SSTS-Ajax for Analysis On-line by Gas Chromatography

Yu Yingtao
State Key Laboratory of C1 Chemical Technology, Department of Chemistry, Tsinghua University, Beijing, 100084, China

Abstract

A switching system of triplet samples (SSTS-Ajax) is introduced to the analysis on-line by gas chromatography. The triplet samples (i.e., a sample and its two duplicates) can be obtained at the same time and then analyzed in turn by using this system. During a reaction, if the analysis of one sample is unsuccessful or the result is abnormal, a duplicate can be kept for a second analysis in the sampling tube without the following on-line analyses interrupted. Alternatively, the triplet samples can be respectively analyzed under different operating conditions, and thus offer more information about the sample. Furthermore, the triplet samples from different points on-line can be obtained alternately or even at the same time with the aforementioned advantages maintained. In addition, six samples from one point on-line can also be obtained at the same time or even at six different times and then analyzed one by one, which is very helpful when the duration of an analysis is much longer than the interval of two continuous sampling operations. The principle and usage of SSTS-Ajax is discussed in detail.

Introduction

In research, the need to analyze samples on-line by using gas chromatography (GC) is often encountered. Because only one set of operating conditions cannot always give satisfying results of all of the components in a complicated sample, various techniques for GC have been developed to obtain more information about the sample. However, having only one sample available for analysis is still inconvenient in some sense, especially when the analysis is unsuccessful or the result is abnormal.

In the present paper, a switching system of triplet samples (SSTS-Ajax) is introduced and can be of great use for on-line GC analysis. The principal functions and advantages of SSTS-Ajax can be generalized as described in the following paragraphs.

By using this system, the triplet samples (i.e., a sample and its two duplicates) can be obtained at the same time and then analyzed in turn. The composition of the sample is the same as that of its duplicates. Thus, it might be convenient for the analyst to examine the repeatability and stability of the instrument used for analysis.

Alternatively, during a reaction, if the analysis of one sample is unsuccessful or the corresponding result is abnormal, a duplicate can be kept for further analysis in the sampling tube without interrupting the whole reaction and following analyses on-line.

The quantity of one sample can be different from that of its duplicates by using sampling tubes of different sizes. Any two or all of the triplet samples can also be injected together as one sample, which is convenient and helpful in constructing a calibration curve.

Moreover, each of the triplet samples can be switched into either column in a GC. If one set of conditions (carrier gas, column, detector, etc.) is not efficient enough for analyzing all of the components in a sample, different operating conditions can be used for the analyses of the triplet samples. Therefore, more information about the sample might be obtained.

Furthermore, the triplet samples from different points on-line can also be obtained alternately or even at the same time with the aforementioned advantages maintained. Obviously, there should be six sampling tubes equipped in SSTS-Ajax if the triplet samples from two different points on-line need to be obtained at the same time.

In addition, all of the six sampling tubes involved in SSTS-Ajax can be employed in the analysis of the sample from one point on-line, which might be especially helpful in constructing a standard curve.

SSTS-Ajax can also offer an important function in an experiment such that the duration of an analysis is much longer than the interval of two contiguous sampling operations. Six samples from one point on-line could be obtained at six different times and kept in the six sampling tubes, respectively;

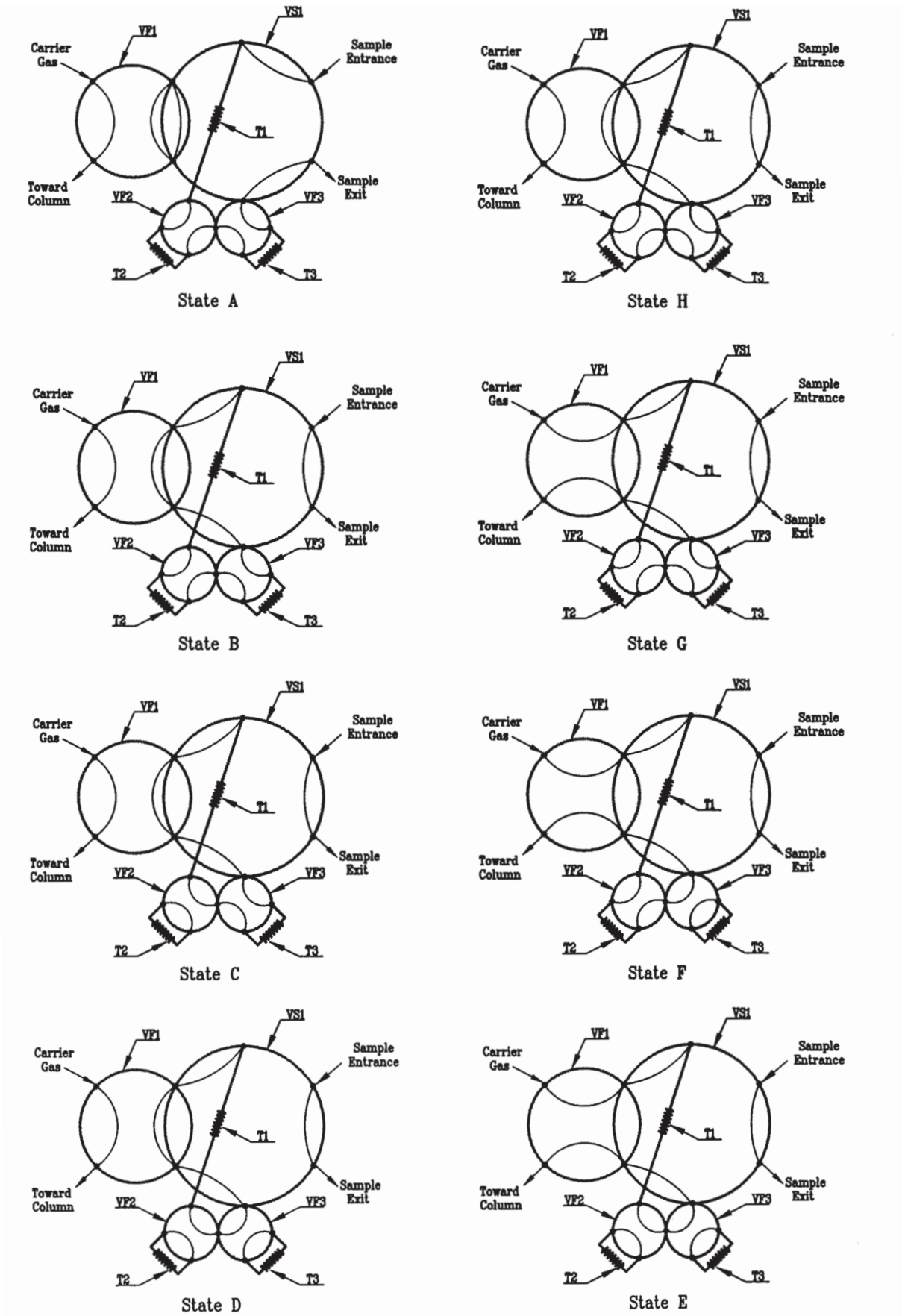

Figure 1. The switching process of triplet sampling at the same time and injecting in turn.

then, the samples corresponding to six different times can be injected and analyzed one by one.

In principle, SSTS-Ajax is easy to operate, and the functions can also be adjusted and enhanced further if desired.

Experimental

To state the principle of SSTS-Ajax clearly, a small combination (including one six-way valve, three four-way valves, and three sampling tubes) should be introduced first. The corresponding schematic diagram of the switching process is shown in Figure 1.

The meanings of the symbols in Figure 1 are listed in Table I and will be also adopted in the following paragraphs and figures. The ending *i* (*i* = 1, 2, 3...) in the symbol is used to number similar sampling tubes, kinds of valves, etc. For example, ENS2 means "the entrance for the sample from point 2 on-line".

The switching process in Figure 1 is illustrated in the following manner. In state A, sample fluid is passing through the three sampling tubes in turn, then switch to VS1. In state B, samples can be kept in the three respective sampling tubes connecting with each other, then switched to VF2. In state C, samples in T1 and T3 are separated from that in T2, then switched to VF3. In state D, samples in T1, T2, and T3 are separated from each other, then switched to VF1. In state E, the sample in T1 is passed into a column by a carrier gas, then switched back to VF2. In state F, the sample in T2 is also injected, then switched back to VF3. In state G, the sample in T3 is injected as well, then switched back to VS1. State H is used to prepare for the next triplet sampling; switch back to VF1 and the combination returns state A.

It can be concluded that, if desired, any two or all of the triplet samples can be injected together as one sample, which is useful in constructing a standard curve. To accomplish switching sampling from two different points on-line alternately, a second six-way valve should be added to the combination mentioned above. The corresponding switching process can be found in Figure 2. By switching VS2, the triplet sampling operations from Point 1 and Point 2 on-line can be completed in turn.

However, to obtain the triplet samples from different points on-line at the same time, six sampling tubes must be employed.

Table I. Definition of the Symbols*

Symbol	Meaning
VF*i*	four-way valve *i*
VS*i*	six-way valve *i*
T*i*	sampling tube *i*
ENS*i*	entrance for the sample from point *i* on-line
EXS*i*	exit for the sample from point *i* on-line

* *i* = 1, 2, 3...

Thus, a new combination is developed on the basis of the discussion mentioned above. Two combinations in Figure 2 are united by two more four-way valves that can be used to control the flow directions of carrier gases and to select columns for analyses, as shown in Figure 3. By switching corresponding valves, four different operating conditions (two kinds of carrier gases combining with two columns) can be available to analyze any one of the triplet samples from point l (or point 2) and point 3 (or point 4) on-line.

Because six sampling tubes are used in Figure 3, it might be necessary to employ all these sampling tubes in sampling from one point at the same time or even at six different times and then analyze the samples obtained one by one. In fact, this function might be especially convenient to chemists. By adding one more six-way valve, this desire can be fulfilled, as shown in Figure 4, which is also a whole schematic diagram of SSTS-Ajax. Owing to the problems in a plain figure, the combination in Figure 4 seems to be much different from that in Figure 3.

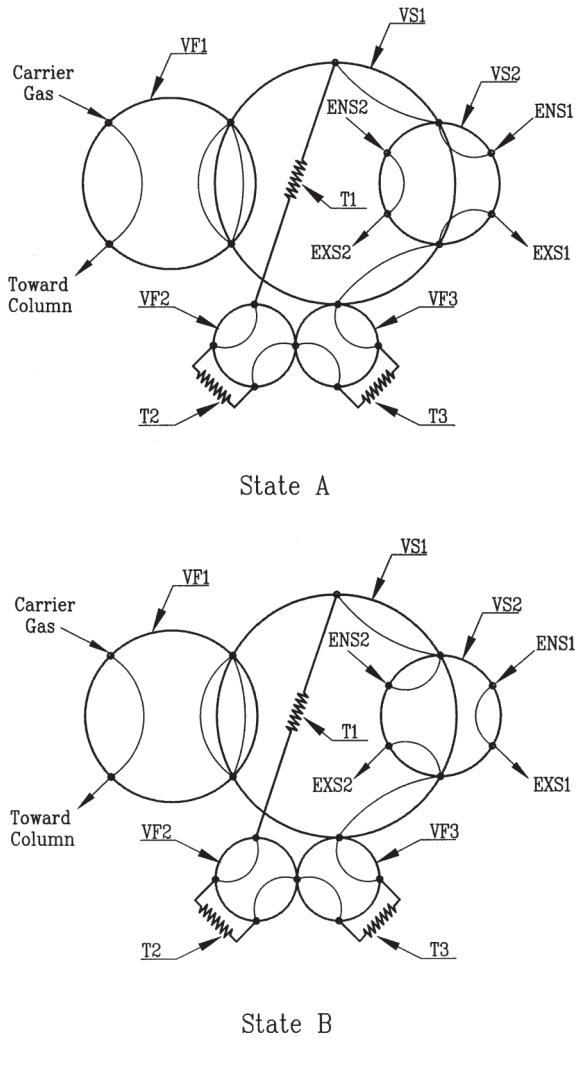

Figure 2. Triplet sampling alternately from two points on-line. State A, T1, T2, and T3 are used for triplet sampling from point 1 on-line; state B, T1, T2, and T3 used for triplet sampling from point 2 on-line.

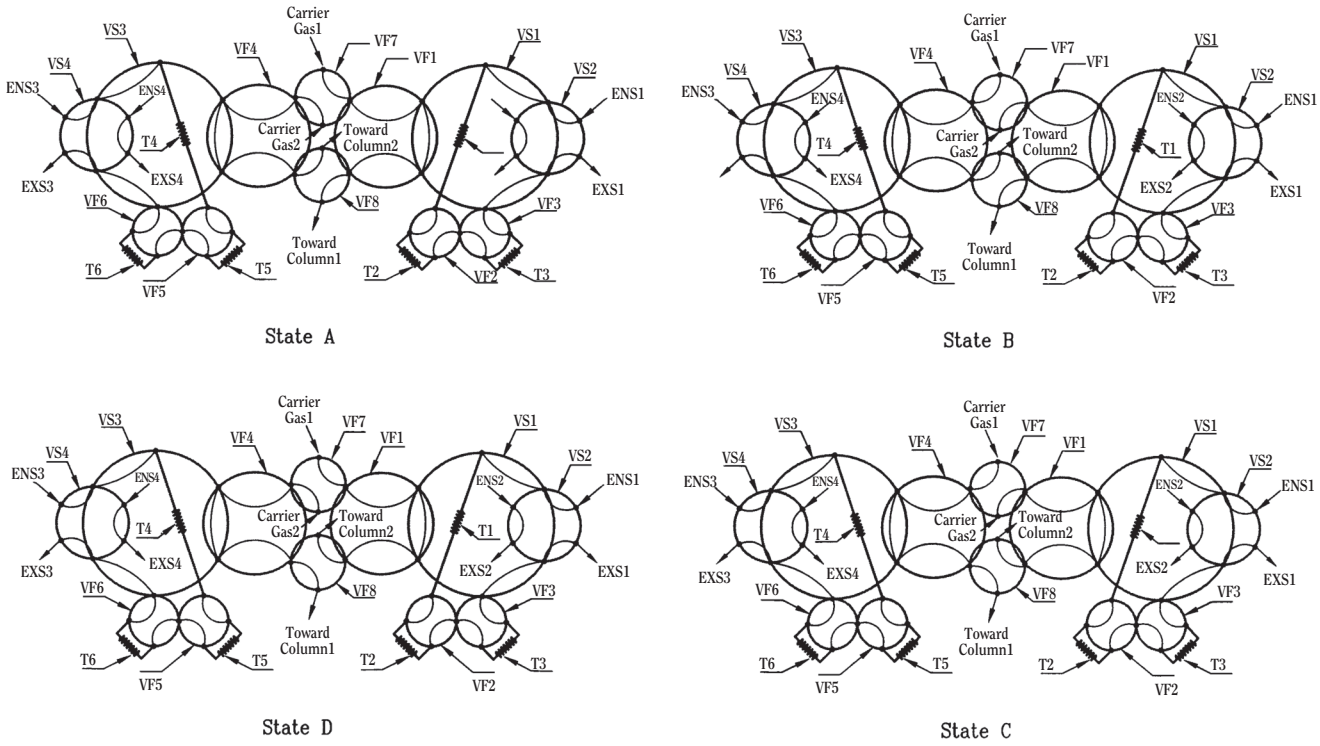

Figure 3. Two four-way valves are used to control analysis conditions. In state A, carrier gas 1 and column 1 are for the analysis of a sample from point 1 (or point 2); carrier gas 2 and column 2 are for that from point 3 (or point 4). In state B, carrier gas 1 and column 2 are for the analysis of a sample from point 3 (or point 4); carrier gas 2 and column 1 are for that from point 1 (or point 2). In state C, carrier gas 1 and column 1 are for the analysis of a sample from point 3 (or point 4); carrier gas 2 and column 2 are for that from point 1 (or point 2). In state D, carrier gas 1 and column 2 are for the analysis of a sample from point 1 (or point 2); carrier gas 2 and column 1 are for that from point 3 (or point 4).

Results and Discussion

It has been mentioned that the triplet samples can be analyzed under different operating conditions. In other words, the adsorbents, inert solid supports, carrier gases, detectors, dimensions of the columns, and flow rates of the carrier gases can all be different from each other in the analyses of the triplet samples. If necessary, one of the triplet samples can even be switched into another GC, which means that the temperature–time curves can also be adjusted conveniently in the analyses of the triplet samples. Of course, the quantity of one sample can be different from that of its duplicate for the purpose of using different analysis conditions. Therefore, much more information about the sample can be obtained.

Using different conditions for analyzing one sample might often provide enough information to a chemist; it is suggested when using SSTS-Ajax that two of the triplet samples be used for analysis in turn and the third one be employed in light of one specific condition: providing the analyses corresponding to the first two of the triplet samples are successful and undoubted, the third of the triplet samples is unnecessary for analysis and should be replaced by the following sample on-line. Therefore, all three of the sampling tubes can be employed in holding the next triplet samples on-line for analysis. Alternatively, if one of the first two results is abnormal and further analysis is needed, the third triplet sample can be kept in the corresponding sampling tube for a special analysis without interrupting the following analyses on-line. In this sense, it seems suitable to call the triplet samples "twin samples and one duplicate".

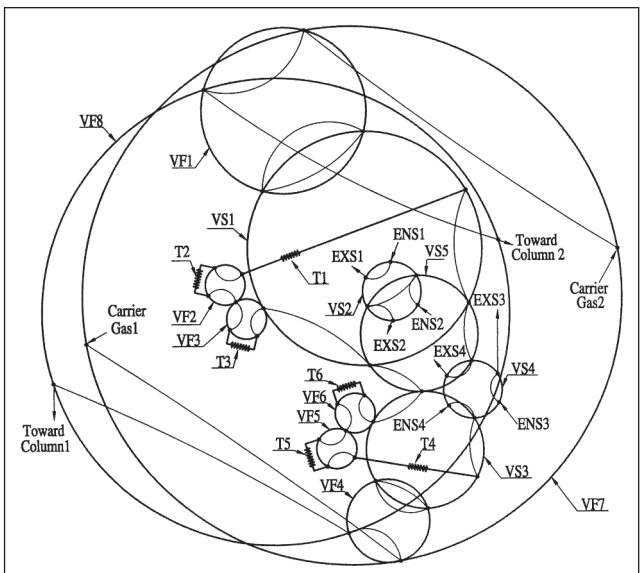

Figure 4. A schematic diagram of SSTS-Ajax. Sample from point 4 is passing through T4, T5, T6, T3, T2, and T1 in turn.

Due to the combinations offered by six different sampling tubes, which could be much more than the twice that of three tubes, all of these sampling tubes can be employed in the

analysis of the sample from one point on-line, which is especially helpful in constructing a standard curve.

It should be noted that VF7 and VF8 in Figure 4 are too big. This is only the schematic diagram in a plain figure. If a stereoscopic concept is built, VS3, VS4, and VS5 need not be in a plane. Thus, much smaller VF7 and VF8 valves can be equipped during manufacture.

In some cases, if the duration of an analysis on-line is much longer than the interval of two contiguous sampling operations, there will not be enough time to complete the analysis of one sample before the next sampling operation. In this case, it is especially useful to employ the six sampling tubes in keeping samples corresponding to six different times, respectively. It can also be found that switch VS5 in Figure 4 is approximately equal to the combination in Figure 3. Thus, the sampling and injecting for SSTS-Ajax can be concluded according to the discussion on Figure 3. Note that the states of VF7 and VF8 for injecting the samples in T1, T2, and T3 are the same, but both are different from that for the injections of T4, T5, and T6.

If desired, SSTS-Ajax can be adjusted and developed further to offer more convenience and advantages. However, the corresponding operation might be more complicated and therefore will not be discussed in this paper.

Considering the dead volume and resistance caused by the multiposition valves, as well as the difficulty that might be encountered in cleaning the whole switching system, a prudent policy should be adopted to employ SSTS-Ajax in liquid chromatography.

Conclusion

In a word, the triplet samples (i.e., a sample and its two duplicates) can be obtained at the same time and then analyzed in turn by using SSTS-Ajax, which can give satisfying result and bring much convenience to on-line GC analysis. The function of SSTS-Ajax can be adjusted in light of special conditions.

References

1. H.C. Li and P.Z. Lu. *Gas Chromatography,* Chapter 9. Shijie Chao, Science Press, Beijing, China, 1993, pp 170–76.

Manuscript accepted March 29, 2000.