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DEVELOPMENT OF A MEASURING SYSTEM FOR THE UNDERGROUND PIPELINES

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Abstract

In this paper, we develop a measuring system for underground pipelines.There are some measuring system for underground pipelines. Most of them are inspection device by television camera. The measuring system is developed in order to measure the linearity of underground pipelines.

The system does not use any laser emitter because of the infrence from the envelopment. The principle of the system mechanism is to sum the relative locations.

Firstly, we make the prototype of the measuring system based on the principle. Secondly, the theorical error of the measuring system is derived from the error of the units which is the element of the system. Finally, we check the performance of the measuring system in the test field to measure a pipeline on the ground.

1 INTRODUCTION

The 40 millions people use the sewerage in Japan. Although the percent of sewered population has been increased in these years, the ratio of sewered population is lower than any other advanced country's as from figure 1-1 to figure 1-4. [Uehara, 1987] This shows us the needs to promote the construction of more swerages in our country. There are two types of method to construct sewer culverts. The one is the open cut method. This method causes traffic blockage because it is conducted at busy and narrow streets, which in fact is the nature of Japan. The other one is the method which creates less traffic at construction sites. (see figure 1-5).

Recently, we have come to use a micro–tunnelling system at a place, such as at a railroad and at a road for constructing culverts, pipes and so on. under the ground. (the micro– tunnelling is one of pipe jacking methods which applies pipes of inner diameter to be less than 800mm.) The reason of adopting the micro–tunnelling system is that we construct culverts and pipes in the depth of life–lines at 5 meters or deeper. We do this because some pipe–lines have been already buried in the underground at the depth of less than 5 meters. The open cut method is costly , takes time and requires larger space in case of the depth of the pipe is more than 5 meters, so it is not advantageous to apply in that case. Moreover the number of construction has been increased at rural cities. At rural cities,it is inclined to use the pipes of which the diameter is below 800 mm. The first time we used the micro– tunnelling system was back in the age of the ancient Rome when sewer pipes was placed under the ground. In Japan, we use the micro–tunnelling system for the first time in 1958 at Amagasaki city.

Now, we apply the system not only in constructing sewer pipes but also in extending telephone cables. Precision is one of the key factors. At present, though, a precision method has not been developed for measuring sewer pipes laid out using the small diameter pipe propulsion technique. In order to improve the accuracy and sophistication of the small diameter pipe propulsion technique, we have been developing linear inspection equipment. This study is derived from the results of "Development of Automatic Control for Micro–tunnelling Systems," a joint research carried out from 1988-90 by the Public Works Research Institute of the Ministry of Construction together with 12 private companies. This joint research is included by the project of "AI Control System for Micro–tunnelling".

2 GUIDELINES OF THE DEVELOPMENT PROJECT

The aims of our research are to develop a measuring robot for the underground pipelines." This robot will be used to measure precisely and in three–dimensions the state of gas pipes, electric and communication cables, and sewage pipes installed using underground propulsion techniques. The specifications required of the robot are as follows:

- The robot must be capable of accurately and reliably measuring the state and workmanship of underground pipes (three–dimensional displacement away from the designed course of the underground pipe lines).
- The robot must not be affected by various factors of temperature, properties of the pipe surface, etc.

3 THEORETICAL PRINCIPLES FOR THE SYSTEM

In utilizing this measuring technique, errors are produced due to the measuring equipment's precision limits such as that of the rotary encoder. We carried out error analysis leading to the following results:

- When a pipeline is comprised of 49 pipes with a total length of 119 meters, the maximum accumulated error is 2.92mm.
- When a pipeline is comprised of 50 pipes with a total length of 122 meters, the maximum accumulated error is 3.04mm.

Based on these results and the goal of precision measuring, we determined that the measuring limit is reached with a total length of 119m. The following is a summary of our measuring method. We suppose there are two connected pipes and the axis of each pipes intersected by two planes. Four figures are formed by the intersections of the two planes and the inner wall of the pipe. We specify the virtual mass of any point on the figures as m (a constant). A three–dimensional equation for the central axis (pipe axis) of each pipe can then be obtained by measuring the three– dimensional coordinates of each figure and determining its center of gravity. This three-dimensional equation allows the relative angle and bearing of bending and the relative amount and bearing of dislocation to be geometrically calculated. Therefore, any three–dimensional displacement from the planned pipeline route of a particular pipeline can be determined by integrating those values. As mentioned above, the robot developed can determine three–dimensional displacement from the planned pipeline route for a particular pipeline by utilizing its measuring apparatus which slides along the inner pipeline wall at the pipe's joints so as to allow the setting up of a three–dimensional equation for the axis of each of the two connected pipes. Figures 3-1, 3-2, and 3-3 show the measuring principle, an overview of the measuring robot, and a measurement flow.

4 OVERVIEW OF THE SYSTEM

4.1 FEATURES OF THE SYSTEM

The robot has the following characteristics: Allows direct measuring of the inside of the underground pipe. Allows measuring over the line's length. Outside disturbances hardly affect the robot's measuring capability due to the use of the mechanical method. Is hardly affected by vibrations or the properties of the pipe's inner surface.

4.2 STRUCTURE OF THE SYSTEM

This system comprises an in–line traveling self–driven unit which moves along the inside of the pipe and an outside control and signal processing unit which controls the in–line traveling unit operating inside the pipe and converts the signals into a suitable form for the particular output. The in–line traveling unit is connected to the control and signal processing device via a signal conductor with the wires wound on a winding drum. The control and signal processing computerized unit consists of a personal computer, CRT, and printer (Figure 4-1 and 4-2). The in–line traveling unit is equipped with a CCD camera to allow close observation of the pipe's inner surface.

4.3 SPECIFICATIONS

1. Type of Pipes Inspected
   Nominal diameter: 700mm (continuous length of 90m)
   Applicable to other pipe diameters

2. Measuring Range

   - Vertical: 60mm from the planned pipeline route
   - Horizontal: 100mm from the planned pipeline route

Table 4-1: PERFORMANCE OF THE SYSTEM

			Comments
Maximum Error	Up–Down	0.81mm	Theorical Error=0.47mm
	Right–Left	0.32mm	
Reproductivity	Up–Down	0.27mm	
	Right–Left	0.12mm	

4.4 PERFORMANCE

4.4.1 TEST METHOD

Measuring tests were conducted on 10 Hume pipes with a normal diameter of 700mm that are utilized in micro–tunnelling work. The pipes were laid out on the ground. Test Results (Figure 4-3, 4-4, 4-5, and 4-6, and Table 4-1) Maximum error was 0.81mm in terms of up–down and right–left displacement and the amount of dislocation. Now, the average value is set as the base because it is difficult to know real base.

4.4.2 MECHANICAL PRECISION

A total length of approximately 24.3m of pipes (10 pipes used in micro–tunnelling) were tested. The results show that an up–down error of 3mm or less and a right–left error of 5mm or less can be obtained at least 90m of pipe length (using 37 pipes that are utilized in micro–tunnelling).

5 DISCUSSIONS

1. It is necessary to review the equipment test method (there is no means available for measuring the true value of the displacement of the piping)

2. To evaluate and determine the continuous length of pipelines that may be precisely measured by this robot (the precision limits).

3. To reduce the measuring time.
   Present measuring time: 3.6 min./bending point (1.0 min./m)
   Goal: 2.2 min./bending point (0.6 min./m)

4. To extend the range of measurable pipe diameters.

5. To develop a system in which a single measuring device is capable of coping with several pipe diameters.

As described above, we developed a measuring robot for the underground pipeline" which can be used to measure precisely and in three-dimensions the state and characteristics of gas pipes, electric and communication cables, and sewages installed by underground propulsion techniques. However, we must continue correcting current problems and also develop new techniques to further improve the propulsion method to which greater importance is likely to be attached in the future.

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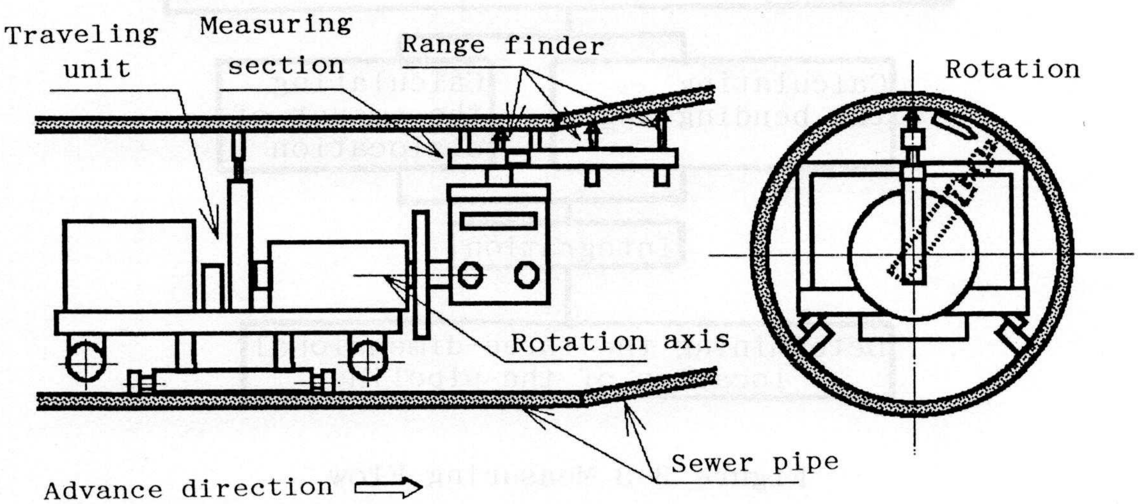


Figure 3-2 Overview of the Measuring Robot

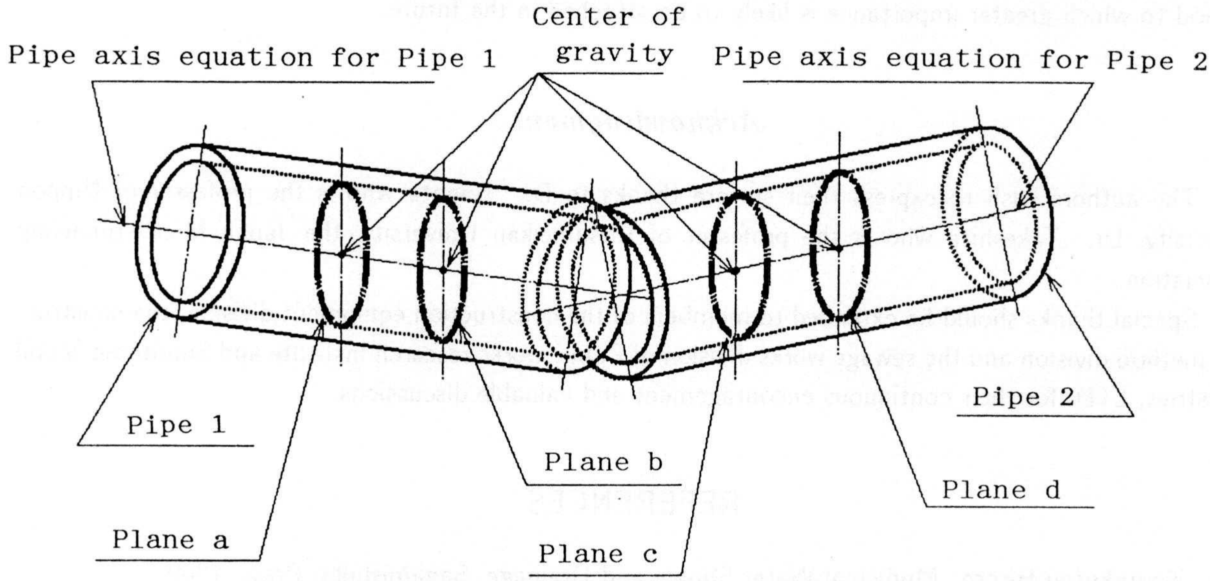


Figure 3-1 Measuring Principle

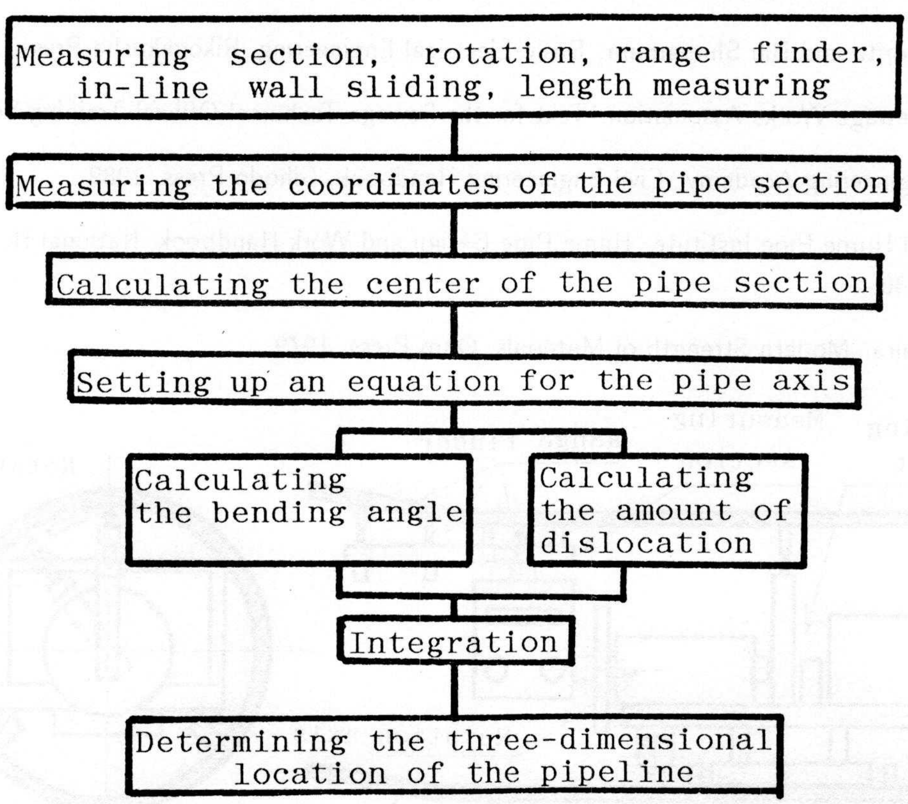


Figure 3-3 Measuring Flow

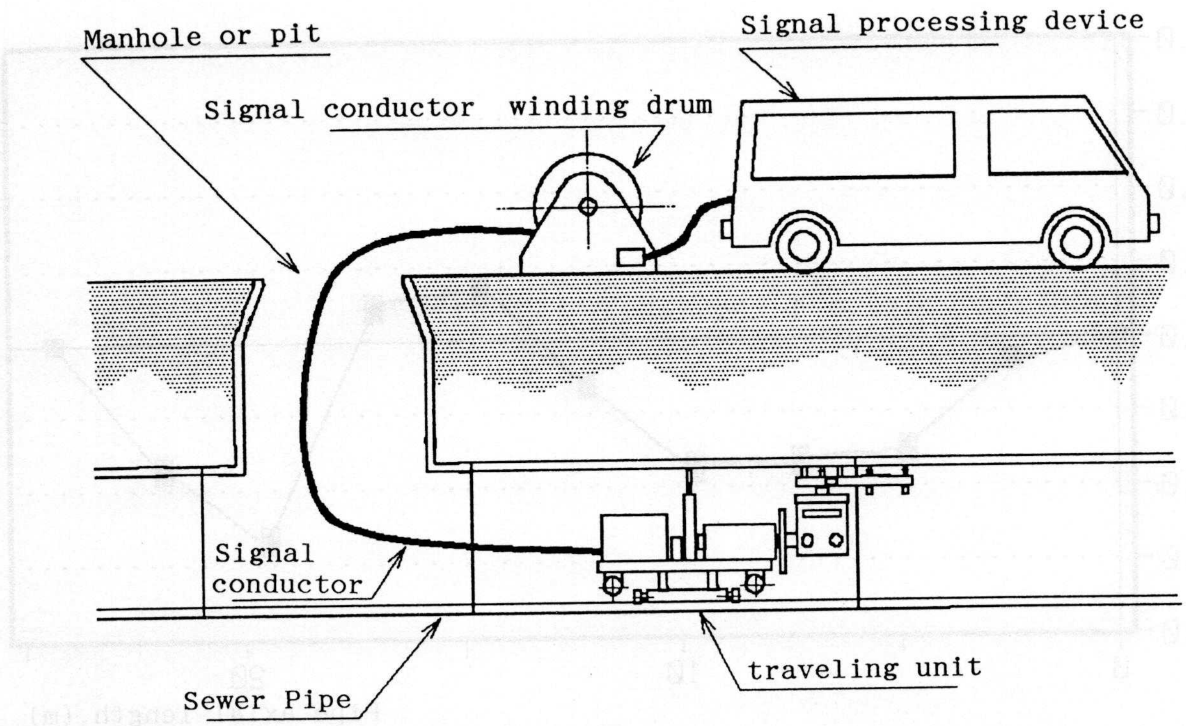
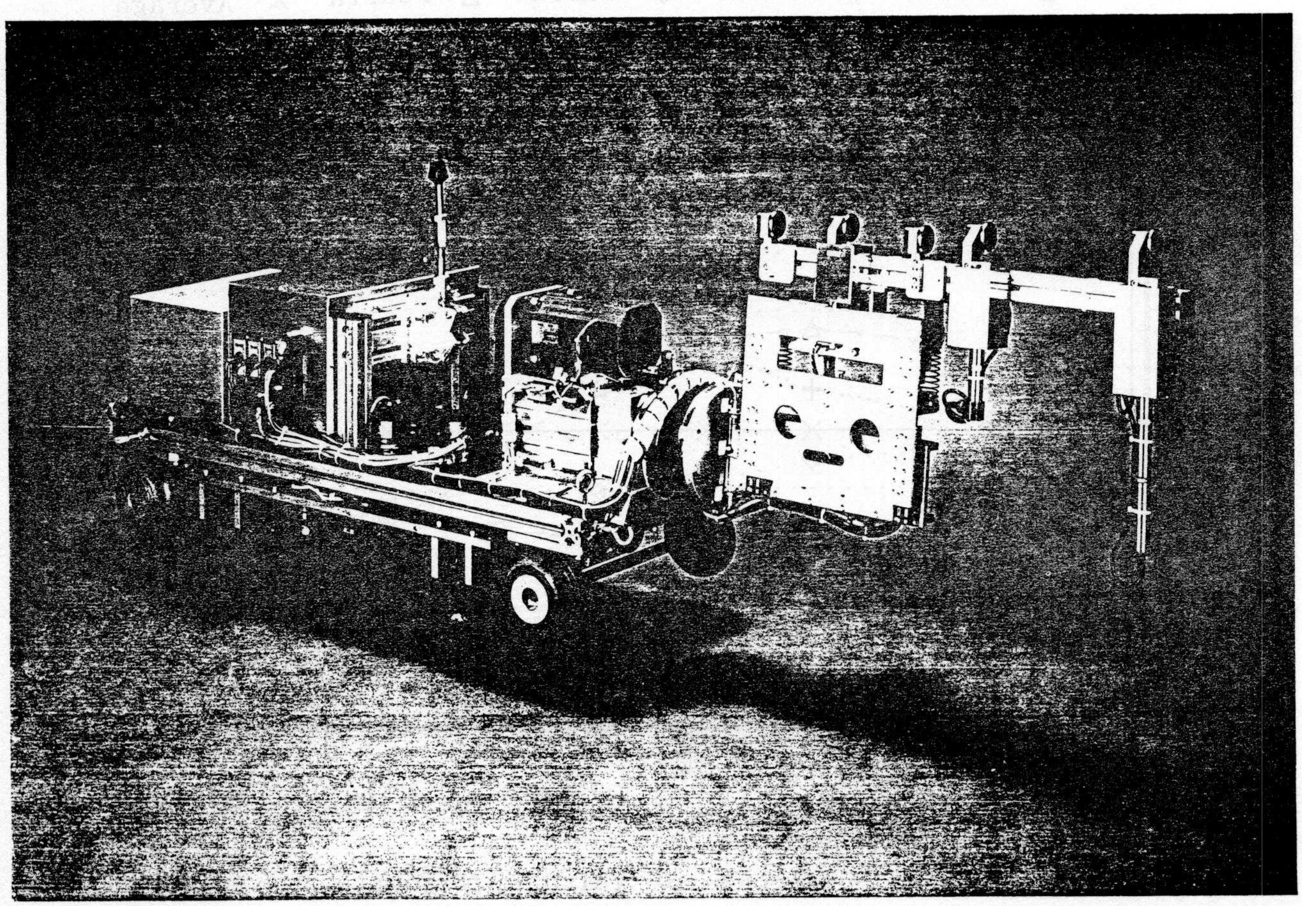


Figure 4-1 Total System



Photograph 4-1 Measuring System

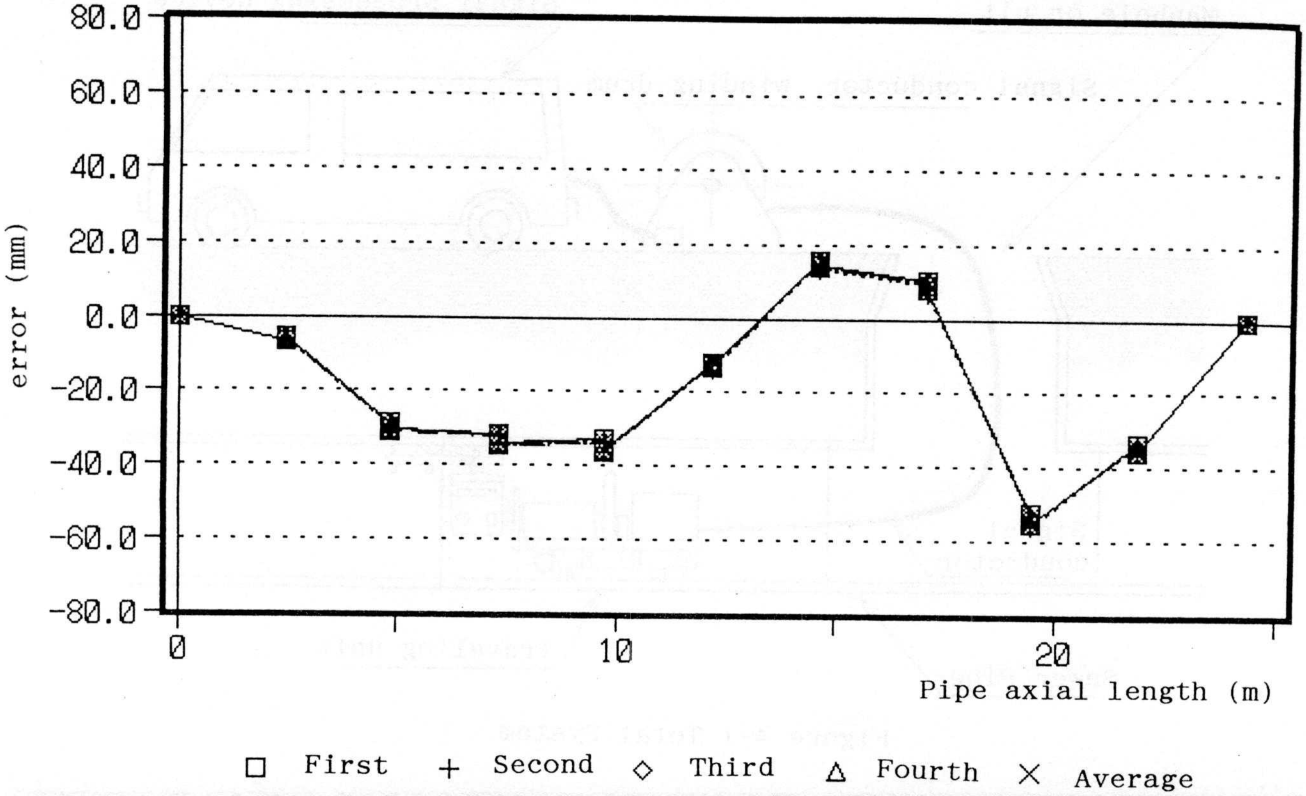


Figure 4-2 Up-down Displacement

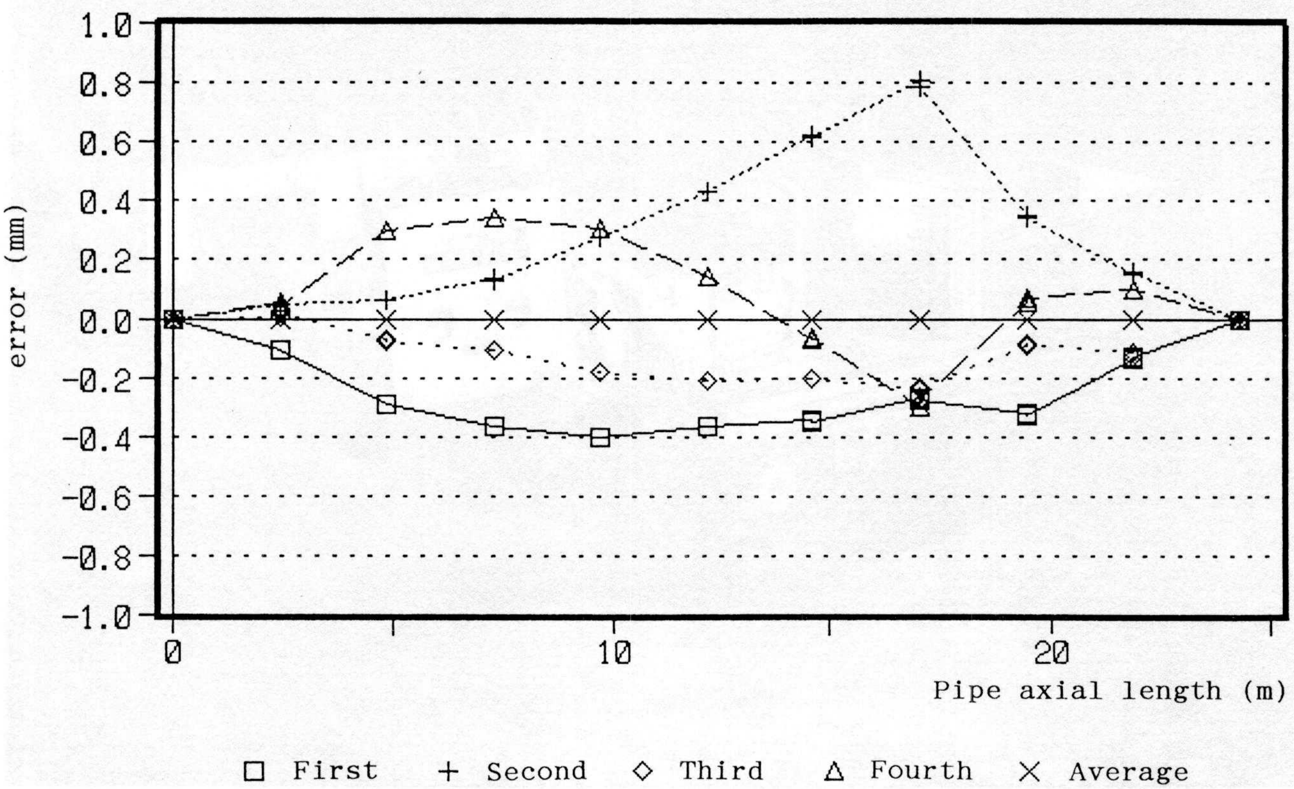


Figure 4-3 Up-down Divergence from the Average Value

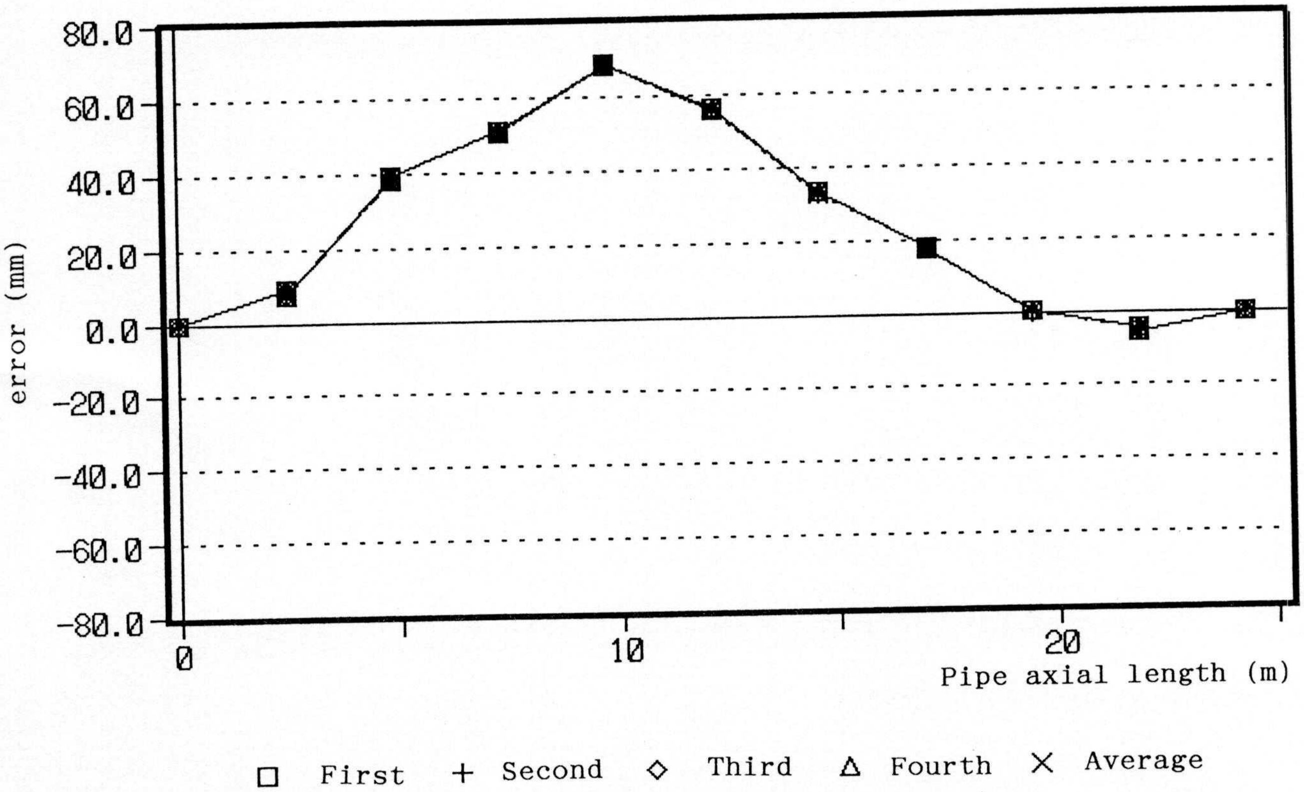


Figure 4-4 Right-left Displacement

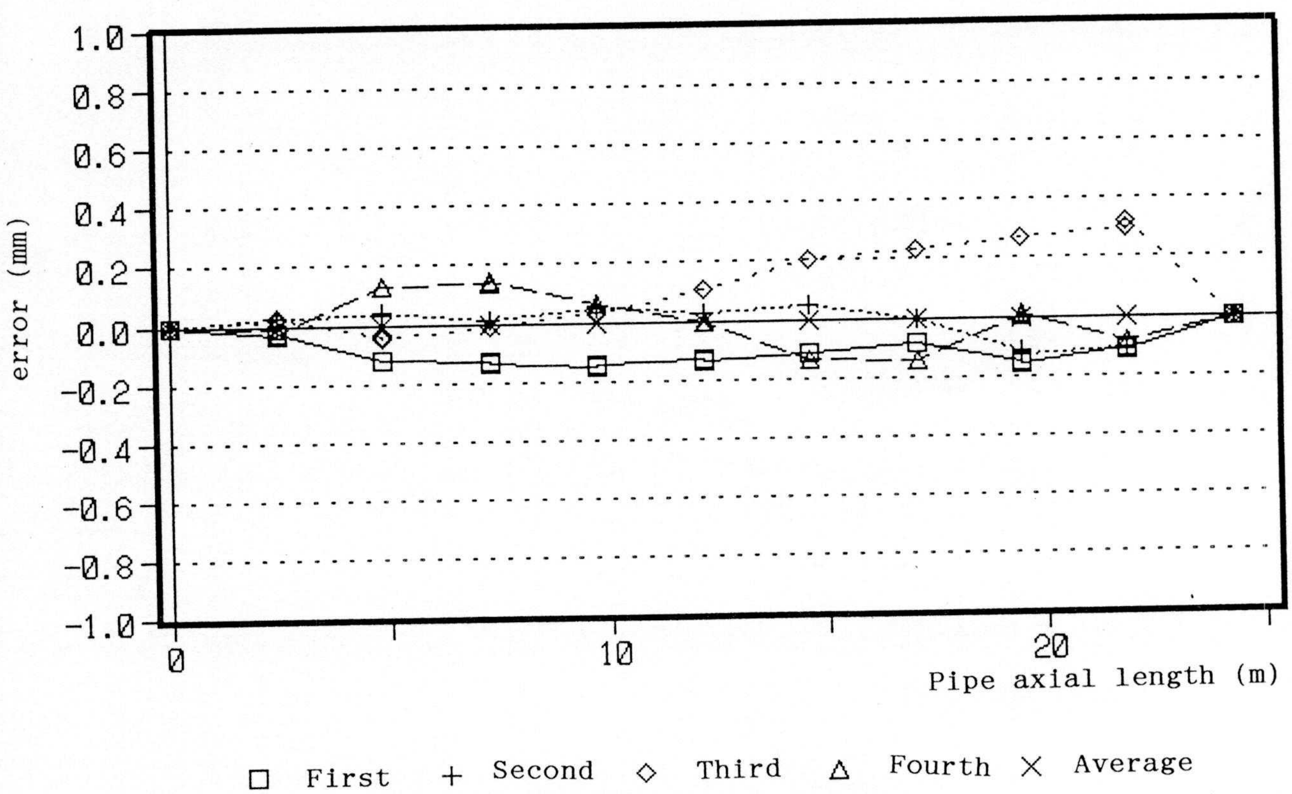


Figure 4-5 Right-left Divergence from the Average Value