Speech Volumes on Bell System Message Circuits—1960 Survey

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Speech volumes of customers on Bell System message circuits have been measured at class 5 offices. Data are presented for intrabuilding, interbuilding, tandem and toll connections. Average speech volumes are lowest for intrabuilding calls and increase in level for the other types of connections, with volumes on toll calls being the highest. In general, volumes on business calls are higher than those on social calls, and men speak louder than women. Speech volumes remain substantially the same in locations comparable to those in a survey made in 1950.

I. INTRODUCTION

The volume of message signals at various points in the telephone network is of importance to those who design and engineer telephone systems and equipment, and ultimately, of course, to the listener at the far end of the connection. This volume is influenced not only by the speech pressure produced by the talker and by his habits in using the telephone set, but also by the characteristics of the set, the battery supply and loop resistance, and the electrical loss (or gain) between the set and the point at which knowledge of the level is desired.

Speech signals are very complex quantities varying in amplitude from instant to instant. They are measured in a prescribed manner on a standardized meter known as a volume indicator. Data obtained using this technique are called speech volumes and are expressed as volume units (VU) on a db scale. Such measurements are of value to engineers who design equipment, determine crosstalk objectives and permissible noise levels, and otherwise engineer the telephone network.

Since changes in the telephone plant affect transmission performance of the lines, and consequently may affect the customers' habits in the use of the telephone set, up-to-date information on customer speech volumes is necessary. When the last general survey of speech volumes on Bell System message circuits was made in 1950–1951,[1] a large percentage of telephone sets were 200 and 300 types.[2] It is now estimated that 65 per cent of the telephone sets are 500 type;[3] finer-gauge conductors are used in the loop plant; and interoffice trunk and toll circuit losses have been reduced.

This paper presents the results of speech volume measurements made in 1959 and 1961. Observations were made in 1959 in cities larger than 10,000 population, and observations were made in 1961 in smaller communities. The aggregate results of the two groups are referred to as the 1960 survey. The particular cities and offices in which speech volumes were measured were selected as representative of the range of offices in the Bell System, but no rigorous sampling procedure was used. It is believed that the conclusions drawn from the data are sufficiently accurate to serve as a guide for plant design. The measurements were made at class 5 (local or end) offices and were limited to the speech volumes of customers connected directly to that office (near-end talker).

II. SUMMARY

More than 14,000 speech volumes were measured in 30 central offices in 23 cities located throughout the United States. These cities varied in size from single-office cities to large metropolitan centers and their suburban areas. Observations were made on intrabuilding, interbuilding, tandem and toll connections (Fig. 1) in crossbar, step-by-step, panel and Community Dial Offices (CDO's). The locations and office designations are shown in Table I. Some observations were also made in the private branch exchange (PBX) in the Murray Hill, New Jersey, location of Bell Telephone Laboratories. These latter measurements were taken in 1959 when the Murray Hill PBX was of the step-by-step type.

The weighted average speech volumes derived in the 1960 survey are shown in Table II. These averages and all others are obtained by weighting the data according to the population represented by each city unless specifically stated otherwise.

Thirty per cent of the intrabuilding calls and 52 per cent of the interbuilding calls were of a business nature. Fifty-eight and 80 per cent of tandem and toll calls, respectively, were of a business nature.

Averages derived in individual class 5 offices are shown in Figs. 2 and 3.

The large spread or variation in speech volume, as shown by standard deviations of 5.9 to 7.3 db, is caused only in small part by differences in transmission losses of various loop lengths and by different telephone set supply currents. This is supported by consideration of the results ob-

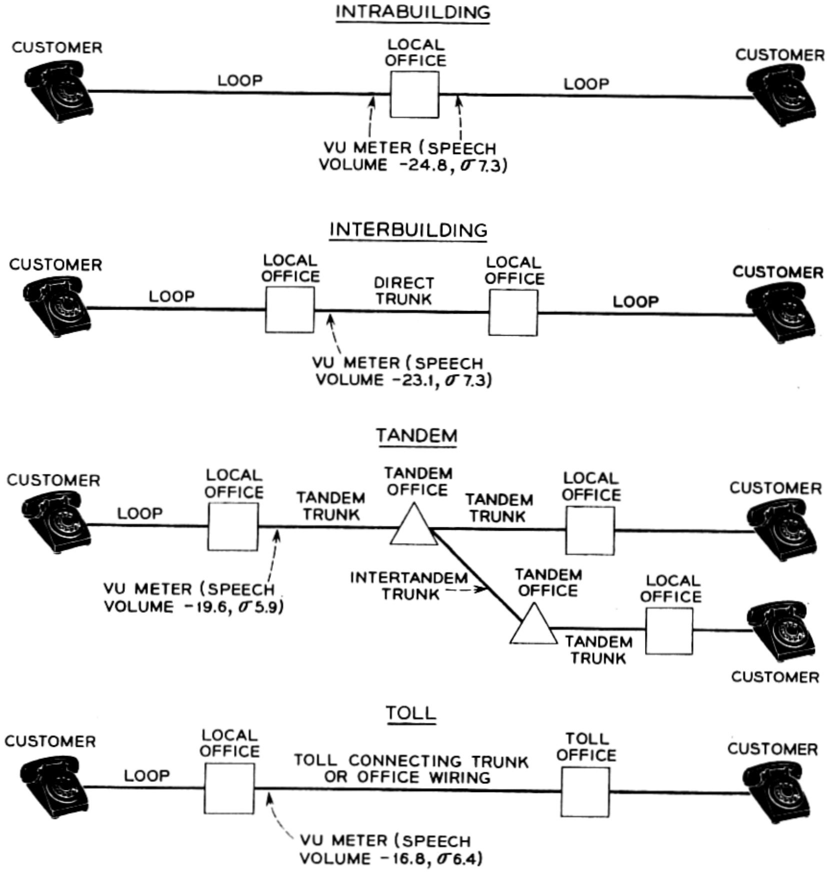

Fig. 1 — Average speech volumes on typical telephone connections (1960 survey).

tained for the PBX at the Murray Hill Bell Telephone Laboratories. In Murray Hill, all extensions had short loops, few of which exceeded 2000 feet. On intra-PBX calls the standard deviation was 5.5 db, indicating that the spread is largely a result of differences in levels and habits of individual speakers.

The variation in the average speech volumes among offices (Fig. 2) is substantial. Examination of the data reveals that speech volumes in New York City average 2 to 3 db higher than in other locations where similar loop plants exist. In general, the higher speech volumes are associ-

TABLE I — SUMMARY OF SPEECH VOLUME DATA

Location	Year Surveyed	1960 Population	Office Designation	Type of Office	Area of Office Sq. Mi.	No. of Stations	Avg. Loop Length* (feet × 10^3)
Atlanta, Ga.	1959	487,455	JA 345	SXS		313,000	8
			CE 7	SXS			8
Auburn, N.Y.	1961	35,249	AL 23	NO 5 XBR	126.5	20,880	8
Austin, Tex.	1959	186,545	GR 37	SXS	26.3	77,000	6
			HO 5	SXS	49.3		8
Boone, Ia.	1961	12,468	GE 2	NO 5 XBR	238.0	7,482	10
Cleveland, Miss.	1961	10,249	VI 3	SXS	180.0	4,501	10
Cortland, N.Y.	1959	19,181	36	SXS	159.4	13,000	10
Drew, Miss.	1961	2,143	745	335 CDO	35.0	724	7
Enid, Okla.	1961	38,859	AD 47	NO 5 XBR	150.0	19,731	9
Ithaca, N.Y.	1959	28,799	234	SXS	134.4	24,000	11
Liberty, Mo.	1961	8,909	STI, THI	NO 5 XBR	180.0	5,296	7
Medford, N.J.	1961	4,356	OL 4	335 CDO	48.0	4,356	7
Moss Point, Miss.	1961	8,510	GR 5	SXS	195.0	3,972	8
Mount Holly, N.J.	1961	13,271	AM 7	NO 5 XBR	54.8	6,686	8
New York, N.Y.	1959	7,810,000	WO 4	NO 1 XBR		4,204,000	3
			SW8, LO5	NO 1 XBR			4.5
			WA 378	PAN			4.5
Pascagoula, Miss.	1961	17,139	SO 2	NO 5 XBR	72.0	8,361	8
Plainfield, N.J.	1959	45,330	PL 4567	NO 1 XBR	49.4	49,660	6
Ridgewood, N.J.	1959	25,391	GI 43	NO 5 XBR	18.3	34,780	8
San Francisco, Cal.	1959	742,855	Main EX7	NO 1 XBR	4.8	519,000	4
			Main YU7	PAN	4.8		4
			MO 4, LO 4	NO 1 XBR	8.2		8
Sioux City, Ia.	1959	89,159	Main 2578	SXS		41,000	8.5
			Morn 6	SXS			7
Skaneateles, N.Y.	1961	2,921	OV 5	SXS	58.0	3,569	9
Trenton, N.J.	1961	114,015	OW 5	SXS		60,000	10
Waukomis, Okla.	1961	516	PL 8	350 CDO	140.0	437	9
Woodland, Cal.	1959	13,524	MO 2	SXS	210.0	8,000	11

* Estimate— except Plainfield and Ridgewood.

ated with the larger cities. Differences in the percentage of business calls are one contributing factor. Others may be talking habits, ambient noise and average length or loss of loops.

As observed in the 1950 survey, speech volumes on long-distance calls increase approximately 1 db for every 1,000 miles.

There is a 4-db variation in the average speech volume of males, depending on the sex of the far-end talker and whether the call is of a

TABLE I — SUMMARY OF SPEECH VOLUME DATA (CONT.)

Location	Near-End Speech Volumes									
	Intrabuilding		Interbuilding			Tandem			Toll	
	Avg. VU	Std. Dev. db	Trunk Loss-db	Avg. VU	Std. Dev. db	Trunk Loss-db	Avg. VU	Std. Dev. db	Avg. VU	Std. Dev. db
Atlanta, Ga.	−22.6	6.2	4.0	−20.9	6.1				−15.4	5.2
			8.0–9.0	−20.1	5.9					
	−23.2	5.5	5.2	−21.5	6.0	4.6	−21.7	5.0	−16.8	5.1
			8.7	−21.4	5.4					
Auburn, N.Y.	−27.3	8.1	3.9	−23.3	6.5				−23.1	5.7
Austin, Tex.	−24.9	6.2	4.7–5.5	−23.8	6.0				−16.4	5.2
	−26.7	6.3								
Boone, Ia.	−27.3	7.7							−21.0	5.8
Cleveland, Miss.	−26.4	7.4							−20.4	6.5
Cortland, N.Y.	−23.5	6.0								
Drew, Miss.	−27.6	8.1								
Enid, Okla.	−28.4	7.0							−20.4	7.5
Ithaca, N.Y.	−25.4	6.7	5.0–6.0	−21.2	6.5				−15.6	4.9
			5.0–6.0	−23.1	6.4					
Liberty, Mo.	−27.4	8.5	3.3–5.7	−27.3	6.5	2.5	−23.2	6.1	−19.6	6.6
Medford, N.J.	−27.6	5.6	5.5	−25.6	7.3					
Moss Point, Miss.	−27.6	6.9	1.2	−26.8	6.3				−21.3	5.3
Mount Holly, N.J.	−26.6	6.3	5.5	−24.1	7.2					
New York, N.Y.	−18.9	5.6	6.5–8.0	−16.2	5.0	1.8–3.4	−17.4	5.3	−11.0	5.2
						8.6	−17.6	4.9		
	−17.7	6.2	6.9–8.8	−16.4	4.9	4.0	−18.1	5.4	−14.2	5.8
						7.7–9.0	−16.4	5.4		
	−18.8	5.8								
Pascagoula, Miss,	−26.0	7.3	1.2	−25.8	6.9					
Plainfield, N.J.	−22.0	6.2	4.7	−20.1	5.6	3.9	−19.9	4.8	−16.9	5.3
			11.0	−19.2	5.0	10.5	−17.0	5.8		
Ridgewood, N.J.	−22.1	5.6	5.0	−21.0	6.2	3.6–4.0	−18.6	5.8	−15.0	5.1
			9.3–10.0	−19.8	5.4	10.1	−18.0	4.8		
San Francisco,	−21.8	5.4	6.6	−19.4	5.9	3.3–4.9	−19.1	4.9	−14.4	4.8
Cal.	−20.0	5.9	6.6–6.7	−20.2	6.2	7.6–7.8	−18.2	5.9	−14.7	4.9
	−24.9	6.7	6.6	−20.2	5.1	3.0	−20.7	5.4	−17.8	4.7
Sioux City, Ia.	−23.8	6.9	3.9	−22.3	5.9				−14.9	5.9
	−24.5	6.6								
Skaneateles, N.Y.	−24.7	7.2	3.9	−24.6	6.4					
Trenton, N.J.	−25.4	6.3								
Waukomis, Okla.	−25.0	6.7								
Woodland, Cal.	−23.9	6.3							−55.8	5.7

TABLE II — SUMMARY OF NEAR-END SPEECH VOLUMES

Type of Connection	Average VU	Standard Deviation db	Maximum Observed VU	Minimum Observed VU
Intrabuilding	−24.8	7.3	−2.1	<−50.0
Interbuilding	−23.1	7.3	−2.6	−46.0
Tandem	−19.6	5.9	−3.0	−40.4
Toll	−16.8	6.4	+5.3	−39.8

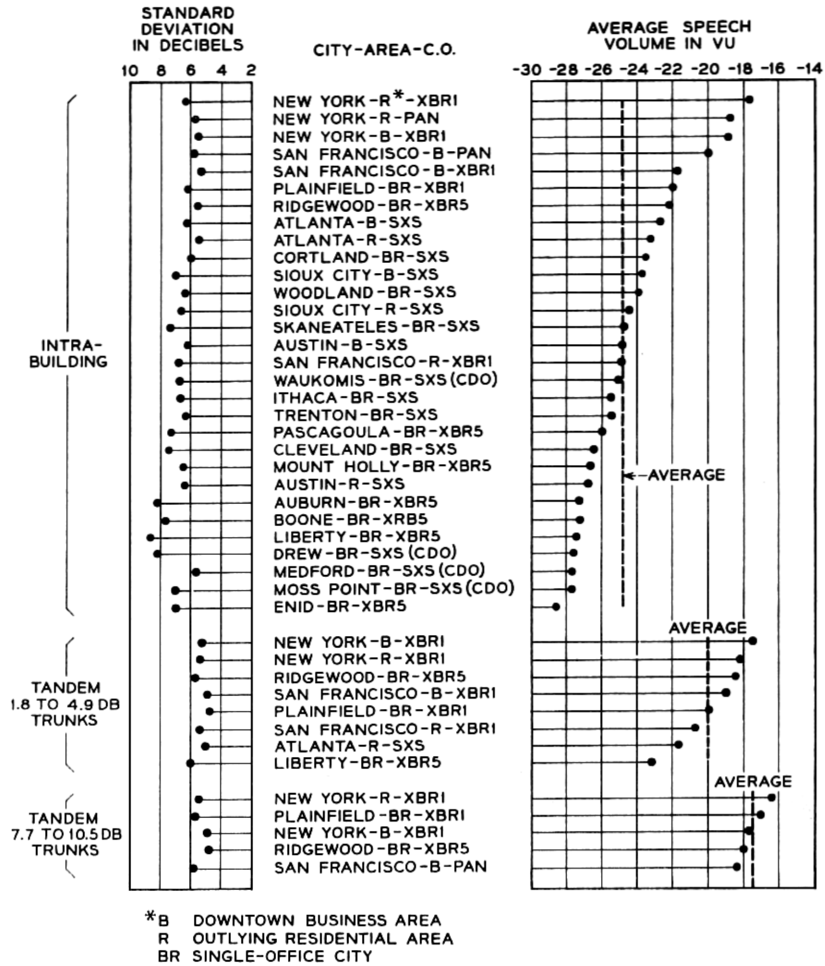

Fig. 2 — Average intrabuilding and tandem speech volumes.

social or business nature. The variation in the average speech volume of females is smaller.

Speech volumes on business calls average slightly higher than those on social calls, partially because business talkers are predominantly men and business calls tend to be over longer distances.

Speech volumes measured in the 1960 survey appear at first glance to be lower than those measured in the 1950 survey, with decreases

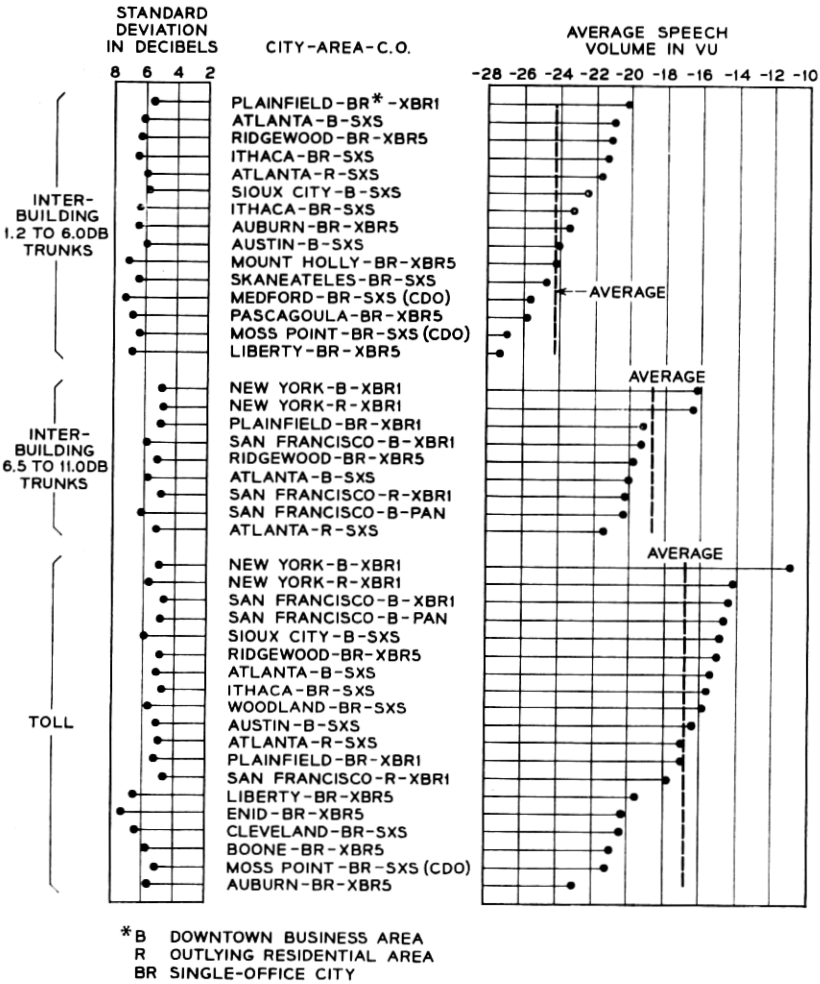

Fig. 3 — Average interbuilding and toll speech volumes.

varying from 2.2 db on tandem calls to 5.8 db on local or intrabuilding calls. However, this is largely due to the fact that New York speech volumes, which are higher than average, comprised more than one-third of the measurements made in 1950. In the wider sample in the present survey, New York City speech volumes account for less than 10 per cent of the total number. For comparable locations, the data of the two surveys are in substantial agreement.

III. DESCRIPTION OF TESTS

Near-end talker volumes were measured in 30 central offices located in 23 cities throughout the United States. Detailed information on the cities and central offices is given in Table I. The communities range in size from 516 people in Waukomis, Oklahoma, to nearly eight million in New York City. The offices included No. 1 crossbar, No. 5 crossbar, step-by-step and panel offices; 350A and 355A Community Dial Offices (CDO's). In larger cities data were obtained in offices in both business and residential areas.

Measurements were made on intrabuilding, interbuilding, tandem and toll connections. The types of connections are illustrated by simple schematics in Fig. 1. In many of the smaller central offices there were neither interbuilding connections nor tandem switching. Toll observations were not made in some locations where the traffic was too slow to warrant spending the amount of time necessary to obtain a complement of measurements.

Records were kept of the sex of the near-end and far-end talker and the nature of the call, whether social or business. Additional information was obtained on loop lengths, trunk losses, and station sets. Most observations were made during the day; however, some observations on toll calls were made in the evening when a greater possibility of obtaining social calls existed.

IV. TEST EQUIPMENT

Measurements were made at convenient circuit locations in each office, using a high-impedance standard volume indicator.[4] Two different models were used, both with a nominal input impedance of 12,500 ohms and a response essentially flat from 50 to 15,000 cps. On one volume indicator the range of volumes which can be read in accordance with the method described below is −32 VU to +30 VU. Speech volumes a few db lower than −32 VU can, however, be estimated with reasonable accuracy. The other instrument has a range of −42 to +20 VU, thus allowing for greater accuracy in reading the low speech volumes. It also has an optional 60-cps elimination filter, the loss of which is not detectable above 300 cps.

Volume indicators are calibrated to read voltage across 600 ohms. However, the impedances of most exchange telephone circuits generally differ substantially from 600 ohms, thereby causing appreciable errors in volume indicator readings. Corrections were computed from the formula

$$C + 10 \log_{10} \left(\frac{600}{|Z|} \right)$$

where $|Z|$ is the magnitude of the impedance of the circuit into which speech volumes are measured, derived from knowledge of the average gauge, length, loading, and termination of the circuit for the type of call being measured. Trunk and loop data were supplied by operating company personnel. The final correction was a weighted average of the corrections at four or five important frequencies in the speech band.

V. TEST PROCEDURE

At the beginning of an observation, the observers waited for the connection to be established and thereby distinguished the near- and far-end talkers by their salutations. In no case was volume used as the sole criterion in identifying the parties, for difference in volume in many cases exceeded the transmission differences between customers.

The standard procedure for measuring speech volumes on telephone message circuits requires taking the arithmetic average of a series of individual volume measurements on each customer. An individual volume measurement is defined as the visual average of five to six of the highest meter deflections over a 3- to 10-second interval. In so doing, the occasional high peaks and the series of low peaks are ignored. An input attenuator, adjustable in 2-db increments, is set to allow the peaks used in determining the average to fall in the region from 0 to -2 VU on the meter scale. About ten individual measurements were averaged to obtain the speech volume of the customer.

For each type of call at a location, speech volumes of 120 to 160 customers were measured by two observers. Preliminary training of all observers consisted of practice in reading volumes from recordings of the 1939 World's Fair telephone exhibit. Throughout the survey the observers rechecked their methods of reading the volume indicator in order to eliminate the possibility of developing poor habits.

VI. METHOD OF COMBINING DATA

The principal objective of these speech volume measurements was to derive a system-wide average and standard deviation for each of the four types of calls. This involves first assuming that the values obtained for an office are representative of similarly located offices throughout the United States, and then combining the data in accordance with the calling rate in the different kinds of areas. Neither of these factors is

TABLE III — U. S. POPULATION STATISTICS 1960: METHOD OF DETERMINING WEIGHTING FACTORS

Population (Thousands)	Number of Cities	Total Population in Cities	Weighting % of Total Population	City Sampled
>1000	5	17,290,300	9.6	New York, N. Y.
500–1000	15	10,442,300	5.8	San Francisco, Cal.
250–500	31	11,078,300	6.2	Atlanta, Ga.
100–250	76	11,078,500	6.2	Austin, Tex. Trenton, N. J.
50–100	178	12,369,300	6.9	Plainfield, N. J. Ridgewood, N. J. Sioux City, I.
25–50	403	14,815,500	8.3	Auburn, N. Y. Enid, Okla. Ithaca, N. Y.
10–25	1099	17,052,500	9.5	Boone, Ia. Cleveland, Miss. Cortland, N. Y. Mount Holly, N. J. Pascagoula, Miss. Woodland, Cal.
5–10	1381	9,697,300	5.4	Liberty, Mo. Moss Point, Miss.
<5	*	75,498,100	42.1	Drew, Miss. Medford, N. J. Skaneateles, N. Y. Waukomis, Okla.
Total		179,322,100	100.0	

* No estimate available. This category includes unincorporated places less than 1000 population and other rural population not included in other categories.

accurately known, but useful values can be obtained by accepting the measured speech volumes as representative and weighting them in accordance with population.

The population statistics and the weighting factors used to obtain the composite averages are given in Table III. The population statistics are taken from the 1960 *Census of Population — Advance Reports* distributed by the U. S. Department of Commerce.

VII. OBSERVATIONS ON INTRABUILDING, INTERBUILDING, TANDEM AND TOLL CONNECTIONS

Average speech volumes obtained in each office are shown in Figs. 2 and 3 for the four types of calls. These averages, when combined using the weighting factors given in Section VI, yield the Bell System averages. These are shown in Table II.

The data for interbuilding and tandem calls shown in Figs. 2 and 3 are separated into two groups according to trunk losses. This illustrates the effect of trunk loss on speech volume. On the average there is a 1-db increase in speech volume for every 3-db increase in trunk loss.

Locations with high speech volumes on intrabuilding calls have consistently high speech volumes on the other types of calls. Conversely, locations with low speech volumes on intrabuilding calls have low speech volumes on other types of calls. The high speech volumes are, with few exceptions, found in the larger cities. Lower-loss loops and a greater incidence of business calls may be contributing factors. Regional speech characteristics and other factors which cannot be ascertained by measurement (for example, some hypothesis has naturally been made on the effect of the faster pace of urban living than rural living on speech volumes) may contribute to the differences in speech volumes from office to office.

The standard deviation associated with the average tandem speech volume is considerably smaller than the standard deviations for the other kinds of calls. This is probably because tandem switching is largely confined to metropolitan areas and the calling population is more homogeneous than if it were scattered throughout the country. This same factor may account for the high average level of this type of call.

VIII. SPEECH VOLUMES OF MALES AND FEMALES ON SOCIAL AND BUSINESS CALLS

The speech volumes of male and female talkers on social and business calls are interesting to note and may be of use in the design of some special systems. The intrabuilding, interbuilding, tandem and toll speech volumes have been combined without any weighting to give an indication of the relative difference in speech volumes as illustrated in Fig. 4. These are averages for all types of connections and therefore do not indicate the actual levels of measured volumes.

The average speech volume of the female talker remains within a 1-db range, whereas that of the male talker drops as much as 4 db when the far-end changes from male to female. Over-all, men tend to talk slightly louder than women, and business conversations are louder than social ones.

Approximately 73 per cent of the business calls observed were made by male speakers, whereas females made 81 per cent of the social calls. The majority of the tandem and toll calls were made by men, and most of the local telephone calls were made by women.

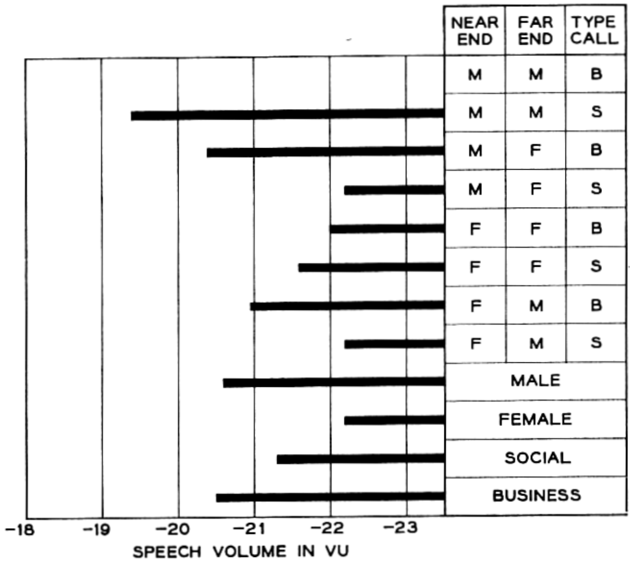

Fig. 4 — Speech volumes of males and females, social and business calls.

IX. DISTANCE EFFECT

In New York special observations were made in several toll centers on circuits to Philadelphia, Chicago and Mexico City. These data are not included in the previously discussed averages. They are summarized in Table IV.

These data illustrate the distance effect observed by V. Subrizi in the 1950 survey. In spite of the lower circuit losses on the long connections, there is an increase in near-end speech volume of approximately 1 db per 1000 miles. This increase may be caused by increased noise and distortion on longer toll connections or may be psychological.

X. PBX OBSERVATIONS

Some preliminary speech volume measurements were made in the 701A PBX at Murray Hill Bell Telephone Laboratories on intra-PBX calls and on tie lines to the West Street, New York, and Whippany, New Jersey, Laboratories. Tie line losses to New York varied from 3.9 to 7.5 db and those to Whippany from 4.0 to 5.0 db. The average speech volumes obtained are shown in Table V.

These volumes are generally higher than the composite averages for local offices. Contributing factors are short loops and the fact that the calls are predominantly made by men talking business. The effect of variation in loop loss on the standard deviation is virtually eliminated in these PBX observations, and variations due to station sets are greatly reduced because their current supply is at a uniformly high level. The standard deviation is still large, indicating that the spread in speech volumes is largely a result of variation in individual habits and speaking levels rather than in loop and station characteristics.

XI. COMPARISON WITH 1950 SPEECH VOLUME SURVEY

One of the interesting questions posed by the surveys in 1950 and 1960 is whether speech volumes are increasing or decreasing. This is a

TABLE IV — LONG DISTANCE OBSERVATIONS AT NEW YORK TOLL CENTERS AT ZERO LEVEL POINT

Terminal	Speech Average VU	Volume Sigma db	Circuit Loss db	Air Miles
Philadelphia	−15.3	4.8	7.8	80
Chicago	−14.3	4.0	6.0	850
Mexico City	−12.7	4.4	5.0	2094

TABLE V — SPEECH VOLUME OBSERVATIONS AT THE MURRAY HILL LABORATORIES PBX

	Average VU	Standard Deviation db
Intra-PBX	−17.8	5.5
Tie line to Whippany, N. J. Laboratories	−17.7	4.7
Tie line to West Street, N. Y. C. Laboratories	−16.7	4.9

TABLE VI — COMPARISON OF SPEECH VOLUMES IN 1950 AND 1960

1950 Survey			1960 Survey		
Connection	Speech Volume		Connection	Speech Volume	
	Avg. VU	Std. Dev. db		Avg. VU	Std. Dev. db
Local	−19.0	5.7	intrabuilding	−24.8	7.3
			interbuilding	−23.1	7.3
Tandem	−17.0	5.8	tandem	−19.2	5.9
Toll	12.0*	5.3*	toll	−16.8	6.4

* Measured at toll office, but corrected back to local office by toll connecting trunk loss.

difficult question to answer, since the two surveys varied widely in scope and since some of the office areas measured in both surveys have changed considerably. A summary of both surveys is shown on Table VI.

The averages for 1950 were obtained in Atlanta, Ga.; Cleveland, O.; and New York, N. Y. Local calls as defined in the 1950 survey include intrabuilding calls and short (or with low-loss trunks) interbuilding and tandem calls.

For locations comparable to the three cities observed in 1950, speech volumes now average 0.5 db lower on local calls and vary from a few tenths of a db to 2 db lower on toll calls. These differences are too small to be considered significant.

XII. LIMITATIONS OF SURVEY

Caution is advised against using these data for engineering systems used by private, military or air control personnel. These data apply only to Bell System customers working into the switched Bell System network. Very much higher talker volumes have been observed in limited measurements of military and private-line networks.

XIII. ACKNOWLEDGMENT

Acknowledgment is gratefully made to the many persons in the operating companies and the American Telephone and Telegraph Company whose cooperation made the survey possible.

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