SOME FIELD TEST RESULTS OF WIND PRESSURES ON A TALL BUILDING

RÉSULTAT DE QUELQUE MESURES DE LA PRESSION DU VENT SUR UN BÂTIMENT HAUT

by
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Summary

Full-scale studies of wind pressures on a tall prismatic building under a strong wind is illustrated herein. The records which were obtained from a propeller-vane anemometer and wind pressure transducers provided on this structure during the highest gust are analyzed to investigate the relationship between them. Then wind effects on this structure such as correlations of the wind and wind pressures, periodic pressure changes which may be caused by Kármán vortices and well correlated ranges of the wind pressure are explained.

1 Introduction

Full-scale studies are without doubt a powerful tool to analyze wind effects on structures. Recently several groups have been engaging in this subject and their results were already reported here and there. It may be considered some of them were stimulated by the report about the full-scale studies presented by Newberry [1)] in the first International Conference on Wind Effects on Buildings and Structures held in Teddington, U. K. in 1963. Japan is seemed to be the most influenced country because BRS type wind pressure transducers were provided at least five buildings in and near Tokyo since then. A tower-like structure of the Hitachi Ltd. for the research of elevator operation is one of them. It was considered to be a convenient structure for wind and earthquake studies as a prototype of high-rise buildings.

By courtesy of the Hitachi Ltd. various instruments have been provided in this structure. Some of the observations will be also reported elsewhere in this proceedings.

Wind pressure transducers have been provided in 1968. Unfortunately only a few data are presently available for study. Simultaneous records of the wind and wind pressures obtained on June 26, 1969 are analyzed herein.

2 Structure and Instruments

This tower-like structure is a near square prismatic steel framed building of 81 meters height and of 22 stories and stands among low and rela-

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tively flat factory buildings scattered among a pine tree grove in the suburbs of Mito City, which is located about 100 km northeast from Tokyo. Its typical floor plan and south elevation are shown in Fig. 1 (a) and (b), respectively. The walls are made of light weight precast concrete panels and steel sashes which are partitioned with I shape mullions.

Dynamical characteristics of the structure were briefly reported by Kishida and others [2] in the proceedings of the Fourth World Conference on Earthquake Engineering held in Chile 1969. The natural periods of the fundamental modes were measured as 1.72 seconds for translation in the east west direction and 0.75 second for torsion, respectively. The natural periods of the translational mode for the north south direction were not reported but considered to be similar to those observed in the other direction. Damping ratios to the critical damping for the fundamental translational and torsional modes were measured as 0.0065 and 0.013, respectively.

Five wind pressure transducers are located vertically on the north and south windows of the upper part of the structure at intervals of 10.5 meters. Unfortunately no transducers could be provided on the other sides since there are no windows on the east side and no approaches to the west windows.

The wind pressure transducers so called BRS type made in the United Kingdom have been mounted to aluminum plates substituted for glasses of sliding windows. Fillers were provided temporary for measurement to minimize the rattling of the windows. Back pressures of the wind pressure transducers have been commonly reserved with vinyl tubes to a small box with a tiny hole opened to the inside of the 13th floor nearly corresponded to the centroid of the measuring points.

A propeller-vane anemometer is also provided about 5 meters above the top of the structure. Wind directions of the anemometer are arranged with respect to the axes of the structure such that the wind normal to the south elevation is detected as the south wind. Locations of the wind pressure transducers on the south windows and the anemometer are also illustrated in Fig. 1 (b).

3 Observed Data

Simultaneous records of the wind and wind pressures were obtained on June 26, 1969 on which a strong wind blew from the Pacific Coast of Japan for a few hours. According to the recorded data, it blew against the southwest corner of the structure at the beginning of the measurement and then shifted gradually against the west surface with about 20 m/s in an average. However the wind fluctuated considerably and a series of gusts continued about a couple of minutes for which sampled data were taken.

The wind and wind pressure data were digitalyzed at intervals of 1.0 and 0.2 second, respectively. Typical data are as shown in Table 1. Run No. 3, No. 7 and No. 16 are the data corresponding to the windward, leeward and parallel sides of the structure against the wind, respectively.

However, even in the windward records a few suction pressures which might be caused by the change of wind direction were observed since the mean wind direction indicated an attacking angle of about 45 degrees at the beginning of the measurement. Run No. 3 is picked up as an example for the lowest suction pressures. On the contrary, Run. No. 7 represents the lowest positive pressure case on the leeward surface. Run No. 16 represents the records from the windows which happened in parallel with the mean wind direction. In this case periodic changes of pressures were slightly observed.

It may be reasonable that the suction pressures fluctuated than the positive pressures. Through the observed data the minimum suction and maximum positive pressures were approximately expressed as

$$\text{min. suction pressure} = m - 5\sigma$$

and

$$\text{max. positive pressure} = m + 2\sigma$$

where m and σ are the mean and standard deviation of the pressures, respectively.

The vertical profile of wind pressures were rather constant at not only the average but also the maximum and minimum values.

4 Correlations

Autocorrelations of the wind speed, wind direction and wind pressures at Run No. 3, No. 7 and No. 16 are shown in Fig. 2 (a), (b) and (c), respectively. Similarly correlation coefficients and cross-correlations of not only the wind pressures between the measuring points but also the wind speed and wind pressures in the same runs are given as in Table 2 and in Fig. 3 (a), (b), (c) and (d), respectively. It may be noticed that negative correlations were frequently developed since suction pressures were expressed as negative values and the wind directions were figured out in clockwise direction from the north with 32 divisions.

The autocorrelations of the wind speed were slowly descending curves with respect to time lags as usual since the fluctuations of the wind speed were relatively small compare to the average. It may be reasonable that the autocorrelations of the wind pressures were influenced by the orientation of the measuring surface against the wind. In fact the autocorrelations of the wind pressures were similar to those of the wind speed when the measuring surface was in the windward. The wind directions, on the other hand, were nearly uncorrelated with the other records in all cases.

Periodic changes of the wind pressures about 4.5 seconds intervals were clearly observed on the autocorrelations and cross-correlations of Run No. 16 at which the north and south measuring surfaces were parallel with the mean wind direction. Moreover, a phase angle of 180 degrees were also observed on the cross-correlations for the same run shown in Fig. 3 (c) and (d) which were obtained from the wind pressures of the north surface and the north and south surfaces, respectively.

The intervals of the periodic changes fluctuated in the range from 2.5 to

4.5 seconds. Supposing that the wind speeds are 20 m/s and the periods of the wind pressure fluctuation are in the range from 2.5 to 4.5 seconds, Strouhal number of this structure is estimated as about 0.10 to 0.16.

Correlation coefficients between the windward pressure transducer points were seemed to be dependent on the fluctuations of the pressures. Relationships between the correlation coefficients and the pressure fluctuations are shown as in Fig. 4. The correlations of the wind pressures between the measuring points became better when the positive pressures prevailed. It seems to be reasonable that the correlation coefficients were almost inversely proportional to the distance between the measuring points.

5 Conclusion

Some of the results from this observation under the wind of about 20 m/s are as follows:

(1) In general, the wind pressures on the leeward surface were nearly uncorrelated to the wind but greatly influenced by the wakes of the structure.

(2) Well correlated ranges of the leeward elevation were estimated as within about 20 meters.

(3) Periodic changes of the wind pressures which might be caused by Kármán vortices were clearly observed on the cross-correlations of the records from the windows along the mean wind direction.

(4) Vortex excitations were not yet synchronized to the natural frequencies of the structure.

(5) A predominant Strouhal number of the structure was considered to be about 0.1.

Acknowledgement

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References

1) Newberry C. W. "The measurement of wind pressures on tall buildings" Proceedings of Wind Effects on Buildings and Structures Vol 1, Teddington, U. K. 1963

2) Kishida H., Matsushita K. and Sakamoto I. "Soil-Structure Interaction of the Elevator Tower and of Concrete Footings" Proceedings of the Fourth World Conference on Earthquake Engineering Vol. 3, Chile, 1969

Table 1 Wind and Wind Pressures

Run / Length of Data (sec)	Wind: Mean / Standard Deviation (m/s)	Wind: Peak Gust (m/s)	Wind: Mean Direction	Measuring Point	Wind Pressures: Mean (kg/m²)	Wind Pressures: Max. (kg/m²)	Wind Pressures: Min. (kg/m²)
No. 3	18.9	22.8	SW	19S*	4.56	10.6	-1.67
				16S	4.75	11.9	-3.07
90	2.26			13S	4.47	10.9	-1.58
				10S	2.89	11.0	-3.71
				7S	1.95	13.6	-4.95
No. 7	21.8	24.2	SW	19N	-6.56	0.35	-14.9
				16N	-6.21	-0.76	-13.2
100	1.90			13N	-6.73	0.19	-27.5
				10N	-3.00	3.89	-17.7
				7N	-0.40	13.7	-15.2
No. 16	19.6	22.7	W	16S	-4.99	5.21	-20.0
				16N	-3.71	10.1	-26.2
180	2.10			13S	-5.95	3.83	-28.7
				13N	-0.37	8.86	-19.2
				10S	-1.21	5.61	-15.0
				10N	-2.26	10.5	-17.4

* S or N indicates the south or the north surface of the structure.

Table 2 Correlation Coefficients

(a) Run No. 3

	Wind Speed	Wind Direction	Wind Pressures 19S	16S	13S	10S	7S
W. Speed	1	.222	.618	.620	.556	.490	.508
W. Direct.		1	-.066	-.025	.001	.082	.184
19S			1	.867	.824	.713	.610
Wind 16S				1	.862	.771	.640
Pres. 13S					1	.856	.703
10S						1	.828
7S							1

(b) Run No. 7

	Wind Speed	Wind Direction	Wind Pressures 19N	16N	13N	10N	7N
W. Speed	1	.166	-.353	-.245	-.106	-.051	-.021
W. Direct.		1	.400	.268	.041	.105	.145
19N			1	.688	.166	.226	.269
Wind 16N				1	.515	.409	.294
Pres. 13N					1	.605	.390
10N						1	.514
7N							1

(c) Run No. 16

	Wind Speed	Wind Direction	16S	16N	13S	13N	10S	10N
W. Speed	1	-.564	-.166	-.246	-.146	-.215	-.228	-.223
W. Direct.		1	-.163	.148	-.116	.079	.035	.208
16S			1	-.189	.606	-.091	.415	.012
Wind 16N				1	-.054	.526	-.051	.079
Pres. 13S					1	.080	.649	.148
13N						1	.117	.373
10S							1	.270
10N								1

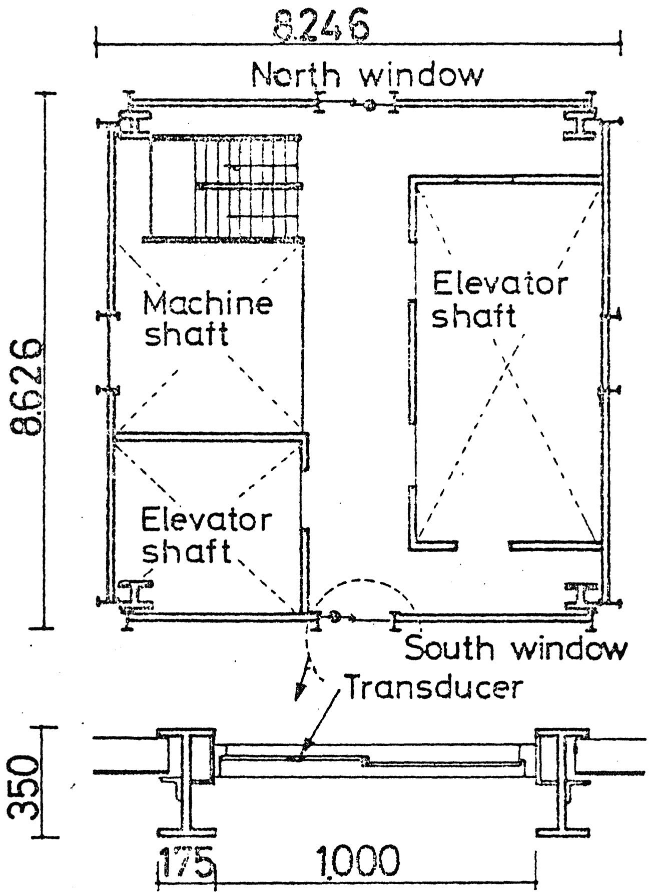


Fig.1(a) Typical Floor Plan

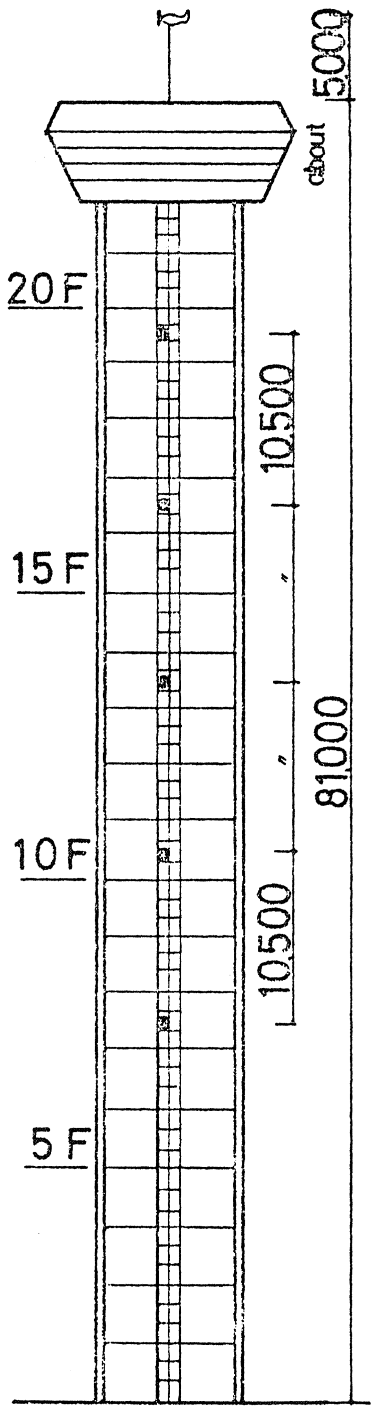


Fig.1(c)
North side
of the building

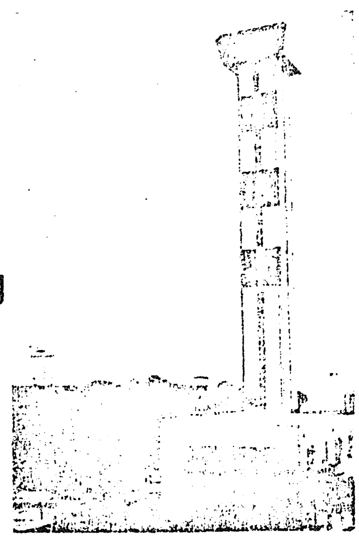


Fig.1 (b)
South Elevation

Fig 2 (a)
Autocorrelations of Run No. 3

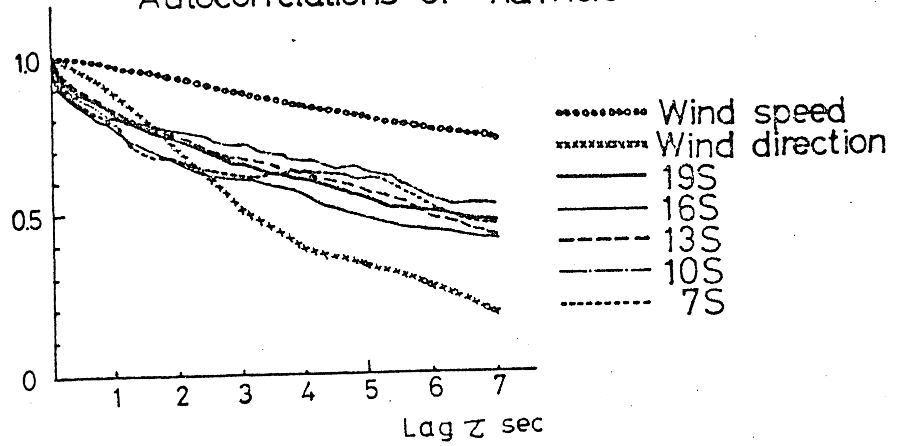


Fig. 2 (b) Autocorrelations of Run No. 7

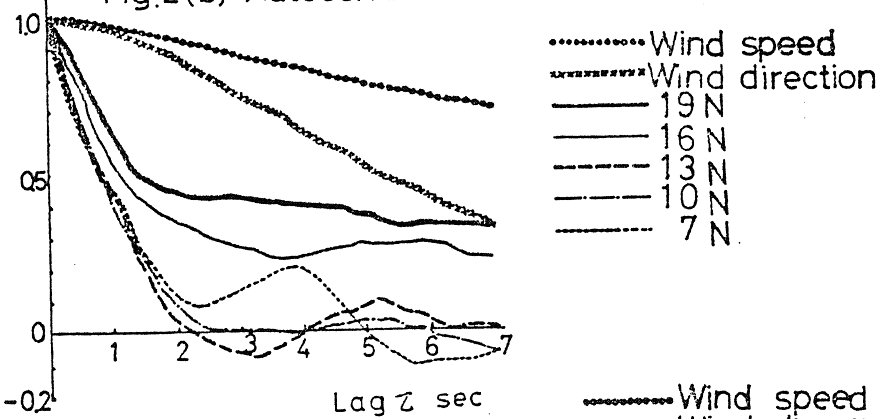
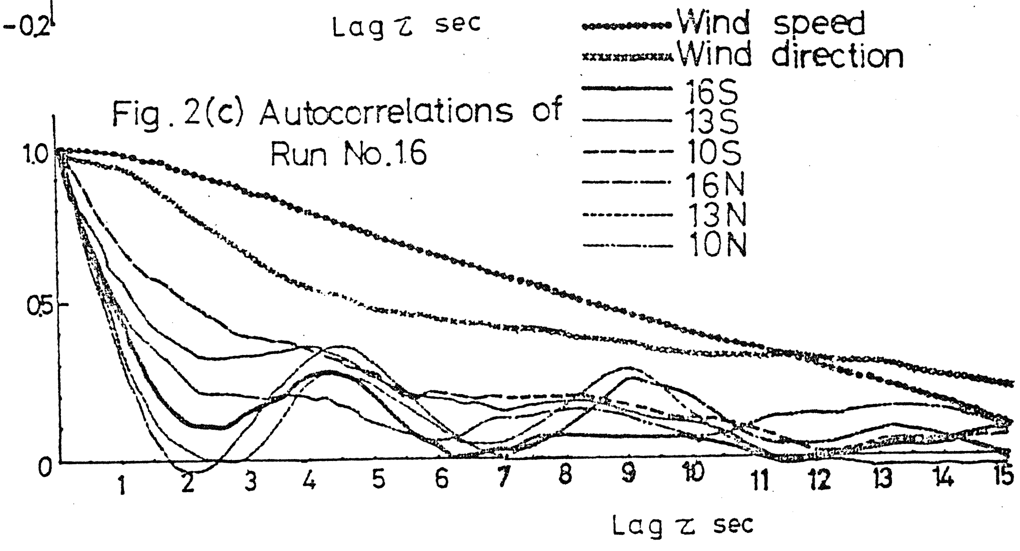


Fig. 2 (c) Autocorrelations of Run No. 16



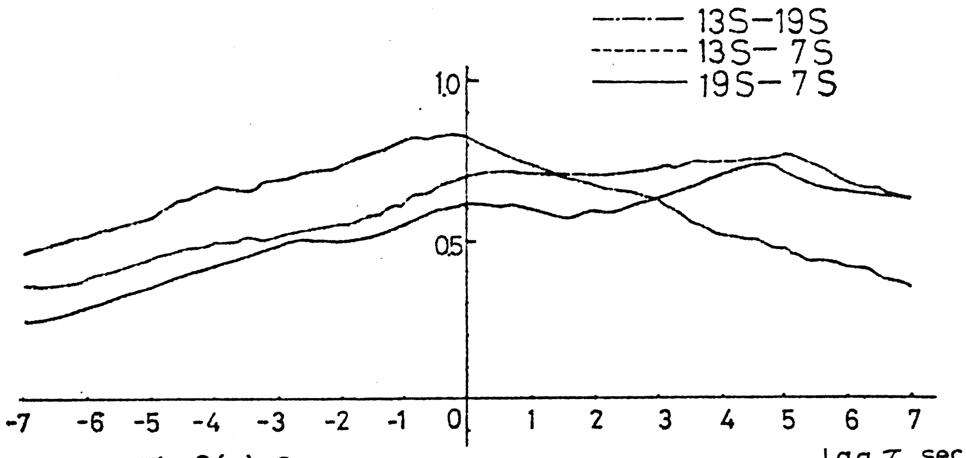


Fig 3(a) Cross-Correlations of Run No.3

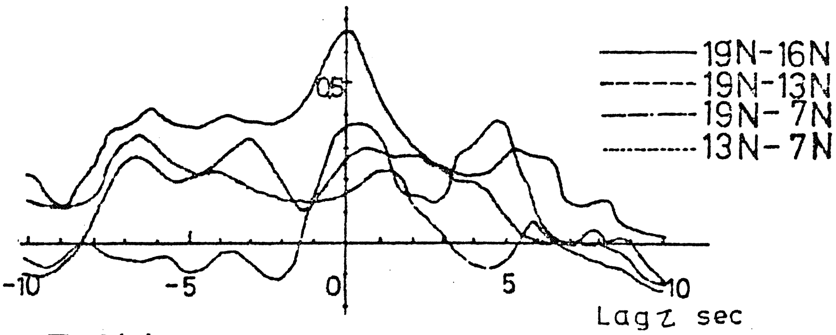


Fig.3(b) Cross-Correlations of Run No.7

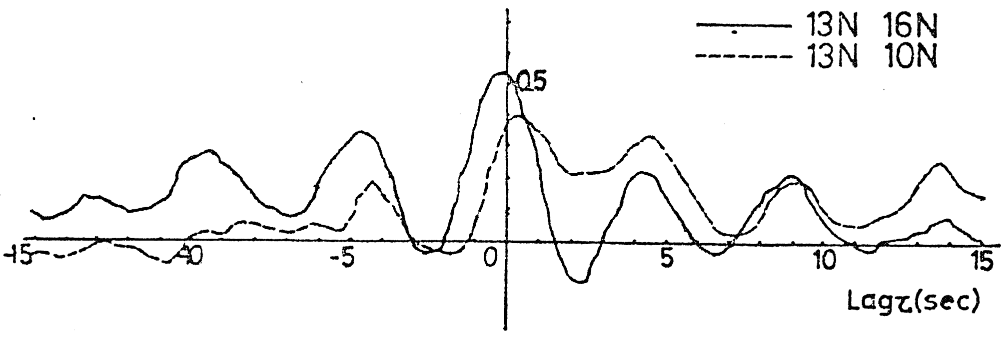


Fig.3(C) Cross-Correlations of Run No.16 (North and North)

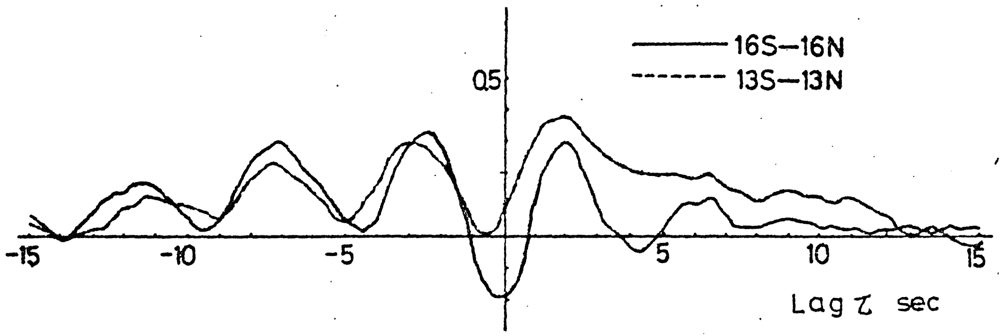


Fig.3(d) Cross-Correlations of Run No.16(North and South)

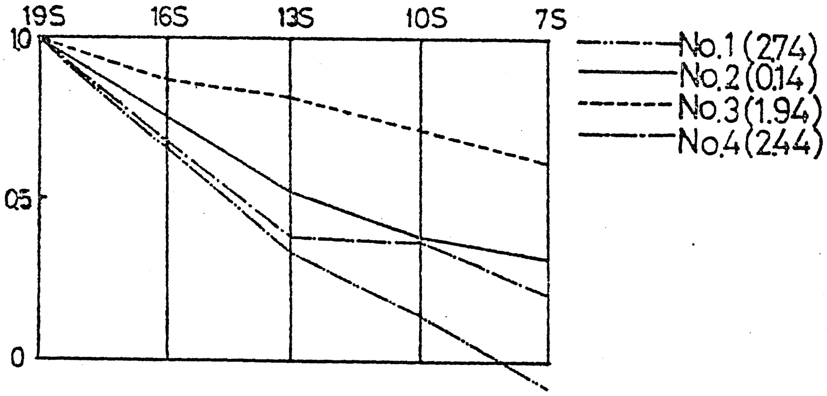


Fig 4 Correlation coefficients between 19S point and other points. Number in parenthesis indicates the ratio of min suction to max positive pressures in 13S