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MOTION CONTROL OF THE PROTON HIGH INTENSITY AREA 180 TON EGYPTIAN WALLS

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Introduction

Two 180 Ton 20' x 7' x 5' steel blocks (called Egyptian walls) are used for radiation shielding in the High Intensity Area Target Box. Each of the walls can be raised to provide access to a B2 magnet and collimator, respectively. Four 100 ton worm gear screw jacks are used to lift each wall. However, due to mechanical restrictions all four jacks could not be mechanically coupled to a single drive. Hence, two separately controlled motors each acting upon two jacks at either end of the wall are used. Described herein is only the control philosophy regarding the use of synchronous motors and control synchros to achieve < ±1/4" deviation in height from one end of the wall to the other while raising it 29 inches in 9 minutes.

Control Philosophy

A block diagram of the system is shown in Figure (1). The two motors are run open loop from standard off the line motor starters. The synchro control transmitter (CX) and control transformer (CT) act

as an error detector to stop the motors in the event that the deviation in jack screw rotation and hence vertical displacement on either end of the wall exceeds a preset limit.

Motors

Allis-Chalmers 15 Hp "synduction" gearmotors are used to drive the jack screw. A "synduction" motor (an Allis-Chalmers trade name) starts like an induction motor, but attains synchronous speed and runs with no slip. Because of the potentially high radiation fields around the motor the following precautions were taken:

1. High temperature class F insulation was specfied
2. The gear box was filled with radiation resistant lubricant
3. Radiation resistant grease was used in the bearings
4. The motor has no parts made of teflon

One of the things thought to be a potential problem was that an error could result from the difference in time it took the two motors to attain synchronous speed. Starting times were checked under no-load conditions and found to be approximately 100 ms. Starting times under load were not checked, but the displacement error measured with the synchros is nearly unobservable (< .005"). In the event that the displacement upon starting was too large, an alternate plan was to use synchronized variable frequency drives whereby the motors would be synchronized from 0 Hz on up to running speed.

Control Synchros

Synchros are basically variable transformers which produce an electrical signal which is a function of angular displacement. A control transmitter (CX), and a control transformer (CT) are mechanically

connected to the outboard side of each set of jack screws, respectively. The relationship between the demodulated output of the CT and angular displacements is:

$$Vo = 3 \sin (\phi_2 - \phi_1) \quad \text{(volts)} \tag{3}$$

where ϕ_2 and ϕ_1, are continuous angular displacements of the CT and CX, respectively.

In order to obtain a range of ±1/4" of jack screw linear displacement, a 16 to 1 gear reducer between the jack screw and the synchros had to be used. Hence, the relationship between the demodulator output voltage (Vo) and the vertical displacement (Y) is

$$Vo = 3 \sin [2\pi (Y_2 - Y_1)] \tag{4}$$

Where Vo = demodulator output or error signal in volts

Y_2, Y_1 = vertical displacement at each end of the wall in inches. (Intially zeroed by surveying the walls).

Thus, the sensitivity of the relative displacement near zero is 18.8 mV/.001" which is substantial. The error signal is displayed on a panel meter-relay calibrated in inches with high and low variable set points which when exceeded stops both of the motors.

Although standard Kearfott synchros were used in the initial installation, they can supply a radiation resistance model of the same type.

Results

Under normal running conditions under load practically zero error (< .005") is exhibited. The meter does indicate a slight oscillation about zero while running which could be caused by a variety of electrical or mechanical phenomena. Because the performance was

much better than expected, the high and low set point trips were set to ±.050". Using the synchros for checking has already proven it's worth. At one point during the installation and check-out period, a coupling between one set of jack screws failed while running and the motors automatically stopped at .050" deviation without incident.

Although not described here, a local push button control station is used to operated the system. In actuality there are three motors and three sets of jack screws. One of the motors and set of jack screw is shared by means of system of moveable levers. Hence, lifting of only one wall at a time is permitted for which there is a series of interlocks and limit switches. In addition, a means of independently controlling the motors in order to recover from an automatic shut-down or for use during system sheck-out are provided.

FERMILAB

ENGINEERING NOTE

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SUBJECT

FIG. (1) BLOCK DIAGRAM OF EGYPTIAN WALL CONTROLS

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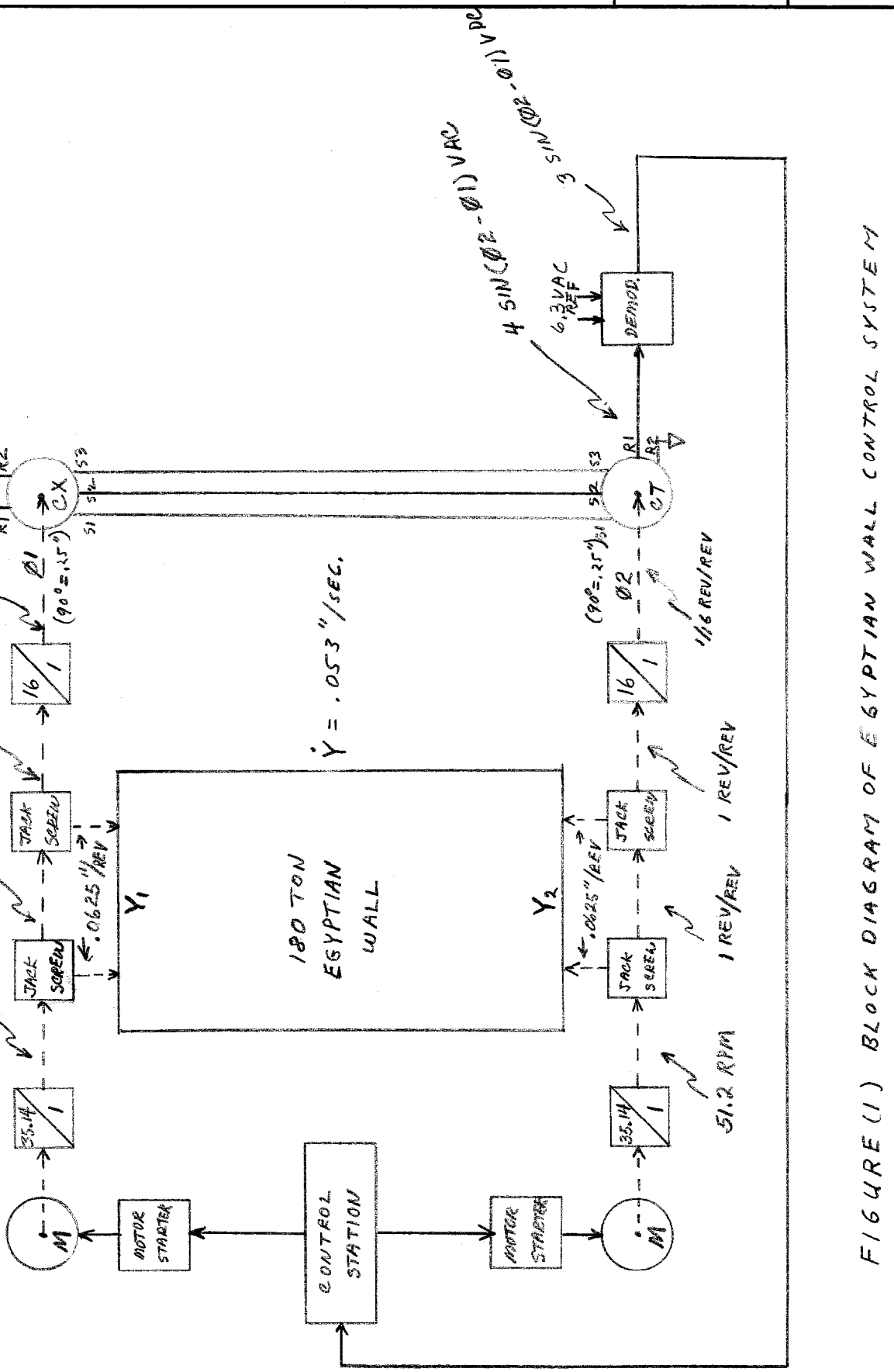

FIGURE (1) BLOCK DIAGRAM OF EGYPTIAN WALL CONTROL SYSTEM