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Results of the Development of a Manipulator with a very large reach

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A B S T R A C T

The paper gives an overview of the work performed in a national project by the companies Putzmeister, AEG and Dornier together with the IPA-Stuttgart.
The principal hardware and software is now completed and tested. The first results show that the specifications of the system can be realized.

1. General remarks

Manipulators with very large reach are very important for construction engineering applications /1/. However these machines are quite difficult from the technical point of view.
Conventional industrial robots are in general low payload devices and this has been state of the art since many years. The laws of physics mitigate against the easy implementation of large devices. As machines become larger, the structure and drives natural frequency decrease, limiting the system gain and rapidly degrading the accuracy and speed of operation of the machine to an impractical level.
To compensate, much more sophisticated mechanical hardware, controller strategies on the system and servo level, sensor systems and drives have to be employed. Not surprisingly the first development of larger manipulators worked on the master/slave principle, where the operator's natural abilities permit many of the machines deficiencies to overcome.
This paper gives a short overview of the measures realized.

2. Mechanical and controller hardware

The layout of the realized mobile manipulator is shown in Figure 1. The main features compared with conventional machinery are:

- o Increase of stiffnes of the arm structure by the factor 5
- o Placement of the valves near to the actuator components
- o Use of high resolution resolvers as path measuring systems due to their reliability in difficult environment
- o Calibration of the zero position by means ot tough-triggers, a system which can be operated by workers in the construction site
- o Use of high tensile steel in order to reduce weight
- o For the first time software tools developed at the IPA for the calculation of the forces and moments were used to find the optimum design

The mechnical hardware was designed and built by Putzmeister, Aichtal. Alltogether two units were built, one unit was aquired by KfK on a commercial contract.
For the controller hardware we started with the existing industrial controller Robotronic 500 from AEG. In this context several hardware-modifications were realized, to mention some of them:

- o Power supply 24V for the whole controller system (and hydraulic servo system)
- o Development of new housings for integration on a mobile truck for the specified environment
- o New electronic hardware for the resolvers considering cable length of more than 50m and EMV-problems
- o Use of an intelligent joystick with advanced man-machine features
- o Use of new NEC-processor with high computation power

The descision to start with an already existing industrial standard turned out to be a happy one considering the time to realize a reliable solution.

3. System level of the controller

Various new software items developed at the IPA together with the AEG had been implemented.
The coordinate transformation software turned out to be a very important factor for the béhaviour of our total system. Altogehter three totally different approaches were realized and tested against the following requirements

- short cycle time (less than 100µs on the AEG-Robotronic 500)
- Smooth movements of the individual axes

- collision avoidanve has to be realized within the given hardware in real-time for a limited number of obstacles
- the selection of independent and non independent axes should depend on the current situation of the manipulator
- compensation of the deflection should be realized within this context

Results of the selected approach are shown in Figure 2 for a horizontal and in Figure 3 for a vertical movement. The implementations of the software on the AEG-controller showed a real-time behaviour of less than 30 s. In this case the computation of the deflection is running in the background.

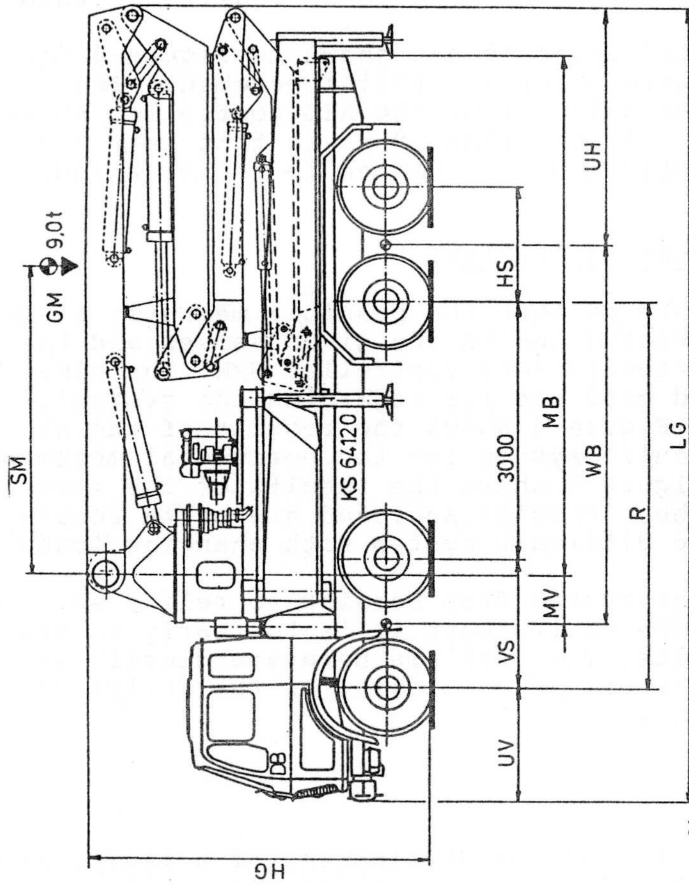
4. Servo level of the Controller

Various simulations showed that the possible measures on the servo level are restricted due to the given valves and the computation power of the current controller H/W. The simulation however showed good results regarding the system's accuracy at the TCP. Figure 4 shows the results of the simulation of the hydraulic system for the horizontal movement shown in Figure 2, Figure 5 shows the results of the movements of Figure 3. These results achieved are quite remarkable considering the difficult system with changing loads and masses.
Considering the sensor system from Dornier to relize an analytical model of the environment it is too early to present here first results. The problems here are closely related to the reduction of the complexity of the analytical model measured by the laser.

5. Conclusion

With the exercise of the of the development of a manipulator with very large reach a great step forward was realized in the last year. The project manager of the TP5-project would like to thank Putzmeister-Maschinenfabrik, AEG-Aktiengesellschaft and Dornier for their fine and fruitful cooperation.

/1/ Wanner et al: Design of a manipulator with very large reach for applications in civil engineering.
Forth International Symposium on Robotics and Artificial Intelligence in Building Construction, Haifa, 1987



Überhang / Overhang %

Reichweitediag. / Working range diagr. KS 49921

Standsicherheitsber. / Check on stability KS 47920

ABUZ KS

* Kann durch Ländervorschriften begrenzt sein
* Can be limited by regional regulations

Alle Maß- und Gewichtsangaben beziehen sich auf die serienmäßige Ausrüstung betriebsbereit ohne Wasser und Zuladung.
Technische Änderungen bezüglich Gewichten & Abmessungen vorbehalten.
All specifications regarding measurement and weight refer to standard equipment, reday-for-operation, without water and load.
Technical alterations referring to weights and measurements are subject to alteration.

	VA [kg]	GG [kg]	HA [kg]
Chassis Gewicht	6200	10400	4200
Zul. Gesamtgewicht *			
Gewogenes Gewicht			
Gerechnetes Gewicht			
Reserve für Zuladung			

	VA [lbs]	GG [lbs]	HA [lbs]
Kerb weight			
GVW			
actual weight			
Calculated weight			
Load capacity			

SG	SM	SP	SAP	SUA	
Gesamt	Schwerpunktsabstand Mast	Pumpe	Armpaket	Unterbau Aufbauein.	
	3600				mm
total weight	Centre of gravity distance boom weight	pump weight	arm assembly	support assembly unit	
					inch

LG	HG	BG	WB	R	VS	HS	UV	UH	MV	MB	UA	UT	FH	
Gesamtlänge	Gesamthöhe	Gesamtbreite	Radstand	Radstand erste VA bis 1. HA	Abstand der 1. VA bis 2. VA	Abstand der 1. HA bis 2. HA	Gesamtüberhang VA	Überhang Mast	Mitte Mastbock bis VA	Mitte Mastbock bis Bezugskante	Aufbaurahmen Überhang	Trichter Überhang	Füllhöhe	
9340	3950	2490	4425	4500	1500	1350	1410	2755	550	6050	—	—	—	mm
Overall lenght	Overall height	Overall width	Wheelbase	Front axle wheelbase up to 1st HA	Distance between the 1st VA and the 2nd VA	Distance between the 1st HA and the 2nd HA	Total forward projection over front axle	overhang boom	Middle o. boom pedestal to front axle	Middle of boom pedestal to fixed measuring point	projection of mounting frame	Total projection to hopper	Filling height	
		98												inch

FH 26/22 mobil
DB 3535/45

Figure 1: Mobile Manipulator FH22

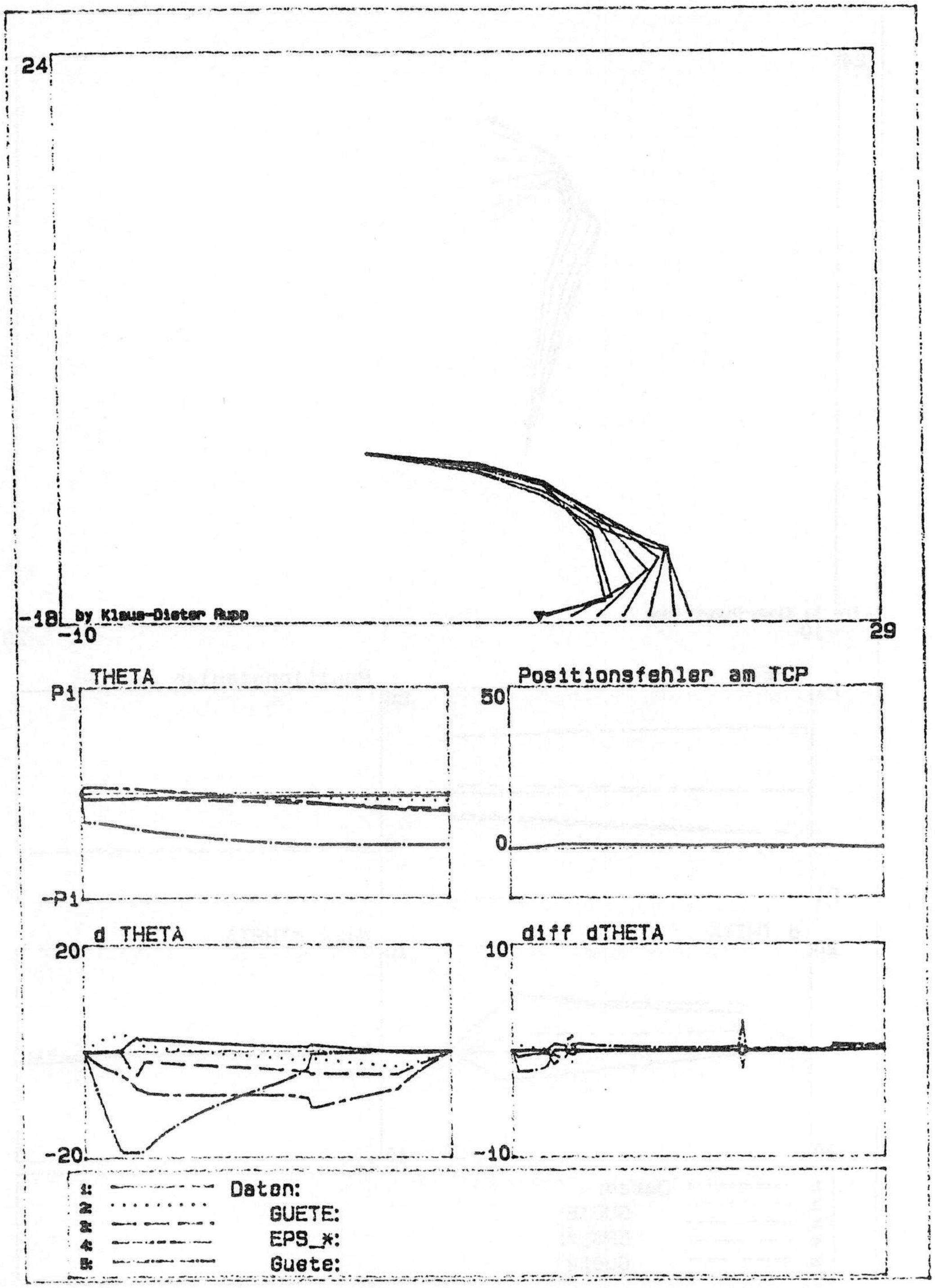


Figure 2: Coordiante transformation
- horizontal movement

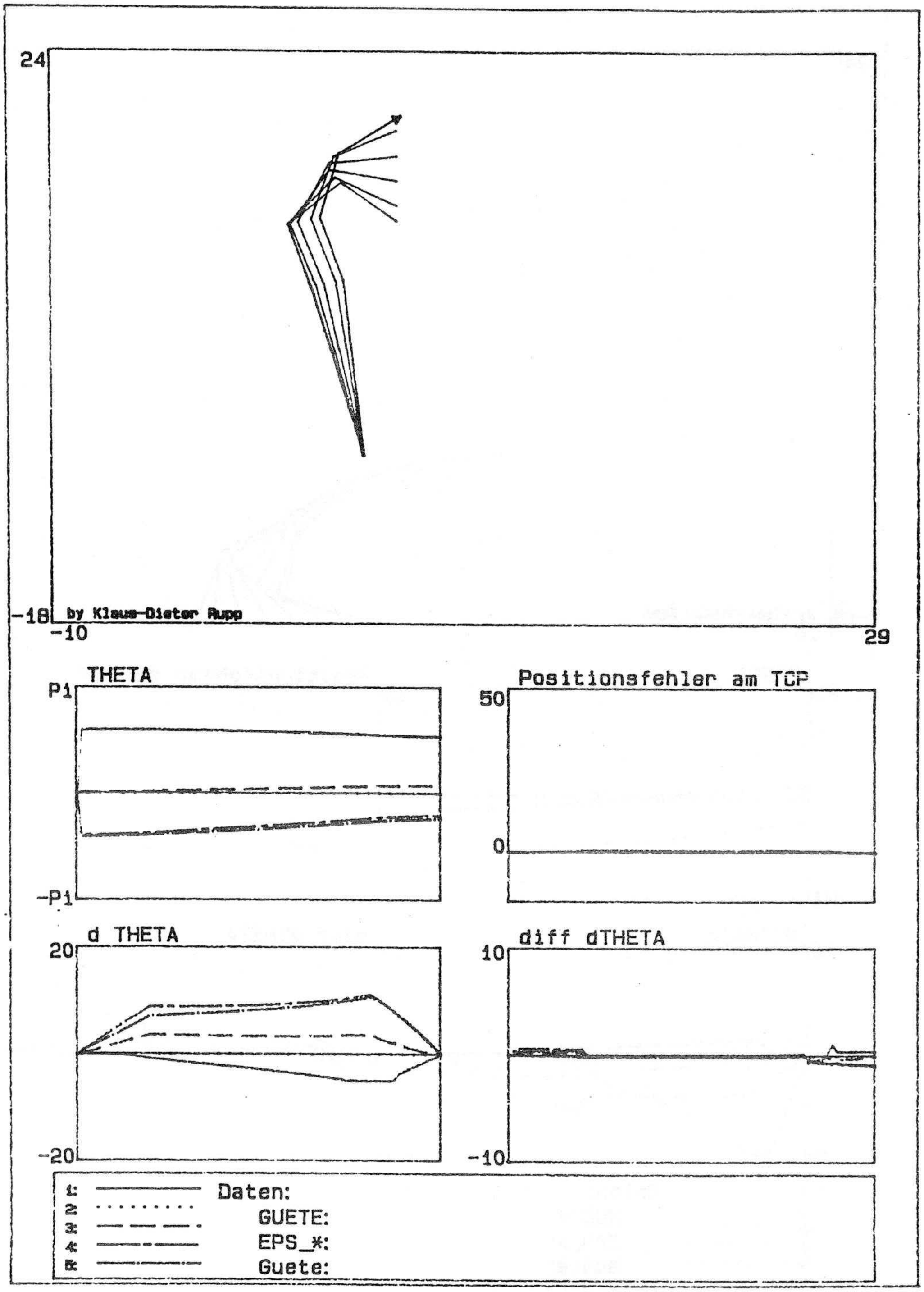


Figure 3: Coordiante transformation
- vertical movement

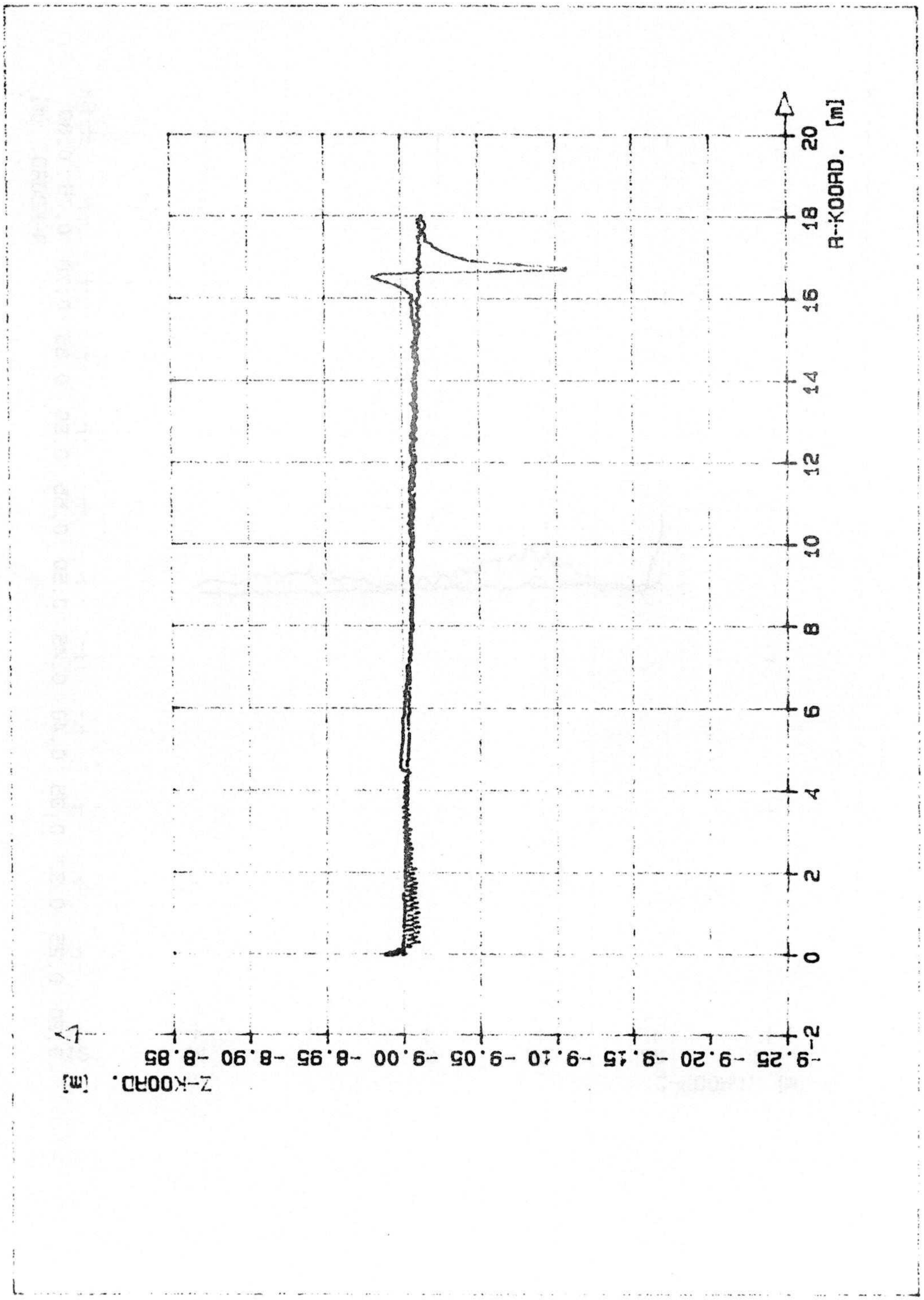


Figure 4: Behaviour at the TCP for the horizontal movement of Figure 2

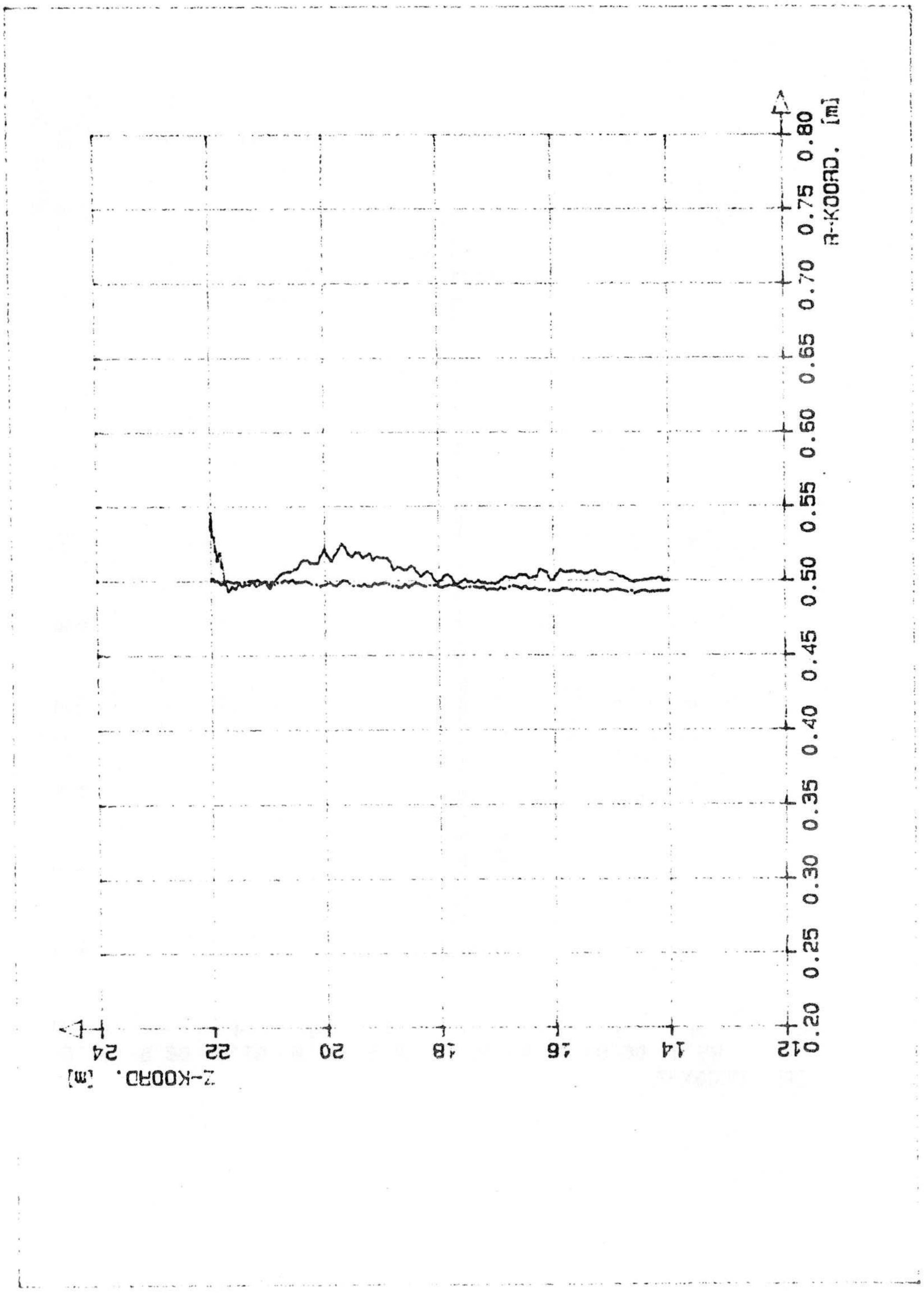


Figure 5: Behaviour at the TCP for the vertical movement of Figure 3