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A Spiral Sequential Sampler for Air and Liquids

Preliminary Results

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Preliminary Results

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A SPIRAL SEQUENTIAL SAMPLER FOR AIR AND LIQUIDS

Preliminary Results

by

Robert P. Vinson[1] and Fred N. Kissell[2]

ABSTRACT

A sequential sampler, based on the Archimedes screw, has been developed by the Bureau of Mines. Its initial purpose was to collect air samples during tracer gas studies in underground mines. However, the basic concept can be applied to other sampling needs, including sampling of liquids. A prototype was built and successfully tested in the Bureau's Experimental Mine at Bruceton, Pa. The simple design makes the sampler inherently durable and low in cost.

INTRODUCTION

A major concern in developing more efficient and safer mining methods is to improve mine ventilation. A recent development by the Bureau of Mines has been the use of the tracer gas SF_6 to determine airflow patterns, air velocity, and air leakage in underground mines.[3] During tracer gas experiments, it became evident that the usefulness of the tracer gas could be greatly expanded by employing a sequential gas sampler. Such a sampler would make it possible to collect more samples from remote locations over a longer period without an increase in manpower. The sampler would need to be of simple design and completely portable. To reduce the chance of clogging from mine dust, it should have few moving parts. It must also meet the intrinsic safety requirements for electrical equipment to be used in underground coal mines.[4] Finally, it must be capable of collecting samples at rates ranging from one per minute to one per hour, depending on the sampling conditions.

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[1] Physicist.

[2] Physical research scientist.

[3] Thimons, E. D., R. J. Bielicki, and F. N. Kissell. Using Sulfur Hexafluoride as a Gaseous Tracer To Study Ventilation Systems in Mines. BuMines RI 7916, 1974, 22 pp.

[4] U.S. Bureau of Mines. Schedule 2G, Electric Motor-Driven Equipment and Assessories. Federal Register, v. 33, No. 54, Mar. 19, 1968, pp. 4660-4671.

Commerically available sequential samplers do not satisfy these requirements. They are relatively complicated devices with numerous valves, lines, collection bottles, etc. They are not very portable and usually require a 110-V-ac power source. None are known to be permissible in methane atmospheres.[5]

A sequential sampler that meets the necessary criteria for mine use has been developed by the Bureau of Mines. Preliminary tests show it can be used for tracer gas studies in underground mines.

PRINCIPLE OF OPERATION

The sequential sampler developed by the Bureau of Mines is basically an Archimedes screw. A section of small-diameter tubing is wound around a cylindrical mandril, leaving both ends of the tubing open (fig. 1). The mandril is tilted about 20° from the horizontal, with the low end partially submerged in a pan of water. The mandril then is rotated by a spring-wound clock motor. As it turns, the open end of the tubing at the low end of the mandril collects some water. As the rotation continues, the tubing comes out of the water and collects an air sample until it once again enters the water. In this way, each air sample is separated by a segment of water. The process is repeated each complete rotation, and successive samples are screwed upwards.

The simplicity of the design has two important advantages: (1) As the instrument has few moving parts, the probability of mechanical failure is very low, and (2) the sampler should be relatively inexpensive to produce.

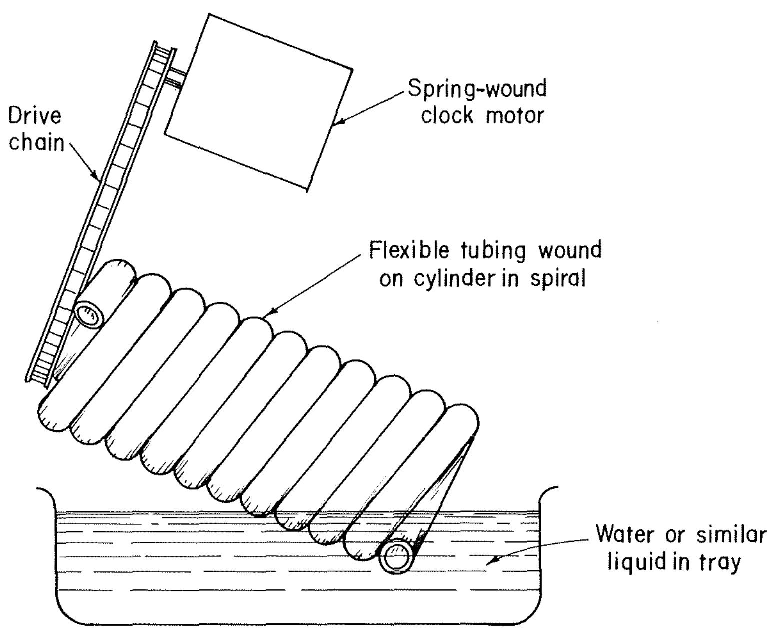

FIGURE 1. - Spiral sampler for air sampling.

The spiral-type sequential sampler also can be used as a liquid sampler by mounting it on floats with the low end of the mandril partially submerged in the liquid to be sampled (fig. 2). Modified in this way, the device can be used to sample streams, rivers, ponds, etc.

The volume, number, and timing of samples can be

[5] American Conference of Governmental Industrial Hygienists. Air Sampling Instruments for Evaluation of Atmospheric Contaminants. Cincinnati, Ohio, 4th ed., 1972, 582 pp.

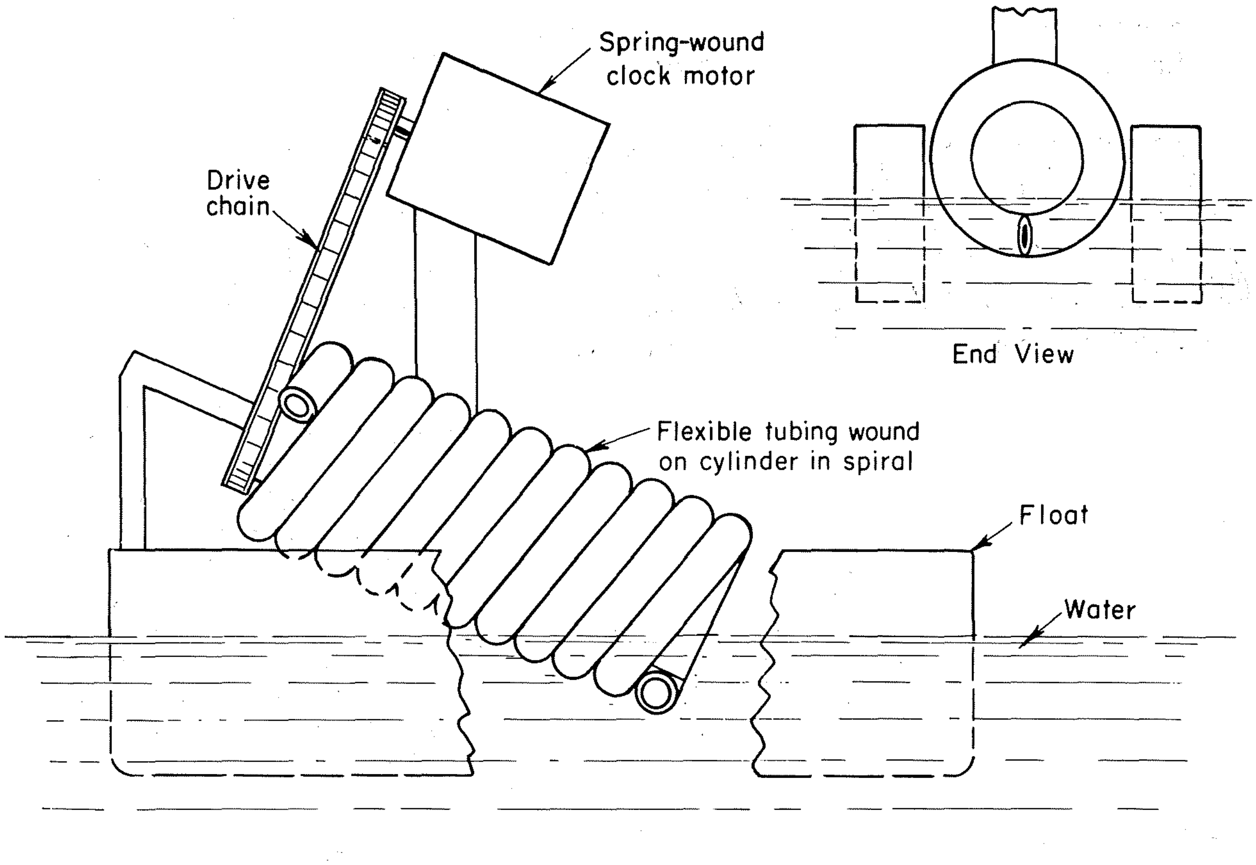

FIGURE 2. - Spiral sampler for water sampling.

varied to meet different needs. The sample volume can be changed by varying the diameter of the spiral, the diameter of the tubing, and the submersion depth. The sampling time and the number of collected samples depend on the number of spirals and the rotation speed.

The most convenient material for the spiral is a flexible plastic tubing. This allows the use of special "pinch bars" (appendix B and fig. B-3) to isolate the individual segments while the sampler is being carried. Withdrawal of samples for analysis also is simplified. An individual segment is simply pierced with a syringe needle and the sample is withdrawn. A new piece of tubing is required the next time the sampler is used.

Unfortunately, flexible tubing has some permeability. If gases are sampled, the time between sampling and withdrawal for analysis cannot be more than a day or so, or else part of the gas will be lost by diffusion. (See appendix A for results of tests to measure the diffusion speed for various materials.)

Loss by gas diffusion can be reduced by using a less permeable tubing material, such as glass. For analysis, a section of plastic tubing is connected to the back end of the glass coil (fig. 3). The plastic is wrapped

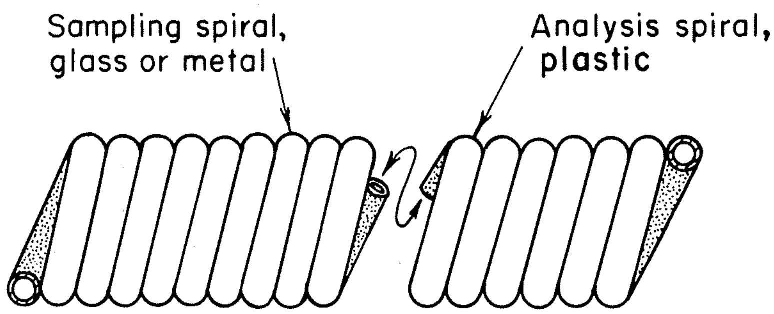

FIGURE 3. - Method of transfer for sample analysis.

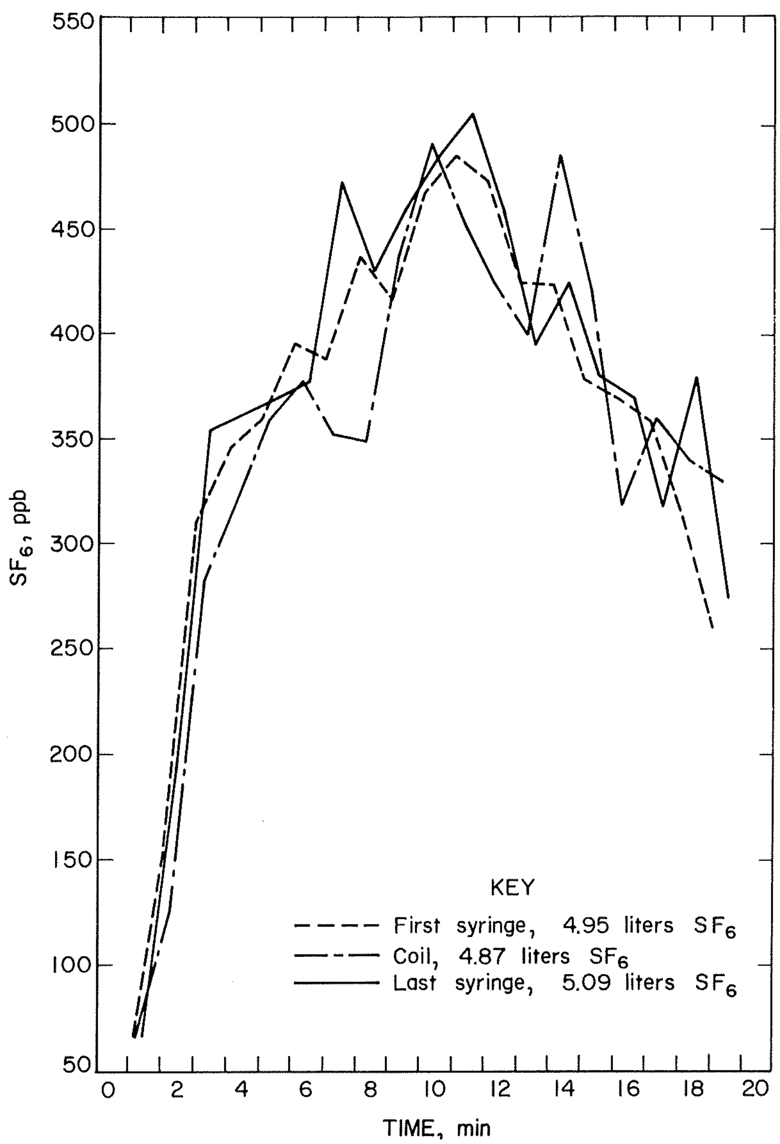

FIGURE 4. - SF_6 concentration versus time.

around its mandril in the same direction as the glass. The mandril and coils are then rotated together, allowing the gas samples and separating water segments to pass into the plastic tubing. Plastic segments are then pierced with a syringe, and a portion of the gas is withdrawn.

With a glass coil "pinch bars" can no longer be used to keep samples separated during transport (appendix B); however, sealing both ends of the coil with airtight rubber caps made the coil a closed system and hindered the water in each segment from splashing into adjacent segments and mixing the air samples.

TESTS AND RESULTS

The sampler was developed initially for SF_6 tracer gas ventilation studies. This meant that only a small volume of air was needed for analysis, since SF_6 can be detected with an electron detection gas chromatograph using only 0.1 ml of air sample for analysis. In this particular application, the sampler was required to contain the sample for at least 2 weeks without any decline in SF_6 due to adsorption or diffusion through the tubing. Glass was found to be the best coil material for retaining SF_6 for this length of time (appendix A).

If any SF_6 was adsorbed by the water separating the segments, the amount was negligible.

A prototype sampler was built for underground use. It was approximately 30 inches long, 6 inches wide, and 12 inches high, and was powered by a spring-wound, chart-drive motor that rotated the mandril at 1 rpm. An in-mine study was conducted with this prototype to get insight into the problems encountered under actual operating conditions and to see if the sampler would collect valid gas samples. The spiral sampler speed was set at 1 rpm, and the sampler was placed in the center of a 6-1/2- by 14-foot entry having an air velocity of 300 ft/min. Approximately 2,000 feet upstream of the sampler, 7.36 liters of SF_6 were released into the mine air. Two 10-cm^3 syringe samples were collected manually for each complete rotation of the mandril at the beginning and end of the air-sampling portion of the rotation. Each coil segment collected a 2.5-cm^3 air sample.

Although the test was stopped before all the released SF_6 has passed the sampling station, equivalent volumes of SF_6 were collected by the coil and syringes. When SF_6 concentrations were plotted against time for the three sets of samples (fig. 4), the resulting curves followed one another closely. This shows that the SF_6 concentration of each coil sample was approximately the same as for the corresponding syringe samples and proves that the coil can collect valid gas samples.

CONCLUSION

A preliminary investigation of the potential of the spiral-type sequential sampler shows that the basic concept is capable of a wide variety of applications, including the sampling of liquids as well as gases. The simple design makes the sampler inherently dependable and low in cost. This indicates that further development would be worthwhile.

APPENDIX A

A series of tests was run using various types of tubing to evaluate their ability to retain SF_6 over periods of 1 day to 2 weeks. The tubing to be tested was wound around the mandril and mounted on the rotating mechanism placed on the sampler. The sampler was then operated repeatedly in an enclosure containing some SF_6. For comparison, a 10-cm^3 syringe sample was taken along with each sample taken in the coil. The two sets of samples were analyzed on a chromatograph for SF_6 content. A "t" test was made on the resulting data (table A-1) to see if there was a significant decrease in SF_6 in the coil compared with the corresponding syringe samples. Plastic tubing held SF_6 on the day the sample was taken, but 1 week later there was a definite drop in concentration. Amber rubber tubing showed a drastic decline in SF_6 the first day. Glass was finally chosen, in preference to copper, as the coil material for SF_6 work because of its lower weight and the fact that liquid levels could be readily observed.

TABLE A-1. - Tubing tests

Tubing material	Percent drop in SF_6 concentration				"t" test at 5-percent confidence level
	Day 0 (4 hours)	Day 3	Day 6	Day 14	
Amber rubber.	8	[1]60	-	-	Significant difference on day 0.
Plastic.	.7	-	[1]17.7	-	Significant difference on day 6.
Glass...	1.0	-	-	[1]5	No significant difference on day 14.
Copper..	.9	-	-	[1]1	Do.

[1]Final test.

APPENDIX B

It may be required, on occasion, to collect instantaneous samples. This can be accomplished with the coupling device (fig. B-1). The driver arm turns the mandril by pushing against the coil catch. Once the mandril is turned 180° (water collection), the unbalancing weight rapidly turns the mandril the other 180° to collect a gas sample.

It may be desired to collect twice as many samples on a mandril of set length. This may be accomplished by a double coil (fig. B-2).

When using plastic tubing for a short time, pinch bars may prove useful for sample transport (fig. B-3).

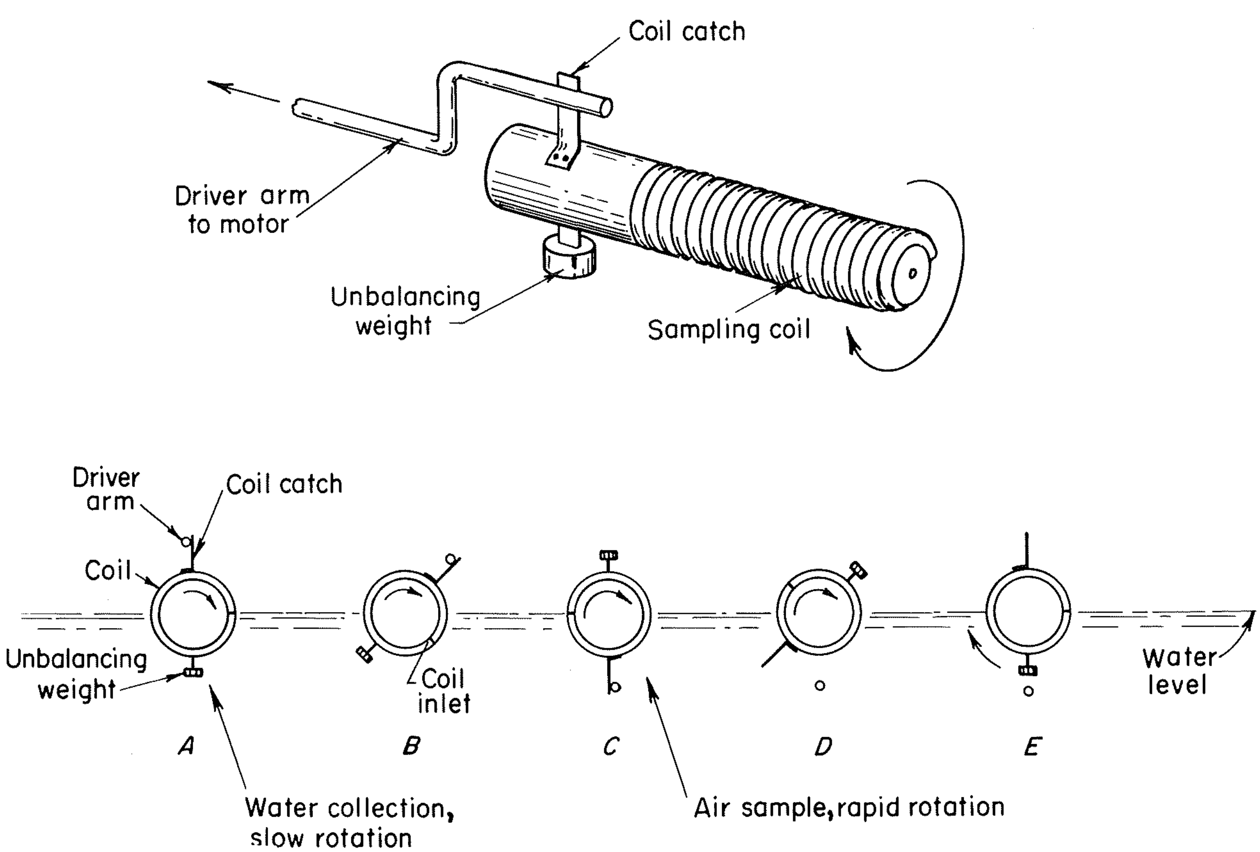

FIGURE B-1. - Coupling device for instantaneous air sample.

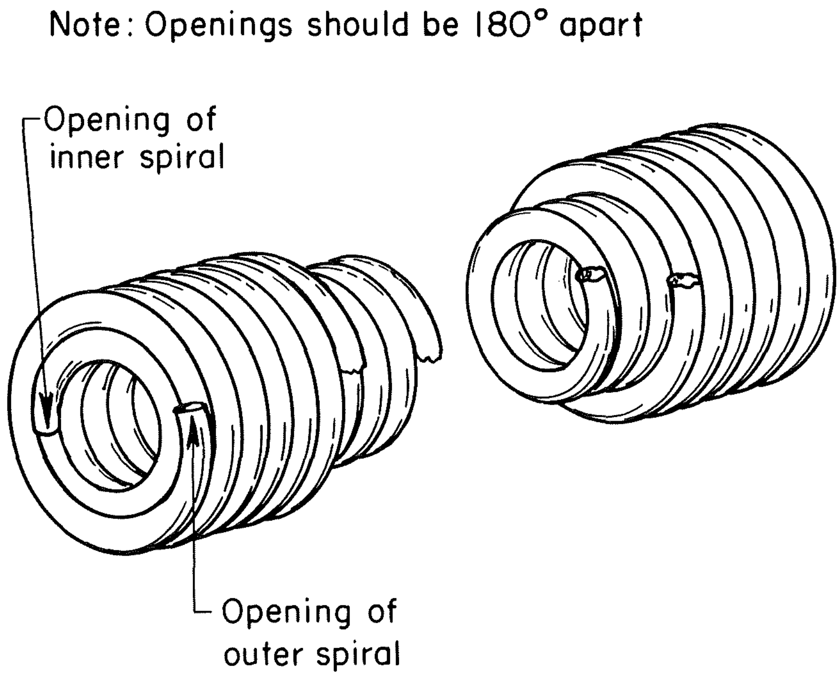

FIGURE B-2. - Method to double the number of sampling chambers.

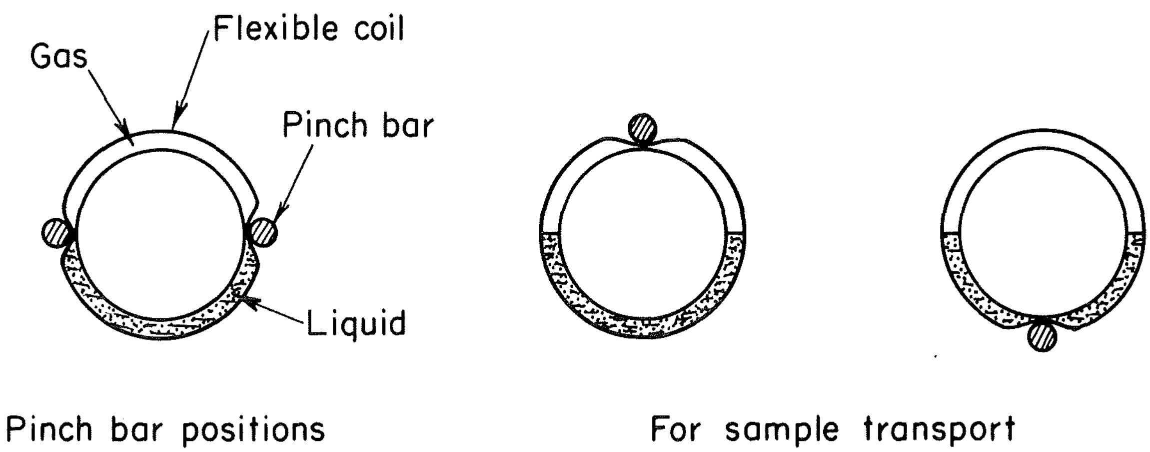

FIGURE B-3. - Pinch bars.

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