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PROGRESS OF MAGNETIC SUSPENSION AND BALANCE SYSTEMS FOR WIND TUNNELS IN THE USSR

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SUMMARY

Magnetic Suspension and Balance Systems (MSBS) for wind tunnels are being developed in order to solve the principal problems of aerodynamics which cannot be solved by conventional means: measurement of aerodynamic loads acting on the aircraft models without the effects of mechanical supporting devices, and study of base pressure, etc. This paper traces the progress of MSBS for wind tunnels in the USSR. The paper describes electromagnetic configuration, position sensing, and control and calibration systems of two wind tunnel MSBS existing in the USSR. The features of high-angle-of-attack control and roll control are discussed. The results of preliminary experiments on high-angle-of-attack and roll controls, digital control, and aerodynamic testing are also presented.

INTRODUCTION

Doctor Grodzovsky G.L. was the first Russian scientist who tried to realize magnetic suspension of the model for the wind tunnel in CAHI in 1947 (ref. 1).

At present there are two systems of electromagnetic suspension for wind tunnels in the USSR. One was constructed in 1983 as a result of collaboration of the MAI and CAHI and was intended for studies of models with six degrees of freedom in a subsonic wind tunnel, the working part of which measured 400 mm × 600 mm (ref. 2).

The second system was created in the MAI in 1989; it is designed for laboratory investigations and for development of the technology of magnetic suspension. The suspension has six degrees of freedom and its working part measures 300 mm × 400 mm. Fig. 1 displays a model suspended in the suspension system of the Moscow Aviation Institute (ref. 3).

ELECTROMAGNETIC CONFIGURATION

Both systems were comprised of seven electromagnets which were arranged as shown in Fig. 2. All electromagnets have copper windings with natural cooling. The bias electromagnets (10, 11) are equipped with motor-driven variacs. The control electromagnets (2, 3, 4, 5) are provided with impulsive bipolar transistorized power sources. The axial electromagnet (1) is equipped with a thyristor power supply.

POSITION SENSING SYSTEM

The optical system for the determination of model position is based on usage of photodiode regions. Rays of lights of special form cross the model as shown in Fig. 3. Position of the model can be calculated with the aid of the measured position of the model shadow on the surfaces of detectors. The original design of the sensitive system (ref. 4) ensures determination of vertical and horizontal displacements of the model in one optical channel as it follows from simple expressions (Fig. 4):

$V1 = K1 \times Y1 + K2 \times Z1;$ $V2 = K1 \times Y1 + K2 \times Z1;$

$V2 - V1 = 2K1 \times Y1;$ $V2 + V1 = 2K2 \times Z1,$

where Y1, Z1 are displacements of the model.

CONTROL SYSTEM

Both systems of electromagnetic suspension have analog control systems. The peculiarity of MSBS for aerodynamic studies is the presence of large air gaps between the model and electromagnets. This presence of large gaps is determined by the demand of the similarity of the experimental conditions to the real ones of aircraft. The natural instability of the suspended object and the existence of limitations for value of control voltages on windings of electromagnets leads to limited area of stability of the model in space and to limited range of permissible aerodynamic leads. Figure 5 presents a structural scheme of the EMS control system in the vertical plane. An analogous scheme is used for stabilization of the model in the lateral plane. Their design-adopted control algorithms provide a maximum area of stability of the suspended object in the presence of limitations of control actions (refs. 5, 6, 7).

EXTREME ATTITUDE TESTING

There is considerable interest in the use of MSBS for suspension of winded models. Not long ago the MSBS of MAI-CAHI was modified. The MSBS was equipped with more powerful electromagnets. The light sources (lamps) and photodiode elements of the optical position sensing system were installed with the possibility of rotation (Fig. 6). This system is very good for setting the model at a high angle of attack. It is only necessary to rotate the lamps and photodiode elements during the operation of the MSBS when the model must be set at a desirable angle of attack. An axisymmetric model was thus successfully suspended over the range of angle of attack from zero to thirty degrees (Fig. 6). An angle of attack range of zero to sixty degrees is expected for axisymmetrical models without relocating lateral electromagnets. Work is presently underway to extend the useful range of angle of attack to sixty degrees. This involves using the digital control system and adaptive control algorithms.

The modified MAI-CAHI MSBS was equipped with eight electromagnets for generation magnetic roll torques (Figs. 2, 7). Several possible constructions of the optical roll attitude sensor were studied. The first successful experiments concerning roll control, including passive and active means, were made (Fig. 6).

CALIBRATING AND AERODYNAMIC TESTING

It is necessary to calibrate a given model before carrying out the aerodynamic testing. In the process of calibration, known values of static forces and moments are applied to the model and position of the model and currents of the electromagnets are measured. The range of applied forces and moments covers the range of expected aerodynamic leads. Several possible equations for magnetic forces and torques were studied. Aerodynamic leads are computed by means of a digital minicomputer PDP 11-34 on the basis of established empirical dependencies between currents of electromagnets, position of the model, and external leads. Magnetic forces and torques can be expressed as the squared forms (ref. 8):

$$Pq = \frac{1}{2}\sum_{k=1}^{n} Ik \sum_{l=1}^{n} Il \times \frac{\partial Lkl}{\partial q},$$

where Pq - force or torque; q - coordinate of position; Lkl - inductances of electromagnets.

The first aerodynamic tests were carried out and showed good results.

CONCLUSION

Present plans are to concentrate on aerodynamic tests, on comparison of conventional means results and MSBS results. Work is presently underway to develop a digital control system. Hardware PDP 11-34, ADC, DAC, and software for a digital control system are in hand now.

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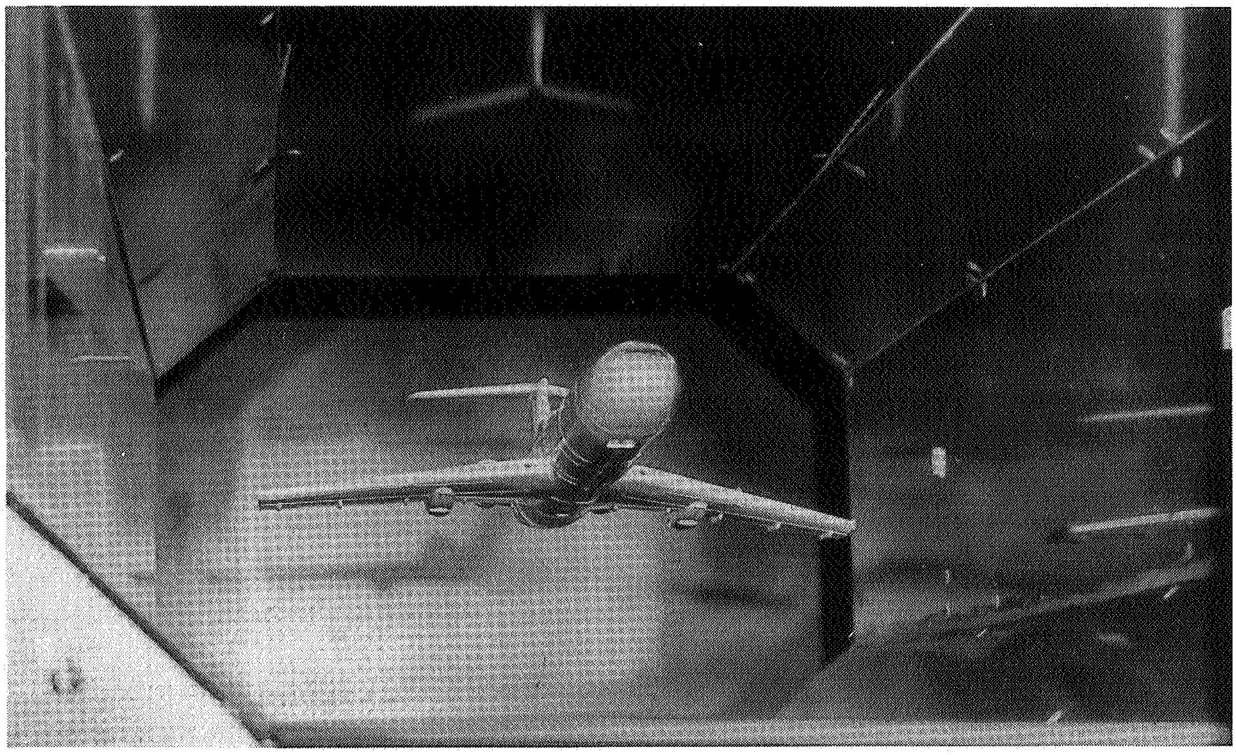

Figure 1. Model in the suspension system of the MAI.

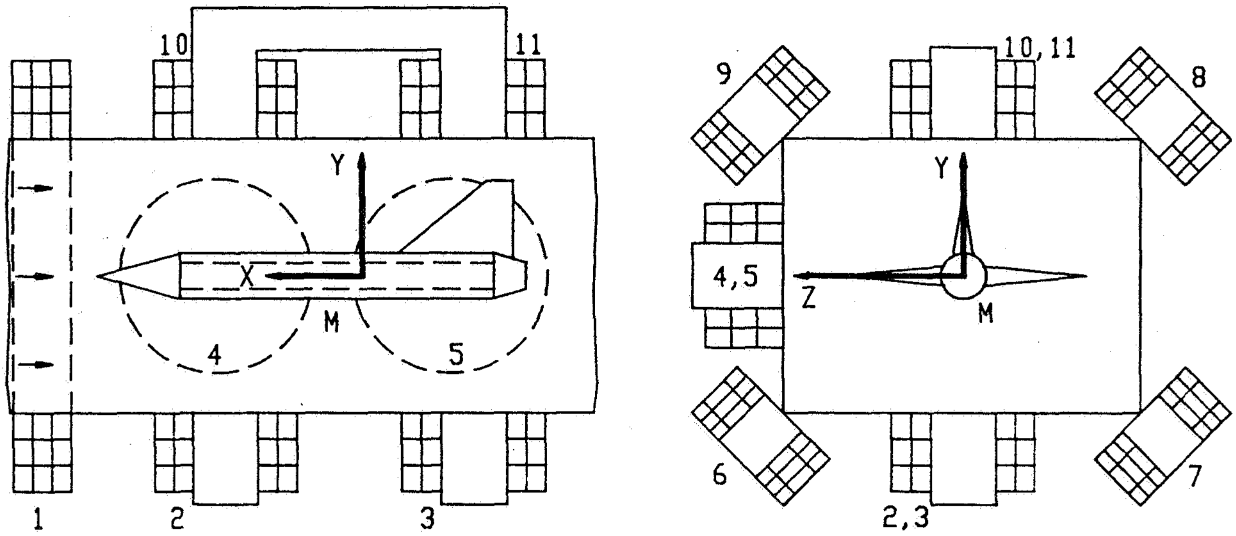

Figure 2. Electromagnet configuration.

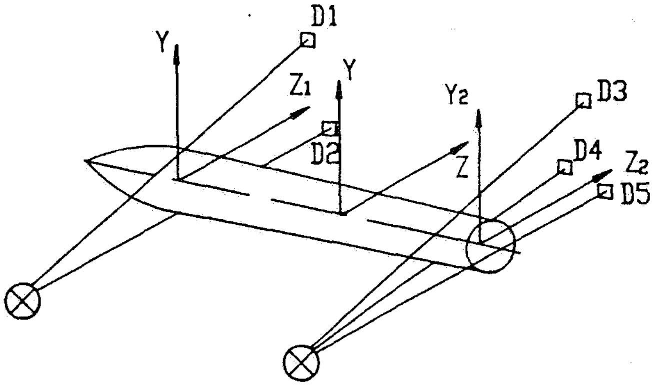

Figure 3. Position sensing system.

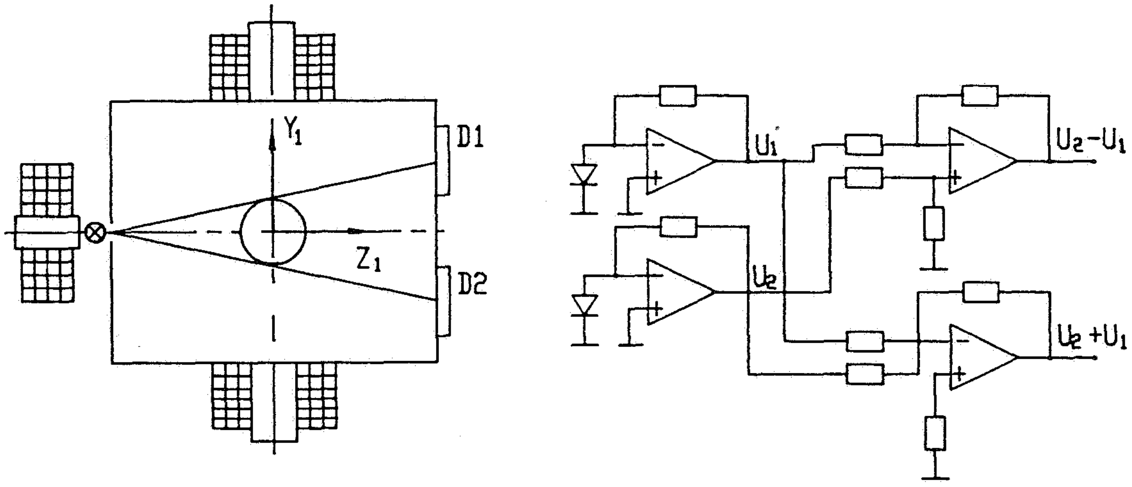

Figure 4. Signal processing.

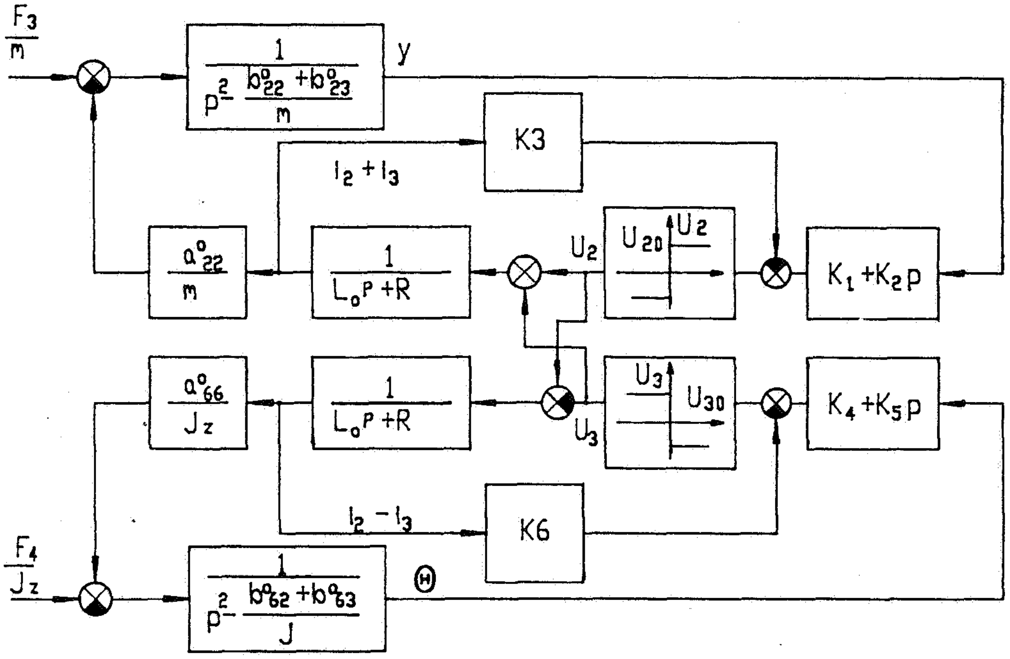

Figure 5. Structural scheme of the EMS control system.

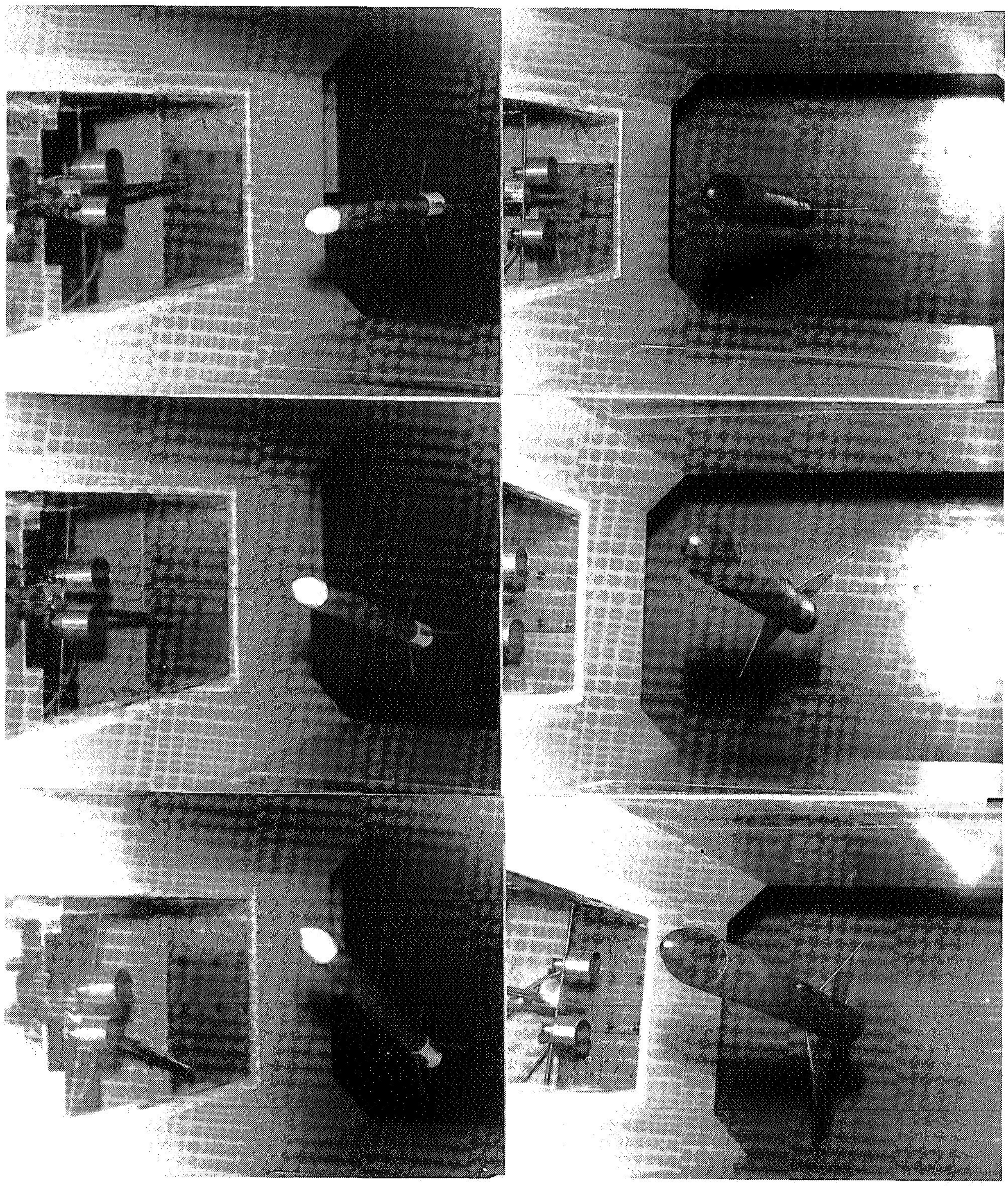

Figure 6. Extreme attitude testing.

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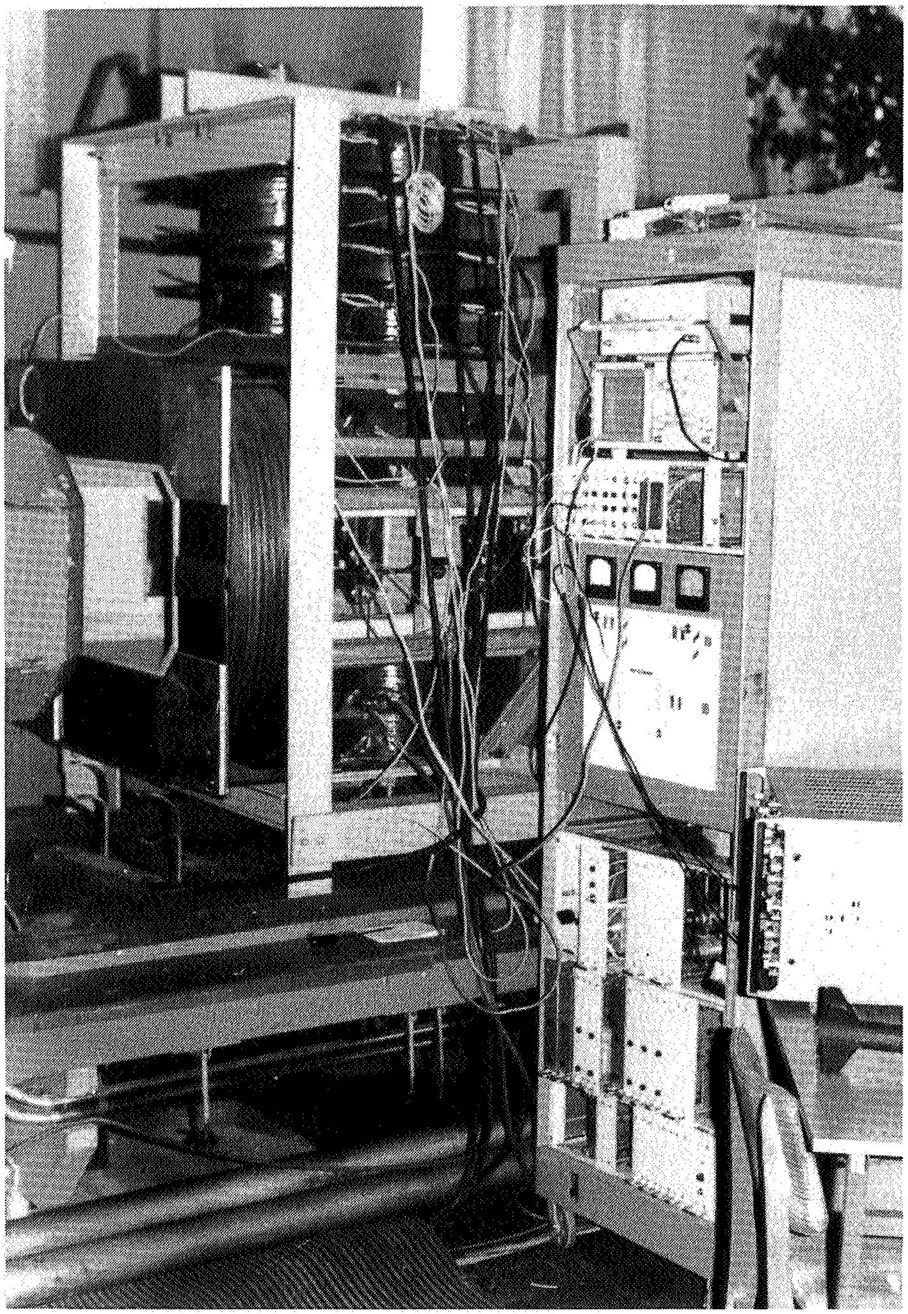

Figure 7. MSBS of the MAI-CAHI.