SWITCHING SYSTEMS MANAGEMENT

STEP-BY-STEP

LOAD ON LAST-TRUNK MEASUREMENT PROCEDURES FOR SUBGROUP MONITORING

CONTENTS PAGE

Figures

Table

1. GENERAL

PURPOSE

1.01 This document describes a procedure which can be used to monitor the traffic performance of Step-by-Step (SXS) switching machines. Presently, congestion in SXS offices is difficult to detect and correct since detailed traffic measurements are generally not obtained. The measurement procedure described herein provides an economical and effective technique for identifying specific graded multiples (subgroups) with unacceptable blocking levels. The basic idea is that one can monitor subgroup performance by measuring the carried load on the last trunk of each subgroup. As the congestion in a subgroup increases, the load carried on the last common trunk also increases. By properly interpreting the last-trunk usage (LTU), one can infer with considerable accuracy the congestion level of the subgroup. Since one needs to make a connection to only one trunk per subgroup, this method makes very efficient use of measurement equipment; in addition, equipment connection and data handling are held to a minimum.

1.02 Whenever this section is reissued, the reason for reissue will be listed in this paragraph.

BACKGROUND

1.03 The idea of using the carried load on the last trunk to monitor subgroup performance was developed in conjunction with service improvement programs involving Bell Telephone Laboratories and several operating companies. Initial success with the procedure has led to detailed studies, making use of a computer program which simulates the call-by-call behavior of a SXS graded trunk subgroup. This computer simulation was used to develop an empirical relation between average LTU for a subgroup and the subgroup's average blocking. Also, one can estimate the offered load and the amount of any overload (in CCS) from the subgroup LTU data. Analytic studies have shown that a 5-day measurement interval, where LTU is measured during a set of hours which included the level busy hour, is sufficient to locate overloaded subgroups which merit corrective action.

APPLICATION OF RESULTS

1.04 Preliminary field trials indicate that roughly 90 percent of all subgroups in a typical SXS train experience a blocking level of less than 2 percent. Despite the uncertainties introduced by measurement and day-to-day variations during the 5-day interval, the LTU technique permits one to identify, with acceptable confidence, those subgroups with no blocking and those with undesirable blocking. The principal application is to locate the subgroups with over 2 percent levels. For subgroups with blocking between 1/2 and 2 percent, the results for five days cannot be used with confidence to rebalance subgroup loads or modify the number of trunks. Adjustment of performance levels to a 1 percent objective should only be based on longer study intervals (for instance, 20 days) and a demonstrated practical need for such adjustments. For maximum effectiveness, the data should be collected in the busy season.

1.05 For one-way trunks, the LTU method applies to configurations with and without rotary out-trunk switches (ROTS), although in both cases additional measurements, ie, all trunks busy or total carried load, are required on the outgoing trunks to diagnose a problem detected by LTU measurements. The LTU procedure is ideally suited to determine the performance of ROTS configurations because it monitors the first possible source of blockages in the ROTS accessing subgroups. Acceptable levels of access subgroup LTU insure that the entire ROTS configuration (access trunks, rotary switches, and outgoing trunks) is adequately engineered.

1.06 For 2-way trunks, the LTU method applies to all trunk groups with ROTS since the ROTS isolates the effects of the trunk selection method (whether from common-control or SXS equipment) at the far end from the LTU measurement. The LTU method is not applicable where selectors directly access (instead of going through ROTS) 2-way interoffice trunks unless, at the far end, the trunks are chosen in the same hunting order as at the near end. For groups where LTU is not applicable, total carried-load measurements should be used, since these should be small groups that are not susceptible to load-imbalance problems because they are either full or nearly full access groups.

1.07 The all trunks busy (ATB) or all trunks usage (ATU) that is measured from the OF lead of an ROTS group can be used in connection with LTU to detect an imbalance between ROTS groups.

2. SXS MONITORING SCHEMES

BASIC SXS PROBLEMS

2.01 Blockages arising from subgroup overloads can occur within the SXS train itself or in outgoing trunk subgroups, and may go undetected. A general overload exists when a majority of the subgroups on a given level at a particular switching stage are overloaded. A focused overload occurs when a few subgroups on a particular level are overloaded.

LAST-TRUNK USAGE (LTU) MEASUREMENT

2.02 The basic idea behind the LTU procedure is that the last-trunk usage can be related to blocking or overflow load, as well as the fraction of calls blocked, for each subgroup. The LTU procedure has several practical advantages which make it ideal for quickly responding to a suspected problem after a brief study.

(a) It is an efficient method for monitoring a subgroup, requiring only one lead and one register per subgroup.

(b) It is relatively easy to wire the single lead to the last trunk correctly.

(c) Wiring can be validated by making the last trunk busy for 15 to 60 minutes during light load hours and checking for the correct usage measurement.

(d) It is not necessary to estimate the average holding time for calls to the subgroup as with last-trunk-busy (LTB) measurements.

This procedure, with a more permanent wiring arrangement, is also appropriate for a continuing service monitoring program because a SXS office can be completely monitored with a relatively small number of usage registers (typically one last trunk for 20 to 30 trunks or selectors).

3. LAST-TRUNK USAGE MEASUREMENT PROCEDURES

CONCEPTS

3.01 The ability of LTU measurements to monitor subgroup blocking has been studied by using a computer simulation model of SXS gradings. Fig. 1 shows the relation between average blocking and average LTU for subgroups with 11, 17, 25, 35, and 45 trunks. The use of average blocking and average LTU is appropriate since, in practice, LTU measurements during a time-consistent hour must be averaged over several days to provide stable results (and reduce the possible impact of a single long-holding time call). Use of the ***low*** day-to-day variation model allows for offered loads to vary on different days. To help determine trunking requirements, Fig. 2 shows the relation between the average overload (in CCS) and average LTU for subgroups of 11 to 45 trunks which do not access ROTS. In certain cases, these relations may also be applied to subgroups that access ROTS.

MEASUREMENT EQUIPMENT

3.02 Last-trunk usage data can be collected on standard traffic usage recorders (TURs) or a variety of vendor equipment. To complete a survey of a SXS office in a reasonable length of time, enough usage registers to cover all suspected trouble areas in a switching stage should be obtained. The use of portable devices and accompanying printers or paper tape is ideally suited for a 5-day study. A convenient place to connect a measurement device to the sleeve lead of the last trunk is at the two terminal strips on the right side of the selector shelf in small SXS offices and at the auxiliary terminal block to the right or left of each distributing terminal assembly (DTA) in larger offices.

3.03 The LTU measurement must be obtained from the sleeve lead, rather than from the R1 (register) lead of the ROTS circuit, to include the time that the last trunk is busy due to ATB conditions on the outgoing trunks. Including this component of usage, which is excluded from measurements on the R1 lead, is important in assessing the congestion level of the accessing subgroups.

3.04 For subgroups which access ROTS, special care must be taken that the measurement equipment connected to the sleeve lead of a last trunk and hence, the sleeve of a rotary switch, does not affect calls. Western Electric Company drawings, SD-30868-01 and SD-30868-02, specify that at most, two TK relays should be permanently connected to the sleeve of the ROTS circuit. When collecting LTU measurements, this limitation can be waived if the input impedance of the usage recorder is at least 6,000 ohms, since a usage recorder is associated with only a few ROTS input sleeves and provides discrete scans. Thus, high impedance usage recorders such as the 4A-TUR are acceptable. Alternatively, low impedance usage recorders may be used if a circuit modification is made. This is required since usage recorders with low impedance such as the 3B-TUR (600 ohms impedance) may cause unguarded conditions on the sleeve leads of the widely used ROTS per SD-30868-01 and SD-30868-02 equipped with release relays (Fig. 12 of SD-30868-01 and FS6, Option E, of SD-30868-02). Modification of the release relays by Option B of FS6, SD-30868-02 prevents the problem. A similar modification for SD-30868-01 will be available by mid-1975.

DATA ANALYSIS

3.05 LTU data should be collected for five days for several hours. The average LTU for each subgroup in each hour should be computed. These hours should include the hour for which the offered load to the level is highest. The average LTU for each subgroup can be used with Table A to determine the subgroup blocking level, rounded to the nearest percent. Any subgroup which exceeds 2 percent blocking is a candidate for corrective action (see 3.09). It should be noted that lower blocking thresholds may be appropriate outside the busy season. Fig. 3 and 4 are copies of the suggested form for collecting the required data. One form will be required for each hour studied.

3.06 Subgroup blocking estimates, for other than the level busy hour, should be examined to see if focused overloads exist. Focused overloads can occur when incoming trunks are assigned so that the loads are not distributed evenly across subgroups. These imbalances violate the basic SXS design assumption that there is equal load to each subgroup on a given level. Focused overloads degrade the average quality of service and may cause a specific group of customers to experience blocking much higher than the average level. This type of overload is not easily detected because (1) it may occur on intermediate subgroups where measurements may not be taken, and (2) measurements of incoming and outgoing traffic are aggregated by trunk group over all subgroups and, as a result, do not point up isolated individual subgroup blockages. The LTU procedure offers an efficient means for finding either focused or general overloads. For instance, a level with nine out of ten subgroups with no blocking and one with 10 percent blocking could show an acceptable ***average*** blocking level despite a serious balance problem. Blocking estimates over 2 percent outside the level busy hour should be identified; someone familiar with both the incoming trunk layout and possible causes for different ***subgroup*** busy hours should examine these exceptions and attempt to understand their causes.

3.07 The procedure for estimating ROTS accessing subgroup blockage levels is identical to the non-ROTS procedure (Fig. 1). However, the overload (in CCS) estimate of Fig. 2 cannot be applied in the ROTS case when the outgoing trunk group is the principal cause of blockages. In this case, busy back (or noncall carrying) usage enters into the LTU measurement, making overload estimation difficult. Experience has shown that the curves of Fig. 2 overestimate the magnitude of the overload in each access subgroup when the outgoing trunks are overloaded. To obtain a more accurate basis for outgoing trunk group adjustments, one must use total carried load estimates and the tables of the Traffic Facilities Practices, Division G, Section 4d. One should check to see if the access subgroups have sufficient capacity to carry the increased load expected with an increase in outgoing trunk group capacity.

3.08 Another possible cause of blockages might be imbalances in the loads offered to the ROTS subgroups; this can be detected by an LTU measurement on all subgroups and corrected by rebalancing ROTS access trunks on ROTS groups. After any changes, another study should be initiated to see if there are any remaining blockages. In some cases, a combination of access subgroup and outgoing trunk blockages may exist. For this case, a 2-step corrective process may be required, or one may decide to add sufficient new capacity in access and outgoing groups to more than compensate for the overloads.

CORRECTIVE ACTION—GENERAL PROCEDURES

3.09 Experience with last-trunk usage studies has shown that blockages may be caused by several types of problems. The following list of typical problems (with a suggested order of attack from 1 through 6) can serve as a guide for investigative and corrective actions when a subgroup indicates high last trunk usage.

(1) Usage register not on last trunk.

Check DTA, wiring of measurement lead, and perform 15-minute make-busy test during light load period. Correct and verify connection.

(2) Trunk made busy or faulty trunk.

Verify proper operation of all trunks in the subgroup. Restore to service.

(3) Changes in grading pattern.

When the number of trunks in a subgroup is engineered, the ultimate number of trunks for the period is provided. Initially, the number of trunks provided may be less than the ultimate number. Generally, the order of reducing the number of trunks in individual subgroups should be from right to left. The standard graded multiple arrangements for trunks from selector multiple to other selectors, trunks or repeaters are found in Dial Facilities Management Practices (DFMP), Division H, Section 2b(1), Fig. 39. For example, there are 40 selectors with 21 trunks shown on the office print. There are only 19 trunks to the distant office. By comparing the two figures, 40 selectors with 21 trunks to 40 selectors with 19 trunks, one can see the exact location of the new straps. Additional information on this subject can be found in Traffic Engineering Practices, Division D, Section 4c.

(4) Load imbalance.

The incoming trunk assignments should be examined when a load imbalance is detected. Then, either rearrange incoming trunks between subgroups or add more trunks to the overloaded subgroups. One might avoid adding new trunks by removing trunks from underloaded subgroups. Use Fig. 2 to estimate the subgroup overload (in CCS). Other points to consider are:

(a) The spread of trunks by originating offices over incoming shelves. The shelf or half-shelf is the basic "load unit" for SXS selectors.

(b) Whether the incoming trunk group is high usage or final. (BSP 795-400-100).

(c) The busy hour of one incoming trunk group versus other trunk groups accessing the same subgroups.

(d) It is essential to know the sequence in which both high usage and final trunks are selected in the distant office to permit the proper spread of high, medium, and low load-carrying trunks over the incoming selector shelves. For example, a No. 4 crossbar office selects an outgoing trunk in ascending or descending numerical order; whereas, a No. 5 crossbar office selects an outgoing trunk at random, if the trunks in the trunk group are evenly spread over all trunk link frames.

(e) It is suggested that individual trunks be assigned weights both in the ***initial*** assignment process, to minimize the possibility of imbalance, and when examining balance problems. This technique enables one to better select those trunks to be moved when rebalancing shelves and subgroups. Trunk weightings of heavy, medium, and light or three (3), two (2), and one (1) provide a reasonable approach to identifying overloaded shelves and the trunks that should be moved.

Rebalancing of incoming trunks over incoming selector shelves and half shelves using the techniques described in (a) through (e) may also eliminate load imbalance between shelves of the same subgroup.

(5) ROTS outgoing trunk group overload.

When all ROTS accessing subgroups on a given level show excessive last-trunk usage, one should examine the outgoing group measurement total carried load to see if an overload exists. When only part of the subgroups that access ROTS groups show excessive LTU, one should examine the data from the OF lead of the ROTS groups to see if an imbalance exists between the groups. In the case of 2-way trunks, the imbalance could be caused by traffic from the far end. The traffic coming through the switch train should also be examined as outlined in (1) through (4) above.

(6) General overload—all subgroups.

Estimate the overload on each subgroup from Fig. 2 (in an ROTS accessing subgroup, this can only be done ***after*** 5). Add trunks to all subgroups. This normally requires the issuance of a traffic order.

In all cases, one should take additional LTU measurements after any corrective action to insure that the blockage is eliminated. Fig. 5 is a block diagram of the LTU "quick-test" procedures.

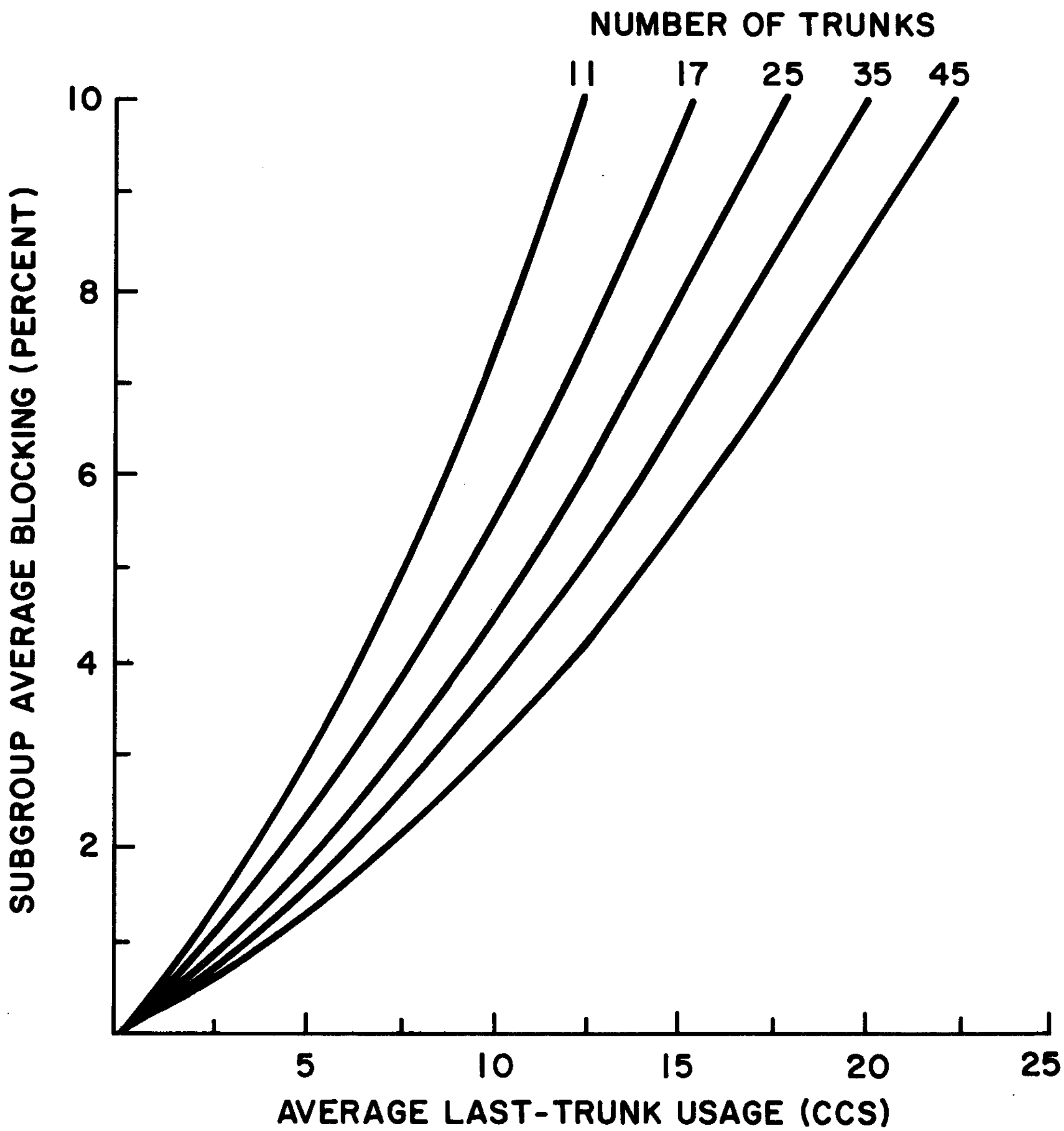

Fig. 1—Subgroup Average Blocking (Percent) Versus Average Last-Trunk Usage for 11, 17, 25, 35, and 45—Trunk Gradings with *Low* Day-to-Day Variation in Offered Load

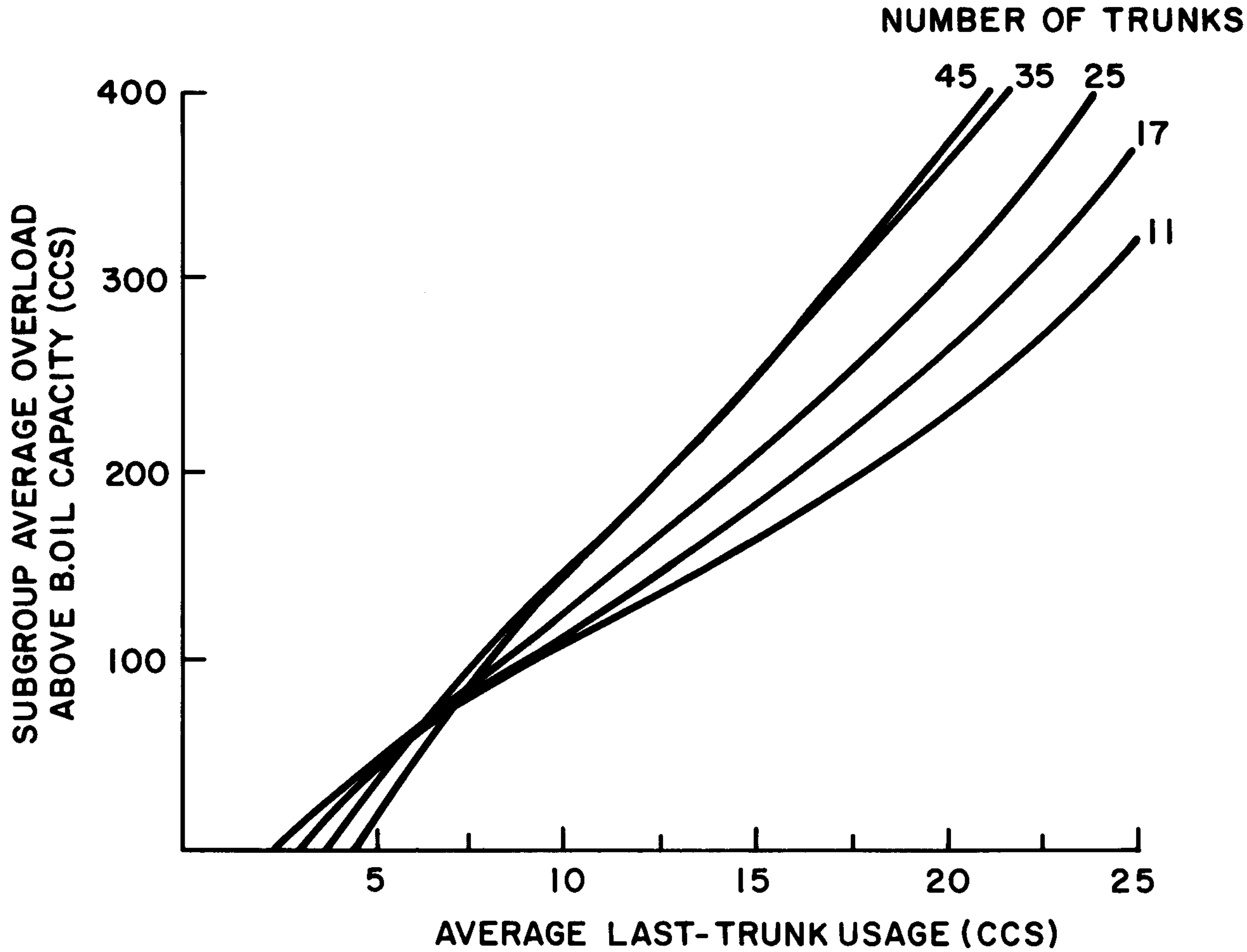

Fig. 2—Subgroup Average Overload Versus Average Last-Trunk Usage for Different Graded Multiple Configurations (Non-ROTS Accessing) with *Low* Day-to-Day Variation in Offered Load

LAST-TRUNK USAGE MEASUREMENT WORK SHEET

OFFICE:	LOCATION:		HOUR:
SELECTOR STAGE:		LEVEL:	ACCESS ROTS? ☐ YES ☐ NO

COMMENTS:

SUBGRP GRADE															
SUBGRP NO.															
LAST TRK NO.															
REGISTER NO.															

DATE	INDIVIDUAL LAST-TRUNK USAGE DATA IN CCS														

SUM LTU															
NO. DAYS															
AVG. LTU															
AVG. BLKING															

TOTAL LTU SUM FOR BUSY-HOUR DETERMINATION ☐

Fig. 3—Sample Work Sheet for LTU Procedure

LAST-TRUNK USAGE MEASUREMENT WORK SHEET

OFFICE: NNX	LOCATION: ANYTOWN, U.S.A		HOUR: 10-11 AM
SELECTOR STAGE: LOCAL 4THS	LEVEL: 7	ACCESS ROTS? ☐ YES ☑ NO	

COMMENTS:

① TRUNK # 278 OUT-OF-SERVICE FOR STUDY PERIOD

② DATA UNAVAILABLE FOR SUBGROUP # 315 ON 1-15-75

SUBGRP GRADE	160/25	160/25	160/25	160/25	80/10										
SUBGRP NO.	312	313	314	315	316										
LAST TRK NO.	200	250	278	308	341										
REGISTER NO.	1	2	3	4	5										

DATE	INDIVIDUAL LAST-TRUNK USAGE DATA IN CCS														
1-13-75	1	12	36	5	0										
1-14-75	3	9	36	3	0										
1-15-75	0	14	36	– ②	0										
1-16-75	3	5	36	5	0										
1-17-75	2	7	36	0	0										

SUM LTU	9	47	180	13	0										
NO. DAYS	5	5	5	4	5										
AVG. LTU	1.8	9.4	36.0	3.3	0.0										
AVG. BLKING	1/2%	4%	– ①	1%	0%										

TOTAL LTU SUM FOR BUSY-HOUR DETERMINATION: 249

Fig. 4—Example of Filled-In Work Sheet

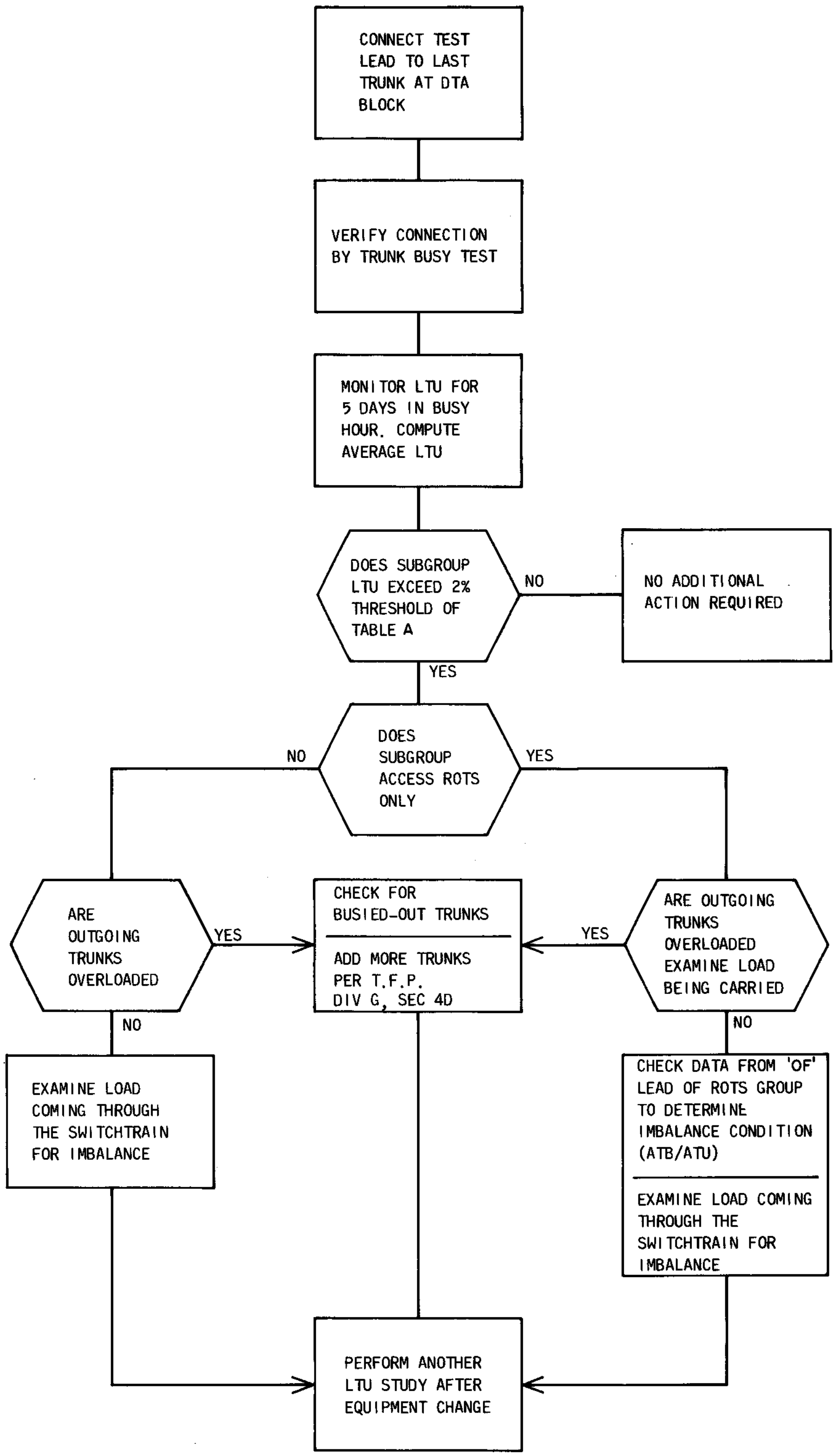

Fig. 5—SXS Subgroup LTU Quick-Test Procedure

TABLE A

AVERAGE VALUE OF LAST–TRUNK USAGE IN CCS FOR BLOCKING LEVELS – ASSUMES LOW DAY–TO–DAY VARIATIONS

NUMBER OF TRUNKS IN SUBGROUP	AVERAGE BLOCKING					
	1/2%	1%	2%	3%	5%	10%
4 to 9	0.5	1.5	2.5	3.5	5.0	10.0
10 to 14	1.1	2.0	3.5	5.2	7.8	13.0
15 to 19	1.4	2.5	4.6	6.3	9.3	15.5
20 to 24	1.6	3.0	5.3	7.2	10.6	17.2
25 to 29	1.8	3.2	5.7	7.8	11.5	18.2
30 to 34	1.9	3.6	6.2	8.5	12.4	19.5
35 to 39	2.1	3.8	6.7	9.1	13.1	20.5
40 to 45	2.4	4.2	7.3	9.8	14.1	21.7

LAST-TRUNK USAGE MEASUREMENT WORK SHEET

OFFICE:	LOCATION:		HOUR:
SELECTOR STAGE:	LEVEL:	ACCESS ROTS? ☐ YES ☐ NO	

COMMENTS:

SUBGRP GRADE															
SUBGRP NO.															
LAST TRK NO.															
REGISTER NO.															

DATE	INDIVIDUAL LAST-TRUNK USAGE DATA IN CCS														

SUM LTU															
NO. DAYS															
AVG. LTU															
AVG. BLKING															

TOTAL LTU SUM FOR BUSY-HOUR DETERMINATION
