INSTRUCTIONS FOR SAMPLING WITH DEPTH-INTEGRATING, SUSPENDED-SEDIMENT SAMPLERS D-74, D-74AL, D-74TM, AND D-74AL-TM

The D-74, the D-74AL, the D-74TM, and the D-74AL-TM comprise a group of samplers designed to collect depth-integrated suspended-sediment samples from streams and open channels. Members of this group have several common features. All are cast from the same pattern so physical dimensions are identical. As shown in Fig. 1, the streamlined bodies are fitted with four vanes which orient and stabilize the samplers in flowing water. Each sampler is equipped with a nozzle and air exhaust tube. These components are designed to collect a filament of water without altering its speed or direction. By sampling in this manner the sample can be analyzed to determine discharge-weighted concentration of suspended sediment. Each member will accept either a quart or pint sample container. The quart container (Owens-Illinois No. 6762) will fit directly into the cavity but the pint container (glass milk bottle) must be used with a special adapter. To facilitate container replacement, all are equipped with a head that pivots downward to expose the cavity. All are designed for cable suspension. They are slotted and drilled to fit a hangar bar and locking pin. Each sampler is shipped with a set of nine nozzles, 3 each 1/8", 3 each 3/16", and 3 each 1/4".

As shown in Table 1, the samplers differ primarily in material and weight. The D-74 or D-74AL may be used when samples are to be analyzed only for suspended-sediment concentration and particle-size distribution. The D-74TM or the D-74AL-TM must be used if samples are to be analyzed for trace quantities of metals. Also to minimize contamination of the sample, the gasket and the nozzles are made of chemically inert substances. Both the body and the head are coated with epoxy paint.

	WEIGHT		MATERIAL			
	Lb.	KG.	HEAD	BODY	NOZZLE	GASKET
D-74	60	(27.3)	Uncoated bronze	Uncoated bronze	Brass	Cell tite neoprene
D-74TM	60	(27.3)	Epoxy coated bronze	Epoxy coated bronze	Nylon	Silicone rubber
D-74AL	30	(13.[illegible])	Uncoated bronze	Uncoated aluminum	Brass	Cell tite neoprene
D-74AL-TM	30	(13.6)	Epoxy coated bronze	Epoxy coated aluminum	Nylon	Silicone rubber

TABLE I

On the D-74AL and D-74AL-TM, the tail cavity is hollow and is vented so that the cavity floods when the sampler enters the water. This feature, along with the bronze head, is necessary to balance the light-weight samplers.

Transit Rates

Depth-integrated samples must be collected by lowering the sampler through the water, quickly reversing direction at the bottom then raising it to the surface. To insure that each sample is properly weighted with depth, the sampler must be lowered at a uniform rate and raised at a uniform rate and the two rates should be as nearly equal as possible. The maximum rate is limited by the volume of the sample container, the nozzle size, velocity profile of the stream, and the angle between the approaching flow and the axis of the nozzle. Both minimum and maximum rates are limited by constraints on sample volume. The combination of the maximum and minimum rates establish a maximum depth of sampling. The limits portrayed graphically in Fig. 2 and 3 are based on the velocity profiles of Fig. 1, Report 6 (1). Briefly, this profile assumes the velocity at the bottom of the stream is half of v_m, the mean velocity for the vertical. The velocity near the surface is 1.16 v_m and the velocity at middepth is 1.05 v_m. Each graph in Fig. 2 and 3 is divided into two regions, labeled "optimum" and "permissible". Operation in the optimum range will yield, with a single integration, a sample volume large enough to facilitate laboratory analysis but small enough to prevent sample water from escaping through the air exhaust line. In some instances, operation in the optimum region may be difficult to achieve in practice. In these instances, operation in the permissible region is allowed; however, the sample volume will be less than optimum. Operation in either region will satisfy all other constraints, but operation outside of these regions will invalidate the sample. An invalid sample must be discarded, a clean bottle inserted, and the integration repeated. For any particular combination of container volume and nozzle size, the sampler should not be used in streams that exceed the absolute maximum depth rating indicated in Fig. 2 and 3.

Sampling Procedure

Selection of the sampling location is an essential first step but will not be discussed in these instructions. The reader is referred to references (2), (3), and (4). To insure the sample collection is compatible with computing and reporting procedures, the number of verticals to be sampled, the precise location of the verticals, and the number of samples at each vertical must be determined before sampling is started.

Prior to collecting each sample, measure the mean velocity and depth at the sampling vertical. If discharge at the section has been measured previously, records that relate gage height to velocity profiles and discharge may provide the necessary data. Refer to Fig. 2 and 3 to determine the correct nozzle size and transit rate. If a choice exists for nozzles, select the largest compatible with transit-rate limits imposed by the reel and operator. Connect the sampler to a hangar bar and the hangar bar to a suspension cable. All hardware, including clamps and cable, are to be as small and streamlined as possible. Suspension cables should not exceed 1/8" in diameter. Bulky hardware adds to drag which will pull the sampler downstream while the sample is being collected. Ideally the sample is to be collected along a vertical line. Both the sixty and thirty-pound samplers will usually require a reel. A hand-crank model is preferred because the transit rate can be controlled. Most powered reels lack the necessary speed control. At the proper transit rate, lower the sampler through the water. When the sampler touches the bottom, quickly reverse rotation of the reel, then at the same rate raise the sampler to the surface.

The following two examples illustrate the use of Fig. 2 and 3:

Example 1. A nominal quart sample is required. The stream depth is 18 feet and the mean velocity at the vertical is 2.1 feet per second. Fig. 2 shows only a 1/8" nozzle and a pint container will sample to 18 feet, therefore two or more samples must be collected to meet the sample volume requirements. Fig. 2 shows that at 18 feet, $\frac{R_T}{v_m}$ must be greater than 0.19 but less 0.2.

$$\text{Minimum } R_T = (2.1)\ (.19) = 0.399 \text{ ft/sec}$$

$$\text{Maximum } R_T = (2.1)\ (0.2) = 0.42 \text{ ft/sec}$$

While submerged the sampler will move through a distance of 36 feet.

Moving at a uniform speed the sampler must spend between $\frac{36}{.399} = 90.2$ seconds and $\frac{36}{.42} = 85.7$ seconds in the water.

Example 2. A nominal quart sample is required, the stream depth is 10 feet and the mean velocity is 2.4 ft/sec. Fig. 3 shows that with a quart container, any of the three nozzles can be used. Tentatively select the 1/4" nozzle.

$$\text{Minimum } R_T/v_m = 0.24$$

$$\text{Maximum } R_T/v_m = 0.29$$

$$\text{Minimum } R_T = 0.24\ (2.4) = 0.58 \text{ ft/sec}$$

$$\text{Maximum } R_T = 0.29\ (2.4) = 0.70 \text{ ft/sec}$$

$$\text{Maximum time in water} = \frac{20}{0.58} = 34.5 \text{ seconds}$$

$$\text{Minimum time in water} = \frac{20}{.7} = 28.6 \text{ seconds}$$

R_T/v_m could be as great as 0.32 if less than an optimum sample volume is acceptable. As with previous computations, this corresponds to a lowering rate of 0.77 ft/sec and a submerged time of 26 seconds. For the 1/4" nozzle the nozzle area is 34.1×10^{-5} ft^2. The sample volume will be $(26)\ (2.4)\ (34.1 \times 10^{-5}) = .02127$ ft^3 (602 ml).

The transit rates from Fig. 2 and 3 are based on the assumption that the sampler intake velocity is equal to the local stream velocity but, in design and construction of samplers, factors such as temperature, surface-tension, and fabrication tolerances require compromises. As water temperature increases, water viscosity decreases, therefore sampling rate increases. In the same flow condition a sampler will sample slightly faster in warm water than in cold water. In velocities less than approximately 0.8 ft/sec a sampler will sample slightly faster than stream velocity. This occurs because the air exhaust is elevated slightly above the nozzle to offset surface-tension forces which, at low velocities, may block flow or permit reverse flow. Each casting and machining operation requires tolerances which lead to slight differences in sampling characteristics. After assembly each sampler is checked and adjusted to minimize variations from the ideal, but still minor variations exist. Experience will indicate the degree of adjustment in transit rate required for a particular sampler. If adjustments exceed 15% of the rate indicated on Fig. 2 and 3, the procedure should be carefully reviewed and the sampler should be checked to insure the gasket is intact, the nozzle is straight and free of burrs, and the air line is free of obstructions. Before retaining a sample, inspect the sample volume. If the volume exceeds 440 ml or 800 ml for pint or quart containers respectively, discard the sample and repeat the integration at a slightly higher transit rate.

If samples from two or more verticals are to be composited prior to analysis, additional constraints apply to transit rates. The volume of each sample must be proportional to the stream discharge it represents. If samples are collected at equally-spaced verticals the sampler must be lowered and raised at the same rate at all verticals. Select the rate from Fig. 2 or 3 and enter the charts for conditions at the deepest vertical. Tentatively select a nozzle, container, and a transit rate, R_T, then for each vertical calculate R_T/v_m based on measured velocity. For each vertical enter the chart at the corresponding depth and compare the calculated R_T/v_m ratio with the maximum. If every ratio falls within either the optimum or permissible range, all verticals can be sampled at the selected transit rate. If one or more ratios fall outside both ranges select a new transit rate and repeat the process. In streams where depths and velocities differ considerably across the section, a single transit rate that satisfies all conditions may not exist. A transit rate suitable for the deep verticals will be too fast for the shallow verticals where velocities are low. The dilemma can be solved by dividing the cross-section into two or more major sections. Select the divisions so that depths and velocities within each section are nearly equal, then for each section select a suitable transit rate. Sample each section and, if desired, composite samples for all verticals within a single section. Because transit rates for different regions may differ, never composite samples from one region with samples from another. When the laboratory analysis is complete, compute the sediment discharge for each region, then sum to obtain the discharge for the entire stream. Samples collected at centroids of equal discharge may be composited only if each sample contains an equal volume. The transit rate may differ from vertical to vertical. If volumes differ by more than ten percent do not composite the samples.

Each sample must be labeled and the following information recorded: name of stream, location of cross-section, date, time of day, gage height, location of the vertical within the cross-section, depth of the vertical, operator's initials or name. Other information such as duration of sampling time and water temperature may be required.

Questions or comments regarding sampler operation should be addressed to:

Hydrologist-in-Charge
Federal Inter-Agency Sedimentation Project
St. Anthony Falls Hydraulic Laboratory
Hennepin Island & Third Ave. S.E.
Minneapolis, Minnesota 55414

Replacement parts are also available from the project.

APPENDIX

CONSTRUCTION OF TRANSIT-RATE DIAGRAM FOR DEPTH-INTEGRATING, SUSPENDED-SEDIMENT SAMPLERS

The diagrams in Fig. 2 and 3 show an optimum range that, for some field conditions, are quite restrictive. The range can be expanded if sample analysis requires less volume than indicated.

The following computation procedure outlines construction of the diagram for any depth-integrating sampler that contains the elements shown on Fig. 4. Equations are based on the development in Report 6[1] Section 8. The following stream velocity profile is assumed:

Relative Depth	Velocity/Mean Velocity In Vertical
0 surface	1.16
.1	1.17
.2	1.16
.3	1.15
.4	1.10
.5	1.05
.6	1.0
.7	.94
.8	.84
.9	.67
1.0 bottom	0.5

A_n = Area of intake nozzle at entrance; sq. ft.
1/8" = 8.52×10^{-5}, 3/16" = 19.2×10^{-5}, 1/4" = 34.1×10^{-5}

D_c = Stream depth at which compression limit at bottom equals compression limit at surface, ft.

h_1 = Atmospheric pressure at water surface = 34 ft. at sea level.

Q_{max} = Maximum volume of sample, cu. ft.

Q_{min} = Minimum volume of sample, cu. ft.

r_b = Relative velocity near stream bottom.

R_T = Transit rate of sampler, ft/sec. Raising rate equals lowering rate.

r_s = Relative velocity at stream surface.

V_1 = Volume of container cu. ft., 1 pt. = 0.01671, 1 qt. = 0.03342.

v_m = Mean stream velocity in vertical, ft/sec.

Point (1)

$$\frac{R_T}{v_m} = \frac{A_n\ r_b\ h_1}{V_1}$$

Point (2)

$$\frac{R_T}{v_m} = \frac{A_n\ r_s\ h_1}{V_1}$$

Point (3)

$$D_c = \frac{h_1\ (r_s - r_b)}{r_b + 1}$$

. For assumed profile this reduces to 15 ft.

Point (4)

$$\frac{R_T}{v_m} = \frac{20\ A_n}{Q_{max}}$$

Point (5)

$$\frac{R_T}{v_m} = \frac{20\ A_n}{Q_{min}}$$

. For both point 4 and point 5 the depth is arbitrarily taken at 10 ft. to facilitate plotting.

After all five points have been plotted, refer to Fig. 4 and connect appropriate points with straight lines. The approach angle limit is fixed at 0.4, however this limit restricts the permissible range, optimum range, and absolute maximum depth only if it plots to the left of point 2. If it falls to the right of point 2 both ranges and the absolute maximum depth are limited by the solid lines through point 3.

REFERENCES

(1) Inter-Agency Committee on Water Resources, "The design of improved types of suspended sediment samplers," Rept. 6, A study of methods used in measurement and analysis of sediment loads in streams; Subcommittee on Sedimentation, Minneapolis, Minnesota, 1952.

(2) Inter-Agency Committee on Water Resources, "Determination of fluvial sediment discharge," Rept. 14, A study of methods used in measurement and analysis of sediment loads in streams; Subcommittee on Sedimentation, Minneapolis, Minnesota, 1963.

(3) American Society of Civil Engineers, "Sedimentation Engineering," by Task Committee, V. A. Vanoni, ed., ASCE, New York, N. Y., 1975.

(4) Guy, H. P., and Norman, V. W.; Field methods for measurement of fluvial sediment, Techniques of water-resources investigations of the U.S. Geological Survey, bk. 3, ch. C2, 1970.

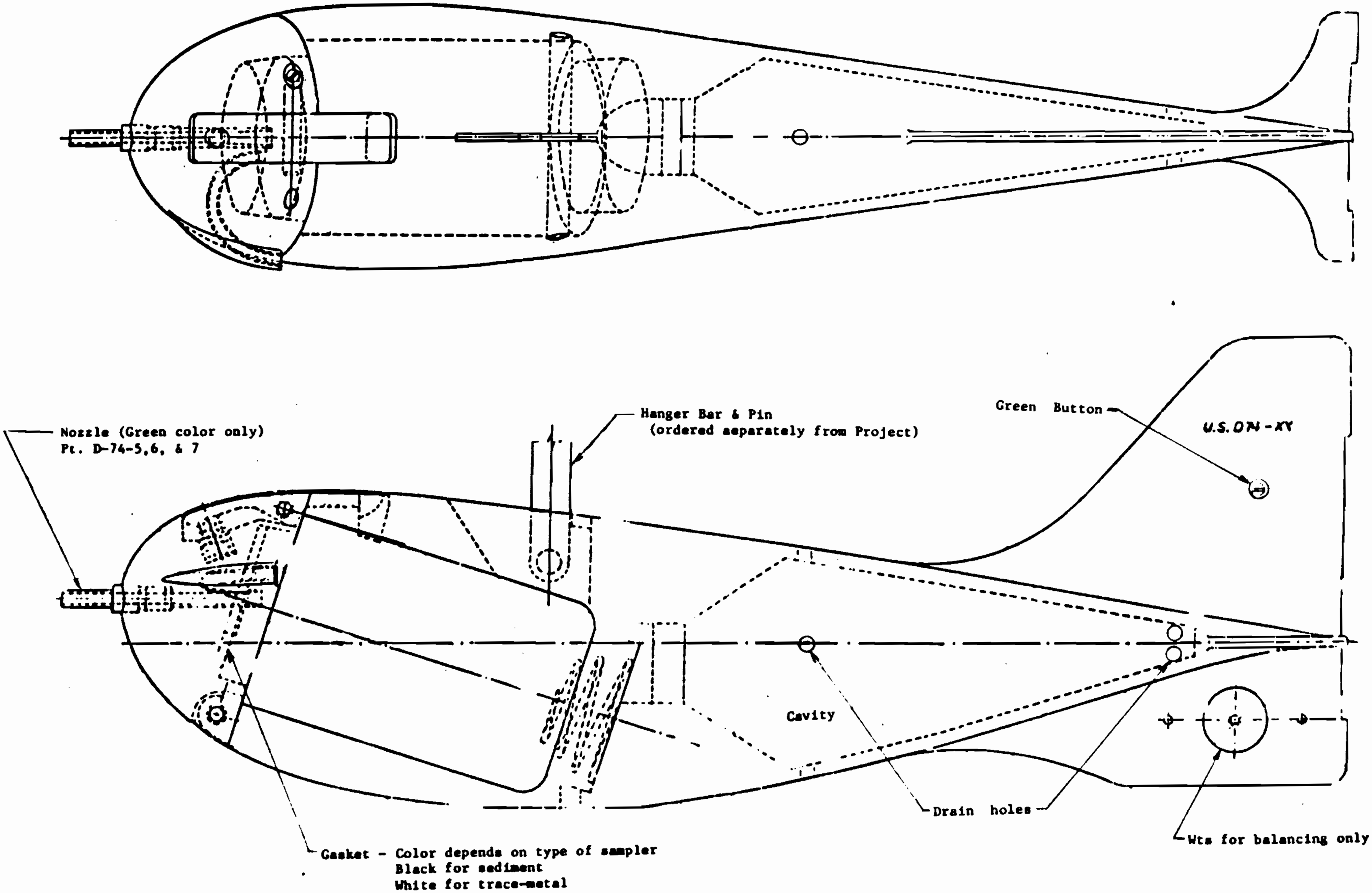

Nozzle (Green color only)
Pt. D-74-5,6, & 7
Hanger Bar & Pin
(ordered separately from Project)
Green Button
U.S. D74-XY
Cavity
Drain holes
Wts for balancing only
Gasket - Color depends on type of sampler
Black for sediment
White for trace-metal

FIGURE 1

TRANSIT RATES FOR DEPTH-INTEGRATING SAMPLERS
D-74, D-74AL, D-74TM, AND D-74AL-TM

PINT SAMPLE CONTAINER
350 ml < Sample Volume < 440 ml

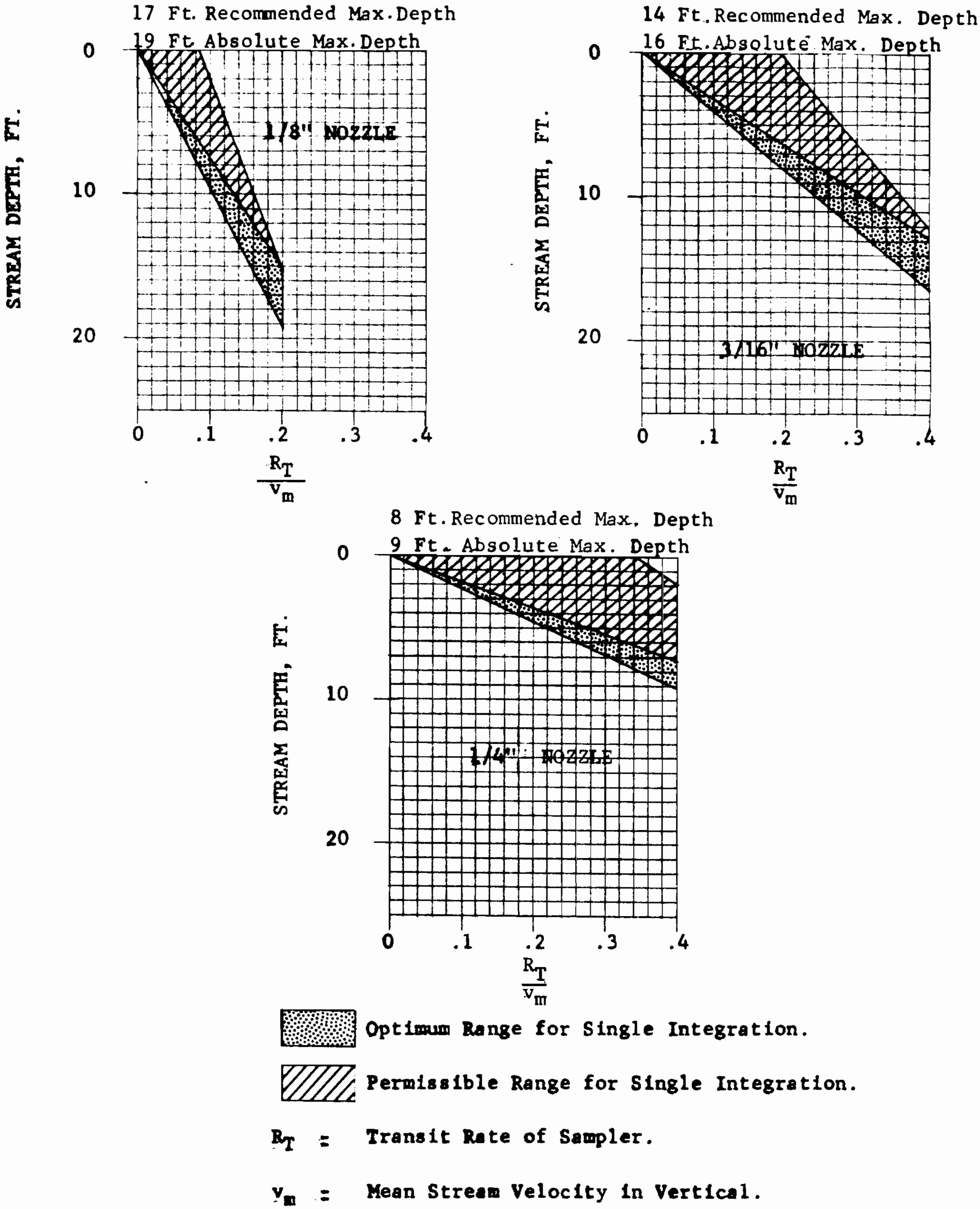
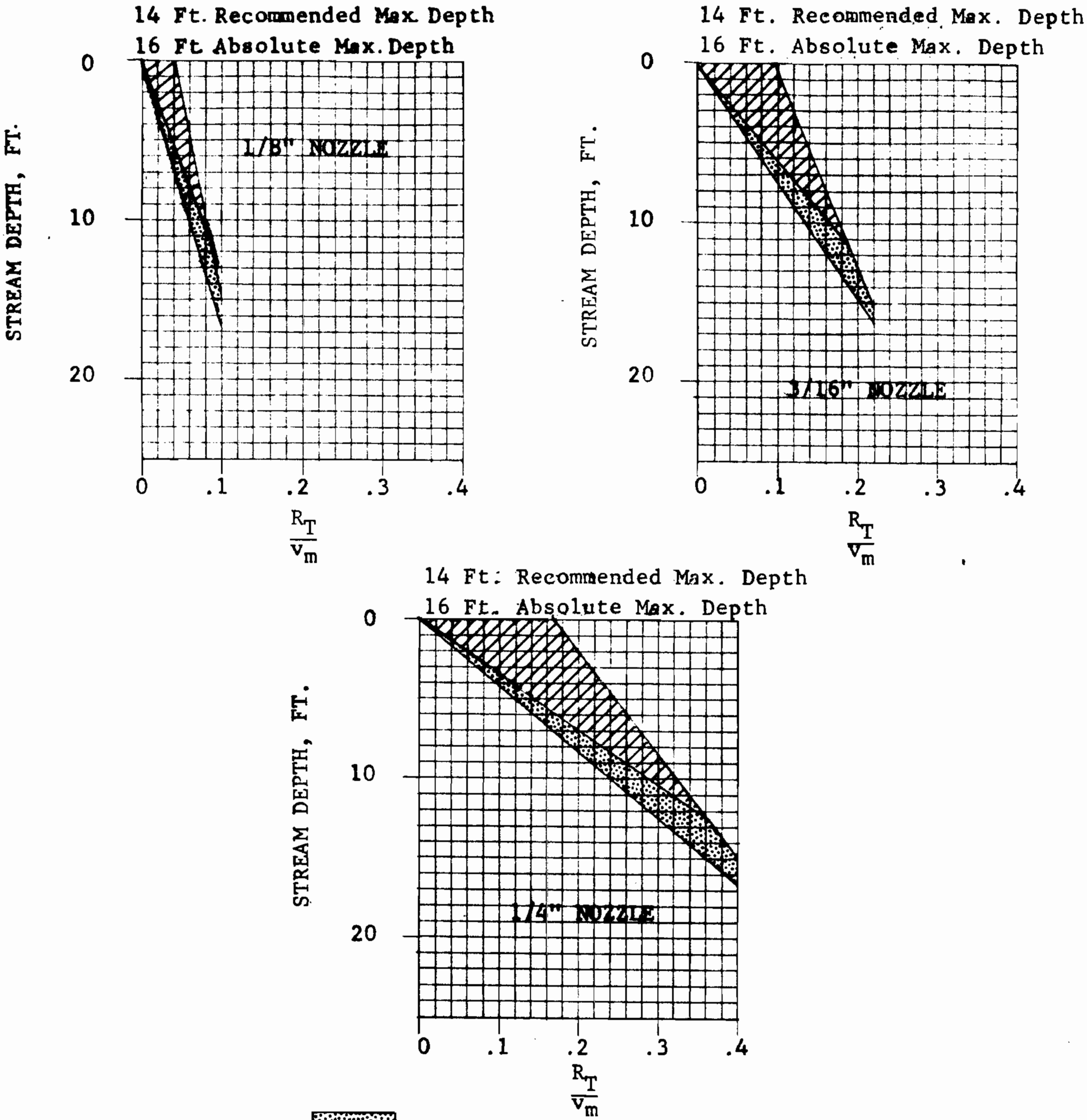


FIGURE 2

TRANSIT RATES FOR DEPTH-INTEGRATING SAMPLERS
D-74, D-74AL, D-74TM, AND D-74AL-TM

QUART SAMPLE CONTAINER
650 ml < Sample Volume < 800 ml



Optimum Range for Single Integration.

Permissible Range for Single Integration.

R_T = Transit Rate of Sampler

v_m = Mean Stream Velocity in Vertical

FIGURE 3

CONSTRUCTION OF DEPTH-TRANSIT RATE DIAGRAM FOR DEPTH-INTEGRATING, SUSPENDED-SEDIMENT SAMPLERS--Ref. (1)

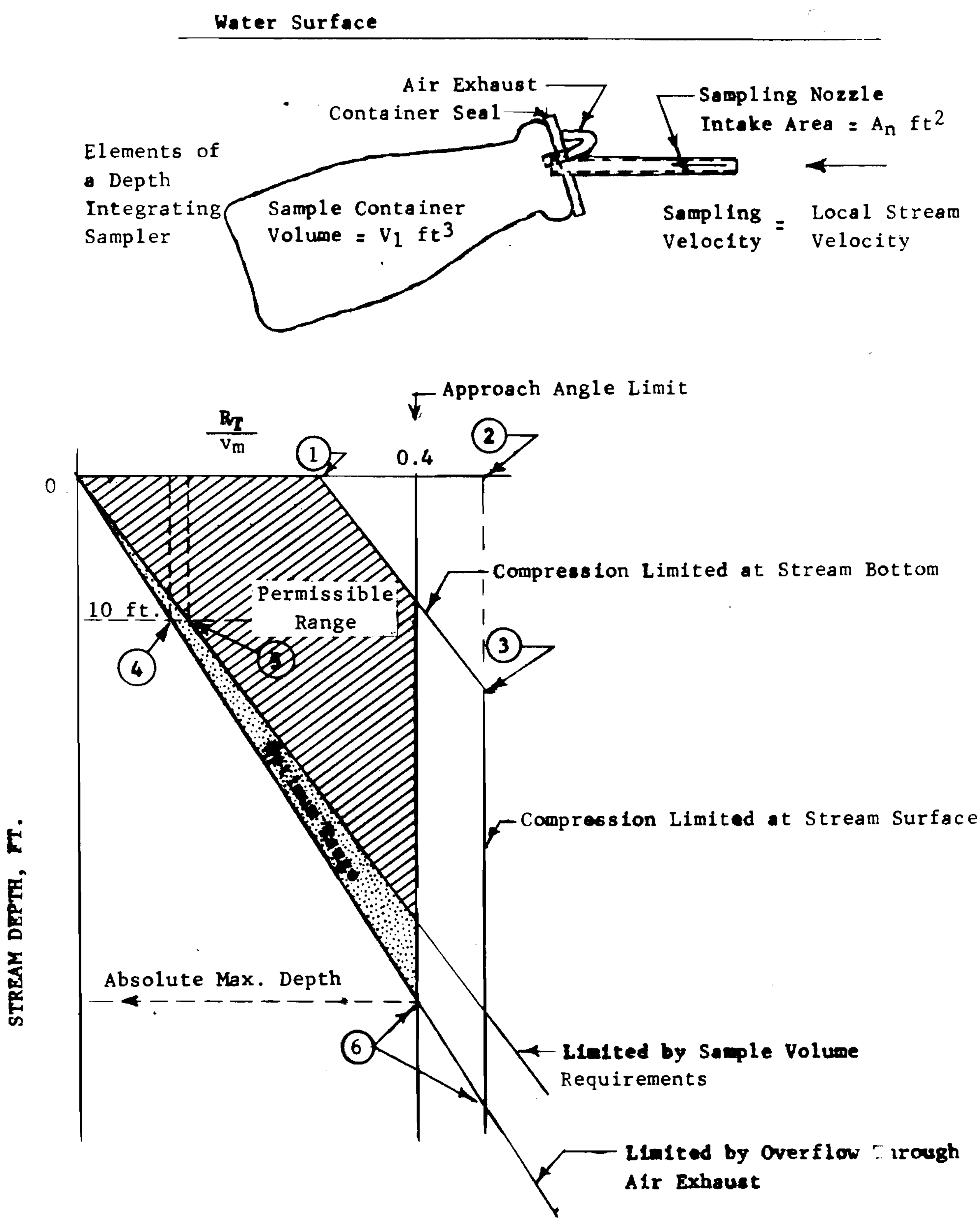


FIGURE 4