sampler is not new. Two of the most elaborate installations which have been tried were reported by Braudeau [1] * and Wilkinson [6].

2. Phases of the investigation--The pumping sampler investigation was in two parts. The first part was the development, operation, and field testing of an intake and pumping system for obtaining representative sediment samples from one point in the cross section of a stream. The second part was the development of three alternate suspended-sediment handling systems: (1) an accumulative-weight system, (2) a volume recording system, and (3) an individual-sample bottling system. The first two systems were field tested and the bottling system was laboratory tested.

* Numbers in brackets indicate references listed on Page 73

II. INTAKE AND PUMPING SYSTEM

3. Basic operating system--The intake system consists of an intake structure with intake port (or opening), fish trap, and lead in (intake) pipes. The pumping system consists of a cycle control system, pump, flushing valve, sample splitter, flow indicator, and flushing-water supply tank.

The basic cycle of operation of the pumping sampler is controlled by the cycle control unit. Just before each sampling period a supply of flushing water is drained out through the intake system to remove any debris or sediment that may have collected in the intake during the interval between pumping cycles. The first portion of the pumped flow is wasted so that the sediment concentration in the system may become constant before the sample is collected. If the pump fails to discharge properly because the intake is covered with sand, or because the water level is below the intake, or for any other reason, a protection system stops the normal cycle for a period of 12 hours. The intake is then automatically flushed and the sampling cycle is restarted. If sampling is normal, the original cycle is restored but if the system does not take a sample, another 12-hour shut-down period begins.

Each of the three sample handling systems: the accumulative-weight recording system (accumulative-weight recording sampler), the volume recording system (volume recording sampler), and the individual-sample bottling system (bottling sampler) required a slightly different cycle of pumping system operation. The following paragraphs describe briefly the main features of the cycle of operation used with each system, and the detailed operation of each system is given in Appendix B.

A schematic diagram of the pumping system for the accumulative-weight recording sampler is shown in Fig. 1. Every 30 minutes a 28-gallon sample (volume controlled by a water level control) is pumped into the sedimentation tank through a 1-in. intake system. Just before each sampling period, 28 gallons of the nearly clear water at the top of the sedimentation tank is drained out through the intake. The pump operates for 4 minutes. During the first 50 seconds the splitter is in the waste position; during the time to pump 28 gallons of water (about 120 seconds) it is in the sampling position; and during the rest of the time it is in the waste position. At the end of any 12-hour interruption of operation by the protection system, 10 gallons of water from an auxiliary supply tank drains into the sedimentation tank to restore the supply of flushing water.

A schematic diagram of the pumping system for the volume recording sampler is shown in Fig. 2. Every 30 minutes a one-gallon sample is pumped through a 3/4-in. intake system into one of 12 sedimentation tubes. A splitter is mounted on the top of one of the tubes so that a portion of the sample is diverted and collected in a pint milk bottle every 6 hours. Just before each sampling period five gallons of flushing water from a supply tank is drained out through the intake. The pump operates for 100 seconds. During the first 50 seconds the splitter is in the waste position; during the next 5 seconds it is in the sampling position; and during the last 45 secs. it is in the waste position. Part of this waste water is used to replenish the flushing-water supply. Water, to flush the intake, both

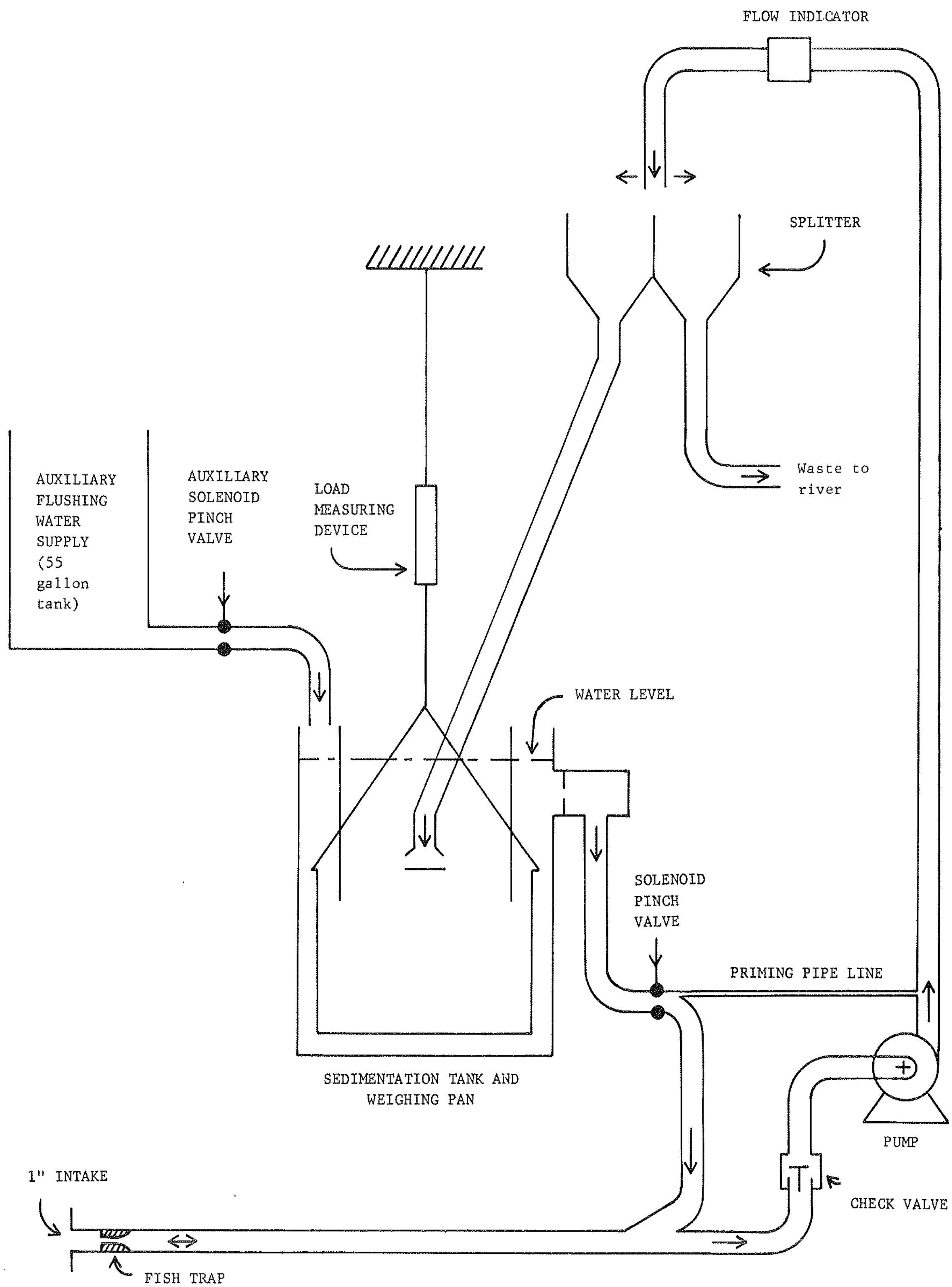


FIG. 1 — SCHEMATIC DIAGRAM OF ACCUMULATIVE-WEIGHT RECORDING SAMPLER

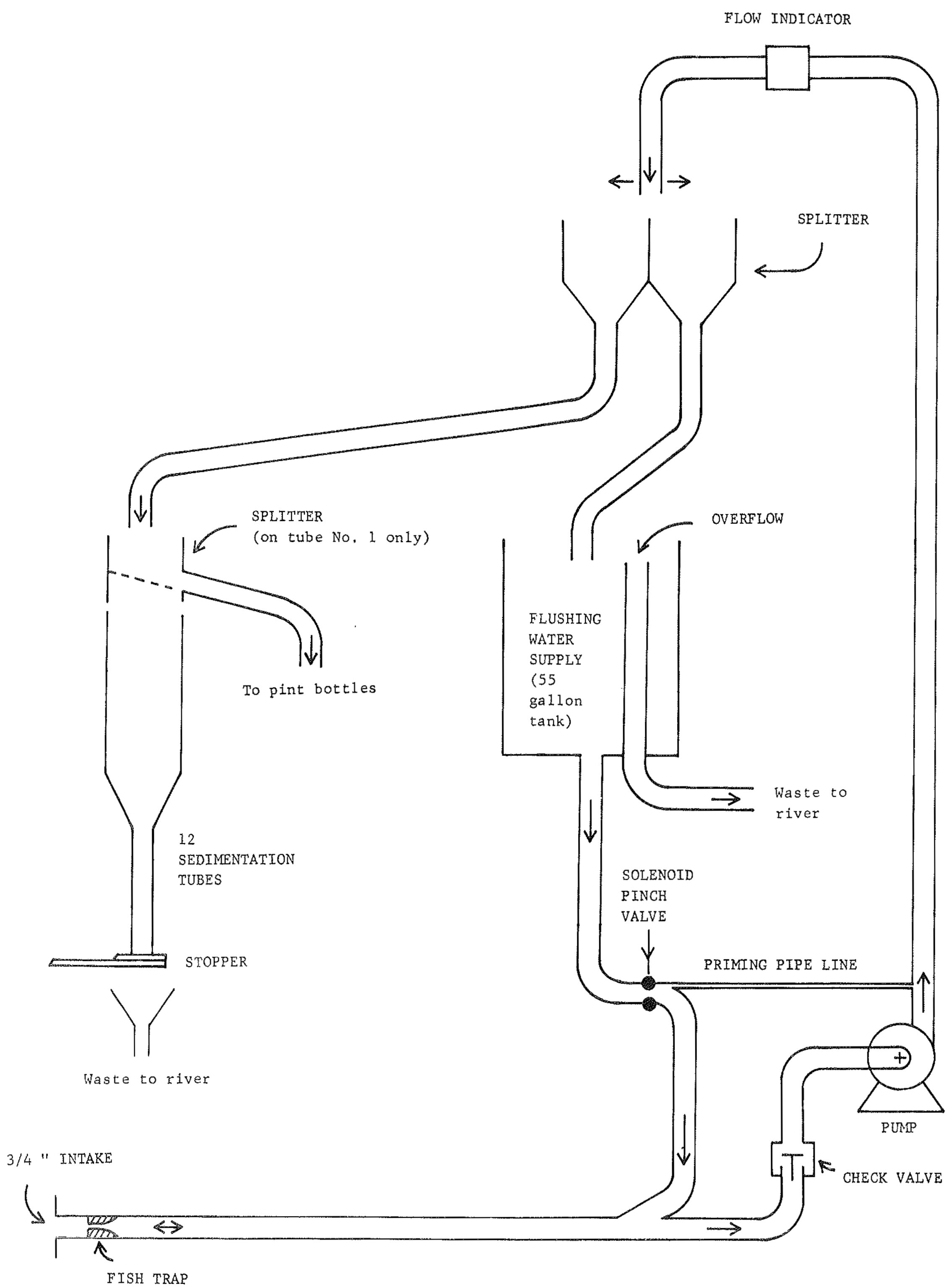


FIG. 2 — SCHEMATIC DIAGRAM OF VOLUME RECORDING SAMPLER

for regular flushing and after a 12-hour protection shutdown, comes from the flushing-water tank.

A schematic diagram of the pumping system for the bottling sampler is shown in Fig. 3. The bottling sampler collects a pint sample every 12 hours during low river stages and every hour during high river stages. Just before sampling, 5 gallons of flushing water from a supply tank is drained out through the intake. The pump operates for 65 seconds. During the first 40 seconds the splitter is in the waste position; during the next 3 seconds it is in the sampling position; and for the last 22 seconds it is in the waste position. Part of this waste water is used to replenish the flushing-water supply. The flushing-water tank supplies water to flush the intake, both for regular flushing and after a 12-hour protection shutdown.

4. Intake--The structure on which the intake is mounted is shown in Fig. 4. The main feature is a guide wall which is parallel to the stream flow. The guide wall is made of two 8-ft, 2x10-in. planks and one 8-ft, 2x6-in. plank mounted on 4x4-in. posts. The wall orients the river flow to provide proper entrance conditions at the intake. The upstream post is fastened to an old bridge pier and the downstream post is braced to the river bank. In four years of operation the intake structure has been damaged only once and that was by the severe ice flow in the spring of 1960.

The flat plate intake port (or opening) consists of a steel plate welded to a pipe coupling and mounted on the face of the guide wall. Three intakes are mounted in the guide wall to provide a choice of intake elevation. Plastic pipe connects the intake to the pump. The diameter of the pipe coupling and connecting plastic pipe is 1-in. for the accumulative-weight recording sampler and 3/4-in. for both the volume recording sampler and bottling sampler. The different types of intakes that have been tested are shown in Fig. 5. In addition to the flat plate intake they include an elbow intake, and three nipple intakes, each threaded into the outer end of the flat plate intake coupling.

5. Fish trap--Several times the pump was damaged by fish that entered the intake. After the fish trap shown in Fig. 6 was installed in the plastic pipe about 5 ft from the end of the intake no further damage occurred. The rectangular constriction has about the same cross sectional area as the inside of the plastic pipe.

All except the smallest fish that enter the intake are trapped ahead of the constricted section and flushed back out the intake during the flushing period of the next pumping cycle. Fish small enough to pass through the constricted section will also pass through the pump without damaging it.

6. Pump and flush valve--On the basis of commercial catalogs and recommendations, a type of pump having a flexible rubber impeller and driven by an electric motor was selected as the most suitable pumping unit. This type of pump is self-priming for suction lifts up to 15 ft, and it will handle a water-sediment mixture which has up to 10 percent of solids by weight.

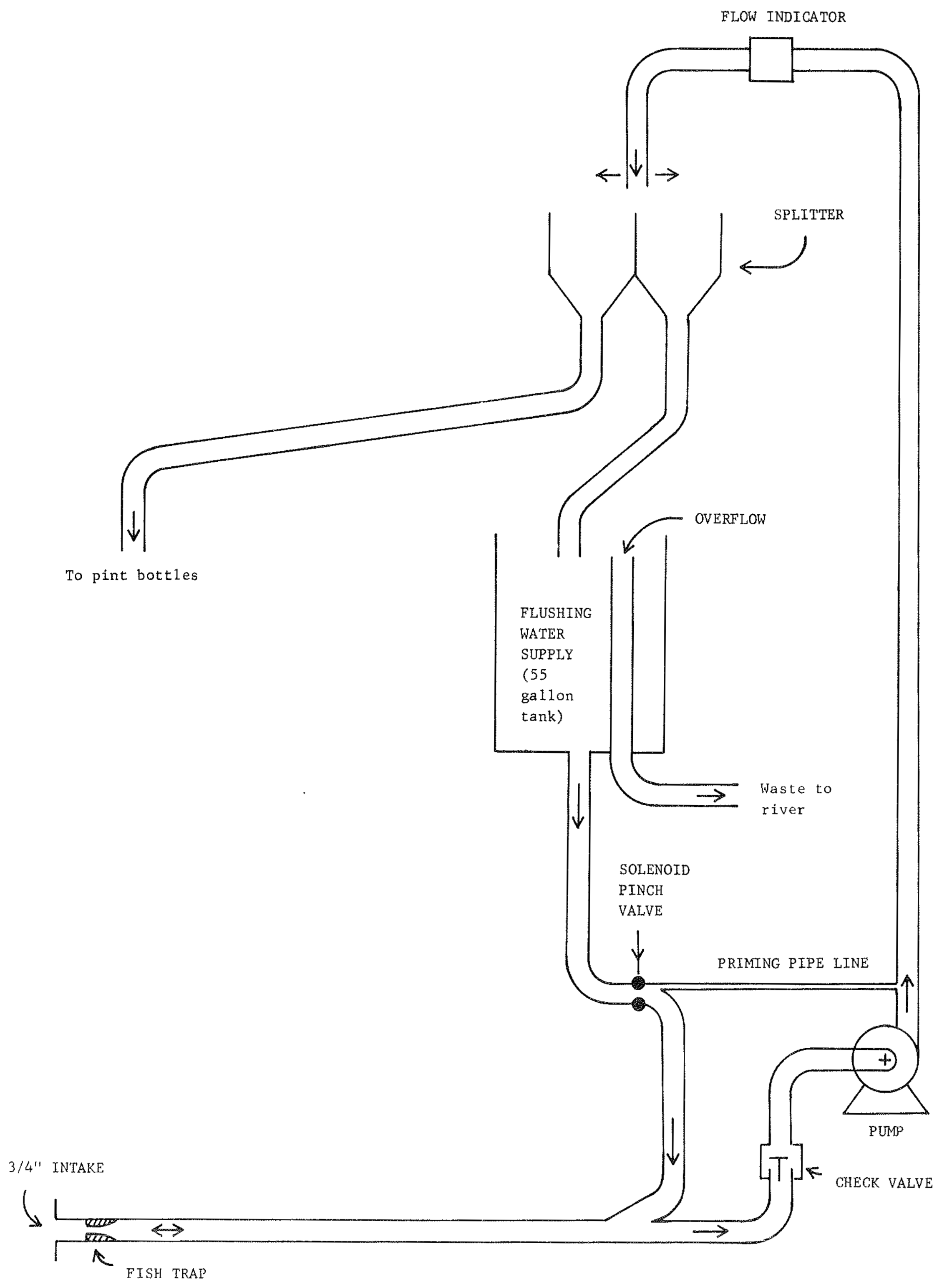


FIG. 3 — SCHEMATIC DIAGRAM OF BOTTLING SAMPLER

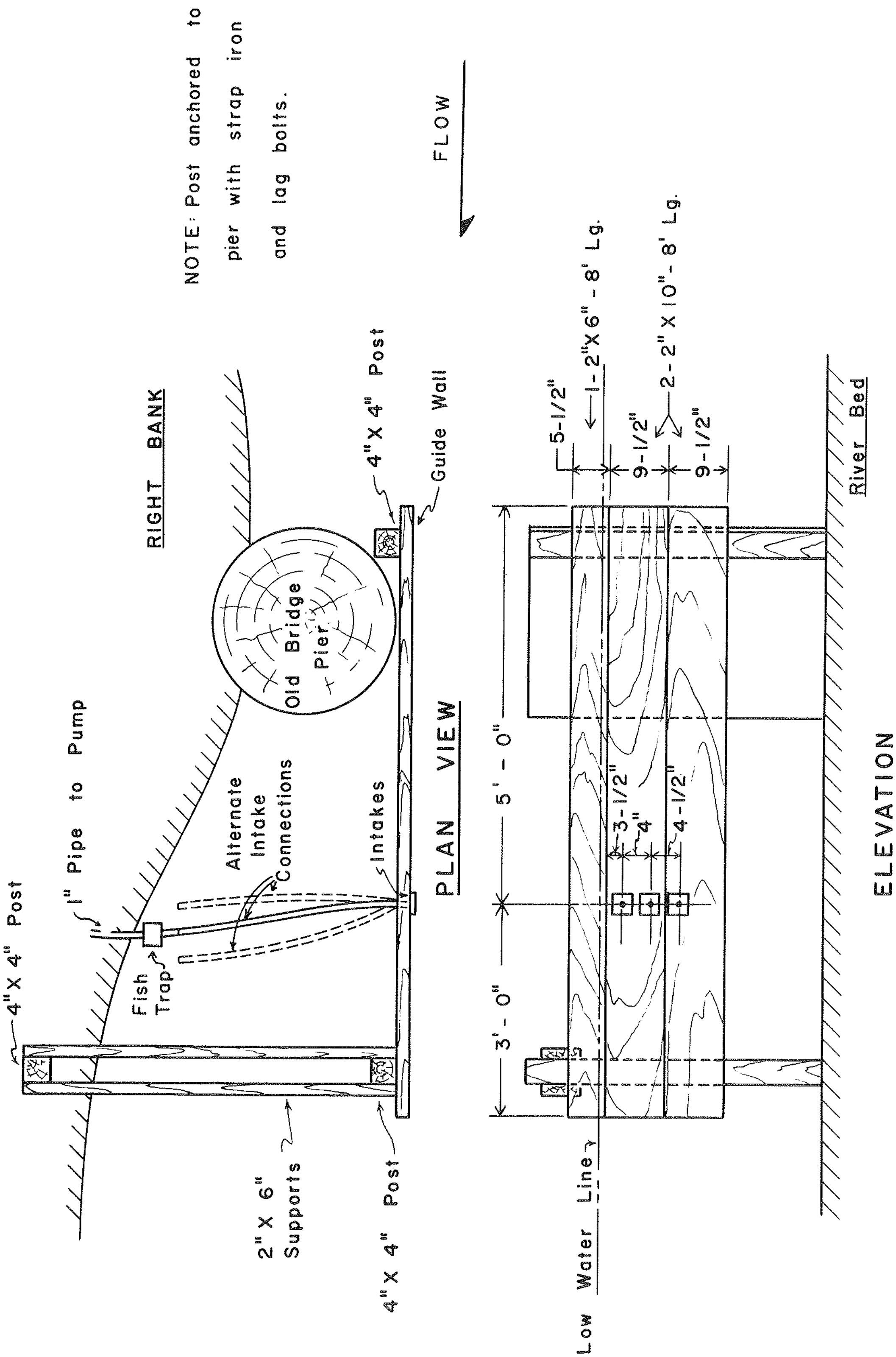


FIG. 4 — INTAKE STRUCTURE

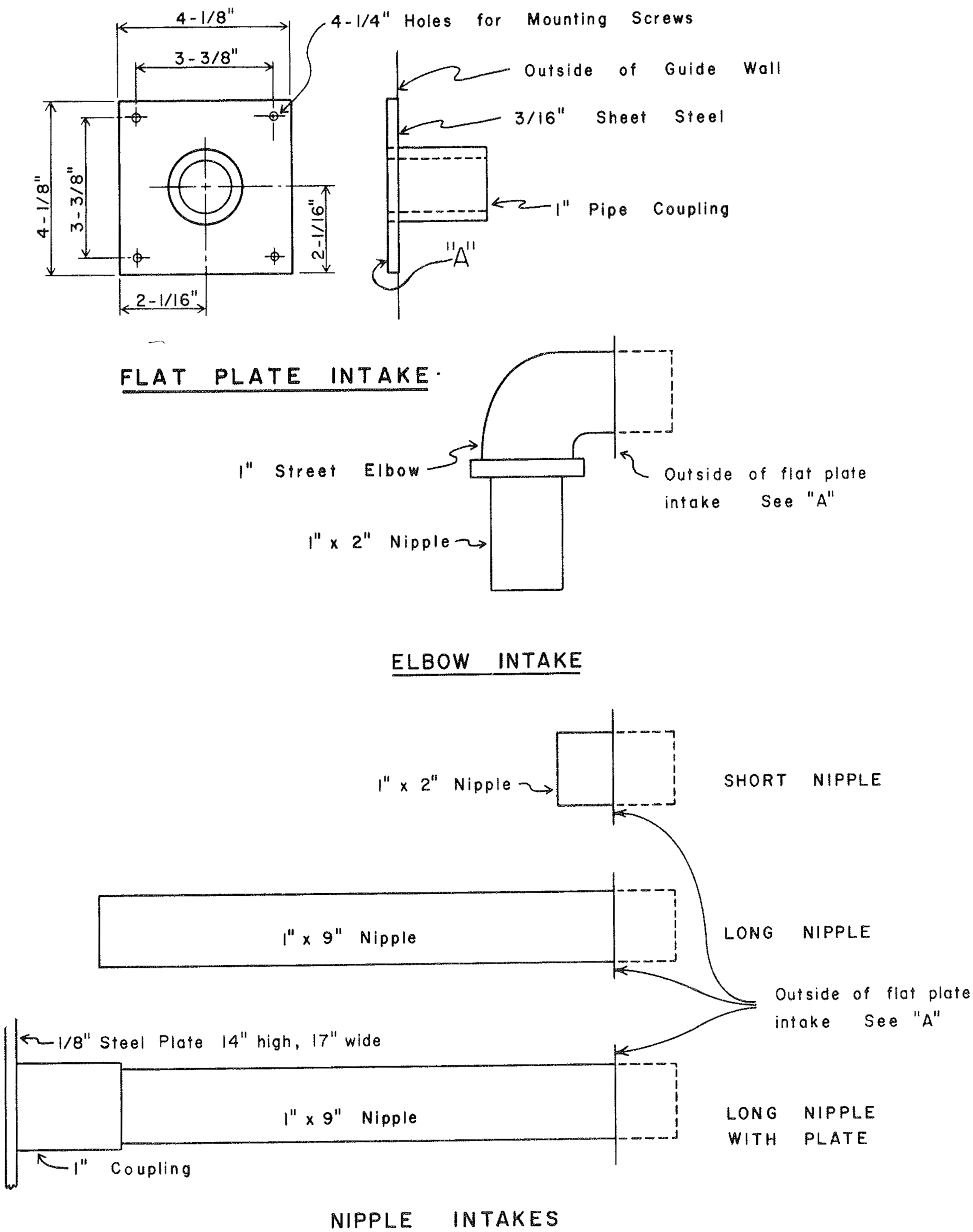
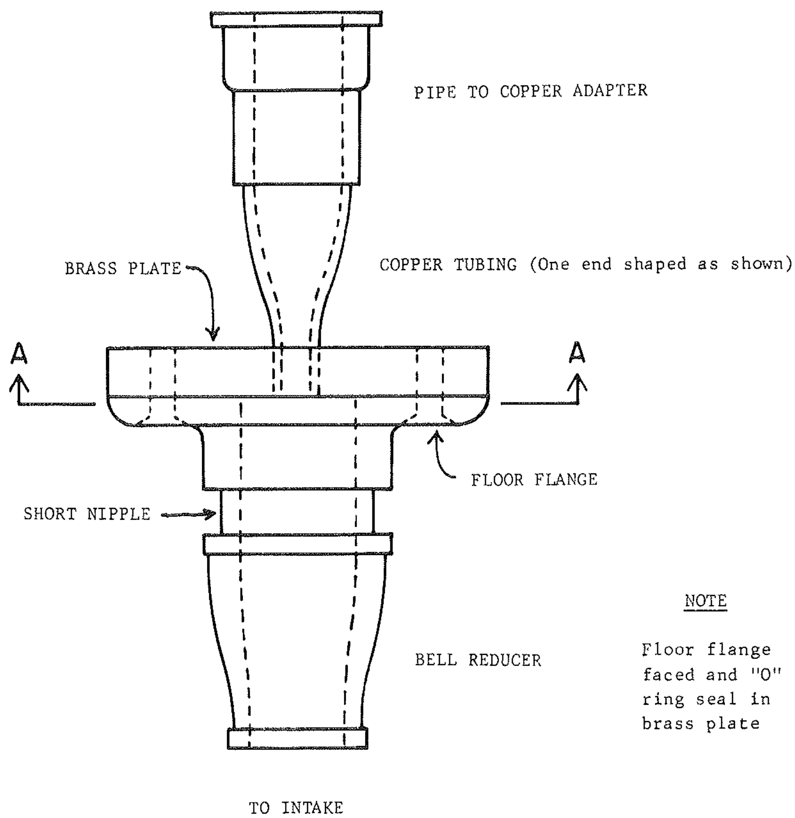
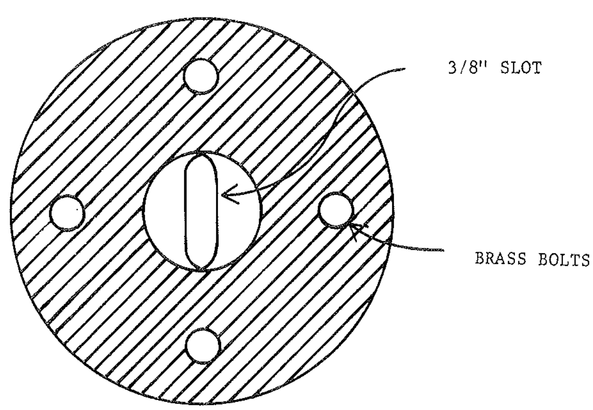


FIG. 5 — TYPES OF INTAKES TESTED





Section A-A

FIG. 6 - FISH TRAP

Two sizes of pumps were used. A pump with 1-in. suction and discharge openings and driven by a one-horsepower, 1,750 rpm, electric motor was chosen for use with the accumulative-weight recording sampler. The pump will discharge 15 gallons of water per minute. The pump size was selected to supply a 28-gallon sample in about 2 minutes. A pump with 3/4-in. garden-hose suction and discharge ports and driven by a 1/4-horsepower, 1,750 rpm, electric motor was chosen for use with the volume recording sampler and the bottling sampler. This pump will discharge 10 gallons of water per minute. The pump size was selected to maintain a velocity of about 4.5 fps in a 3/4-in. diameter intake. The pipe sizes of 1-in. and 3/4-in. were selected so that the intake velocity would be at least 4.5 fps, to prevent sediment from settling in the intake and pumping system during sampling. The total pumping head was about 42 ft (18 ft lift and 24 ft friction head) at the St. Paul, Nebr., site. A check valve was installed to maintain prime in the pump. Also a small pipe from the flushing line was installed to supply extra water to restore prime when a twig or other debris prevented the check valve from closing between pumping cycles.

A normally-closed solenoid operated pinch valve was used for control of the flushing water. This valve was selected because it was more economical than other types of electrically operated valves.

7. Sample Splitter--The splitter assembly is shown in Fig. 7. The supply line from the pump to the splitter is a flexible 1-in. pipe for the accumulative-weight recording sampler. The supply line from the pump to the splitter is a 3/4-in. garden hose except for the selection of 1-in. flexible pipe through the flow indicator for the volume recording sampler and the bottling sampler. A rotary solenoid moves the splitter arm between the waste position and the sample position. The sample line and waste line are 1-in. plastic pipe.

8. Flow indicator--The 12-hour protection system is actuated by the flow indicator shown in Fig. 8. The 1-in. flexible rubber tubing which passes through the flow indicator is a horizontal section of the supply line from the pump to the splitter. The flow indicator is mounted on the splitter arm. Whenever the pump is discharging, the weight of the water flowing through the rubber tubing compresses the coil spring and depresses the push rod to the flow indicator switch which opens the circuit to the protection system and turns on the white light. The white light indicates that the sampler is operating. Whenever the pump fails to discharge during a pumping cycle, the flow indicator switch remains closed which energizes the protection circuit and activates the time delay relay.

9. Flushing-water supply--The flushing water for the accumulative-weight recording sampler is supplied from the sedimentation tank, (Fig. 1). The auxiliary flushing water for the accumulative-weight recording sampler (Fig. 1), and flushing water for the volume recording sampler and bottling sampler (Figs. 2 and 3), are supplied from standard 55 gallon tanks. The auxiliary flushing-water tank is filled whenever the sampler is serviced. The other flushing-water tanks are filled with the waste discharge from the splitter and each is equipped with an overflow drain.

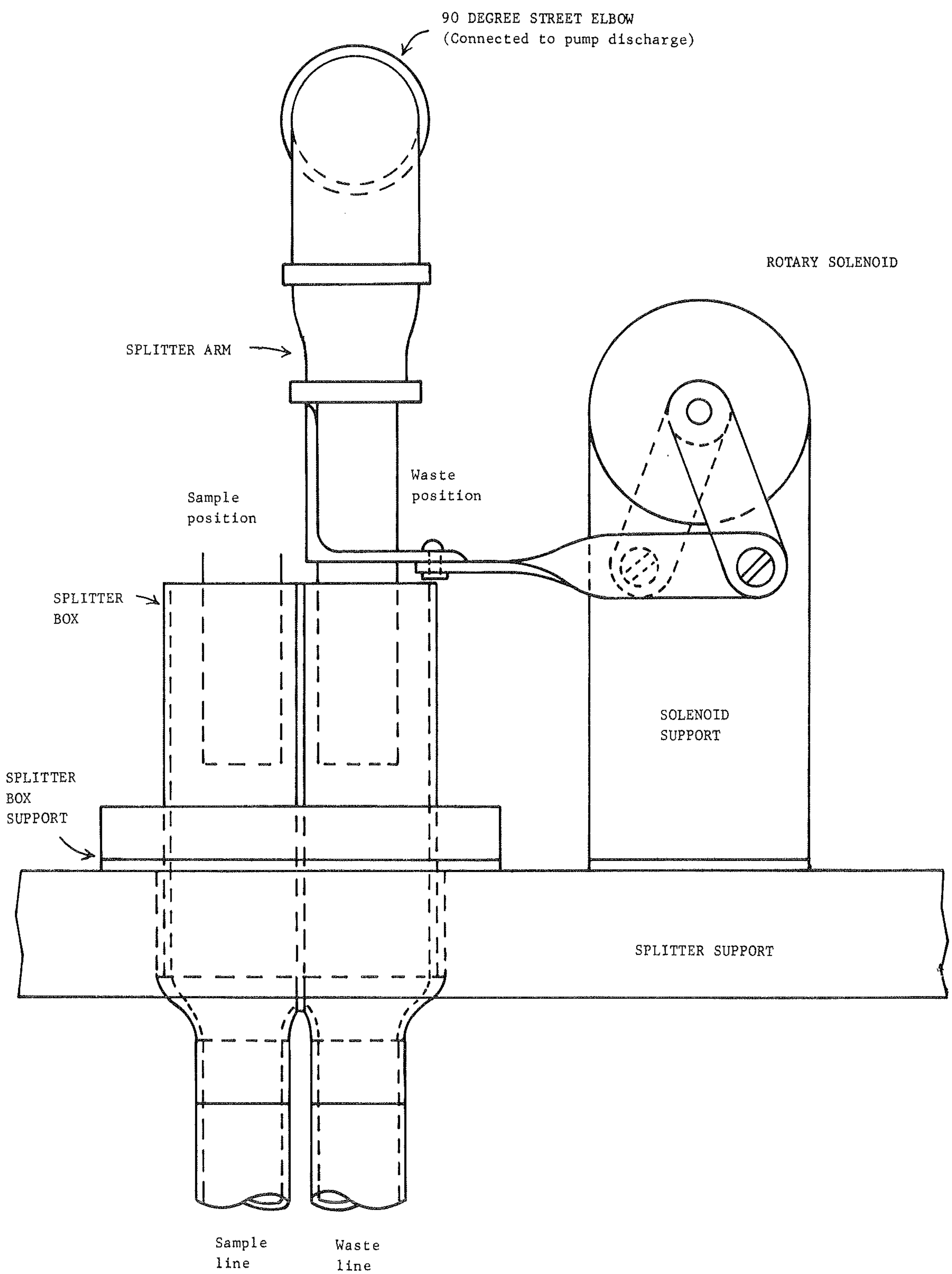


FIG. 7 — SPLITTER ASSEMBLY

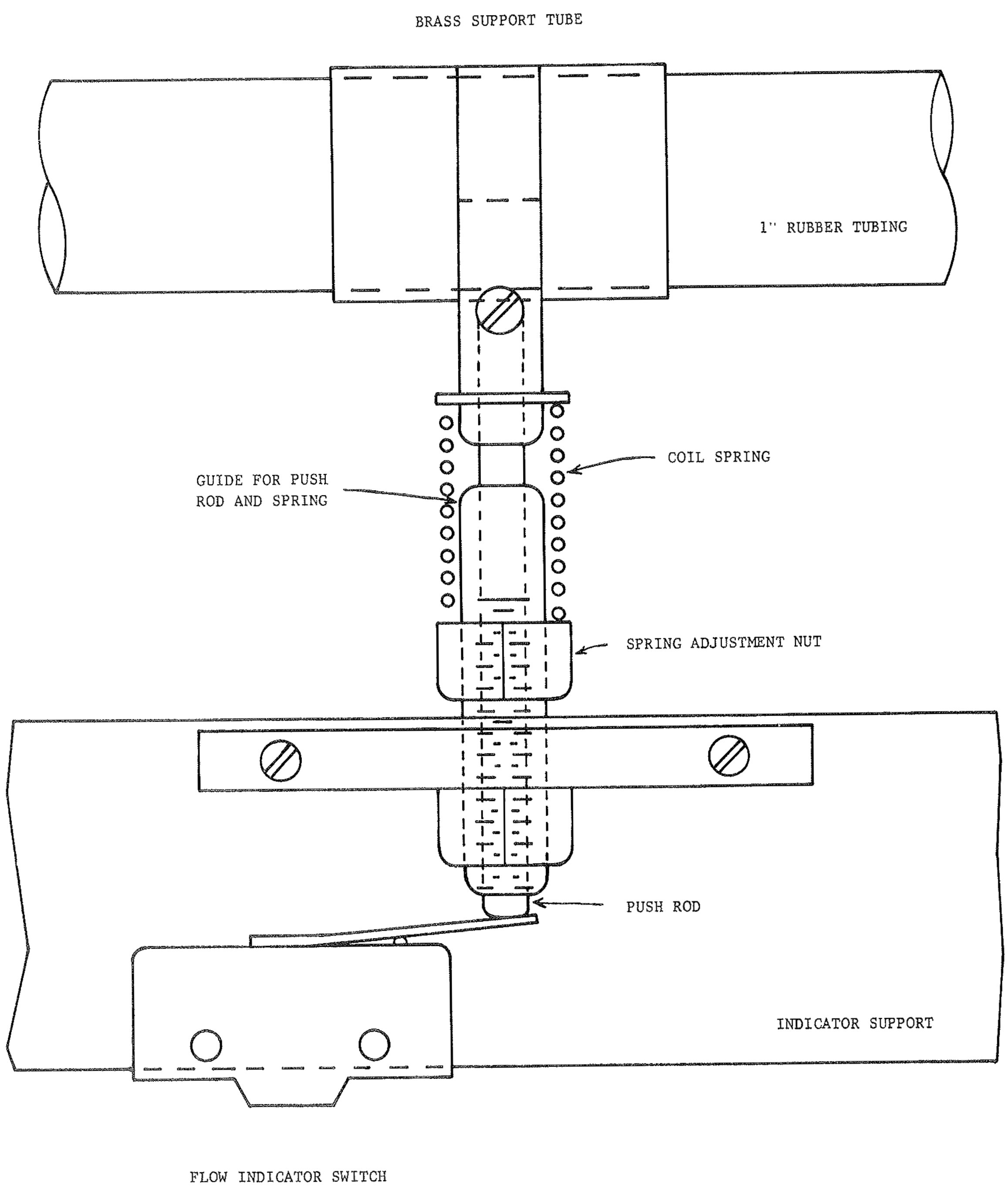


FIG. 8 — FLOW INDICATOR

III. FIELD TESTS OF INTAKE AND PUMPING SYSTEM

10. Location of field testing site--The site for field tests and field operation of the pumping samplers was on the North Loup River 3 miles north of St. Paul, Nebr. (See Figs. 9 and 10). The sampler installation was built on the south bank of the river 230 ft downstream from the bridge on U. S. Highway 281. This site was chosen for the field study because the North Loup River has continuous water and sediment discharge, a U. S. Geological Survey stream gaging and sediment-sampling station was located there, and electric power was readily available. The river banks at the site are sufficiently high to prevent submergance of equipment during flood flows. A bend in the river upstream from the highway bridge tends to concentrate the flow near the south bank, a condition which simplified the design of the intake structure.

11. North Loup River--The North Loup River flows in a general southeasterly direction, and joins the Middle Loup River 4 miles below St. Paul, Nebr., to form the Loup River. The North Loup River is about 190 miles long. The main tributary is the Calamus River which joins the North Loup River near Burwell, Nebr., 60 miles above St. Paul.

The upper two-thirds of the North Loup Basin is in the sandhills region of north-central Nebraska. The sandhills are blanketed by dune sand of varying depths on moderate slopes that are stabilized by grass cover. The rest of the basin is overlain with loess on rolling to steep slopes, and it is used for general farming.

12. Stream Flow Pattern--The North Loup River upstream from St. Paul has a drainage area of 4,460 square miles, of which only about 1,270 square miles contributes directly to surface runoff. The soil in the sandhill region readily absorbs rainfall, and drainage out of the region is from ground water which provides stable stream flow. In contrast, storm runoff from the loess area produces large fluctuations in stream discharge.

The average discharge of the North Loup River over 53 years of record (1894-1915, 1928-60) was 982 cfs (cubic feet per second). [U. S. Geol. Survey Water-Supply Paper 1710] The maximum discharge during the above period was 90,000 cfs on June 6, 1896, and minimum daily flow was 85 cfs on August 8, 1941. Water discharges during the periods that the pumping sampler was in operation are summarized in Table 1. The mean daily discharge was 1,051 cfs for the 80 day operating period in 1957, 929 cfs for the 162 day period in 1958, 770 cfs for the 182 day period in 1959, 799 cfs for the 168 day period in 1960, and 806 cfs for the 173 day period in 1961. The maximum daily discharge within the periods of sampler operation was 4,860 cfs on July 24, 1958 and the minimum daily discharge was 259 cfs on July 18, 1961.

13. Suspended sediment--Records of suspended-sediment discharge of the North Loup River near St. Paul, Nebr., are available from April 11, 1946 to June 30, 1953. [U. S. Geol. Survey Water-Supply Paper 1291] The maximum daily sediment discharge during the above period was 463,000 tons on June 22, 1947, and the minimum daily sediment discharge was 20 tons on August 3, 1946 and February 22, 1953. During the same period the maximum mean daily sediment concentration was

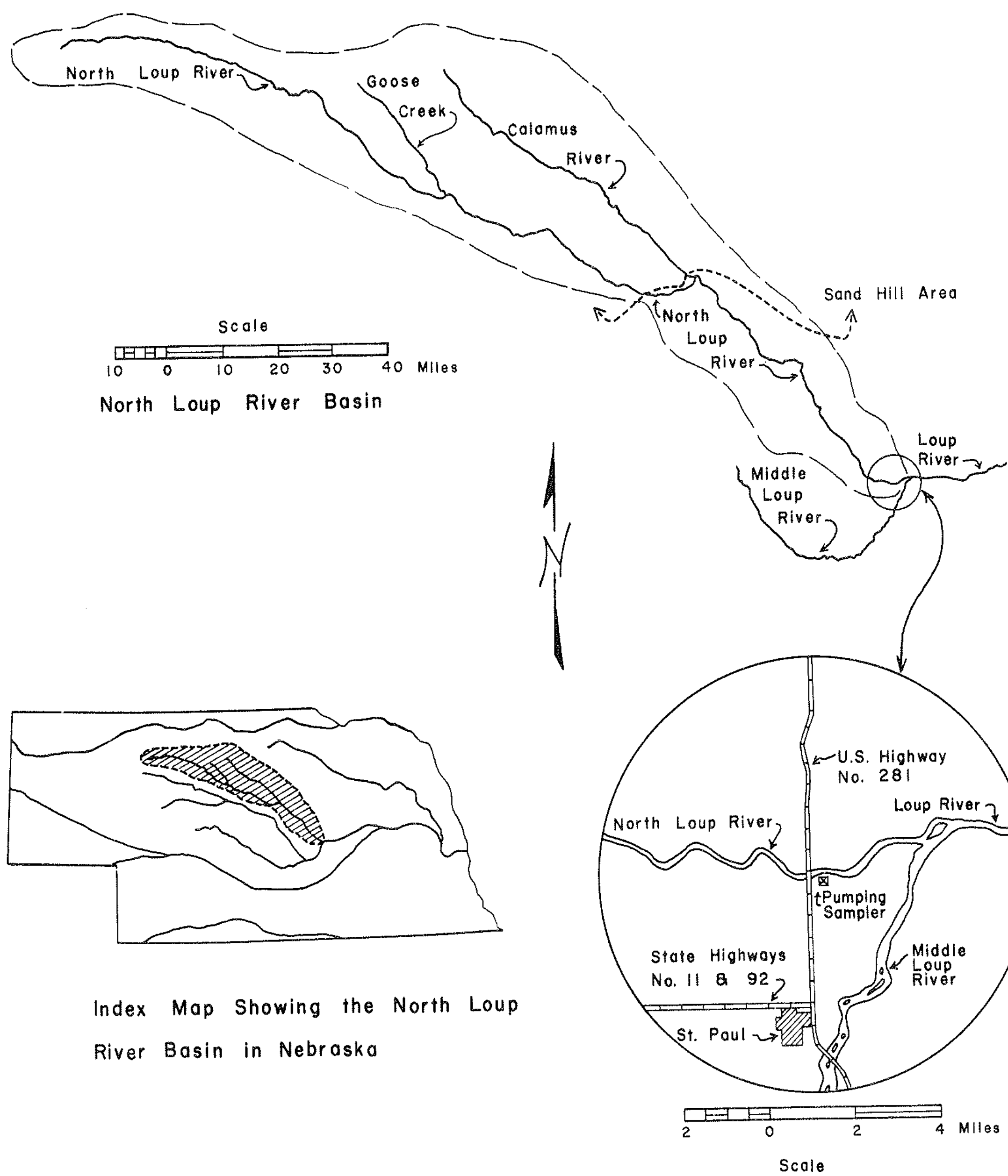


FIG. 9 — LOCATION OF FIELD TESTING SITE

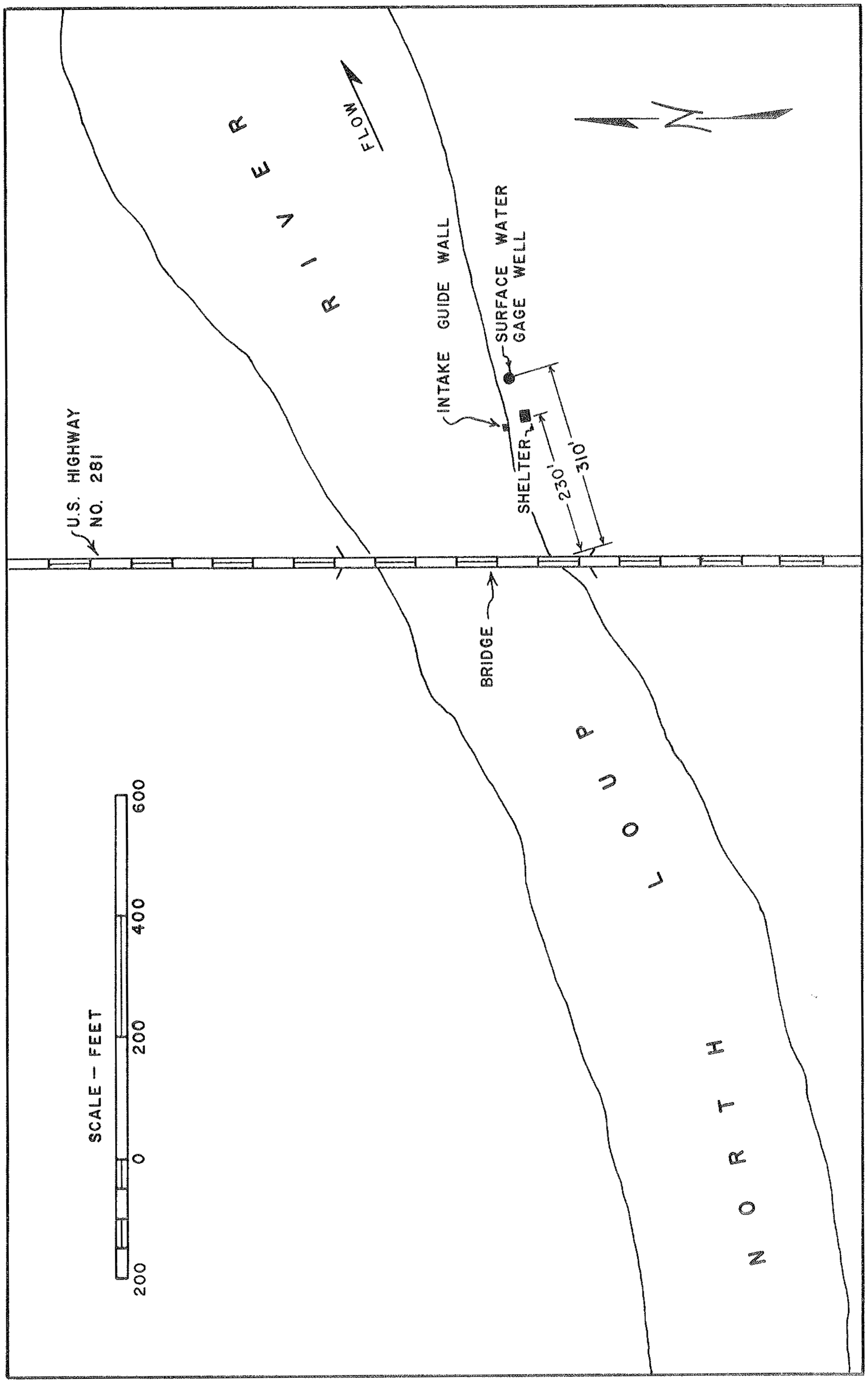


FIG. 10 — REACH OF THE NORTH LOUP RIVER NEAR ST. PAUL, NEBR.

TABLE 1

SUMMARY OF WATER DISCHARGE NORTH LOUP RIVER FOR PERIODS OF SAMPLER OPERATION
(cfs)

	No. Days	Mean	Maximum	Minimum
1957 (September 2 - November 20)				
September 2-30	29	957	2,670	544
October	31	1,095	2,440	836
November 1-20	20	1,119	1,350	968
Period	80	1,051	2,670 on 9/14	544 on 9/3-4
1958 (April 30 - October 8)				
April 30	1	1,450	1,450	1,450
May	31	1,016	1,370	790
June	30	913	1,170	696
July	31	1,435	4,860	685
August	31	558	1,030	406
September	30	711	1,280	452
October 1-8	8	891	942	836
Period	162	929	4,860 on 7/24	406 on 8/21
1959 (April 28 - October 26)				
April 28-30	3	1,087	1,130	1,040
May	31	1,060	1,370	824
June	30	738	1,730	526
July	31	675	2,020	291
August	31	450	588	303
September	30	721	1,070	509
October 1-26	26	976	1,090	824
Period	182	770	2,020 on 7/6	291 on 7/31

	No. Days	Mean	Maximum	Minimum
1960 (May 18 - November 1)				
May 18-31	14	1,258	1,620	1,110
June	30	961	1,760	727
July	31	668	1,180	393
August	31	577	1,180	334
September	30	667	968	406
October	31	912	1,050	817
November 1	1	922	922	922
Period	168	799	1,760 on 6/19	334 on 8/4
1961 (April 14 - October 3)				
April 14-30	17	960	1,240	791
May	31	1,153	3,370	832
June	30	947	3,250	654
July	31	463	778	259
August	31	575	1,070	298
September	30	806	1,100	548
October 1-3	3	887	922	847
Period	173	806	3,370 on 5/31	259 on 7/18

The figures shown from September 1957 to September 1960 are from U. S. Geol. Survey Water-Supply Papers 1510, 1560, 1630, and 1710. The figures shown from October 1960 to October 1961 are from provisional records and are subject to revision.

17,200 ppm (parts per million) on April 27, 1951, and the maximum observed concentration was 33,600 ppm at 9:45 a.m., April 27, 1951.

Periodic suspended-sediment discharge measurements were made on the North Loup River near St. Paul, Nebr., from July 1, 1953 to September 30, 1961. Results of the measurements made during periods of sampler operation are shown in Table 2. The maximum observed concentration for the above period was 23,000 ppm at 9:30 a.m., July 9, 1958.

The size gradation of the suspended sediment at the St. Paul test site is shown in Fig. 11. The main source of suspended sediment during high flows is storm runoff from the loess region in the lower part of the North Loup River basin. Size analyses of suspended-sediment samples from periods of high flow show that the median particle size is about 9 microns (Fig. 11-A). During periods of low stream flow the main source of suspended sediment is stream channel material which originated in the sand hill area. Size analyses of suspended-sediment samples collected during periods of low flow show that the median particle size is about 69 microns (Fig. 11-B). (Fig. 11-C shows the size gradation of the suspended sediment at the Dunning test site described in Section 18.)

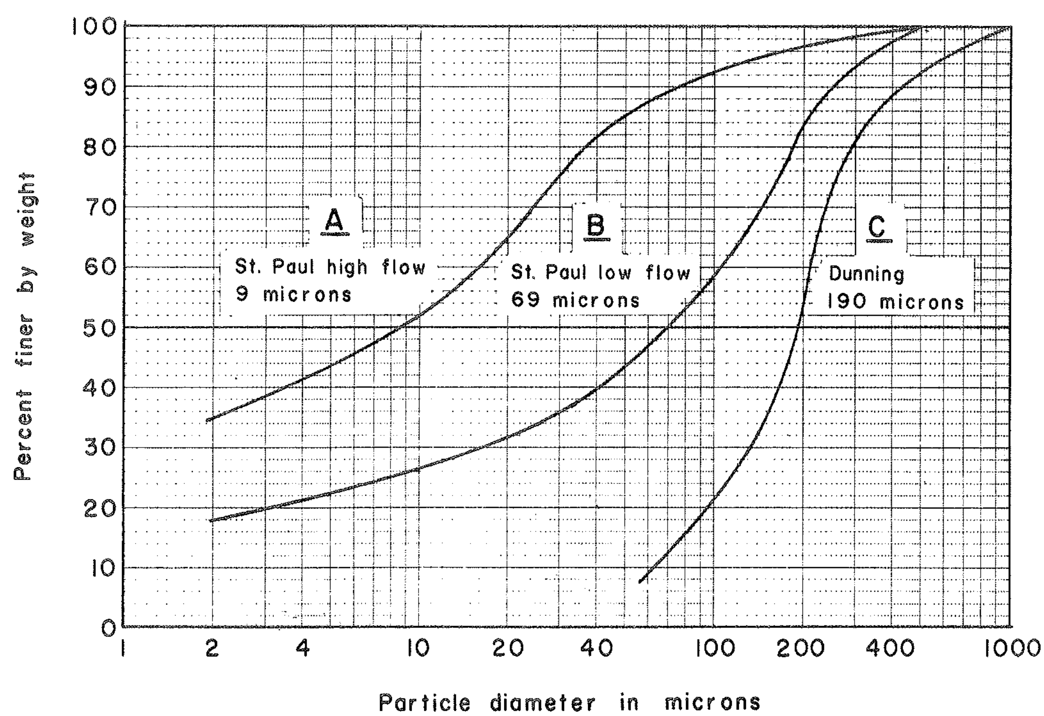


FIG. 11 SIZE GRADATION OF SUSPENDED SEDIMENT AT FIELD TEST SITES

TABLE 2

SEDIMENT DISCHARGE MEASUREMENTS NORTH LOUP RIVER
FOR PERIODS OF SAMPLER OPERATION

Date	Time	Location	Suspended Sediment								
			Concentration (ppm)	Percent finer than indicated size (microns)							
				2	4	16	62	125	250	500	1,000
				Pipette analyses			Visual accumulation tube analyses				
1957 (September 2 - November 20)											
Sept. 16	10:25 am	Bridge	536	22	22	30	50	68	87	100	--
Sept. 30	4:25 pm	Bridge	260	--	--	--	43	60	91	100	--
Oct. 14	11:40 am	Bridge	343	--	--	--	43	58	73	100	--
Oct. 28	12:35 pm	Bridge	430	--	--	--	26	46	82	98	100
Nov. 12	10:10 am	Bridge	356	--	--	--	25	42	77	99	100
1958 (April 30 - October 8)											
May 12	12:40 pm	Bridge	226	--	--	--	35	53	78	100	--
May 26	10:45 am	Bridge	313	--	--	--	44	56	80	98	100
June 9	11:10 am	Bridge	278	--	--	--	48	63	92	100	--
June 17	5:15 pm	S.W. gage	302	--	--	--	--	--	--	--	--
June 23	12:50 pm	Bridge	291	--	--	--	58	72	92	100	--
July 7	6:10 pm	Bridge	771	45	53	68	89	94	98	100	--
July 9	3:00 pm	Bridge	11,200	42	54	69	93	96	98	100	--
July 20	9:25 am	Bridge	3,700	27	30	41	88	92	97	100	--
July 21	2:55 pm	Bridge	2,740	11	12	17	71	79	91	100	--
Aug. 4	11:15 am	Bridge	257	--	--	--	77	86	99	100	--
Aug. 18	12:30 pm	Bridge	150	--	--	--	83	90	98	100	--
Aug. 26	1:50 pm	S.W. gage	311	--	--	--	--	--	--	--	--
Sept. 8	12:10 pm	Bridge	350	--	--	--	68	77	94	100	--
1959 (April 28 - October 26)											
June 3	1:15 pm	Samp. Intake	246	--	--	--	--	--	--	--	--
June 24	10:35 am	Samp. Intake	543	--	--	--	--	--	--	--	--
Aug. 22	1:35 pm	Samp. Intake	166	--	--	--	--	--	--	--	--
1960 (May 18 - November 1)											
July 14	4:45 pm	Samp. Intake	418	--	--	--	--	--	--	--	--
Sept. 14	4:30 pm	Samp. Intake	200	--	--	--	--	--	--	--	--
1961 (April 14 - October 3)											
May 16	11:15 am	Samp. Intake	400	--	--	--	--	--	--	--	--
June 20	4:50 pm	Samp. Intake	371	--	--	--	--	--	--	--	--
Sept. 14	1:00 pm	Samp. Intake	548	--	--	--	--	--	--	--	--

The figures shown for September, 1957, are from U. S. Geol. Survey Water-Supply Paper 1521. The figures shown from October, 1957, to September, 1961 are from provisional records and are subject to revision.

14. Shelter--An 8 by 10 ft frame building (Fig. 12) to shelter the test equipment was constructed 30 ft from the right bank of the river and 230 ft downstream from the highway bridge. A sedimentation tank and pumping equipment are contained in the shelter foundation. A waste way carries unwanted samples back to the stream. The large double door on the stream side of the building is an exit for emptying the weighing pan. A 110-220 volt electric service is supplied by the local R.E.A. Company.

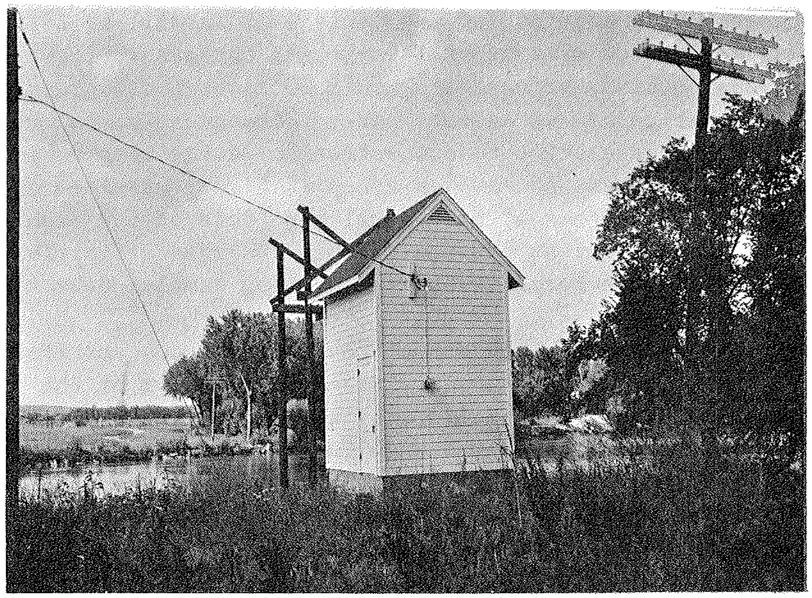


FIG. 12A

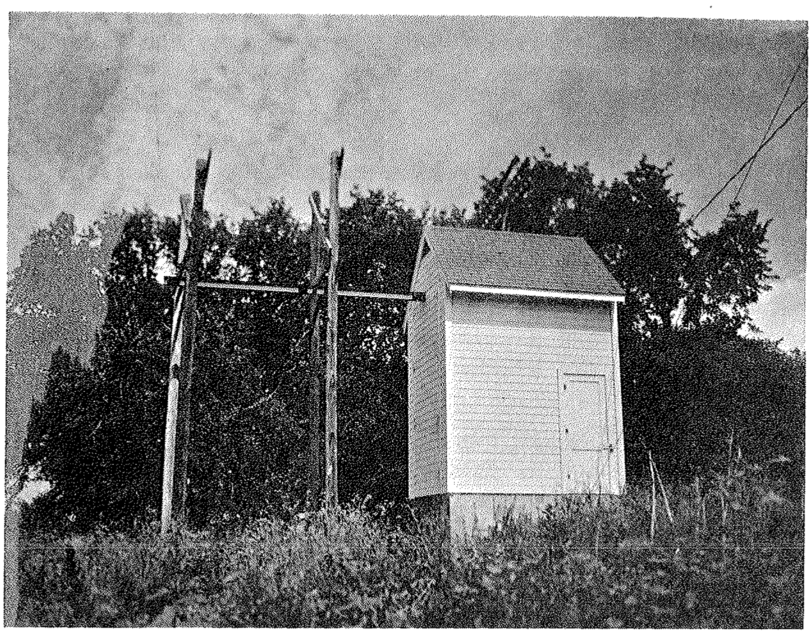


FIG. 12B

FIG. 12 PUMPING SAMPLER SHELTER

15. Field testing program--Suspended-sediment samples were collected and analysed to determine the following basic pumping sampler relationships:

(1) Basically, a pumping sampler is used to determine the concentration of suspended sediment at the sampler intake (point of sample intake from river). So a primary problem of pumping sampler usage is determination of the relationship of the average concentration in the stream cross section to that at the sampler intake. The relationship is needed before pumping sampler data can be used to define concentration of suspended sediment in the stream cross section. The relationship depends on many variables; it will be different at different sites; and at a given site it will vary with changes in local conditions. Therefore, an extensive study at one site would not contribute greatly to the understanding of the relationship at another site. Consequently, the relationship of concentration in the cross section to concentration at the sampler intake was determined only for a few series of samples taken at different times during the sampling season. These samples showed the general magnitude of the problem on a stream such as the North Loup River at St. Paul, Nebr. Further definition of the relationship was not considered necessary to the pumping sampler development program.

(2) The relationship of the sediment concentration in pumped samples to that in the river at the sampler intake is a measure of the efficiency of the pumping sampler intake. The uniformity of concentration during the sampling time as shown later in Table 5, and the high velocity in the intake system both show that there is no accumulation of sediment in the intake system during sampling. Therefore, the relationship between concentration in the pumped samples and in those taken at the sampler intake is a measure of the sampling efficiency of the intake port or opening. Velocity past the intake and size of sediment involved are the two main variables that affect intake efficiency. As a part of the intake development program samples were taken at the St. Paul site and analyzed to define the pumping sampler intake efficiency. An additional series of tests was made on the Middle Loup River near Dunning, Nebr. where the sediment in suspension was coarser than that at St. Paul.

The intake efficiency is based on the concentration in the pumped samples. Any losses in the flushing water (Section 27), or errors in recording the concentration in the samples, are not part of the intake efficiency.

(3) The splitter should remain in the presampling, or waste position until the concentration in the pumped sample becomes uniform. A study of the length of time required to reach uniformity was a part of the splitter development program.

16. Relation of sediment concentration in the river to that at the sampler intake--At various times throught the period of sampler operation depth integrated suspended-sediment samples were taken at 20 or more verticals in the river cross section near the gaging station at the St. Paul sampling site for comparison with samples taken from the river at the sampler intake. The cross section samples were collected from the downstream side of the highway bridge or by wading at, or near, the pumping sampler intake. Samples were collected using a U. S. DH-48 or a U. S. D-49 suspended sediment sampler. Samples at the pumping sampler intake

were taken with the U. S. DH-48 nozzle held at the intake elevation and about six inches from the intake opening.

Data from the samples show the general cross section to intake relationship at the St. Paul sampling site. The average sediment concentration based on the cross section samples ranged from 150 ppm to 11,200 ppm. The ratio of the average concentration in the river to the concentration at the intake ranged from 0.97 to 1.67 (Table 3). During the summer of 1959 the Nebraska State Highway Department dumped fill along the right bank of the river to protect the bridge abutment. The fill caused the main flow of the river to move away from the right bank and from the sample intake. The deflection of the river flow increased the cross section ratio. Also, low water discharge during the 1961 operational period further increased the cross section ratio.

TABLE 3

CROSS SECTION SAMPLES NORTH LOUP RIVER NEAR ST. PAUL NEBR.

Date	Cross Section Samples			Intake Samples		Cross Section Ratio (1)
	Time	Location	Avg. Conc. (ppm)	Time	Conc. (ppm)	
6/9/58	10:45 am	Bridge	278	11:55 am	280	0.99
6/17/58	5:15 pm	S.W. gage	302	5:25 pm	236	1.28
6/23/58	12:30 pm	Bridge	291	1:50 pm	225	1.29
7/7/58	6:10 pm	Bridge	771	7:05 pm	747	1.03
7/9/58	3:00 pm	Bridge	11,200	4:45 pm	10,200	1.10
8/18/58	12:30 pm	Bridge	150	1:10 pm	155	0.97
8/26/58	1:50 pm	S.W. gage	311	2:10 pm	218	1.43
6/3/59	1:15 pm	Samp. Intake	246	1:35 pm	208	1.18
6/24/59	10:35 am	Samp. Intake	543	10:45 am	414	1.31
8/22/59	1:35 pm	Samp. Intake	166	1:40 pm	127	1.31
7/14/60	4:45 pm	Samp. Intake	418	5:05 pm	320	1.31
9/14/60	4:30 pm	Samp. Intake	200	4:45 pm	145	1.37
5/16/61	11:15 am	Samp. Intake	400	11:40 am	239	1.67
6/20/61	4:50 pm	Samp. Intake	371	5:00 pm	229	1.62
9/14/61	1:00 pm	Samp. Intake	548	1:15 pm	342	1.60

(1) Cross Section ratio is the average cross section conc./intake conc.

17. Intake tests at St. Paul site--Nearly simultaneous samples were collected from the splitter discharge and from the river at the sampler intake at the St. Paul sampling site. Samples at the sampler intake were taken as explained in the preceding section. The relationship of the concentration of the pumped sample taken at the splitter to that of the river at the intake (intake efficiency) was

determined periodically. The flat plate intake, elbow intake, and nipple intakes shown in Fig. 5 were tested.

The average velocity of the river at the intake is about 1.4 fps. The velocity of the sample pumped through the intake opening is about 4.5 fps. So the velocity ratio is about 3 to 1. The suspended-sediment discharge in the North Loup River past the gaging station is described in Section 13.

The results of the flat plate intake tests at St. Paul are shown in Fig. 13 and in Appendix A, Table 10. Concentrations shown are averages of two or more bottle samples and those taken just outside the sampler intake ranged from 146 ppm to 20,900 ppm. Equal concentrations at the splitter and at the sampler intake are shown by the 45^{o} diagonal line. The intake efficiency (splitter concentration/ intake concentration) ranged from 0.94 to 1.11.

The results of the modified intake tests at St. Paul are shown in Fig. 14 and 15 and Appendix A, Tables 11 and 12. The modified intakes could not be tested in high sediment concentrations because the intake structure is not sufficiently accessible for changing intakes during periods of high flow. The intake efficiency ranged from 0.94 to 1.11.

18. Intake tests at Dunning site--A portable pumping system was operated at the turbulence flume on the Middle Loup River at Dunning, Nebr., to test different types of intakes in flow carrying sediments coarser than that at the St. Paul site. The turbulence flume is a structure for inducing turbulence sufficient to suspend the total sediment load of a stream, [2]. A 2x12 in. plank 10 ft long was mounted on the bridge piling to form a guide wall. The end of the guide wall extended downstream from the piling and the intake was mounted directly above the measuring sill. The suction line to the pump was a 1-in. plastic pipe 50 ft long. Flow was controlled by a manual pinch valve on the discharge port of the pump. The total depth of water at the intake was 1.2 ft and the intake was located 0.5 ft above the measuring sill. The average velocity of the river at the intake was 4.92 fps. Size analyses of the suspended-sediment discharge passing over the measuring sill of the turbulence flume at the sampler intake show that the median particle size is about 190 microns (Fig. 11-C).

Results of the Dunning intake tests are shown in Table 4. The intakes tested were the same as those tested at the St. Paul installation with the addition of 1/2-in. and 2-in. flat plate intakes. When the ratio of intake velocity to stream velocity was greater than 0.60, the 1-in. flat plate intake had an intake efficiency (sample concentration/river concentration at sampler intake) of around 0.80; but the intake efficiency dropped sharply when the velocity ratio fell below 0.60. The 2-in. flat plate intake maintained a high intake efficiency for lower velocity ratios.

19. Evalutation of intake tests--Ideally the pumping sampler would sample as accurately as a point integrating sampler [4]. Because this accuracy cannot be obtained for many conditions, an attempt was made to develop an intake system that would collect a point sample having a concentration related to that in the stream. A correction factor can be determined to adjust the sample concentration.

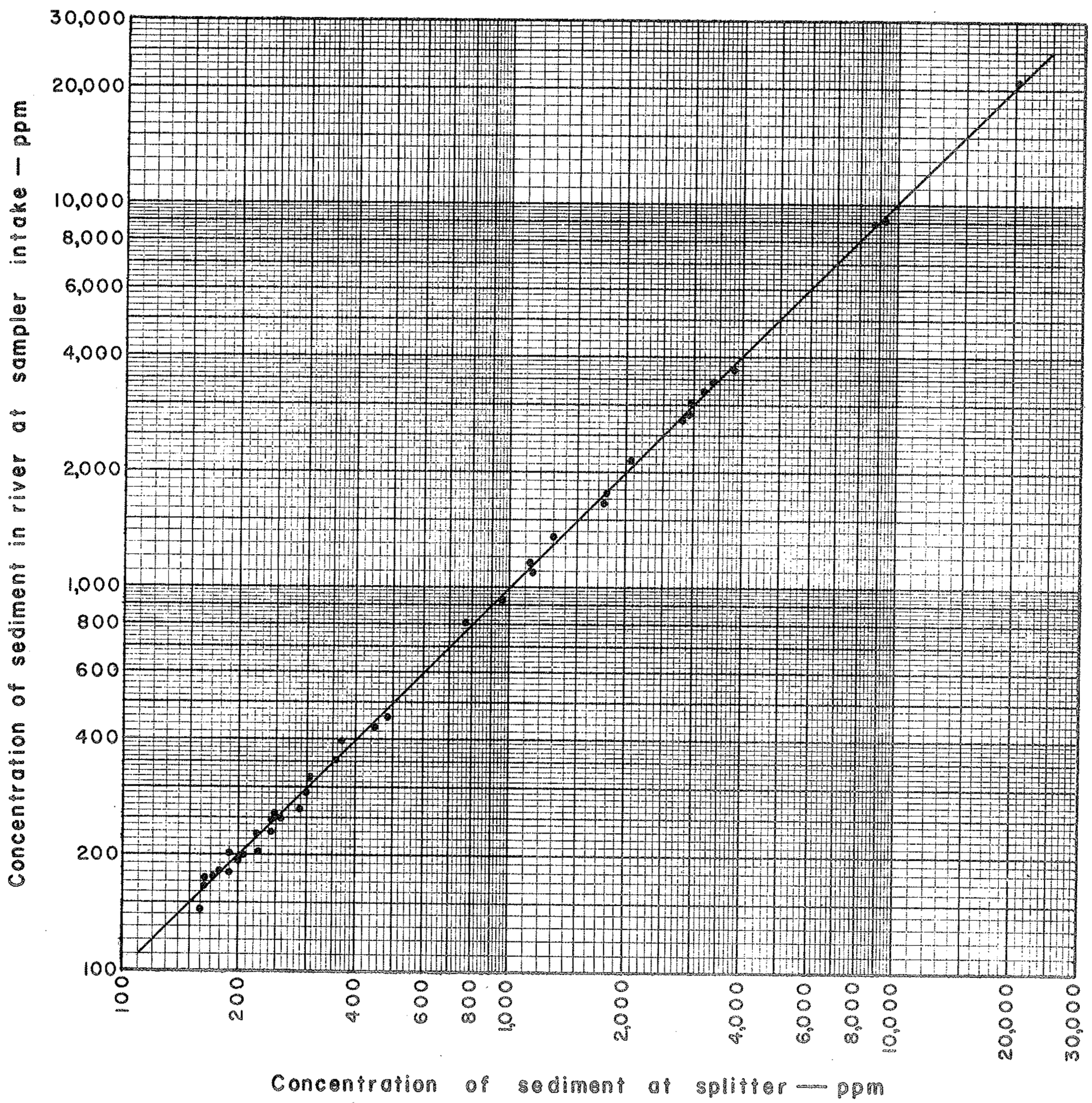


FIG. 13 — RESULTS OF FLAT PLATE INTAKE TESTS AT ST. PAUL

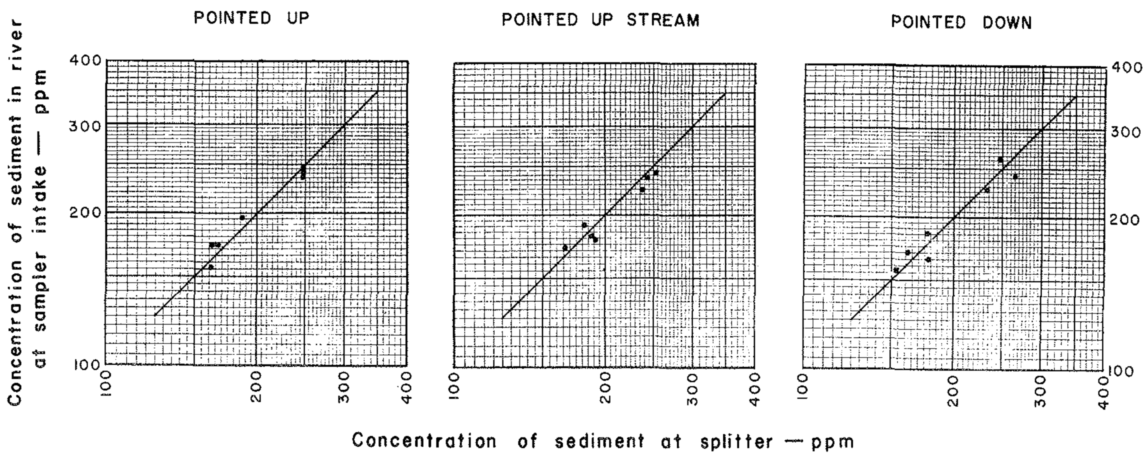


FIG. 14 RESULTS OF ELBOW INTAKE TESTS AT ST. PAUL

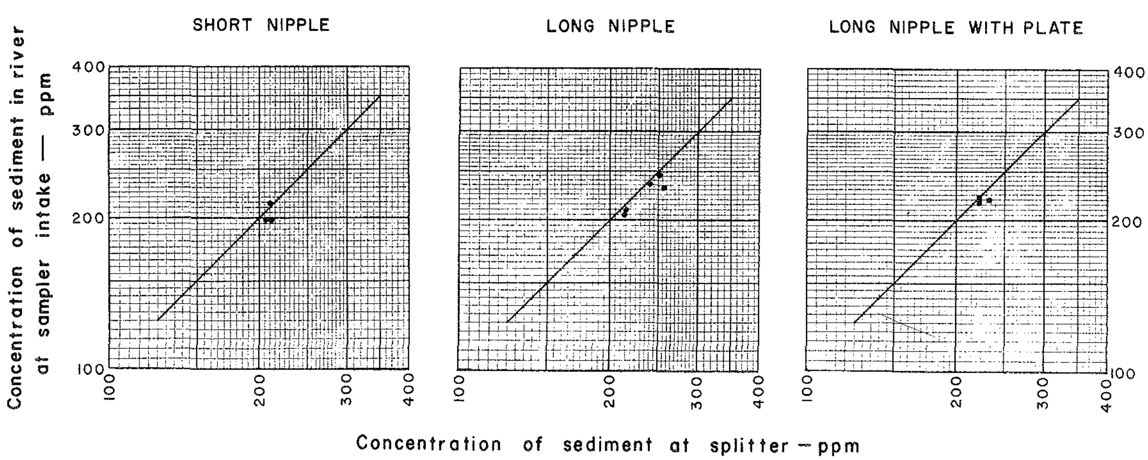


FIG. 15 — RESULTS OF NIPPLE INTAKE TESTS AT ST. PAUL

TABLE 4

INTAKE TESTS AT DUNNING, NEBR.
[Samples collected 6/5/59]

Intake	Time	Intake Velocity (fps)	Velocity Ratio (1)	Pumped Sample Conc. (ppm)	River Sample Conc. (ppm)(2)	Intake Efficiency (3)
1" Flat plate	11:20 am	6.96	1.41	2,140	2,845	0.75
	2:25 pm	6.96	1.41	1,770	2,170	0.82
	3:55 pm	6.96	1.41	1,320	1,720	0.77
	11:55 am	3.18	0.65	1,650	1,800	0.92
	2:30 pm	2.67	0.54	1,880	2,680	0.70
	3:58 pm	3.47	0.70	1,420	1,720	0.83
	4:02 pm	1.82	0.37	994	1,720	0.58
	4:05 pm	1.44	0.29	717	1,720	0.42
2" Flat plate	3:05 pm	2.27	0.46	1,290	1,870	0.69
	3:10 pm	0.81	0.16	1,280	1,780	0.72
1/2" Flat plate	3:35 pm	20.94	4.26	977	1,960	0.50
	3:40 pm	9.62	1.96	997	2,020	0.49
1" x 2" Nipple	1:15 pm	10.45	2.12	1,040	859	1.21
	1:20 pm	4.00	0.81	750	967	0.79
1" x 9" Nipple	1:30 pm	10.45	2.12	719	830	0.87
	1:35 pm	4.00	0.81	750	989	0.76
1" El. pointed Downstream	1:40 pm	10.45	2.12	686	960	0.71
	1:45 pm	4.36	0.89	842	975	0.86
1" El. pointed Upstream	1:50 pm	10.45	2.12	1,460	1,670	0.87
	1:55 pm	4.00	0.81	1,070	980	1.09
1" El. pointed Up	2:00 pm	10.45	2.12	1,130	1,140	0.00
	2:05 pm	4.35	0.89	1,120	1,040	1.08

(1) Intake velocity divided by 4.92 (average velocity of river at sampler intake).
(2) At sampler intake.
(3) Concentration in pumped sample divided by concentration in river sample.

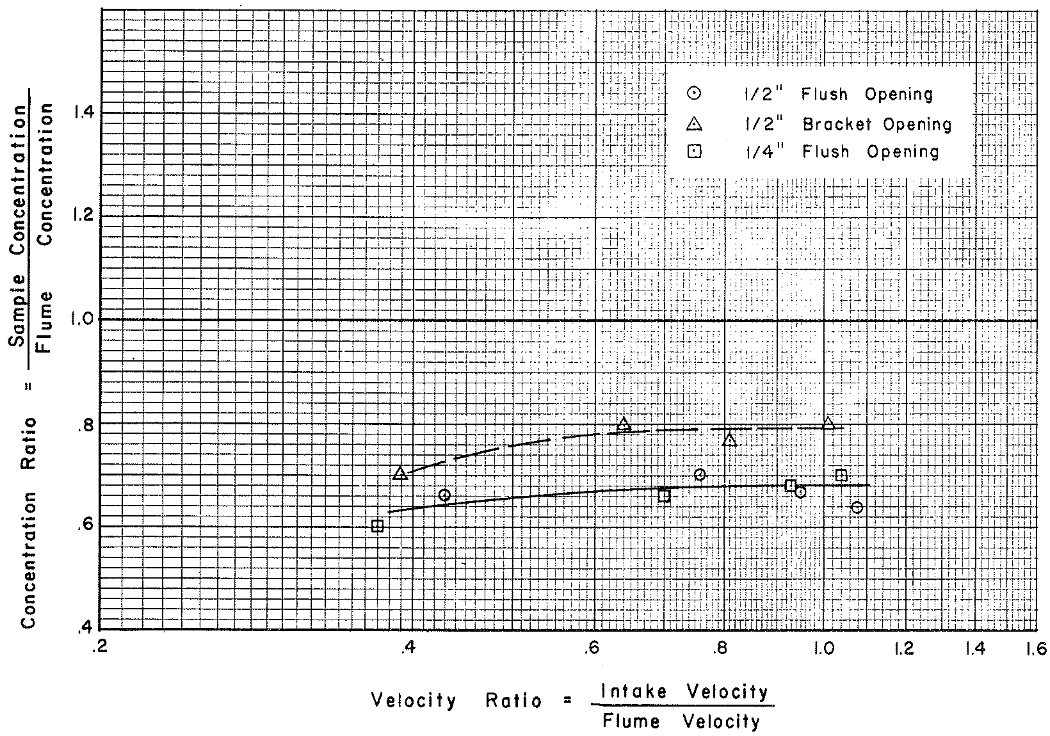
An intake structure that will withstand the dynamic forces of the stream and an intake opening that will give trouble-free operation were considered more important than optimum intake efficiency. From the standpoint of dependable operation the intake structure (Fig. 4) and the flat plate intake (Fig. 5) were satisfactory at the St. Paul test site.

The first of two series of laboratory investigations on flat plate intakes was made at the University of Iowa of 1940-41. [3] The tests were made on a vertical flat plate set parallel to the flow. When a water-sediment suspension enters a flat plate intake the momentum of the sediment resists the right-angle change of direction of flow, and some of the sediment separates from the flow that enters the intake. For sediments with mean sizes of 150 and 450 microns the Iowa tests showed that the concentration of sediment in the samples collected through the flat plate intake was much less than that in the flume flow. Because coarse particles have a greater resistance to change of direction than fine particles have, the difference in concentration in sample and flume was greater for the coarser sediment.

The second series of laboratory tests on the flat plate intake was made by B. C. Colby at Colorado State University in 1959. The tests were conducted in a flume 2 ft wide and the flow was 1 ft deep with a velocity of 8.5 fps. Suspended sediment of 550 microns size was circulated in concentration of about 1,000 ppm. Tests were made on 1/2-in. and 1/4-in. flat plate intakes and a 1/2-in. bracket intake which was obtained by placing a horizontal shelf 2 in. wide and 6 in. long just under the 1/2-in. flat plate intake opening. The intakes were much too large for dependable testing in the flume. Also, the concentration of sediment in the flume could not be determined accurately for the immediate area from which the sample was taken. The results of the Colorado tests (Shown in Fig. 16) indicate less sediment concentration in the sample than in the flume flow. The addition of the horizontal shelf slightly reduced the sampling error. The 550-micron sediment and high flume velocity would represent extreme field conditions so that sampling errors were probably unusually high. The tests further indicated that the sampling error tends to become constant at higher velocity ratios.

The flat plate intake and the modified intakes (Fig. 5) were field tested at the St. Paul and Dunning sites. The St. Paul tests showed that, for a low-velocity stream with suspended sediment in the fine sand sizes and smaller (Fig. 11-A,B), the intake efficiency (ratio of pumped sample concentration to river concentration at intake was very nearly unity (Fig. 13). Also, the tests indicated that the sampling efficiency of the flat plate intake was as good as that of the modified intakes (Fig. 14 and 15). The Dunning tests showed that, for a high-velocity stream with suspended sediment consisting of coarse sands (Fig. 11-C, the intake efficiency is considerably less than one (Table 4).

Although field and laboratory intake tests were not extensive enough to justify final conclusions, it seems that an intake efficiency above 80 percent could be obtained for most river conditions. At most sampler sites a few check samples will establish a correction factor for intake efficiency. Because the flat plate intake is less likely to catch river debris, it is recommended for sites where the intake correction factor is neither extremely large nor highly variable.



FLUME VELOCITY 8.5 FT PER SEC; 550 MICRON SEDIMENT

FIG. 16 RESULTS OF COLORADO INTAKE TESTS

20. Splitter timing tests--Three tests were made in which a series of 7 to 13 individual samples were collected at the splitter discharge to determine the length of time required for the pump to obtain a representative sample from the river. The first sample in each of the three tests was collected 5 seconds after the pump started. Additional samples were collected at 10 to 30 second intervals during a period of about 2-1/2 minutes. The results of these tests are shown in Table 5. In each of the tests the sediment concentration in the splitter discharge became constant about 30 seconds after the silt pump started. As a result of these tests the pumping controls are set so that the splitter remains in the presampling or waste position from 40 to 50 seconds. The uniform sediment concentration in the splitter discharge is an indication that none of the sediment is depositing in the intake and pumping system during the pumping cycle.

TABLE 5

SPLITTER TIMING TESTS

Time delay secs	Sample Concentration (ppm)			
	5/14/58 10:00 am	5/14/58 2:05 pm	7/9/58 6:30 pm	
0				Tests to determine time for concentration in pumped sample to become uniform. Time delay is from time pump started to time collection of sample started. Sampling time about 5 secs per sample.
5	43	353	2,920	
10			6,510	
15	379	556		
20			8,950	
25		1,710		
30	454		8,990	
35		1,780		
45		1,780	9,030	
60	448	1,730	9,060	
75		1,770	9,020	
90	442	1,800	9,030	
105		1,740	9,050	
120	465	1,770	9,090	
135		1,770		
150	453	1,820		
165		1,720		

IV. OPERATIONAL RECORD OF INTAKE AND PUMPING SYSTEM

21. Period of operation--The pumping sampler was operated from September to November, 1957, and for several of the warmer months each year from 1958 to 1961. The system was shut down during the winter because of the 500 mile travel distance to the station and the expense of keeping the intake free of ice.

22. The operational record--The operational record of the pumping sampler including the periods and causes of operational failures is shown in Fig. 17. The first period of operation in 1957 (September 2--November 20, 1957) was for checking the general operation of the system. There were two operational failures during this period. The first failure was caused by a malfunction of the water level control in the sedimentation tank. An early winter freeze and heater failure caused the second operational failure.

During the 1958 season (April 30--October 8, 1958) the sampler operated 123 days of the 162 day period for a 76 percent record. There were six operational failures during this period. Three of the failures were due to fish that entered the intake pipe. The fish either caught in the check valve and stopped the flow to the pump, or entered the pump and damaged the impeller. The other three failures were caused by the shifting of the river bed which covered the intake with sediment.

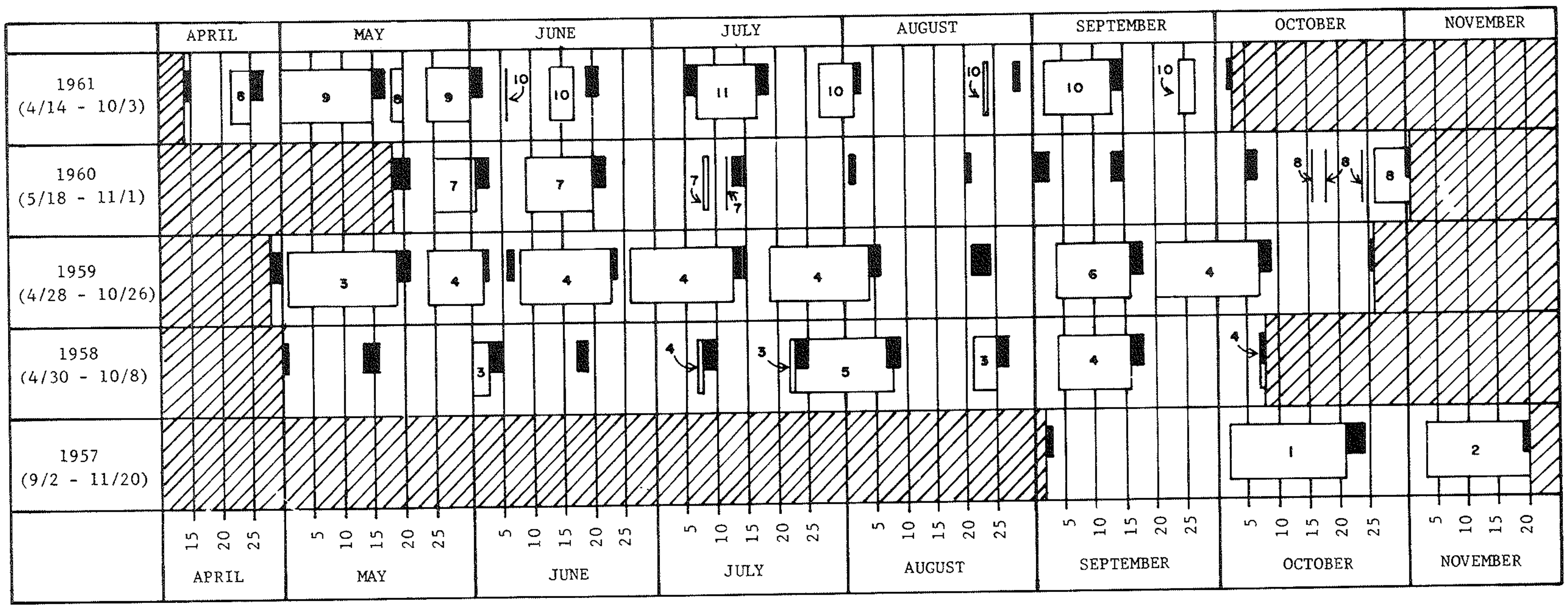
During the 1959 season (April 28--October 26, 1959) the intermittent pumping sampler was in operation only 77 days of the 182 day period for a 42 percent record. There were seven operational failures during this period. The first failure was caused by a fish that entered the intake. Five failures were caused by silt that covered the intake and one failure was caused by a malfunction of the pump relay.

During the 1960 season (May 18--November 1) the sampler operated 136 days of the 168 day period for a 81 percent record. There were eight operational failures. Four failures were caused by malfunction of the initial flow indicator, and four failures were caused by silt that covered the intake.

During the 1961 season (April 14--October 3) the sampler operated 106 days of the 173 day period for a 61 percent record. There were 11 operational failures. Two failures were caused by silt that covered the intake. Two failures were caused by blown fuses. Six failures were due to plugging of the throttling valve. The sampler was shut down for one period to repair the volume recording sampler.

23. Evaluation of operational record--The original design of the pumping system was modified slightly between the 1957 and 1958 operating seasons. The tendency of the original float control to stick and prevent the completion of the splitter cycle was corrected.

Originally the pump operated without sufficient water when the intake was obstructed. A number of pump impellers were ruined and the pump shaft was damaged so that the pump had to be repaired. On July 23, 1958 a protection switch was



Personnel at station

CAUSES OF OPERATIONAL FAILURES

1 Float control not operating
2 Water in pump froze because of heater failure
3 Fish entered intake opening
4 Silt over intake opening
5 Pump damaged and needed overhauling
6 Pump relay stuck
7 Flow contacts coated - on 12-hour protection cycle most or all of day
8 Silt over intake opening - on 12-hour protection cycle most or all of day
9 Fuse blown by light shorting
10 Throttle valve plugged - on 12-hour protection cycle most or all of day
11 Volume recorder shut down for repair

FIG. 17 — PUMPING SAMPLER OPERATIONAL RECORD

installed on the splitter control of the accumulative-weight recorder. This switch shut off the pumping system whenever the intake became plugged, or the stream fell below the intake, or the pump failed to discharge for any other reason. The addition of the protection switch prevented any further pump damage, even though the sampler station was visited only every 2 or 3 weeks. During the remainder of the 1958 operating season the protection switch shut off the pumping system 3 times. Each shutdown just preceded a servicing period, and the length of the shutdown was usually short. However, during the 1959 season of operation most shutdowns occurred soon after servicing visits to the station and shutdown periods were longer. During most of the 1959 season water discharge was low. The low-water discharge past the intake structure allowed silt and sand to cover the intake opening several times.

A flow indicator and 12-hour protection system described in Sections 3 and 8, were designed in an attempt to shorten the shutdown periods. Four types of flow indicators were tried. The original flow indicator was installed at the beginning of the 1960 operating period. It depended upon the conductivity of an electrical circuit when water was flowing through the pump. However, fine sediment coated the electrodes between inspection trips so that the 12-hour protection system sometimes discontinued routine sampling even though the intake was clear. On July 14, 1960 the electrode flow indicator was replaced by a mechanically operated switch in the water-level control of the accumulative-weight recording sampler. The float-switch flow indicator worked very well but it could not be used on the timer controlled splitter arm of the volume recording sampler and of the bottling sampler. A vacuum-switch flow indicator mounted on the intake port of the pump was tested. The vacuum switch actuated the 12-hour protection system whenever the level of the river fell below the intake opening, but when the intake became plugged, the vacuum switch did not actuate the 12-hour protection system even though the pump lost its prime. The weight-actuated flow indicator (Section 8) has been used since the beginning of the 1961 operating period and it has worked very well.

On September 4, 1959 the pump relay failed. The original pump relay was used near load capacity. Continual operation near load capacity or occasional overloading damaged the relay contacts and caused the relay to stick in the closed position. Installation of a higher capacity relay corrected this difficulty.

There were three pumping system failures of the volume recording sampler during the 1961 operation period. The large discharge of the 1-in. pumping system used at the St. Paul site caused water to splash over the top of the splitter box and over the top of the sedimentation tubes. The splashed water shorted out the electrical system and stopped operation. Twice shorts blew fuses and once they ruined a limit switch and damaged the drive gear of the volume recording unit.

The flow was throttled down by partly closing a section of the pipe from the pump to the splitter with a clamp. Six periods of pumping system shutdown occurred at times of high sediment concentration when clogging of the constricted section actuated the 12-hour protection system. The difficulty was cured by using a smaller pump and 3/4-in. pumping system, which eliminated the need for the throttling device and also eliminated this source of trouble.

Operational failures have been caused by fish in the intake. A number of devices to keep fish from entering the intake were considered. An electric fish repelling device to mount on the intake guide wall was designed by the U. S. Fish and Wildlife Service. However, this was not used because of possible hazards. An intake guard of coarse wire screen was tried but it soon became clogged with grass and straw. Then the plastic pipe was clamped about 5 ft from the river intake to form a slit 3/8-in. wide. This was later replaced by the fish trap described in Section 5. The trap has successfully prevented fish from harming the pumping system.

The pumping system has failed several times in the past but in each case the cause of failure has been eliminated. Although the 12-hour protection system has reduced the shutdown periods, silt covering the intake is still the major cause of operational failure.

Three intakes were mounted in the face of the guide wall so the intake elevation could be changed as the river bed shifted. The intake can be easily adjusted to the desired elevation at the time the station is inspected but the intake can become obstructed by silt between inspection trips. In a deep river the intake can be placed far enough above the river bed to assure continuous operation, but the use of the present type of intake structure in a shallow shifting river requires frequent inspection to prevent operational failure.

V. ACCUMULATIVE-WEIGHT RECORDING SYSTEM

24. Basic weight recording system--The accumulative-weight recording system shown in Figs. 1 and 18, records the weight of the sediment accumulated during a sampling period. The sediment settles on a weighing pan suspended near the bottom of the sedimentation tank. A load measuring device is placed between the hoist and weighing pan and the accumulated load is recorded by a line graph recorder. The cycle of operation is explained in detail in Section 53 of Appendix B.

25. Sedimentation tank--The sedimentation tank is shown in Fig. 18. The tank is 4 ft 8 in. square and 6 ft deep. The wall is water-proofed concrete block and the floor is concrete. A floor drain and valve provide for emptying the tank.

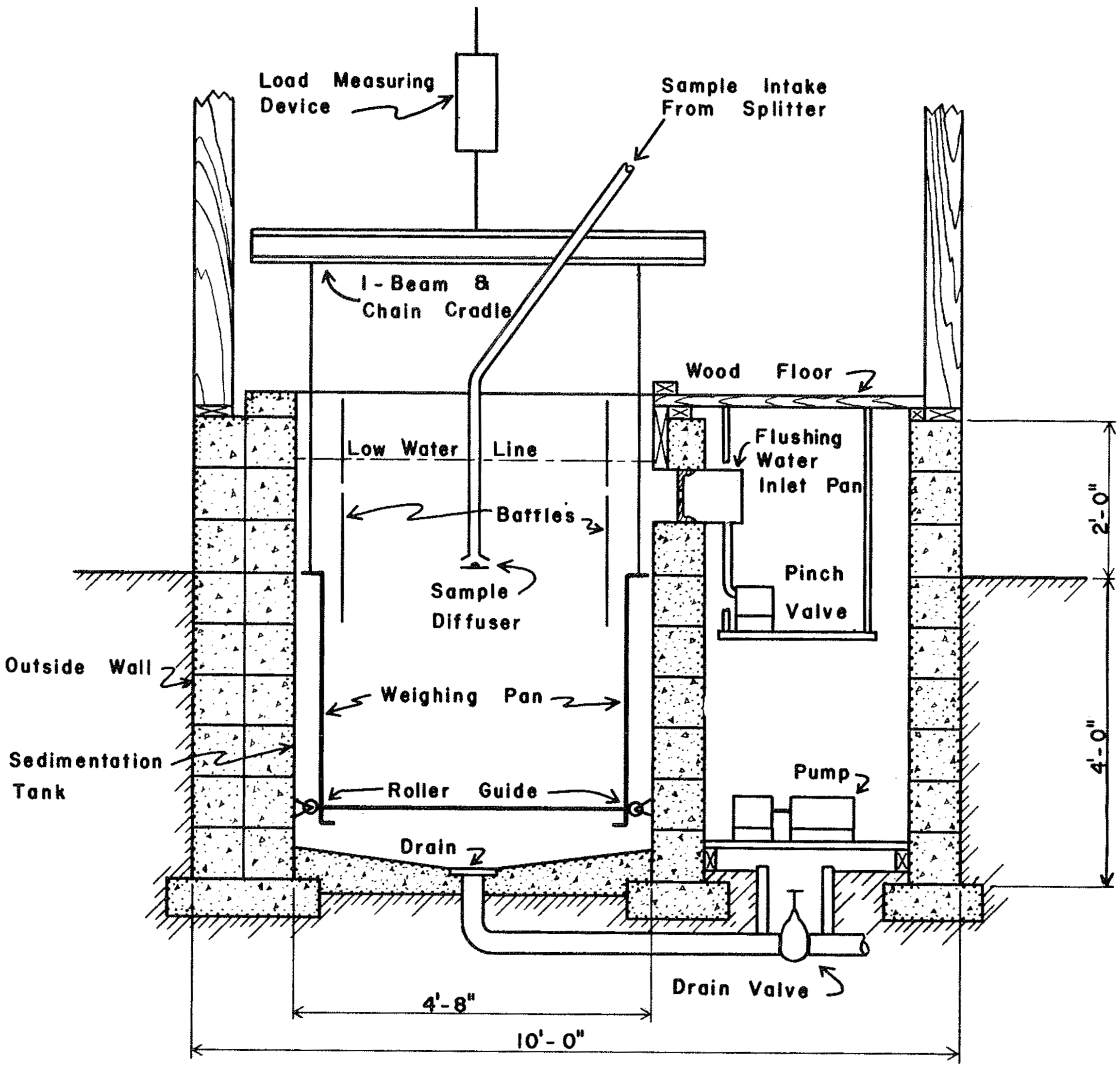
The sample from the splitter enters the tank through a diffuser that helps reduce the disturbing effect of the entering sample.

Clear water from the top of the sedimentation tank enters the solenoid pinch valve through an inlet pan. The water enters the pan through a series of ten 1-in. holes. This large hole area reduces the velocity of the flushing water that flows between the sedimentation tank and the pan and prevents water from being drawn from the lower levels of the tank.

Four sheet metal baffles direct the suspended sediment into the weighing pan. (See Fig. 18) The baffles are connected at the edges to form an open bottom box 3 ft square and 3 ft deep. The baffles contain a series of small openings just below the water surface to reduce circulation under the baffles when water is entering or leaving the sedimentation tank.

26. Weighing pan--The aluminum weighing pan, shown in Fig. 18 and 19, is 4 ft square and 3 ft deep. An I-beam and chain cradle suspends the weighing pan from the hoist. Roller guides mounted on the sides of the sedimentation tank reduce friction between the weighing pan and tank. The hoist is hung on an I-beam trolley so that the weighing pan can be moved outside the shelter. One side of the weighing pan is hinged at the top so that it can be opened to dump the sediment.

27. Tests of concentration in flushing water--When the pumped sample enters the sedimentation tank of the accumulative-weight recording system some of the fine sediment is raised toward the water surface by water circulation. This fine sediment does not settle below the elevation of the inlet holes in the flushing-water inlet pan (about 10 in. below the water surface) during the 25 minutes between pumping cycles. Periodic samples of the flushing-water discharge were collected to determine the amount of suspended sediment lost from the sedimentation tank. The results of the analysis of these samples are shown in Table 6. In the 11 tests the sediment concentration in the flushing water ranged from 11 to 36 percent of that in the river at the sampler intake. An average of 23 percent of the sediment obtained in the pumped sample was lost with the flushing water. The addition of a flocculating agent would decrease the settling time of these fine sediments and reduce the sediment concentration in the flushing water.



ELEVATION

FIG. 18 — SEDIMENTATION TANK AND PIT DETAILS

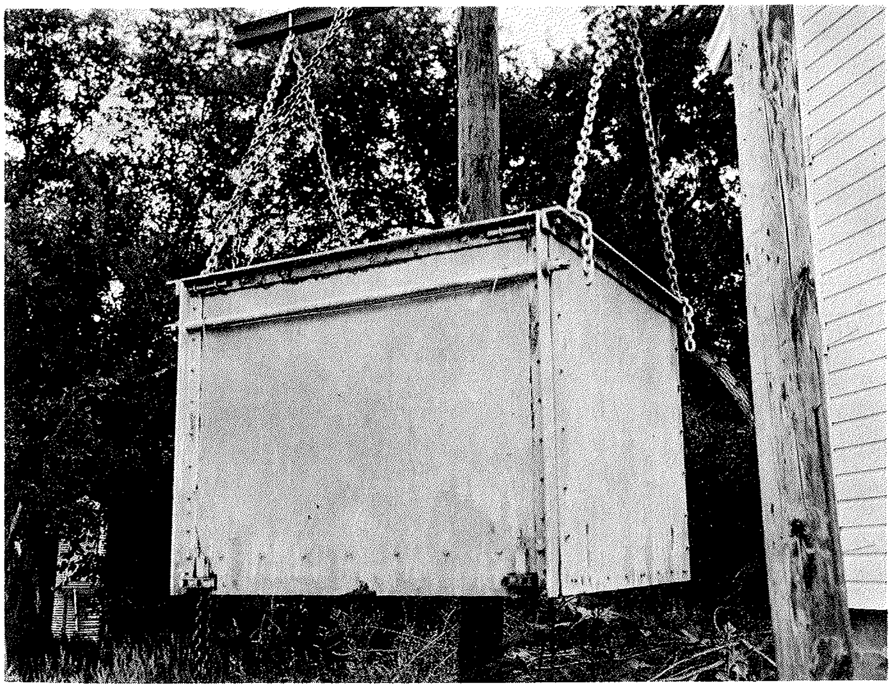


FIG. 19A

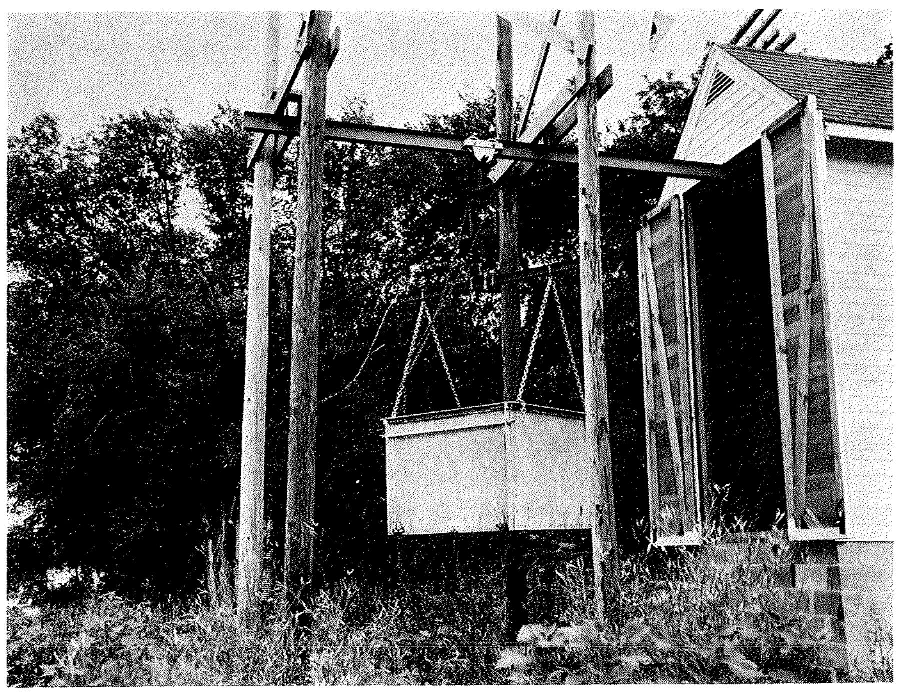


FIG. 19B

FIG. 19 — WEIGHING PAN

TABLE 6

TESTS OF SEDIMENT CONCENTRATION IN FLUSHING WATER

Date	Time	Intake Samples		Flushing Samples		Percent Loss
		No.	Avg. Conc. (ppm)	No.	Avg. Conc. (ppm)	
8/26/58	11:25 am	3	221	6	78	35
do	1:25 pm	3	224	3	77	34
do	2:25 pm	3	222	3	80	36
9/17/58	1:00 pm	3	364	3	63	17
do	1:30 pm	3	366	3	72	20
6/3/59	2:05 pm	2	204	2	34	17
6/7/59	2:10 pm	2	178	2	54	30
6/23/59	2:40 pm	2	1,180	2	128	11
6/24/59	11:10 am	2	418	2	66	17
10/8/59	9:15 am	2	1,340	2	265	20
do	4:45 pm	2	808	2	98	12
					Average loss	23

28. Crane scale--The crane scale, shown in Fig. 20, is an electrical load pick-up device. It contains a load sensitive column to which are bonded four wire strain gages. These gages form an electrical balanced-resistance bridge. The load sensitive member and strain gages are enclosed in a tubular shell. The shell and load sensitive member are screwed and pinned to an eye at one end and a swivel hook at the other. A four wire cable connects the crane scale to the recorder.

The circuit diagram of the crane scale is shown in Fig. 21. When a load is lifted, the strain changes the resistance in the strain gages and unbalances the bridge. The recorder supplies a fixed voltage to the crane scale bridge and the output voltage is proportional to the bridge unbalance and also to the load.

The load capacity of the crane scale is 2,500 pounds with a maximum deflection of 1/16 of an inch.

29. Recorder--The strip-chart recorder, shown in Fig. 22, consists basically of an automatic null-balancing measuring circuit with its power supply, a pointer indicator, and a recording pen.

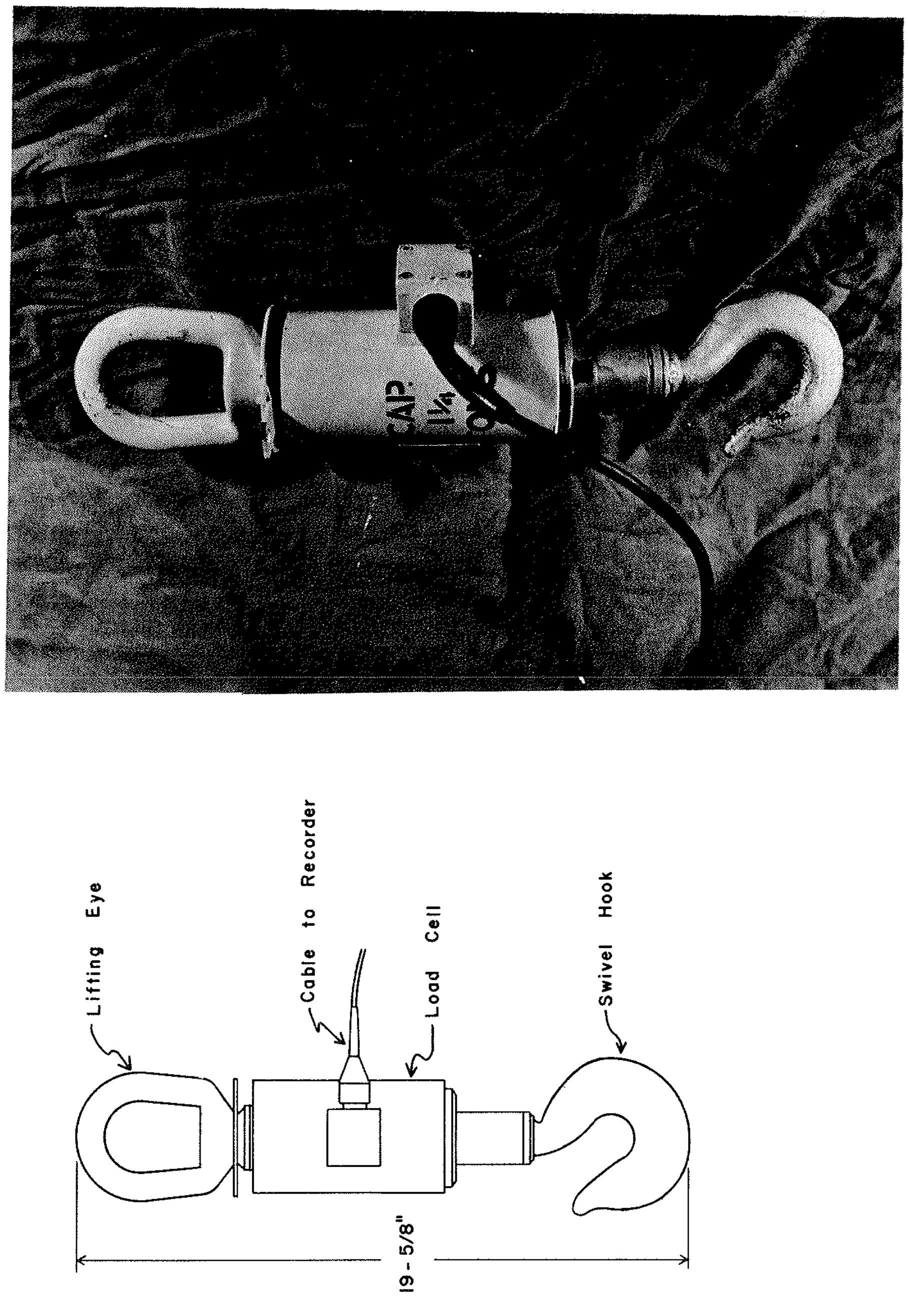


FIG. 20 — CRANE SCALE

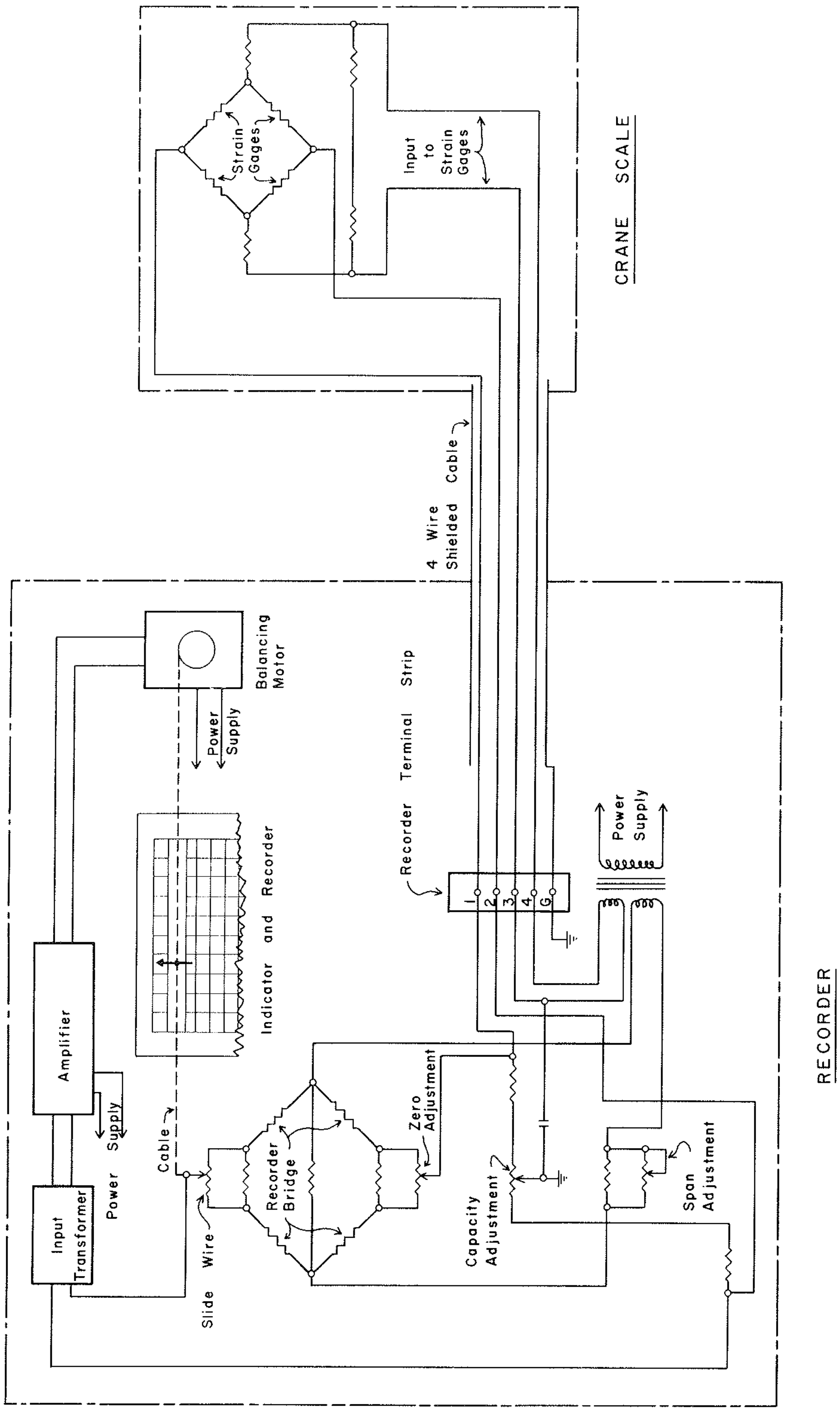


FIG. 21 — RECORDER AND CRANE SCALE CIRCUIT DIAGRAM

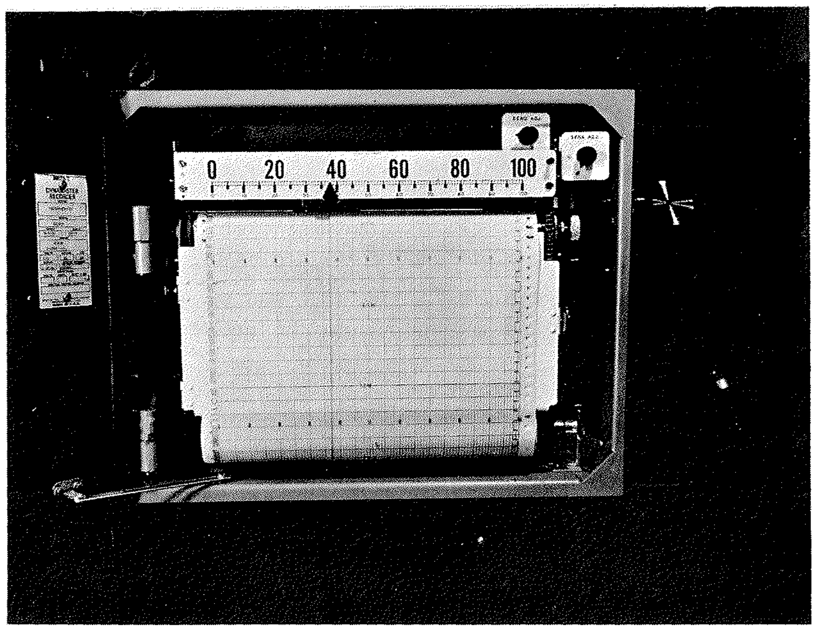


FIG. 22 STRIP-CHART RECORDER

The circuit diagram of the recorder is shown in Fig. 21. The power supply energizes the internal recording bridge as well as the crane scale bridge. The output voltages from the two bridges are compared in the recorder. The difference between the two output voltages is amplified and used to drive a balancing motor which in turn drives a slide wire contact arm in the direction that reduces the difference to zero. The slidewire constitutes one leg of the instrument bridge measuring circuit, and consequently the bridge output voltage is proportional to the slidewire contact position. The pointer indicator and recording pen are mechanically linked to the slidewire and the strip chart is graduated so that the indicator and pen show the load on the crane scale.

30. Computation of sediment concentration--The concentration of suspended sediment in the pumped sample is equal to

$$C = \frac{D_W}{P} \times 10^6 \quad \text{. . . . . (1)}$$

where-

C is the average concentration of suspended sediment (ppm) for a given period of time.

D_W is the dry weight of the suspended sediment (lbs) for the time period.

P is the total weight (lbs) of the pumped sample for the time period.

Because the weighing pan is suspended in water the submerged, or wet weight, of the sediment is recorded. If W_w is the submerged weight of the sediment, the dry weight of the sediment is-

$$D_w = \frac{2.65}{1.65} \times W_w = 1.606 \times W_w \quad . . . . (2)$$

For any given period of time the submerged weight of the sediment is the difference between the recorder readings at the beginning and end of the measuring period. Substituting the submerged weight of the sediment in equation 1-

$$C = \frac{1.606\ W_w}{P} \times 10^6 \quad . . . . (3)$$

The sample volume is controlled by limit switches on the water level control. The average cross sectional area of the sedimentation tank between high and low water elevations was determined to be 21.79 sq ft. Periodic measurements of the high and low water elevations were made and the average difference was 0.174 ft. Therefore the average volume of the pumped sample is 21.79 x 0.174 or 3.79 cu ft. The weight of the pumped sample per cycle is 3.79 x 62.3 or 236 lbs. The assumption of 62.4 lb per cu ft is adequate over the range of temperature and concentration contemplated. If N is the number of pumping cycles during the measuring period, the total weight of the pumped sample will be-

$$P = 236N \quad . . . . (4)$$

The present intermittent pumping sampler has two pumping cycles per hour. By substituting 236N for P in equation 3 the average concentration of the suspended sediment in the pumped sample for a given period of time becomes-

$$C = \frac{1.606\ W_w}{236N} \times 10^6 . . . . (5)$$

31. Operation of crane scale and recorder system--The crane scale and recorder system was field tested from October 23, 1957 through the remainder of the 1957 operating season, and through all of the 1958 operating season.

The load capacity of the crane scale is 2,500 lbs. Because the submerged weight of the weighing pan and suspension cradle is 325 lbs the system will weigh a sediment accumulation up to about 2,150 lbs.

The recorder chart, Fig. 23, is a 120-ft strip chart 12 in. wide which has an 11-in. calibrated scale of 0-100. Therefore each line on the chart represents one percent of the 2,500 lb total load or 25 lbs. The chart can be read to the nearest five lbs. The chart speed is 3/4 in. per hour.

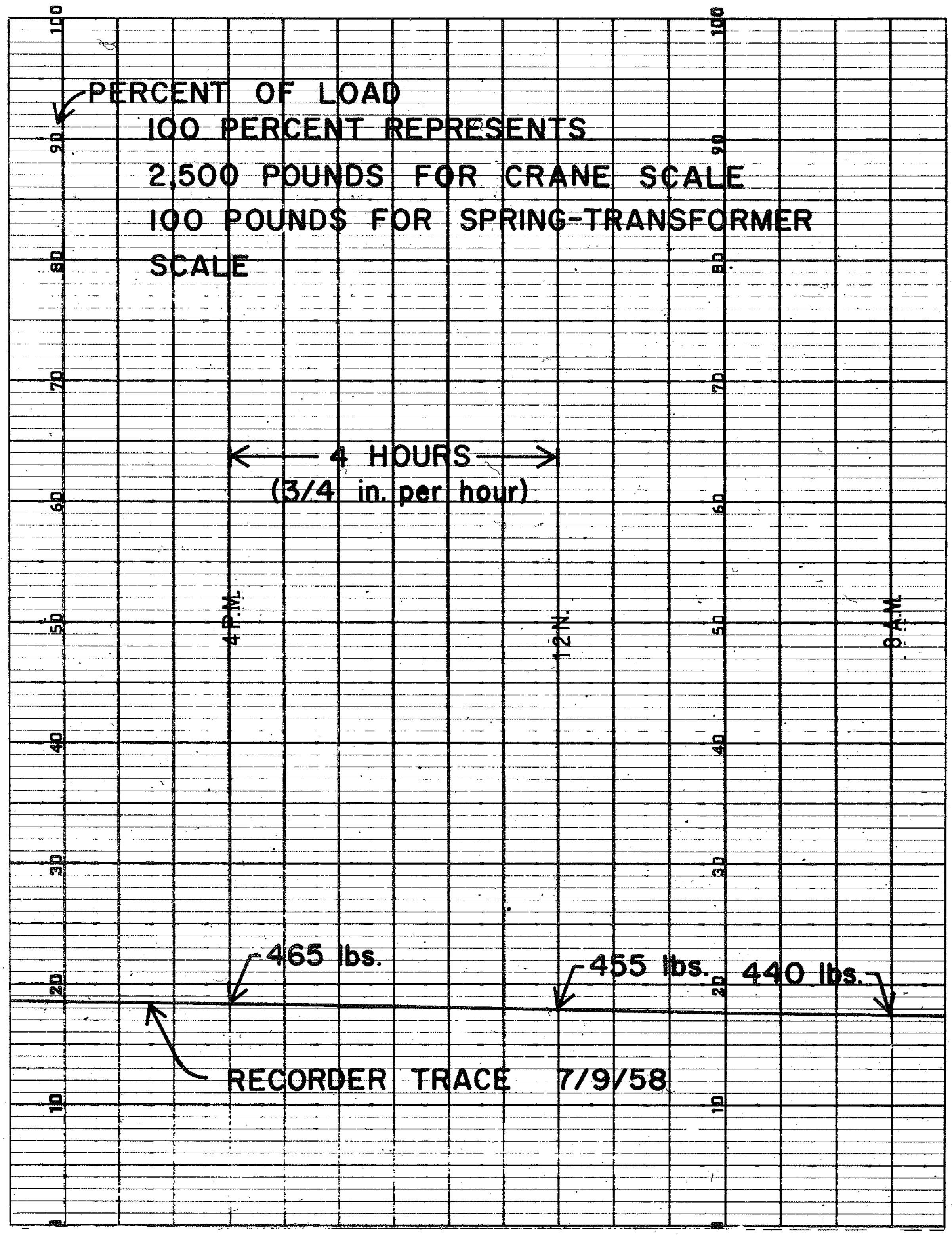


FIG. 23 — RECORDER CHART

The first period of storm runoff during sampler operation was on July 9, 1958. The recorder trace of part of this day is shown in Fig. 23. Four-hour-average sediment concentrations were computed from the recorder trace and from samples collected at the intake during the day. These results are shown in Table 7. The accumulative-weight recorder efficiency is expressed as the ratio of sample concentration determined from the recorder chart to concentration in the river at the intake. The 32 percent difference between the average concentration in the river and that from the recorder for the day agrees reasonably well with the flushing water tests, Section 27. Because the sediment discharge for the storm period consisted mostly of material finer than usual, the sediment lost in the flushing water would be greater than usual.

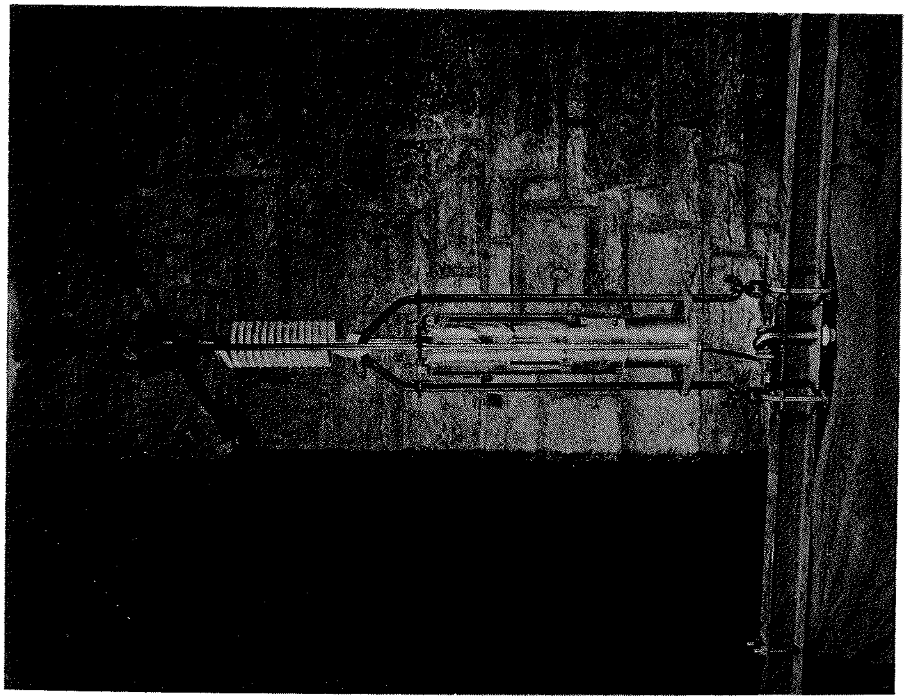
TABLE 7

ACCUMULATIVE-WEIGHT RECORDER EFFICIENCY
July 9, 1958

Clock Time	Recorder Trace Reading (lbs)	Wet wt. Sediment added (lbs)	Concentration from Recorder (ppm)	Avg. Conc. from River Samples (ppm)	Recorder Efficiency (percent)
12 am	410				
4 am	420	10	8,510	9,940	86
8 am	440	20	17,000	22,900	74
12 m	455	15	12,800	19,800	65
4 pm	465	10	8,510	12,500	68
8 pm	470	5	4,250	9,180	46
12 pm	475	5	4,250	7,020	60
Average for day			9,220	13,600	68

As the recorder trace is readable only to the nearest 5 lbs, the actual weight may be in error by 2-1/2 lbs. This represents a four-hour-average concentration of 2,120 ppm and a daily average concentration of 354 ppm.

32. Spring-transformer scale--A more sensitive weighing system, the spring-transformer scale shown in Fig. 24, was designed to replace the crane scale so that concentrations could be measured more accurately and for shorter periods of time. The scale is sensitive to the nearest one pound. The unit contains a coil extension load spring, linearly-variable differential transformer, and a transformer core stepping device. The load spring has a 1,400 lb capacity and it deflects about 1/4 in. per 100 lbs. The differential transformer measures the deflection of the load spring in 1/4-in., or about 100-lb, increments. The measuring increments are controlled by the transformer core stepping system shown in Fig. 25.



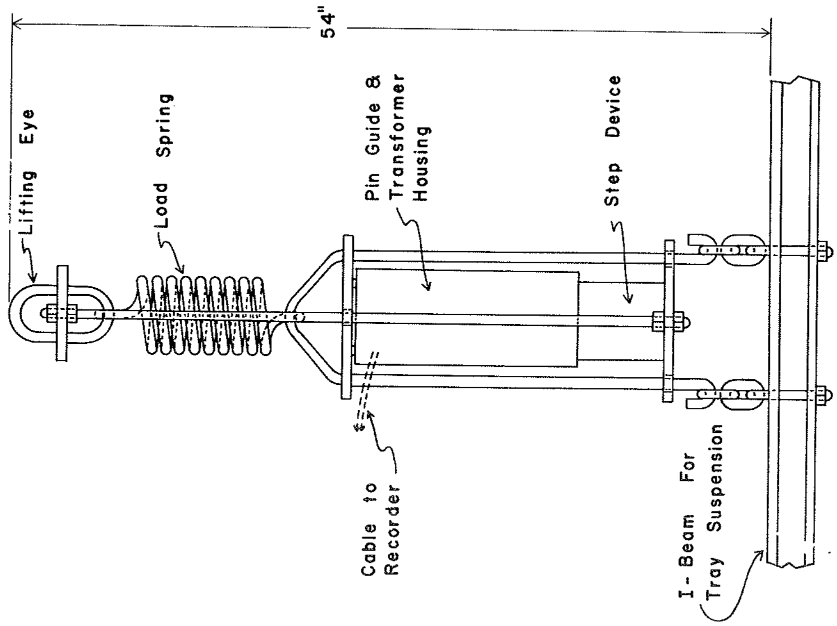


FIG. 24 — SPRING-TRANSFORMER SCALE

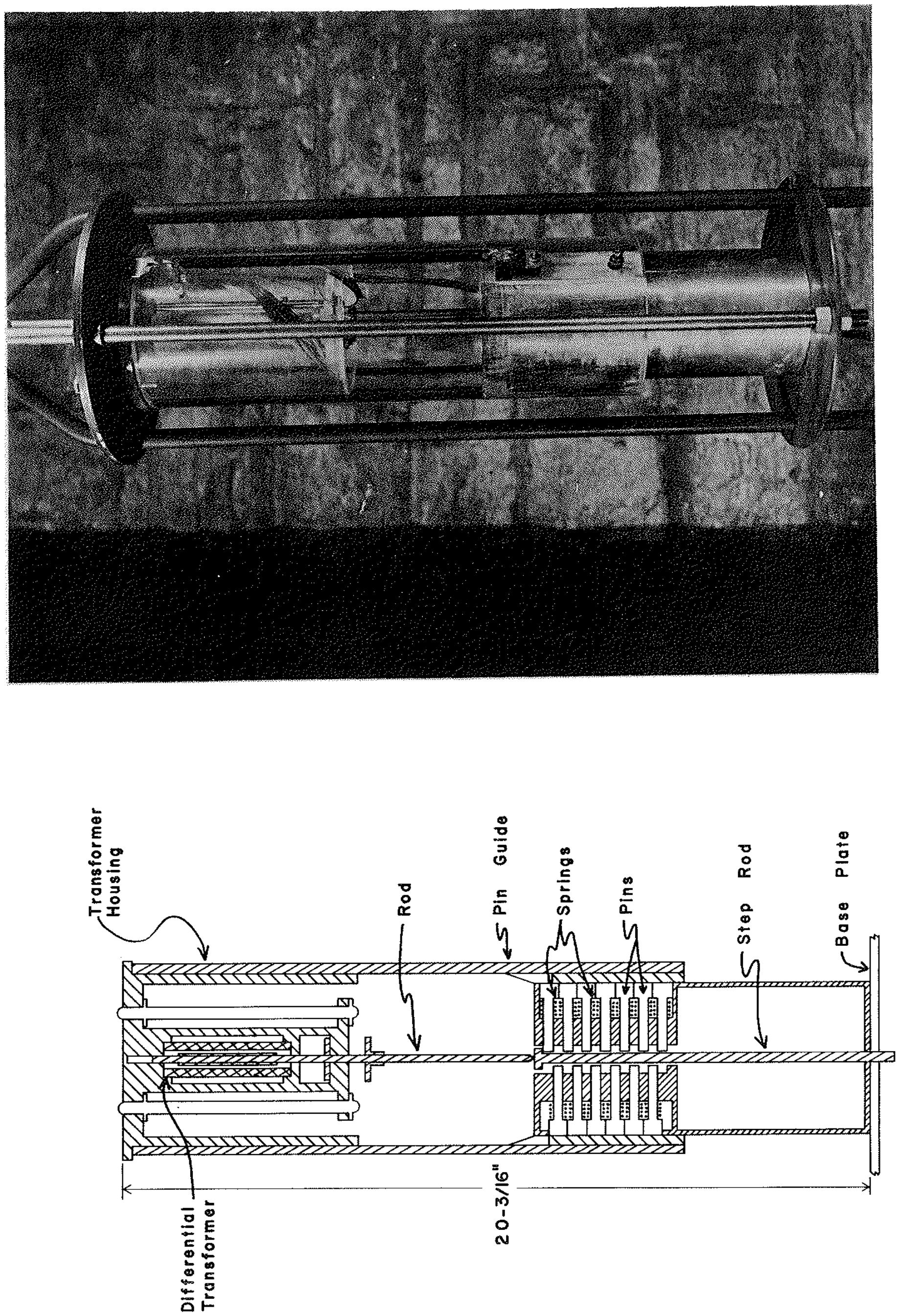


FIG. 25— STEPPING SYSTEM FOR SPRING-TRANSFORMER SCALE

When an accumulative load builds up on the spring-transformer scale, the transformer housing and pin guide move downward toward the base plate. The transformer core leaves the center or zero position and approaches the top of the transformer. After the transformer housing and pin guide have traveled 1/4 in. (equivalent to a load of 100 lbs) the pin guide clears the top pin and the pin moves to its outer position. The step rod drops 1/4 in. to the next lower pin and the transformer core drops back to the zero position. This operation continues for the 12 remaining pins. Because the recorder indicator and pen drop back to the zero reading after each 100 lbs of accumulative loading, the total load on the spring-transformer scale is the reading on the recorder plus 100 times the number of pins tripped in the transformer core stepping system.

The circuit diagram of the spring-transformer scale is shown in Fig. 26. The linearly-variable differential transformer is an electromechanical transducer which produces an electrical output proportional to the displacement of a movable core. The transformer consists of coils axially spaced on a cylindrical coil form and a rod-shaped magnetic core which provides a preferred path for the magnetic flux between the coils.

When the primary, or center coil, is energized with alternating current, voltages are induced in the secondary, or outer coils. The secondary coils are connected in series opposition, so that the two voltages in the secondary circuit are opposite in phase. The net output of the transformer is the difference of these voltages. When the core is in the center position, the output voltage is zero. As the core is displaced from the center position the transformer produces a differential voltage that varies linearly with the core displacement. Only the upper half of the core movement is used in the spring-transformer scale.

Originally the weight record varied with temperature. A series of tests showed that the coil resistance in the differential transformer increased with an increase of air temperature. The temperature effect was eliminated by adding to the differential transformer circuit a thermistor with a negative temperature coefficient.

Two shielded 2-wire cables connect the spring-transformer scale to the recorder. The recorder supplies a fixed voltage to the differential transformer and the output voltage is fed back to the recorder through a partial bridge circuit. This circuit cuts down the output voltage and changes phase to match the recorder bridge. Movement of the transformer core unbalances the output voltages between the differential transformer and recorder bridge. The difference between the two output voltages is amplified and used to drive the balancing motor which in turn drives the slidewire arm in the direction that reduces the difference to zero.

33. Operation of the spring-transformer scale--The spring-transformer scale was field tested during the 1959 and 1960 operating seasons. Because of low water discharge and operational failures of the pumping sampler during the 1959 operational period, the field test was restricted to a short period of time and light sediment loading. During part of the operating period the recorder trace was very unstable. After the recorder was brought back to the laboratory at the end of the

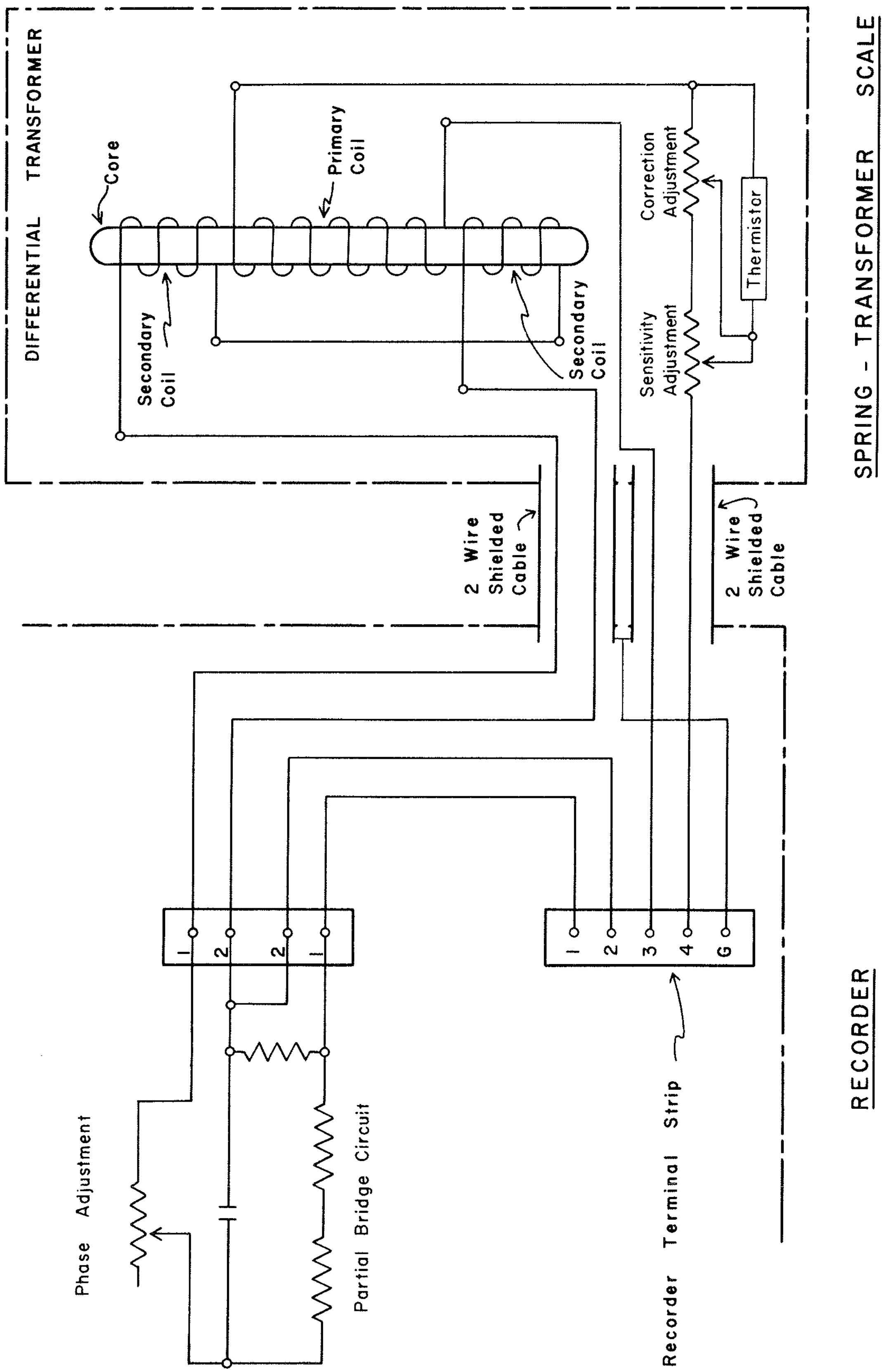


FIG. 26 — SPRING-TRANSFORMER SCALE CIRCUIT DIAGRAM

operation period a faulty wire connection was found in the recorder input circuit. Vibration of the recorder during periods of pump operation caused intermittent breaking of electrical contact at the faulty connection.

Daily air temperature fluctuations in the sampler shelter caused corresponding fluctuations in the recorder readings. The recorder indicated a smaller load during the afternoon maximum air temperature. Between the 1959 and 1960 operating periods the thermistor described in Section 32 was added.

Low-water discharge and low sediment concentrations during the 1960 operating season restricted the field testing of the modified spring-transformer scale to a light loading. Large daily air temperature fluctuations permitted testing of the temperature compensating circuit. During the first part of the operation period several periodic resettings of the sensitivity and correction adjustments were required to obtain the correct setting for various temperature fluctuations. Finally, a setting was obtained that cut the variation of the recorder trace down to one unit.

VI. VOLUME RECORDING SYSTEM

34. Basic volume recording system--The volume recording system (Fig. 27) consists of a 16 mm movie camera, a bottle rack containing 72 pint milk bottles, and a wheel that carries 12 sedimentation tubes.

When the system is in operation, a sample is pumped into one of the sedimentation tubes each half hour. About 5-1/2 hours later the camera takes a picture of the sediment accumulation in the constricted section of the tube and also of the height of water in the tube. The tube then drains in preparation for filling again six hours after the previous sample was taken in that same tube. Because the volume of each sedimentation tube has been calibrated against height of filling, the pictures can be used to obtain volume concentration for each sample. The relation of volume concentration and weight concentration has been determined for various size ranges of the sediment encountered at the St. Paul testing site. Thus every half hour the weight concentration from the tubes can be determined indirectly.

A splitter mounted on top of one of the 12 sedimentation tubes diverts part of the sample into one of the milk bottles every 6 hours. The sediment in the bottle sample may be analyzed later as a check on the concentration of sediment from the pictures. The cycle of operation is explained in detail in Section 54 of Appendix B.

35. Sedimentation tubes and wheel--The sedimentation tubes are shown in Figs. 27 and 28. The tubes are made from standard glass tubing and have a constricted section at the bottom. The tube constrictions are of three sizes, (1/2 in., 9/16 in., and 3/4 in. inside diameter) to provide a range in sensitivity and sediment capacity for different sampling conditions. If desired, 2 or 3 different tube sizes may be used on one wheel to get a better definition of the extremes of sediment concentration.

The sedimentation tube wheel is made of aluminum. The two support plates are 30 in. in diameter and are spaced 10 in. apart. A 1.9 rpm gear motor drives both the tube wheel and bottle rack. A limit switch and twelve adjustable arms mounted at the edge of the lower support plate control the movement of the tube wheel.

Fig. 29 shows the sedimentation tube stopper and dumping mechanism. A tube stopper arm faced with a rubber pad is mounted below each of the 12 sedimentation tubes. A permanent magnet mounted on each stopper arm support holds the stopper pads firmly against the sedimentation tube. At the time a tube is to be drained its stopper arm is over the dumping solenoid arm. When the rotary solenoid is actuated, the upper leg of the solenoid arm knocks the stopper arm away from the magnet and the lower leg of the solenoid arm forces the push rod upward, which moves the stopper arm and stopper pad away from the sedimentation tube. After the tube has drained, the rotary solenoid is released and the stopper arm drops back to its closed position, where it is again held securely by the magnet.

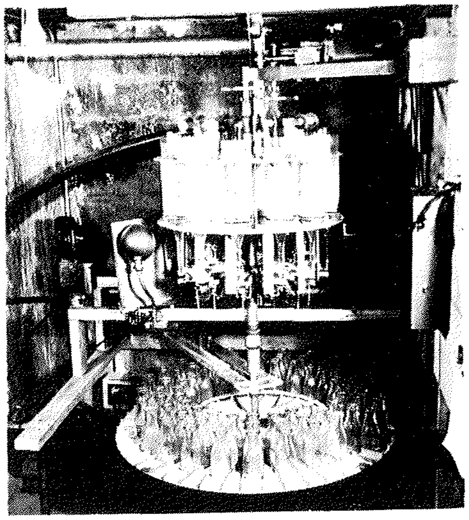


FIG. 27A

FIG. 27B

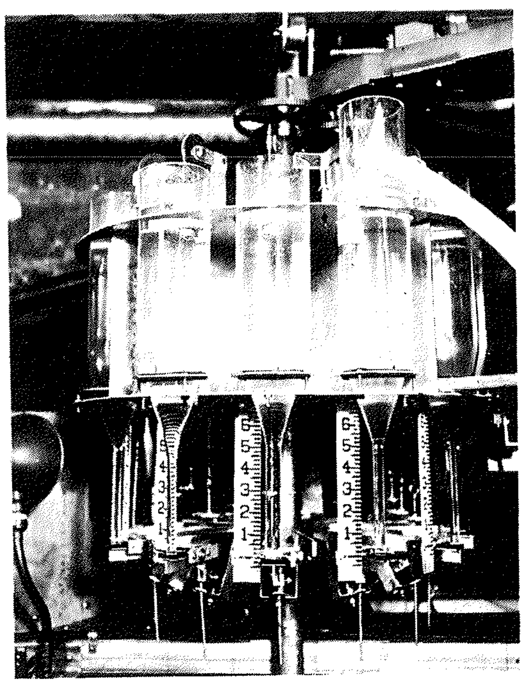


FIG. 27C

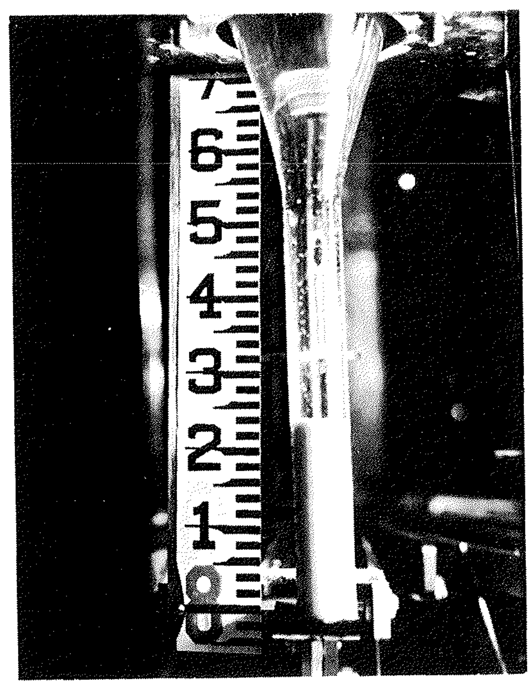


FIG. 27D

FIG. 27 - VOLUME RECORDING SAMPLER

36. Camera--The 16 mm movie camera photographs the constricted section of the sedimentation tube 5-1/2 hours after the sample is pumped into the tube. An enlarged view of this picture is shown in Fig. 27D. The height of sediment and of water in the tube is measured with a standard level rod scale, which can be read to the nearest hundredth of a foot. The water level in the tube is indicated by a disk connected to a float at the top of the sedimentation tube.

The camera is solenoid actuated to expose one frame at a time. Each complete winding of the camera spring will provide for shooting 40 ft of film which is enough to last 18 days at the 30 minute cycle frequency. Two 50 watt incandescent bulbs illuminate the sedimentation tube.

37. Bottle rack--The bottle rack is shown in Fig. 27. Each time a sample is pumped into tube number one the sample splitter diverts a part of the sample into a funnel that discharges through a bottle feeder tube into one of 72 pint milk bottles on the bottle rack. The bottles are arranged on the bottle rack in an inward spiral of 24 bottles to each revolution. The bottles rack progresses one bottle width (1/24 rev.) for each revolution of the sedimentation wheel. A differential pulley arrangement moves the bottle feeder tube inward a distance of one bottle width for each revolution of the bottle rack. The bottle rack revolves three times to fill the 72 bottles. The 72 bottles provide an 18 day capacity at the 30 minute sampling frequency.

38. Determination of sediment concentration--Each of the 12 sedimentation tubes was calibrated to determine the relation of column height (or volume) to sediment weight for the sediments encountered at the St. Paul station. Also a determination of the disk elevation for a 2,000 g sample and the sample weight

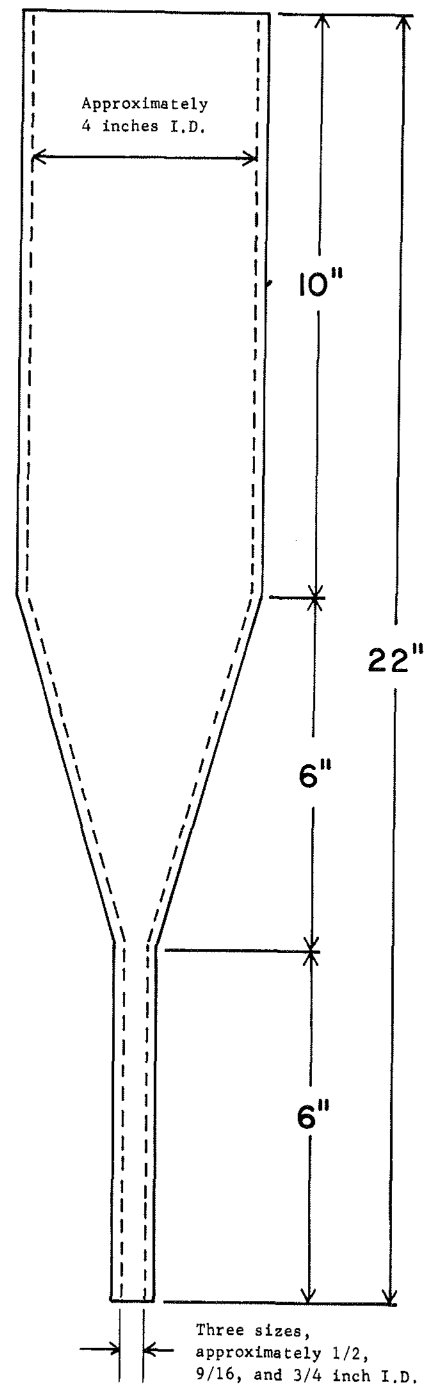


FIG. 28 SEDIMENTATION TUBE

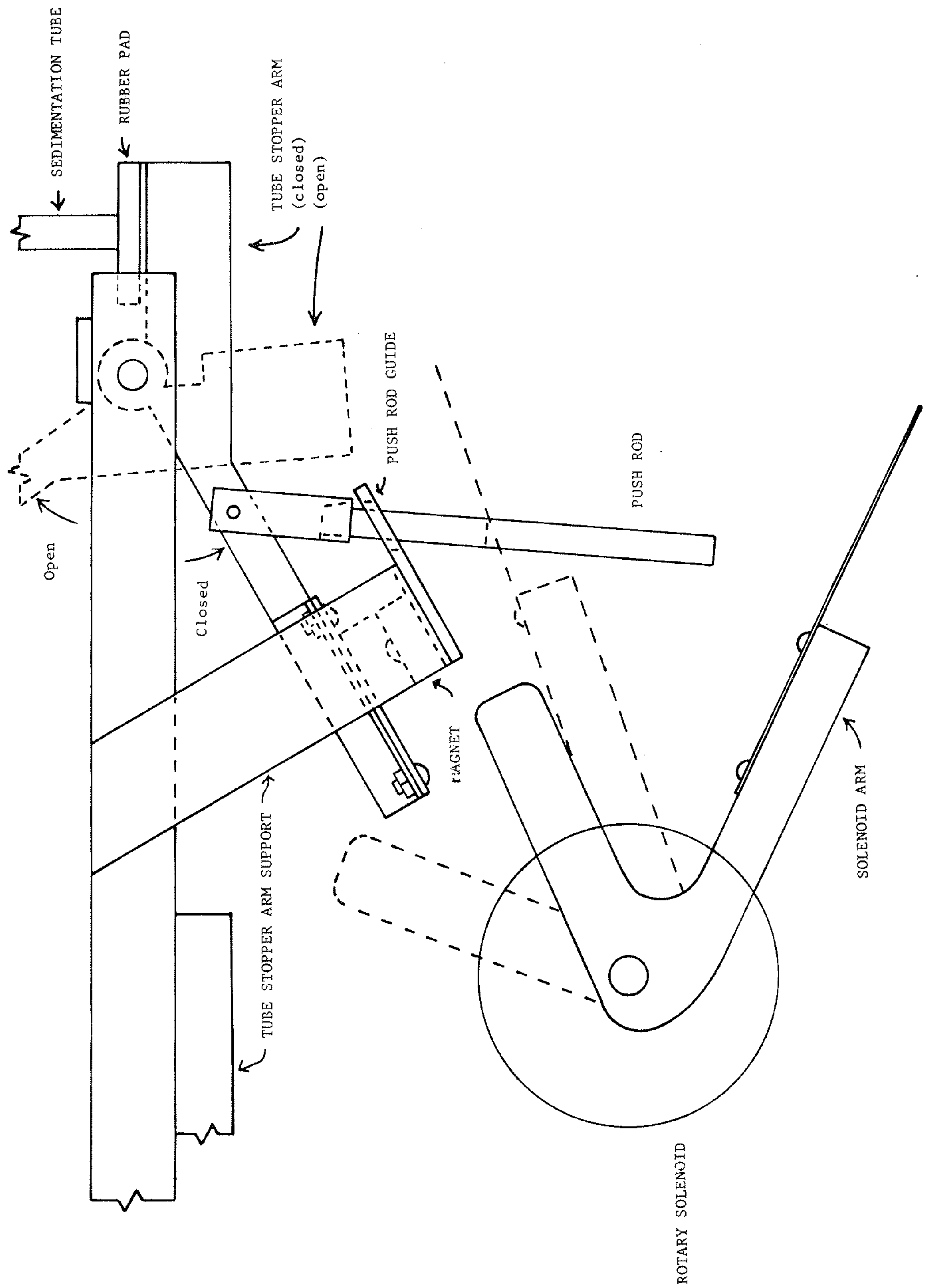


FIG. 29 — SEDIMENTATION TUBE STOPPER AND DUMPING MECHANISM

increments for each 0.01 ft change in column height was made for each tube. The results of this tube calibration are shown in Table 8.

The sediment concentration in a tube may be determined as follows:

Data from Fig. 27D (film record)
Tube number 8
Elevation of accumulated sediment 0.235 ft
Elevation of water level disk 0.32 ft

Data from Table 8 (tube calibration chart)
Weight of sediment (The elevation of the accumulated sediment, 0.235 ft, is between 0.200 ft for 29 g and 0.265 for 34 g.)
$29 + (.035/.065) \times 5 = 32$ g
Height of 2,000 g sample 0.50 ft
Change in weight of sample 27.8 g/0.01 ft
Weight of sample (The elevation of the water level disk is below 0.50 ft so the sample weight is greater than 2,000 g.)
$2{,}000 + 27.8 \times (50-32) = 2{,}500$ g

Concentration of sample $= 32/2{,}500 \times 10^6 = 12{,}800$ ppm

39. Operation of volume recording sampler--The volume recording sampler was operated from September 2, 1960 through the remainder of the 1960 operating season, and through all of the 1961 operating season.

The original tube stopper and dumping mechanism consisted of a rubber stopper pad mounted in a plastic cylinder. A spring loaded stopper arm supported the plastic cylinder and held the stopper pad firmly against the sedimentation tube. The tubes were drained when the stopper arm moved under a dumping cam which forced the cylinder, and stopper pad downward about 1/8 in. With the 1/8-in. dumping clearance, there was no sudden rush of water from the tubes and no splashing over the top of the plastic cylinder but sometimes compacted sediment prevented drainage of the small diameter tubes. Also small pieces of straw or small twigs occasionally lodged between the stopper pad and sedimentation tube preventing complete closure of the stopper pad. The tube stopper and dumping mechanism described in Section 35 were installed between the 1960 and 1961 operating seasons. Initial operating difficulties during the 1961 season were corrected by adding larger push rods and making minor adjustments.

During the 1960 operating season the water sample level of the volume recording sampler was photographed directly. Two mirrors were used to project the water level image from the top of the tube to the camera. One half of the picture showed the sediment level in the constricted section of the tube and the other half of the picture showed the water level near the top of the tube. The photographs were hard to read because the view of the upper section of the tube was distorted and the view of the lower section of the tube was small. The addition of a water level float and indicator disk at each tube permitted the camera to be closer to the tube. The resulting photographs, such as Fig. 27D, are much easier to read.

TABLE 8

TUBE CALIBRATION, VOLUME RECORDING SAMPLER

Tube Number	1	2	3	4	5	6	7	8	9	10	11	12
Nominal Tube Diameter (in.)	1/2	1/2	3/4	1/2	9/16	3/4	9/16	3/4	3/4	1/2	1/2	3/4
Height of 2,000 g sample (ft)	.42	.42	.46	.50	.45	.53	.40	.50	.41	.50	.53	.46
Change in wt of sample (g/.01 ft)	26.3	27.8	27.3	26.6	27.8	31.2	26.1	27.8	27.8	27.8	27.8	30.6
Weight of sediment (g)	Elevation of accumulated sediment (ft)											
0	.005	.000	.005	.000	.000	.000	.000	.000	.000	.000	.000	.000
1	.015	.010	.010	.010	.005	.005	.010	.005	.005	.015	.005	.005
3	.040	.040	.025	.035	.030	.025	.030	.020	.020	.035	.030	.020
5	.065	.065	.035	.065	.055	.035	.060	.035	.035	.065	.065	.030
7	.100	.095	.045	.095	.080	.045	.085	.045	.045	.090	.095	.040
9	.125	.120	.055	.120	.100	.055	.105	.055	.055	.120	.125	.050
14	.210	.205	.100	.205	.165	.100	.180	.090	.085	.205	.205	.085
19	.290	.285	.130	.285	.245	.135	.250	.125	.125	.285	.290	.125
24	.380	.365	.165	.365	.320	.170	.325	.160	.160	.365	.370	.165
29	.445	.440	.205	.445	.390	.205	.400	.200	.200	.450	.450	.200
34	.575	.570	.285	.570	.520	.285	.520	.255	.270	.565	.555	.265
39	---	---	.365	---	.585	.360	.590	.345	.350	---	---	.345
44	---	---	.445	---	---	.440	---	.425	.430	---	---	.425
49	---	---	.520	---	---	.515	---	.500	.505	---	---	.500
54	---	---	.560	---	---	.575	---	.565	.570	---	---	.565

The three operational failures of the volume recording sampler during the 1961 operating season were described in Section 23. Twice water splashing on the photography illumination light caused short circuits and burned out the control circuit fuse. The light was rewired into a separate fuse circuit so that the sampler would continue to operate if the light shorted out. The drive gear of the sedimentation tube wheel was damaged when splashed water shorted out the wheel motor limit switch and allowed the wheel motor to operate continuously. The wheel control circuit was rewired so that the wheel motor can operate only when the 1/6-rpm timing motor operates. Thus the wheel motor cannot operate long enough to damage the drive gears even if the sedimentation tube wheel becomes obstructed between inspection trips. The circuit modifications will prevent operational failures of the volume recording sampler if water splashing occurs. A smaller pump is now used in the sampler and water is less likely to splash on the photography illumination light and wheel motor limit switch.

The river discharge was low during the operating period and there were few opportunities to test the volume recording sampler in high suspended-sediment discharges. The sampler was in operation during one period of storm runoff, 5/31-6/2/61. The computed data from the recorder for this period of storm runoff is shown in Table 9.

During the storm runoff the suspended sediment consisted mainly of silt and clay so that part of the sediment did not settle during the allotted time of 5-1/2 hours. In the first samples the concentration of unsettled sediment was great enough to mask out the water-sediment interface in the sedimentation tube so that concentrations in the tubes could not be computed. In the later samples the concentration of the unsettled sediment dropped sufficiently to permit reading of the water-sediment interface, but the computed tube concentrations required corrections to allow for the unsettled sediment. Addition of a flocculating agent would decrease the settling time of fine sediments and prevent masking out of the water-sediment interface in the tube pictures, but it would also change the weight-height relationship of the tube calibrations.

The calibration of the sedimentation tubes, Table 8, was based mainly on sediments in the sand sizes. Because most of the suspended sediment in the storm runoff consisted of silt and clay, corrections in the concentration computed from the calibration were required to allow for the change in the weight-height relationship in the tubes. The concentrations of the bottle rack samples were used to correct the tube concentrations that were computed from Table 8. Results of analyses of bottle rack samples are shown in Table 13, Appendix A.

TABLE 9

VOLUME RECORDER RECORD
May 31 to June 2, 1961

Date	Time	Concentration (ppm)				Date	Time	Concentration (ppm)			
		Intake	Bottle	Tube				Intake	Bottle	Tube	
				Computed	Corrected					Computed	Corrected
5/31/61	1:30 pm	8,980	- -	- -	- -	6/1/61	11:45 am	- -	- -	16,100	6,400
	1:55 pm	- -	8,840	- -	- -		2:30 pm	- -	5,980	- -	- -
	2:10 pm	- -	- -	18,400	7,730		3:30 pm	- -	- -	9,010	5,950
	2:30 pm	- -	- -	16,500	6,760		4:15 pm	- -	- -	8,000	5,600
	3:15 pm	- -	6,730	- -	- -		5:15 pm	- -	- -	8,700	6,090
	4:15 pm	- -	- -	11,400	6,840		6:00 pm	- -	- -	8,580	6,010
	5:15 pm	- -	- -	9,500	6,180		6:30 pm	- -	5,950	6,110	5,950
	5:45 pm	5,680	- -	7,820	5,470		6:55 pm	5,430	- -	- -	- -
	6:45 pm	- -	- -	9,810	6,870		7:00 pm	- -	- -	5,700	5,700
	8:15 pm	- -	5,270	7,140	5,280		8:00 pm	- -	- -	4,910	4,910
	9:15 pm	- -	- -	7,610	5,330		9:00 pm	- -	- -	5,000	5,000
	10:15 pm	- -	- -	8,740	5,240		10:00 pm	- -	- -	4,690	4,690
	11:45 pm	- -	- -	10,000	5,500		11:00 pm	- -	- -	4,120	4,120
6/1/61	1:15 am	- -	- -	10,300	5,250	6/2/61	12:30 am	- -	4,090	4,060	4,060
	2:15 am	- -	5,140	- -	- -		1:30 am	- -	- -	3,820	3,820
	3:15 am	- -	- -	15,100	5,280		2:30 am	- -	- -	2,910	2,910
	5:45 am	- -	- -	17,800	6,230		3:30 am	- -	- -	2,790	2,790
	6:45 am	- -	- -	12,500	6,250		5:00 am	- -	- -	2,600	2,600
	7:00 am	5,850	- -	- -	- -		6:30 am	- -	3,080	2,720	2,720
	8:15 am	- -	6,940	- -	- -		8:10 am	2,780	- -	- -	- -
	9:15 am	- -	- -	14,900	6,700		12:30 pm	- -	2,260	2,230	2,230

VII. INDIVIDUAL-SAMPLE BOTTLING SYSTEM

40. Basic bottling system--The individual-sample bottling system, shown in Fig. 30, consists of a bottle rack carrying 145 pint milk bottles. When the system is in operation a sample is pumped into one of the pint bottles every 12 hours during low river stages and every hour during high river stages. The samples are sent to the laboratory for analysis.

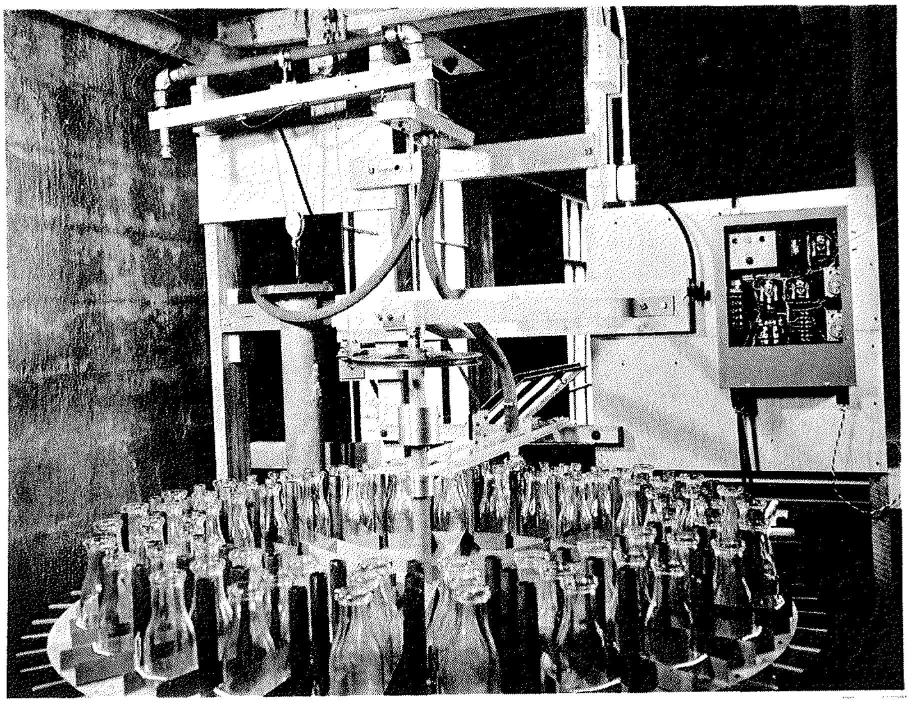
The present bottling sampler operates on a 110 V.A.C. power supply. It could be adapted to battery power. The cycle of operation is explained in detail in Section 55 of Appendix B.

41. Bottle rack--The bottle rack for the bottling sampler is similar to that for the volume recording system. The main difference is that the bottle rack for the bottling sampler contains two tiers so that its capacity is 145 bottles. The sample from the splitter is fed into the bottles through a bottle feeder tube. The bottles are arranged on each of the two tiers in inward spirals. The bottle rows of the bottom tier are positioned midway between the bottle rows of the top tier. Copper tubes are mounted in the top tier to direct the flow from the bottle feeder tube to the bottles of the lower tier. The bottle rack makes 48 stops per revolution. A differential pulley arrangement moves the bottle feeder tube inward a distance of one bottle width for each revolution of the bottle rack. Three revolutions of the bottle rack are required for filling the 145 bottles.

The bottle rack is driven by a 25 lb weight. A wire cable connects the weight to a drive pulley. The weight drops within a 4 in. pipe which is filled with water. The outside diameter of the weight is 1/16 in. less than the inside diameter of the pipe. The clearance between the weight and pipe is small enough to prevent rapid acceleration of the bottle rack.

Forty-eight stop pins are mounted along the outer edge of the bottle rack opposite each row of bottles and copper feed tubes. A solenoid operated stop mechanism checks the movement of the bottle rack (See Fig. 31). This bottle rack stop mechanism was designed by Dewey Weibley, an observer for the Quality of Water Branch of the Geological Survey in Harrisburg, Pa. At the end of each sampling period the rotary solenoid actuates the rocker arm which raises stop rod "A" and lowers stop rod "B" long enough for stop pin "1" (opposite bottle just filled) to pass under stop rod "A" and for the wheel to rotate until stop pin "2" strikes stop rod "B". The solenoid is then deactivated and the stop rods move back to their normal position. The wheel rotates until it is stopped when the next pin ("3") strikes stop rod "A". This places the next bottle or copper feed tube under the bottle feed tube.

42. Operation of the bottling sampler--The bottling sampler was built and laboratory tested during the spring and summer of 1961. The sampler was not field tested at the St. Paul, Nebr., testing station because most of the components of the sampler had already been tested there.



. 30A

FIG. 30B

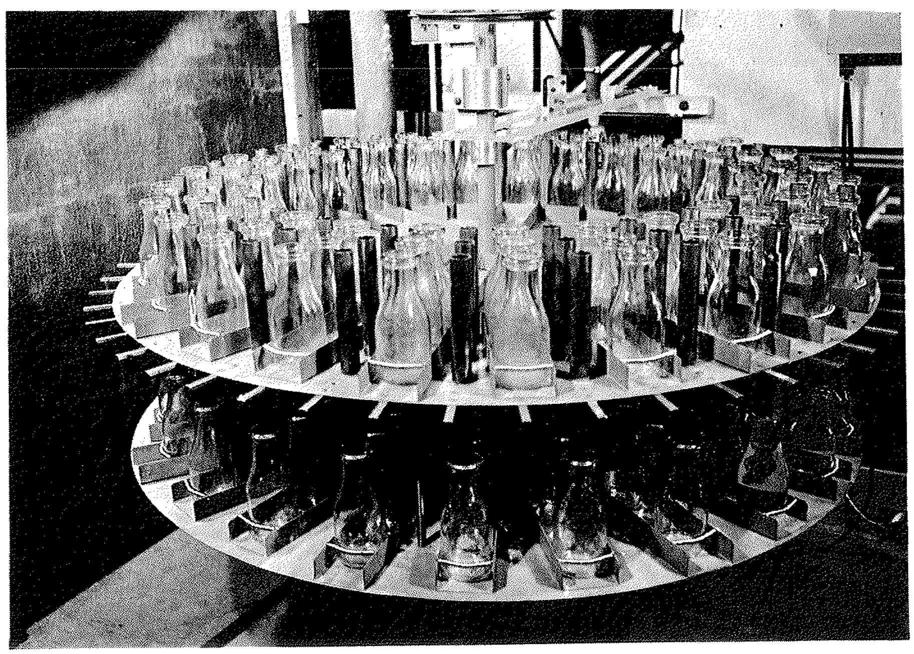


FIG. 30 - INDIVIDUAL-SAMPLE BOTTLING SYSTEM

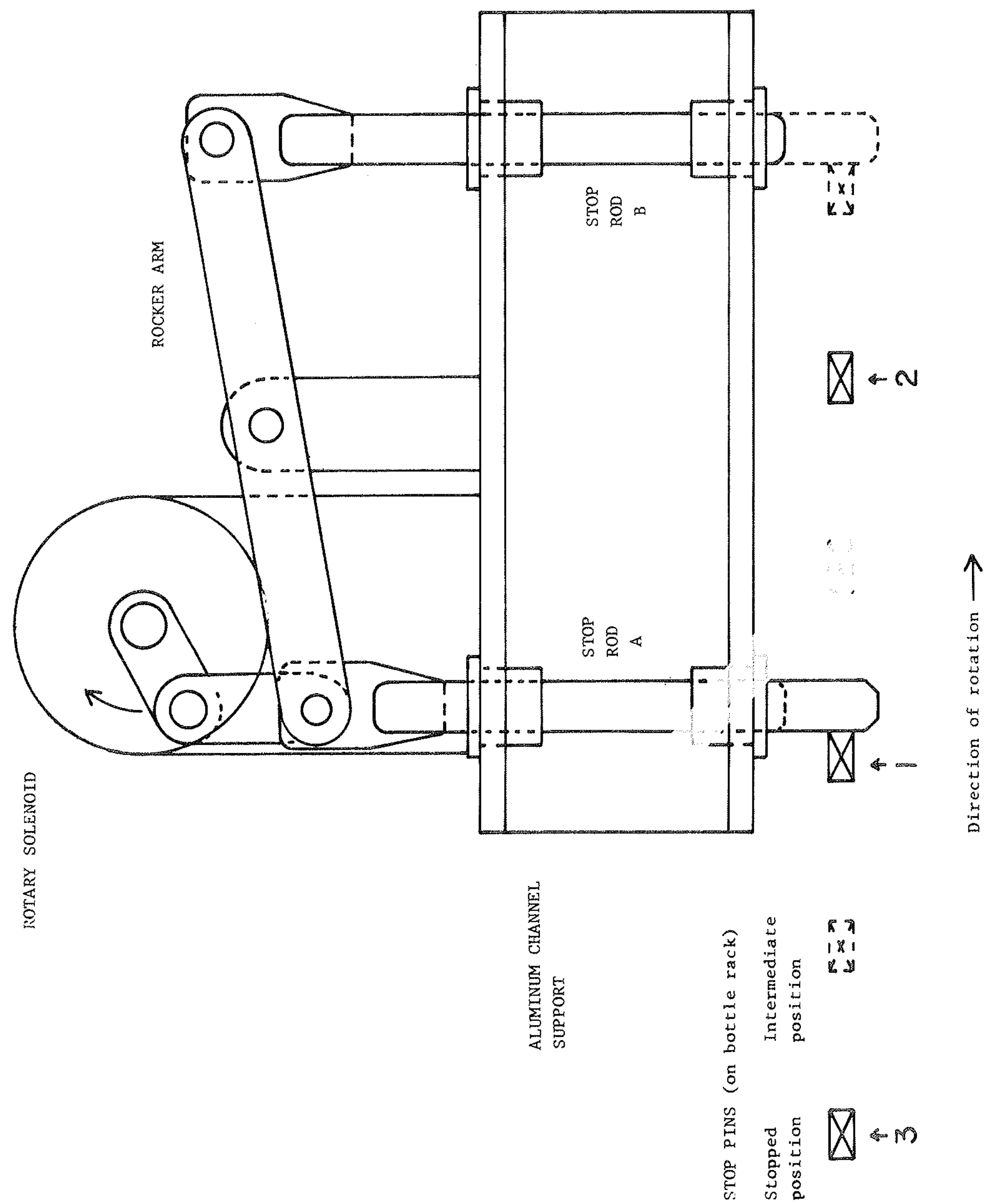


FIG. 31 — BOTTLE RACK STOP MECHANISM

VIII. INSTALLATION AND COST

43. Intake and shelter--The installation of the intake structure will vary for each pumping sampler site depending upon the anticipated stream flow, variation of water depth, and type of stream bank. A long guide wall similar to that used at the St. Paul site, Fig. 4, is recommended for streams containing coarse sediment.

Each type of pumping sampler requires a different shelter. A minimum recommended shelter size for each of the three pumping samples is given in Sections 44-46.

Because the intake and shelter requirements are different for each pumping sampler installation the inter-agency project will not attempt to supply intake and shelter parts. Usually the shelter, intake structure, and lead in pipes will be provided by the field office installing the pumping sampler. The materials for the intake structure at the St. Paul site cost about $20 and the intake was installed by two men in about four hours.

44. Accumulative-weight recording sampler--The accumulative-weight recording sampler is best suited to operation on large rivers with high suspended-sediment concentration; it does not record rapid changes in concentration. For maximum sensitivity the suspended sediment should be mostly in the sand and coarse silt sizes. The river should have high banks to permit drainage of the waste water and sedimentation tank.

The accumulative-weight recording sampler requires a shelter similar to that described in Section 14. The shelter should be at least 8 by 10 ft and 12 ft high. A 110 V.A.C. electric service with a 60 ampere capacity is required.

The requirements of a large shelter and a sedimentation tank make the accumulative-weight recording sampler the least easily moved of the 3 pumping samplers. The pump, pinch valves, splitter, weighing pan, baffles, weighing device, recorder, and possibly the shelter could be moved from site to site but the sedimentation tank would have to be rebuilt at each new site.

The cost of the accumulative-weight recording sampler excluding intake, shelter and sedimentation tank is about $2,500. The cost of constructing the shelter and sedimentation tank at the St. Paul site was $1,000.

45. Volume recording sampler--The volume recording sampler will record moderate to sudden changes in sediment concentration, so that it can be used on streams that are too flashy for the accumulative-weight recording sampler. For maximum sensitivity the suspended sediment should be mostly in the coarse silt and sand sizes. The range of suspended-sediment concentration and size anticipated at a site determines the diameters of the constricted sections of the sedimentation tubes that should be used.

The recommended shelter size for the volume recording sampler is 8 by 10 ft and 9 ft high. All of the equipment is located on or above the floor level of the shelter so that no pit or basement is required. The installation can be moved from site to site easily if the shelter is a knockdown panel type. A 110 V.A.C. electric service with a 30 ampere capacity is required.

The volume recording sampler can be disassembled and moved from site to site. Exclusive of the shelter, two men can disassemble the sampler and load it on to a truck in one day, and reassemble it in two days. Adjustment of the sampler at the new site may require one man for an additional day or two.

The volume recording sampler costs about $2,700, excluding intake and shelter.

46. Bottling sampler--Primarily the bottling sampler was designed to operate on ephemeral or flashy type streams, but it would operate on any type of stream.

The bottling sampler requires a shelter of at least 6 by 8 ft and 6 ft high. The shelter is easier to move from site to site if it is built in panels. The bottling sampler is the most easily moved of the three pumping samplers. The sampler can be constructed to operate from an 110 V.A.C. electric supply or from a battery.

The cost of the bottling sampler is about $1,700, excluding intake, shelter, and power supply.

47. Availability--The three intermittent pumping samplers, excluding intake and shelter, can be made on order from Federal agencies. Bottles and glassware will not normally be supplied but can be furnished for an additional cost. It is more satisfactory to obtain the bottles and have the sedimentation tubes made locally. Orders should be addressed to the District Engineer, U. S. Army Engineer District, Post Office and Custom House, St. Paul 1, Minnesota.

IX. CONCLUDING REMARKS

48. The pumping system--One problem inherent in any system for pumping sediment samples from a stream is the difference between the average sediment concentration in the stream cross section and the sediment concentration at the sampler intake (point of sample intake from river). The average sediment concentration of the North Loup River near St. Paul, Nebr., was 30 percent greater than the concentration at the sampler intake (Table 3). For many streams the average sediment concentration in the stream cross section will be much closer to that at the sampler intake, but for others the difference will be greater, especially for sand sizes of sediment. If the intake is located carefully and if a ratio of average sediment concentration in the stream cross section to concentration at the sampler intake is determined for a range of stream stage and sediment size, the uncertainty in the relation between the two will seldom prevent adequate sampling.

At the St. Paul, Nebr., site, the concentration in the samples collected was almost identical to that in the river at the sampler intake (Fig. 13), but this relation was for a low-velocity stream with sediment in the fine sand sizes and smaller. Samples pumped from high-velocity streams that carry suspended sediment of coarse sands may have concentration as low as 80 percent of the concentration at the intake, (Table 4). The relation between the concentration at the intake and that in the samples can be established over a range of sampling conditions. The concentration at the intake can be determined from the concentration in the samples.

During the first full season of operation in 1958 the pumping sampler operated 76 percent of the time, but because of frequent failures due to low river discharge it operated only 42 percent of the time for the 1959 season. Operation of the sampler was increased to 81 percent of the 1960 operating season by addition of the 12-hour protective cutoff system. Operation of the sampler dropped to 61 percent in 1961 because of the use of an oversized pump in the volume recording sampler. This operational record was obtained for experimental equipment on which frequent modifications were being tested; and at a site 500 miles from the home office. As operational failures occurred in the pumping system, the cause of the failure was found and eliminated.

The biggest problem in maintaining continuous operation is outside the pumping system. Sediment frequently covers the intake. The pumping system has been improved so that it will restart operation if the sediment washes away and uncovers the intake. However, with the present intake structure frequent maintenance is required if sampling is to be continuous in a shallow, shifting stream.

The pumping samplers can sample the suspended-sediment concentration in a stream automatically. The samples are obtained at predetermined time intervals. The main problem is not in the pumping system but it is in placing the intake for the pumping system at a point in the stream where samples are reasonable representative and where the intake will be in water throughout the period between service visits.

49. Recording and analysis of samples--Three different systems were designed and constructed for recording and analyzing the samples obtained by pumping:

A. The accumulative-weight recording sampler collects a 28-gallon sample every 30 minutes. The sample is pumped into a sedimentation tank and the suspended sediment is weighed as it deposits on a weighing pan near the bottom of the sedimentation tank.

   During periods of very fine suspended-sediment discharge (Table 2), the flushing water removes up to 35 percent of the sample concentration from the sedimentation tank. The average sediment loss of the accumulative-weight recording system was 23 percent (Table 6). Addition of a flocculating agent would decrease the sediment loss.

   The spring-transformer scale is sensitive to one pound of deposited sediment which represents a single-sample concentration of about 7,000 ppm, a four-hour average concentration (8 samples) of 900 ppm, and a daily average concentration (48 samples) of 150 ppm. The accumulative-weight recorder will accurately measure concentrations of sand sizes of sediment during periods of steady or slowly changing river concentrations, but sudden changes will not be recorded.

   A record of sediment concentration is obtained without laboratory analysis of samples, without transportation of samples, and without the services of someone to take daily or more frequent samples.

   The accumulative-weight recording sampler may be used for large streams and canals with moderately uniform discharge and with high concentrations of suspended sediment of sand sizes. The sampler will operate even when there is considerable debris in the flow.

B. The volume recording sampler collects a gallon sample every 30 minutes. The sample is pumped into a sedimentation tube. About 5-1/2 hours later a camera takes a picture of the water level indicator and of the accumulated sediment at the bottom of the tube. A splitter is mounted on top of one of the tubes so that a pint sample is diverted and bottled every 6 hours.

   If the suspended sediment in the pumped sample contains a large quantity of clay and fine silt, the water-sediment interface in the tube may be masked out by sediments still in suspension at the time the photograph of the tube is taken. Addition of a flocculating agent would prevent the masking out of the water-sediment interface but would change the weight-height calibration of the tube.

   A separate reading of sediment concentration is obtained every 30 minutes. Also every six hours a bottle sample is taken for laboratory analysis to determine low sediment concentrations or to check on the recorder analysis at higher concentrations.

The accuracy of the analysis from the photographs should be good for fairly high concentrations of suspended sediments of silt and sand sizes. The sampler can define rapid changes in stream concentrations.

The sampler may be used for streams that contain high and rapidly changing concentrations of sediments of coarse silt and sand sizes. Under favorable conditions a record of sediment concentrations can be obtained without laboratory analysis of sediment samples. Normally, some samples will require transportation to the laboratory for analysis as individual or composite samples.

C. The bottling sampler collects a pint sample every 12 hours during low river stages and every hour during high river stages. Other time cycles could also be used. The sample is pumped into one of 145 milk bottles for analysis in the laboratory at another time. The sampler was built and laboratory tested but it was not field tested at the St. Paul, Nebr., site because most of the components of the sampler had already been tested there.

The bottling sampler merely obtains samples according to a preset time schedule, it does not determine or record concentration. The sampler is more efficient on fine sediments than on coarse, but can handle coarse sediments adequately. The sample concentrations can be determined accurately in the laboratory. The sampler can be moved from site to site if necessary.

The major use of the sampler will probably be at sites where personnel are not available to take samples, but the sampler can be used at a wide variety of locations. The sampler was designed primarily for use on ephemeral streams where the cost of analysis of a few samples in the laboratory in a season is less important than a simple, movable, and economical sampler installation.

The bottling sampler appears to be a practical instrument. The accumulative-weight recording sampler and the volume recording sampler are usable under a limited range of conditions.

50. Cooperative field tests--The volume recording sampler and bottling sampler have been loaned to field offices for further testing.

The volume recording sampler was loaned to the Agricultural Research Service at the U.S. Sedimentation Laboratory, University, Miss., on November 10, 1961. Mr. Carl R. Miller is director of the laboratory and Mr. Robert F. Piest is in charge of operating the sampler. The sampler is installed on Laboratory Creek which is adjacent to the Sedimentation Laboratory.

The loan of the volume recording sampler is for a tentative period of 18 months. During this period interim reports on the operation of the sampler will be submitted and a summary report will be submitted at the end of the period. After receipt of the summary report, project personnel will evaluate the desirability of continuing operation of the sampler at Laboratory Creek.

The bottling sampler was loaned to the U.S. Geological Survey, Quality of Water Branch, field office at Harrisburg, Pa., on August 21, 1961. Mr. John R. George, Geologist-in-Charge, supervises operation of this sampler which is installed 30 miles northeast of Harrisburg on Bixler Run near Loysville, Pennsylvania. Bixler Run is a tributary of the Susquehanna River. Because the drainage area of the stream is only 15 square miles the stream is relatively flashy.

The loan of the bottling sampler is for a tentative period of 14 months. During this period interim reports on the operation of the sampler will be submitted and a summary report will be submitted at the end of the period. After receipt of the summary report, an evaluation will be made by project personnel to determine the desirability of continuing operation of the sampler at Bixler Run.

51. Future Development--At the end of a year or two the field experience of the volume recording sampler and bottling sampler will be reviewed. Further development and the correction of deficiencies will be considered at that time.

It is recommended that general use of the samplers be delayed until completion of the field tests. However, any of the three pumping samplers will be built to fill specific orders from Federal Agencies.

LIST OF REFERENCES

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2. Hubbell, D. W. and Matejka, D. Q.; 1959, "Investigations of Sediment Transportation Middle Loup River at Dunning, Nebraska," U. S. Geological Survey Water-Supply Paper 1476, pp. 11-12.

3. Interagency Report No. 5;* 1941, "Laboratory Investigation of Suspended-Sediment Samplers," pp. 59-67.

4. Interagency Report No. 6;* 1952, "The Design of Improved Types of Suspended-Sediment Samplers," p. 64.

5. Welborn, C. T.; 1961, "Remote Controlled Marking Pen for Stevens Recorder," Personal communication.

6. Wilkinson, R.; 1954, "An Automatic Sampler for Intermittent Flows of Water," Instrument Practice, May, pp. 414-415.

* These are reports of the cooperative project "A Study of Methods Used in Measurement and Analysis of Sediment Loads in Streams," of which the present report is also a part.

X. APPENDIX A

52. Data tables--Tables 10, 11, and 12 show the results of the intake tests at the St. Paul, Nebr., site. These tests are described in Section 17.

Part of the bottle rack samples collected by the volume recording sampler were analyzed for sediment concentration. The results of the analyses are shown in Table 13.

TABLE 10

TESTS OF FLAT PLATE INTAKE AT ST. PAUL

Date of Sampling	Time	River Samples (1)		Splitter Samples		Intake Eff. (2)
		Number	Avg.Conc. (ppm)	Number	Avg.Conc. (ppm)	
4/30/58	9:50 am	6	262	6	284	1.08
	5:30 pm	6	230	3	241	1.05
5/14/58	10:30 am	6	926	3	950	1.03
	11:55 am	6	1,100	3	1,130	1.03
	2:20 pm	6	1,690	3	1,720	1.02
	3:05 pm	6	1,780	3	1,780	1.00
	3:35 pm	6	2,110	3	2,030	0.96
	4:35 pm	6	2,780	3	2,800	1.01
	5:15 pm	6	2,860	3	2,890	1.01
	6:00 pm	6	3,020	3	2,990	0.99
	6:30 pm	6	3,220	3	3,200	0.99
6/3/58	12:55 pm	6	181	6	188	1.04
6/4/58	3:00 pm	3	164	3	163	0.99
	3:30 pm	3	180	3	179	0.99
	4:00 pm	3	172	3	165	0.96
6/17/58	10:30 am	3	223	3	224	1.00
6/18/58	12:00 m	3	197	3	200	1.02
	12:30 pm	3	199	3	205	1.03
	4:30 pm	3	207	3	225	1.09
7/9/58	9:30 am	3	20,900	3	20,500	0.98
	6:00 pm	3	9,220	3	9,180	1.00
7/10/58	8:00 am	3	3,730	3	3,720	1.00
	9:00 am	3	3,420	3	3,360	0.98
8/26/58	10:00 am	3	250	3	251	1.00
	10:30 am	3	247	3	243	0.98
	3:30 pm	3	256	3	249	0.97
9/17/58	12:30 pm	3	393	3	370	0.94
	2:30 pm	3	357	3	359	1.01
6/3/59	2:10 pm	2	204	2	226	1.11
6/7/59	1:10 pm	2	178	2	172	0.97
6/23/59	2:40 pm	2	1,180	2	1,130	0.96
6/24/59	11:10 am	2	418	2	426	1.02
10/8/59	9:15 am	2	1,340	2	1,300	0.97
	4:45 pm	2	808	2	778	0.96
7/14/60	5:10 pm	2	320	2	307	0.96
				Bottle Rack Samples		
9/13/60	6:15 pm	2	175	1	168	0.96
9/14/60	4:45 pm	2	146	1	160	1.10
5/16/61	1:15 pm	2	201	1	190	0.95
5/31/61	1:30 pm	2	8,980	1	8,840	0.98
6/19/61	1:50 pm	2	292	1	298	1.02
6/20/61	4:50 pm	2	229	1	249	1.09
9/13/61	5:30 pm	2	460	1	486	1.06

(1) At sampler intake

(2) Concentration of splitter sample/concentration of river sample.

TABLE 11

TESTS OF ELBOW INTAKE AT ST. PAUL

Date of Sampling	Time	River Samples (1)		Splitter Samples		Intake Eff. (2)
		Number	Avg.Conc. (ppm)	Number	Avg.Conc. (ppm)	
Pointed up.						
6/3/58	2:50 pm	6	174	6	164	0.94
6/4/58	1:00 pm	3	196	3	186	0.95
	1:30 pm	3	156	3	162	1.04
	2:00 pm	3	173	3	167	0.96
6/17/58	11:50 am	3	248	3	248	1.00
	12:00 m	3	236	3	248	1.05
	12:30 pm	3	240	3	246	1.02
Pointed up stream.						
6/3/58	1:00 pm	6	181	6	188	1.04
6/4/58	10:30 am	3	191	3	181	0.95
	11:00 am	3	180	3	190	1.06
	11:30 am	3	173	3	167	0.96
6/17/58	1:30 pm	3	238	3	243	1.02
	2:00 pm	3	243	3	254	1.04
	2:30 pm	3	225	3	237	1.05
Pointed down.						
6/3/58	3:30 pm	6	156	6	154	0.99
6/4/58	8:30 am	3	170	3	161	0.95
	9:00 am	3	186	3	177	0.95
	9:30 am	3	165	3	179	1.08
6/17/58	10:50 am	3	228	3	232	1.02
	11:00 am	3	241	3	265	1.10
	11:30 am	3	264	3	257	0.97

TABLE 12

TESTS OF NIPPLE INTAKE AT ST. PAUL

Date of Sampling	Time	River Samples (1)		Splitter Samples		Intake Eff. (2)
		Number	Avg.Conc. (ppm)	Number	Avg.Conc. (ppm)	
Short Nipple						
6/18/58	1:15 pm	3	198	3	210	1.06
	1:30 pm	3	213	3	211	0.99
	2:00 pm	3	199	3	207	1.04
Long Nipple						
6/17/58	3:00 pm	3	236	3	240	1.02
	3:30 pm	3	231	3	256	1.11
	4:00 pm	3	246	3	251	1.02
6/18/58	3:00 pm	3	205	3	214	1.04
	3:30 pm	3	209	3	215	1.03
Long Nipple with Plate						
6/17/58	4:30 pm	3	219	3	231	1.05
	5:00 pm	3	223	3	222	1.00
	5:30 pm	3	223	3	219	0.98

(1) At sampler intake.
(2) Concentration of splitter sample/concentration of river sample.

TABLE 13

SEDIMENT CONCENTRATION OF VOLUME RECORDER BOTTLE RACK SAMPLES
[ppm]

1960				1961			
Bottle No.	Date	Time	Conc.	Bottle No.	Date	Time	Conc.
1	9/2	3:20 pm	685	1	5/16	1:15 pm	190
2		3:50 pm	146	2	5/21	3:15 pm	93
3		4:00 pm	143	3	5/31	1:55 pm	8,840
4		5:50 pm	200	4		3:15 pm	6,730
5		10:00 pm	160	5		8:15 pm	5,270
6	9/3	4:00 am	378	6	6/1	2:15 am	5,140
7		8:00 am	180	7		8:15 am	6,940
8		2:00 pm	569	8		12:30 pm	5,980
9		8:00 pm	157	1		6:30 pm	5,950
10	9/4	8:00 pm	124	2	6/2	12:30 am	4,090
11	9/5	8:00 pm	134	3		6:30 am	3,080
12	9/6	8:00 pm	175	4		12:30 pm	2,260
13	9/8	8:00 pm	133	5		6:30 pm	1,210
14	9/10	8:00 pm	132	8	6/3	11:30 am	449
19	9/13	6:15 pm	175	12	6/4	11:30 am	150
22	9/14	10:00 am	180	17	6/7	7:00 am	237
1		5:40 pm	160	27	6/9	7:00 pm	421
7	9/16	5:00 am	152	36	6/12	7:00 am	256
13	9/17	5:00 pm	215	40	6/14	3:00 pm	214
14		11:00 pm	251	47	6/16	9:00 am	172
15	9/18	5:00 am	297	53	6/19	1:45 pm	298
16		11:00 am	319	1	6/20	4:30 pm	249
22	9/19	11:00 pm	519	3	6/21	4:30 am	278
25	9/20	5:00 pm	250	1	8/3	5:30 pm	217
28	9/21	11:00 am	218	4	8/4	5:30 pm	134
34	9/22	11:00 pm	230	8	8/5	5:30 pm	102
1	10/6	11:40 am	238	12	8/6	5:30 pm	105
2		5:10 pm	283	16	8/7	5:30 pm	74
3		11:10 pm	224	20	8/8	5:30 pm	92
16	10/9	4:10 pm	323	24	8/9	5:30 pm	257
				2	8/28	10:30 am	159
				7	8/30	4:30 am	143
				11	8/31	4:30 am	156
				14		10:30 pm	104
				22	9/13	1:40 pm	409
				1		5:30 pm	486

XI. APPENDIX B

53. Cycle of operation, accumulative-weight recording sampler--The cycling of the accumulative-weight recording sampler is controlled by the electrical system shown in Fig. 32, which operates as follows:

a. The cycle of operation starts when the 1/30-rpm timing motor and cam open the flush solenoid pinch valve, so that the top 2 in. of supernatant liquid drains out through the intake.

b. When the water level in the sedimentation tank reaches a predetermined level the lower limit switch of the water level control closes the solenoid pinch valve and starts the silt pump and 1/4-rpm timing motor. The silt pump interlock relay prevents the pinch valve from opening when the silt pump is operating. The weight of the water in the flow indicator depresses the indicator switch, and the switch cuts off the current to the protection circuit and turns on the white light.

c. During the first 50 seconds that the silt pump operates the splitter is in the waste position to allow the sediment concentration in the pumped flow to become constant.

d. At the end of the waste time a cam on the 1/4-rpm timing motor activates the splitter solenoid through the upper limit switch of the water level control which moves the splitter supply line to the sampling position.

e. After the water level in the sedimentation tank has risen 2 in., the upper limit switch of the water level control opens, and deactivates the splitter solenoid. The splitter supply line moves back to the waste position.

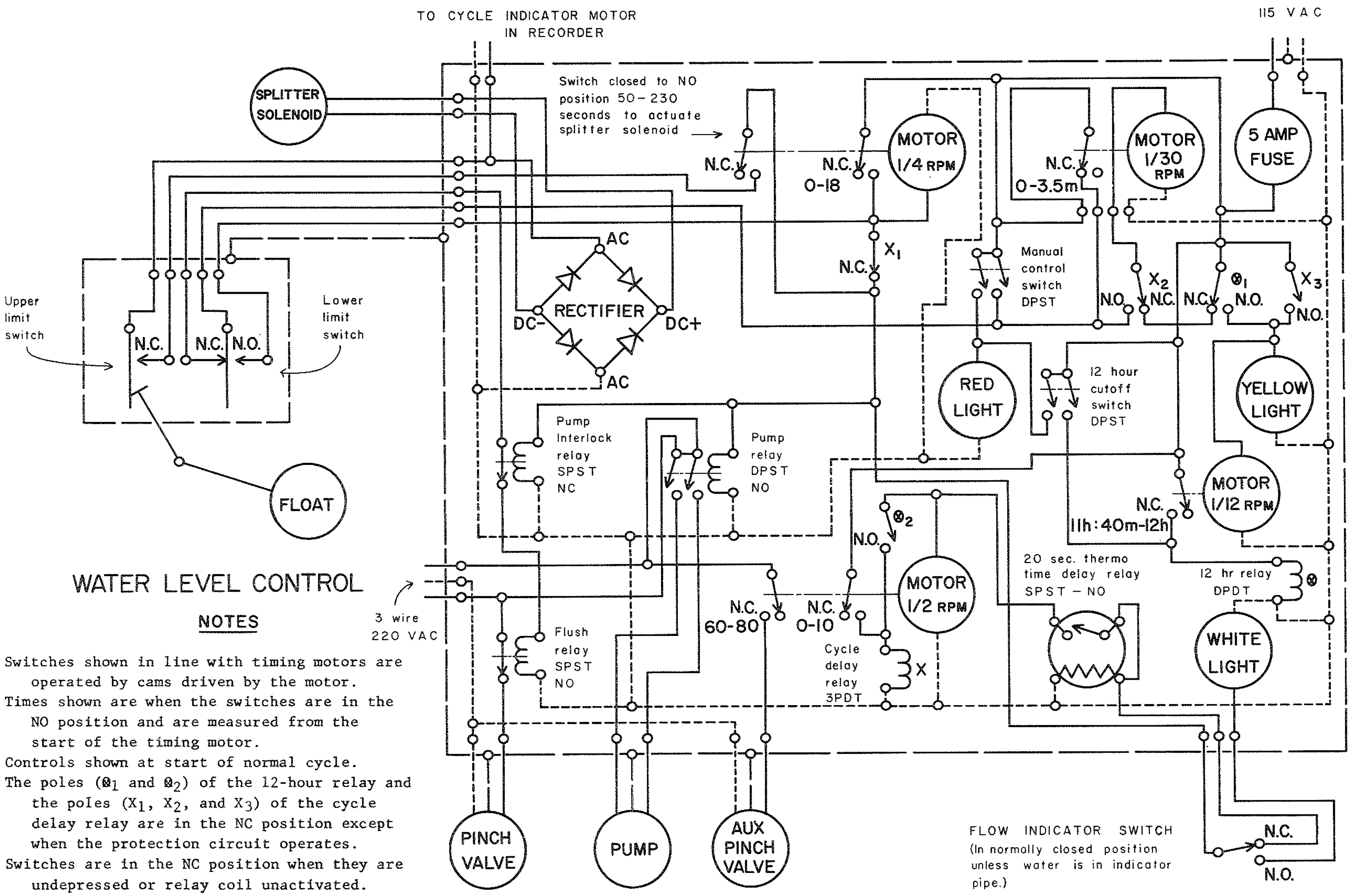
f. The silt pump continues to discharge into the wasteway until the pump has run a total time of four minutes, then the pump is stopped by a cam on the 1/4-rpm timing motor.

g. Because the 1/30-rpm timing motor continues to run, the cycle is repeated every 30 minutes.

h. If the silt pump fails to bring in a sample because the intake is covered with sand or the water level falls below the intake, the protection system discontinues the normal cycle of operation as follows:

   (1) Water stops flowing through the flow indicator. The indicator switch closes and actuates the time delay relay.

   (2) If flow is not restarted through the flow indicator within 20 seconds, the time delay relay closes and starts the 1/2-rpm timing motor.



NOTES

Switches shown in line with timing motors are operated by cams driven by the motor.

Times shown are when the switches are in the NO position and are measured from the start of the timing motor.

Controls shown at start of normal cycle.

The poles ($\otimes_1$ and $\otimes_2$) of the 12-hour relay and the poles (X_1, X_2, and X_3) of the cycle delay relay are in the NC position except when the protection circuit operates.

Switches are in the NC position when they are undepressed or relay coil unactivated.

FIG. 32 — CONTROL SYSTEM FOR ACCUMULATIVE-WEIGHT RECORDING SAMPLER

(3) Ten seconds after the 1/2-rpm timing motor starts, a cam on the 1/2-rpm timing motor activates the cycle delay relay (X).

(4) The first pole of the cycle delay relay (X_1) opens and stops the silt pump and 1/2-rpm timing motor. If the silt pump stops within 50 seconds after starting the splitter will not move to the sampling position.

(5) The second pole of the cycle delay relay (X_2) switches the feed for the 1/30-rpm timing motor to the timing motor cam so that the motor will stop after 3-1/2 minutes.

(6) The third pole of the cycle delay relay (X_3) starts the 1/12-rph timing motor. The yellow light glows while the 1/12-rph motor is on.

(7) After 11 hours and 40 minutes a cam on the 1/12-rph timing motor activates the 12 hour relay (Ø).

(8) The first pole on the 12 hour relay ($Ø_1$) switches the feed from the 1/30-rpm timing motor to the 1/12-rph timing motor.

(9) The second pole on the 12 hour relay ($Ø_2$) restarts the 1/2-rpm timing motor. A cam on the 1/2-rpm timing motor stops the motor after one revolution and shuts off the time delay relay.

(10) A second cam on the 1/2-rpm timing motor activates an auxiliary solenoid pinch valve which permits 10 gallons of flushing water to enter the sedimentation tank from an auxiliary supply tank.

(11) The cam on the 1/12-rph timing motor, which shuts off the 12 hour relay, stops the motor after one revolution and restarts the 1/30-rpm timing motor.

(12) The cam on the 1/30-rpm timing motor starts the normal cycle of operation (a-g).

(13) If the silt pump brings in a sample, the normal series of cycles are continued but if the silt pump fails to bring in a sample the protection cycle (h) is repeated.

The manual control switch can be used to operate the pumping cycle between regular cycle periods and to operate the silt pump to fill the sedimentation tank. The 12-hour cutoff switch can be used to activate 12-hour relay (Ø) prior to the normal protection cycle time of 11 hours and 40 minutes Step (7). After steps (8) through (10) are completed the 12-hour cutoff switch is turned off, and the 1/30-rpm timing motor resumes the normal cycle of operation. The red light is on whenever the manual control switch or the 12-hour switch is closed.

Whenever the splitter solenoid is activated the cycle indicator motor is activated. This motor operates an auxiliary pen in the load recorder to make a series of short dashes on the right side of the recorder chart. (See Fig. 33).

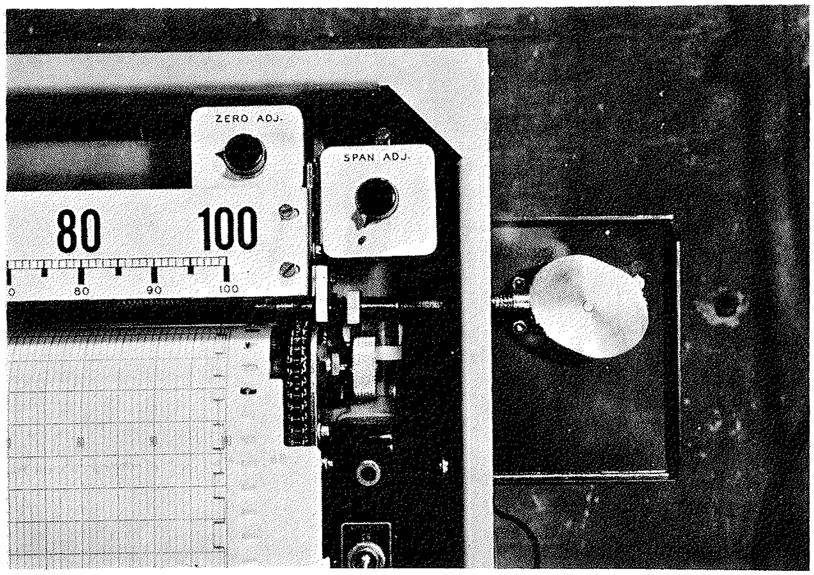


FIG. 33— CYCLE INDICATOR FOR ACCUMULATIVE-WEIGHT RECORDING SAMPLER

54. Cycle of operation, volume recording-sampler--The cycling of the volume recording sampler is controlled by the electrical system shown in Fig. 34 and 35 which operates as follows:

a. The cycle of operation starts when the 1/30-rpm timing motor and cam start the 1/3-rpm timing motor and 1/6-rpm timing motor (in wheel control section). After one revolution the 1/3-rpm and the 1/6-rpm timing motors are stopped by the first cam on each of the timing motors.

b. The second cam on the 1/3-rpm timing motor opens the solenoid pinch valve for 45 seconds during which time part of the flushing water drains from the flushing-water supply tank out through the intake.

c. The second cam on the 1/6-rpm timing motor activates the camera solenoid to photograph the sediment accumulation and water height in the sedimentation tube.

d. The third cam on the 1/6-rpm timing motor starts the wheel motor. A limit switch stops the wheel motor when the next sedimentation tube is in position.

NOTE: Controls shown in position at start of normal cycle.
The poles ($\otimes_1$ and $\otimes_2$) of the 12-hour relay and the poles (X_1, X_2, and X_3) of the cycle delay relay are in the normal position except when the protection circuit operates.

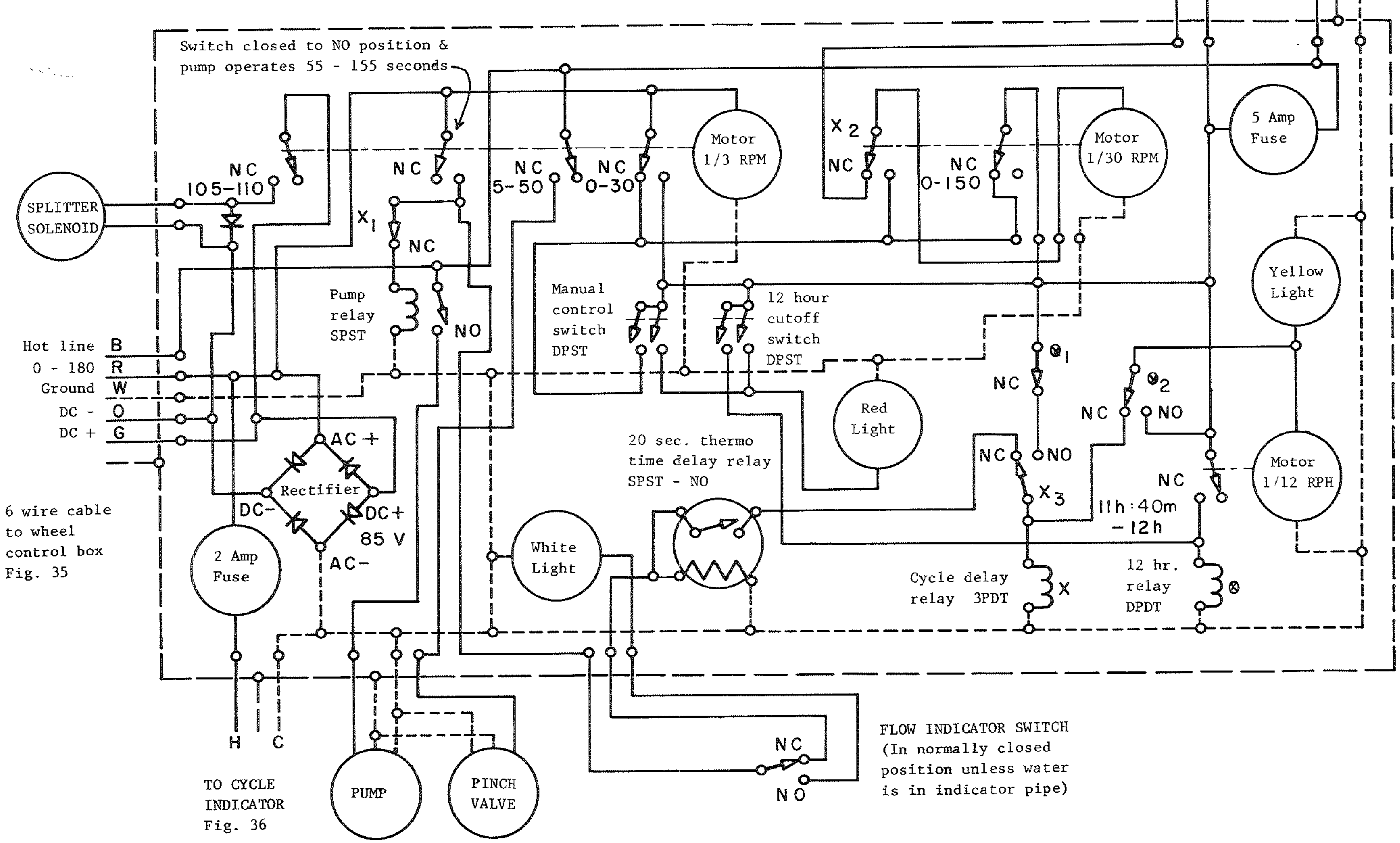


FIG. 34 — PUMPING CONTROLS FOR VOLUME RECORDING SAMPLER

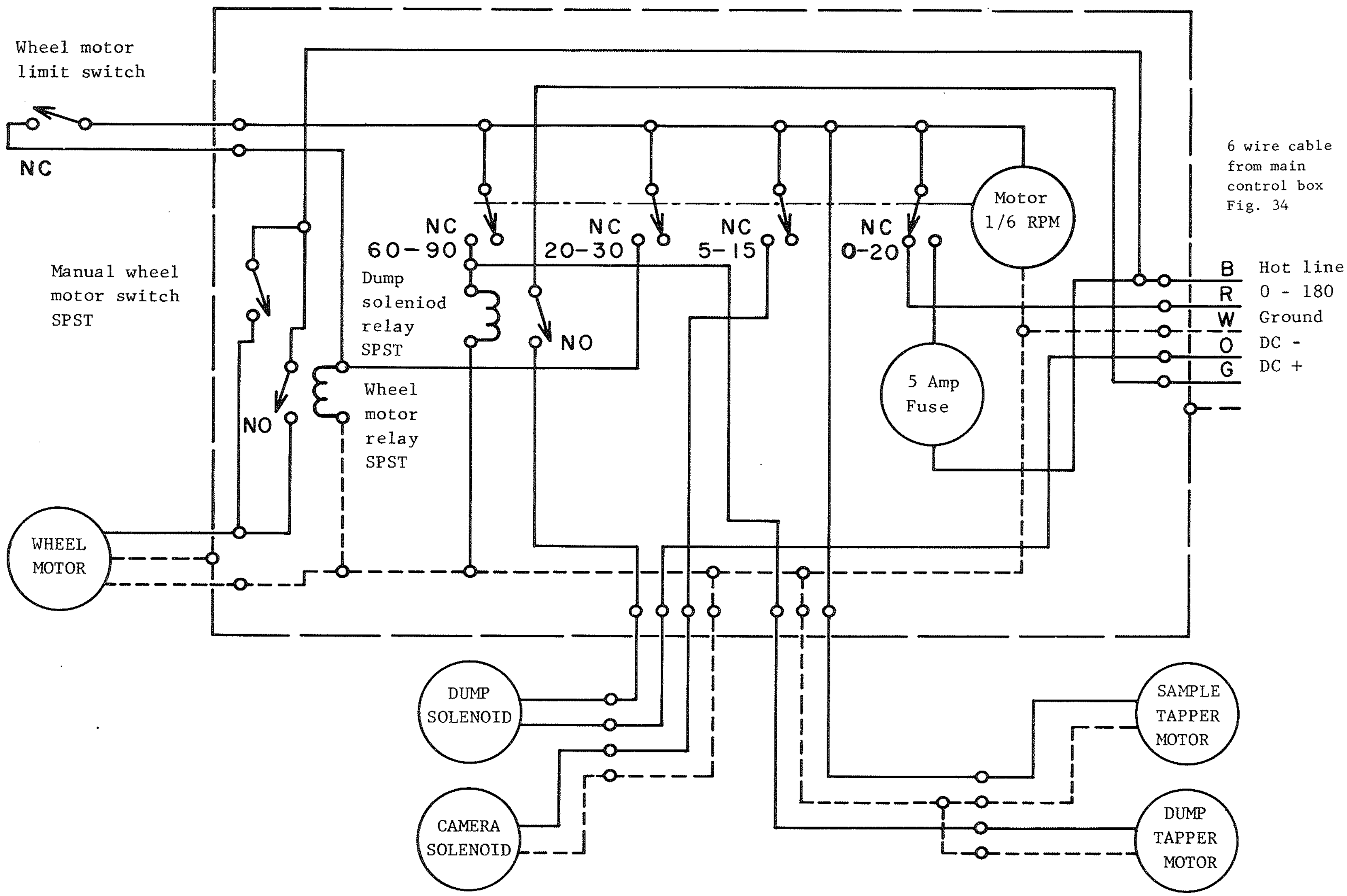


FIG. 35— WHEEL CONTROLS FOR VOLUME RECORDING SAMPLER

e. The third cam on the 1/3-rpm timing motor activates the silt pump for 100 seconds. The weight of the water in the flow indicator depresses the indicator switch, and the switch cuts off the current to the protection circuit and turns on the white light.

f. During the first 50 seconds that the silt pump operates the splitter is in the waste position to allow the sediment concentration in the pumped flow to become constant.

g. The fourth cam on the 1/6-rpm timing motor activates the dump solenoid and dump tapper motor to drain the sedimentation tube (same tube as photographed by Step c). The dump tapper operates for 30 seconds to loosen the accumulated sediment.

h. At the end of the waste time the fourth cam on the 1/3-rpm timing motor activates the splitter solenoid which moves the supply line to the sampling position for about 5 seconds (long enough to collect a 1-gallon sample in the sedimentation tube which was drained during the previous cycle).

i. The silt pump continues to discharge into the wasteway for the remainder of the 100 seconds. This waste water is used to replenish the flushing-water supply tank.

j. The sample tapper motor operates during the 6 minutes that the 1/6-rpm timing motor operates. The sample tapper assures even compaction of the accumulated sediment.

k. Because the 1/30-rpm timing motor continues to run, the cycle is repeated every 30 minutes.

l. If the silt pump fails to bring in a sample because the intake is covered with sand,or the water level falls below the intake, or for any other reason the protection system will discontinue the normal cycle of operation as follows:

   (1) Water stops flowing through the flow indicator. The indicator switch closes and actuates the time delay relay.

   (2) If flow does not restart through the flow indicator within 20 seconds, the time delay relay closes and activates the cycle delay relay (X) and starts the 1/12-rph timing motor. The yellow light is on while the 1/12-rph motor is on.

   (3) The first pole of the cycle delay relay (X_1) opens and stops the silt pump.

(4) The second pole of the cycle delay relay (X_2) switches the feed for the 1/30-rpm timing motor to its cam so that the motor will stop after 2-1/2 minutes.

(5) The third pole of the cycle delay relay (X_3) switches the feed for the cycle delay relay (X) and 1/12-rph timing motor from the time delay relay to the first pole of the 12 hour relay (Ω_1).

(6) After 11 hours and 40 minutes a cam on the 1/12-rph timing motor activates the 12 hour relay (Ω).

(7) The first pole of the 12-hour relay (Ω_1) opens and shuts off the cycle delay relay (X).

(8) The second pole of the 12-hour relay (Ω_2) switches the feed of the 1/12-rph timing motor from the third pole of the cycle delay relay (X_3) to the hot line.

(9) The cam on the 1/12-rph timing motor stops the motor after one revolution, shuts off the 12 hour relay, and restarts the 1/30-rpm timing motor.

(10) The cam on the 1/30-rpm timing motor starts the normal cycle of operation (a-k).

(11) If the silt pump brings in a sample, the normal series of cycles are continued but if the silt pump fails to bring in a sample, the safety cycle (1) is repeated.

The manual control switch can be used to operate the pumping cycle between regular cycle periods. The 12-hour cutoff switch can be used to activate the 12-hour relay (Ω) prior to the normal protection cycle time of 11 hours and 40 minutes Step (6). After the 12-hour cutoff switch is turned off, the 1/30-rpm timing motor and normal cycle of operation is restarted. The red light is on whenever the manual control switch or 12-hour cutoff switch is closed.

A low-water cutoff and cycle indicator is provided by a gage house control circuit (Fig. 36). During periods of no flow the mercury float switch remains open so that the coil of the low-water cutoff relay is dead and the relay switch is open. When there is water in the river and gage well the mercury float switch is closed and the coil of the low-water cutoff relay is activated thus closing the relay switch.

Whenever the 1/3-rpm timing motor is running, the coil of the indicator pen is activated. The indicator pen is a modified time indicator pen on a Stevens model A-35 water stage recorder. This indicating system was first used by Welborn. [5] The indicator pen makes a series of short dashes on the right side of the water-stage recorder chart. (See Fig. 37)

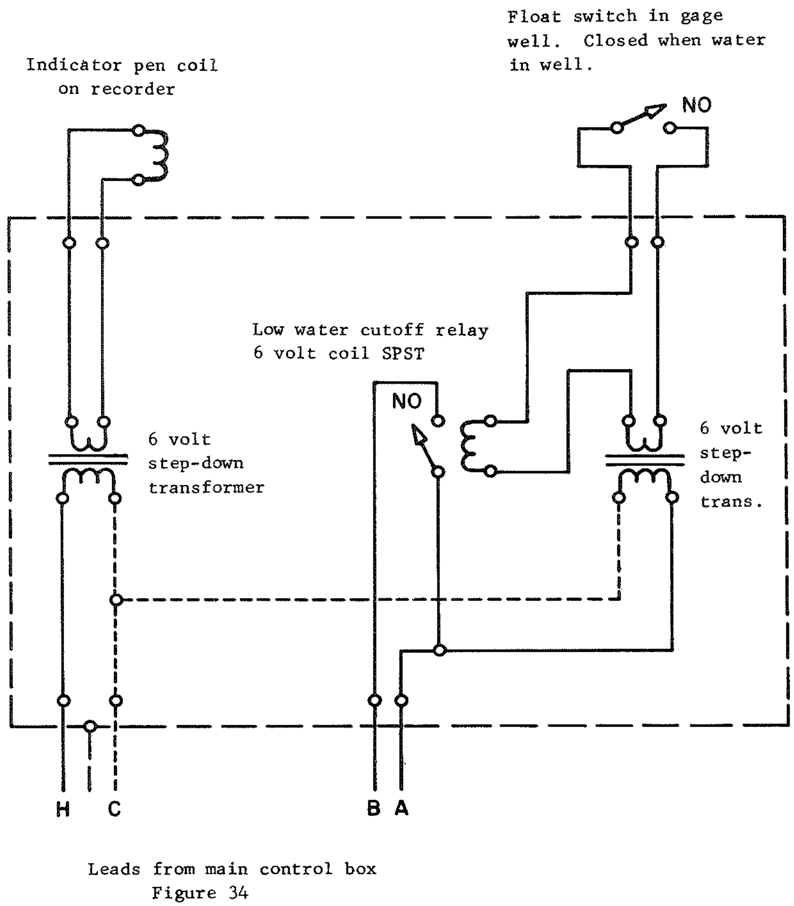


FIG. 36 — GAGE HOUSE CONTROL UNIT FOR VOLUME RECORDING SAMPLER

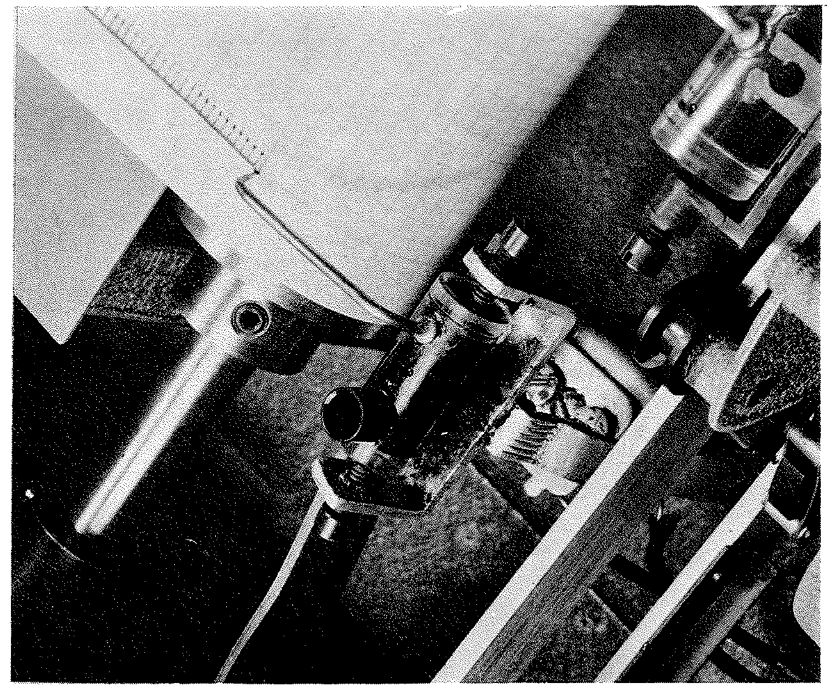


FIG. 37 — CYCLE INDICATOR FOR VOLUME RECORDING SAMPLER AND BOTTLING SAMPLER

55. Cycle of operation, bottling sampler--The cycling of the bottling sampler is controlled by the electrical system shown in Fig. 38 & 39. The dual sampling frequency of the bottle-wheel sampler is controlled by a float switch in the water level gage well and cycle frequency relay in the gage house control (Fig. 39). During low flow the mercury float switch remains open and the cycle frequency relay remains in the closed position. At a predetermined river stage the mercury float switch closes and activates the cycle frequency relay coil which opens the relay switch. The cycle of operation of the bottle wheel sampler is as follows:

1. Low river stage operation (cycle frequency relay in closed position).

   a. The cycle of operation starts when the 1/12-rph timing motor and cam activate the 12-hour relay (θ).

   b. The first pole (θ_1) of the 12 hour relay starts the 1-rph timing motor. The second cam on the 1-rph timing motor starts the 1/2-rpm timing motor. The second cam on the 1-rph timing motor and the first cam on the 1/2-rpm timing motor stop each motor after one revolution.

   c. The second cam on the 1/2-rpm timing motor opens the solenoid pinch valve for 40 seconds so that part of the flushing water from the flushing-water supply tank drains out through the intake.

   d. The third cam on the 1/2-rpm timing motor activates the silt pump for 65 seconds. The weight of the water in the flow indicator depresses the indicator switch, and the switch cuts off the current to the protection circuit and turns on the white light.

   e. During the first 40 seconds that the silt pump operates the splitter is in the waste position to allow the sediment concentration in the pumped flow to become constant.

   f. At the end of the waste time the fourth cam on the 1/2-rpm timing motor activates the splitter solenoid which moves the supply line to the sampling position for about three seconds (long enough to collect a sample in one of the pint milk bottles).

   g. The silt pump continues to discharge into the wasteway for the remainder of the 65 seconds. This waste water is used to replenish the flushing-water supply.

   h. The fifth cam on the 1/2-rpm timing motor activates the wheel solenoid and bottle rack stop mechanism (Fig. 31). The stop mechanism controls the movement of the bottle rack so that the next bottle is moved into the sampling position. (See Section 41).

   i. Because the 1/12-rpm timing motor continues to run, the cycle is repeated every 12 hours.

NOTE: Controls shown in position at start of 12-hour cycle.
The poles (X_1 and X_2) of the cycle delay relay are in the normal position except when the protection circuit operates.
The poles ($\otimes_1$ and $\otimes_2$) of the 12-hour relay are in the normal position during the one hour cycles.

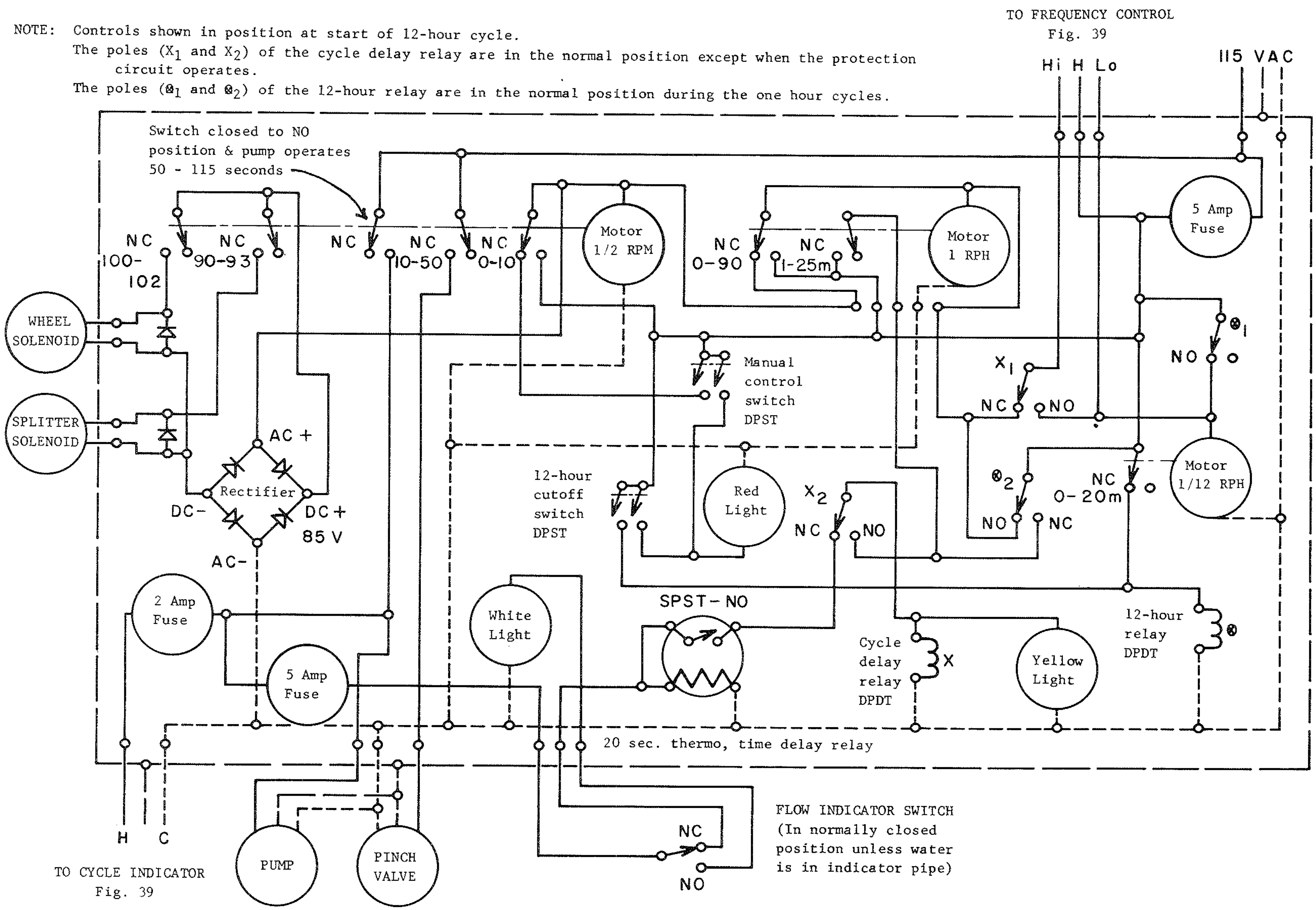


FIG. 38 → CONTROL SYSTEM FOR BOTTLING SAMPLER

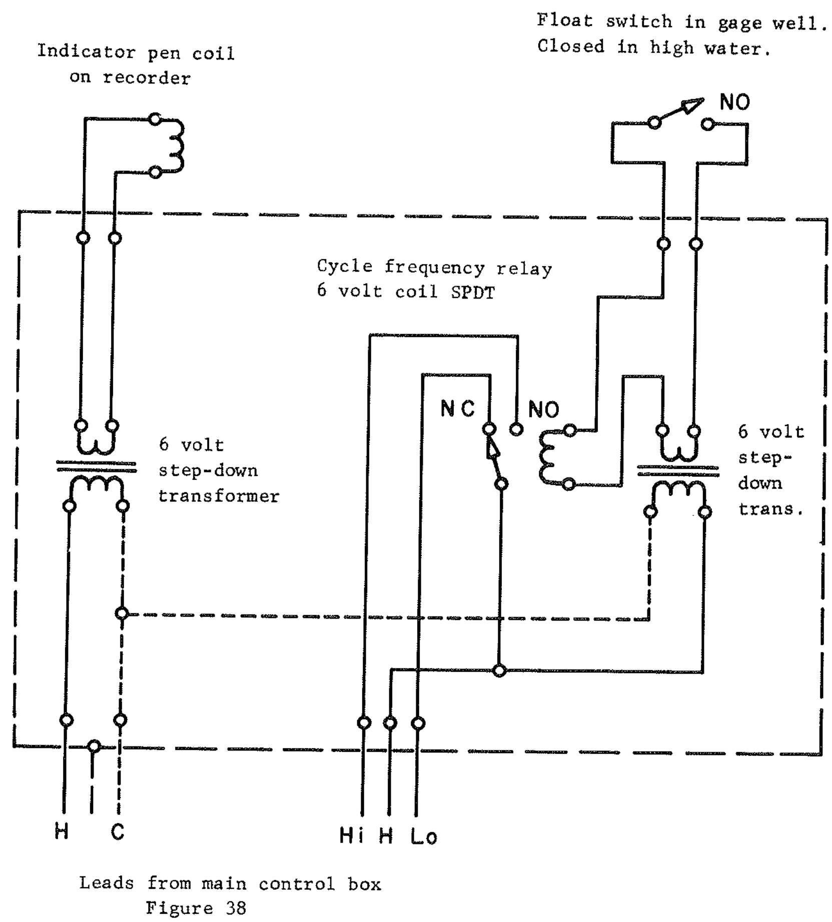


FIG. 39 GAGE HOUSE CONTROL UNIT FOR BOTTLING SAMPLER

2. High river stage operation (cycle frequency relay in normally open position).

   a. The first pole (Ω_1) of the 12-hour relay stops the 1/12-rph timing motor and the cycle frequency relay switch feeds the 1-rph timing motor.

   b. The cycle of operation starts when the second cam on the 1-rph timing motor starts the 1/2-rpm timing motor. The first cam on the 1/2-rpm timing motor stops the 1/2-rpm timing motor after one revolution.

   c. The cycle of operation is continued in the same sequence as 1-c through 1-h.

   d. Because the 1-rph timing motor continues to run, the cycle is repeated every hour.

3. Protection cycle

   a. If the silt pump fails to bring in a sample because the intake is plugged or the stream is below the intake, the protection system discontinues the normal cycle of operation.

   b. Water stops flowing through the flow indicator, The indicator switch closes and actuates the time delay relay.

   c. If flow is not restarted through the flow indicator within 20 seconds, the time delay relay closes and activates the cycle delay relay (X). The yellow light glows while the cycle delay relay is on.

   d. The feed from the cycle frequency relay comes through the first pole (X_1) of the cycle delay relay which switches the feed from the 1-rph timing motor to the 1/12-rph timing motor. After one revolution the 1-rph timing motor is stopped by its second cam.

   e. The second pole (X_2) of the cycle delay relay switches the feed of the cycle delay relay (X) from the time delay relay to the first cam of the 1-rph timing motor.

   f. Twenty minutes after the protection cycle started the second pole (Ω_2) of the 12-hour relay closes and feeds the cycle delay relay (X) after the first cam of the 1-rph timing motor opens.

   g. Twelve hours after the protection cycle started the cam on the 1/12-rph timing motor closes and activates the 12 hour relay (Ω).

   h. The second pole (Ω_2) of the 12 hour relay shuts off the cycle delay relay (X). The first pole (X_1) of the cycle delay relay starts the 1-rph timing motor and the normal cycle of operation.

   i. If the silt pump brings in a sample, the normal cycle of operation is continued but if the silt pump fails to bring in a sample, the protection cycle is repeated.

The manual control switch can be used to operate the pumping cycle between regular cycle periods. The 12-hour safety cutoff switch can be used to activate the 12-hour relay prior to the normal 12-hour protection cycle time. The red light is on whenever the manual control switch or the 12-hour safety cutoff switch is closed.

Whenever the 1/2-rpm timing motor is running, the coil of a cycle indicator pen is activated. This indicator pen is the same as shown in Fig. 37 for the sediment-wheel recorder.