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MASTER-SLAVE MANIPULATOR
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MASTER SLAVE MANIPULATOR *

Experimental Model

A device for manipulating a pair of tongs behind a shielding barrier has been built and tested. It is called a Master-Slave Manipulator because the slave tongs move in exact correspondence with a master handle. The "slave hands" follow the master hands in complete synchronism.

The test model is entirely mechanical in all functions. The slave tongs are displaced from the master handle by about 3 feet and move in exact synchronism in displacement, rotation and tong opening and closing. This is accomplished by a minimum number of independent motions including: Three effectively lineal motions; three rotating motions, and one motion to open and close the jaws. There are, therefore, seven completely independent mechanical connections or linkages between the master handle and the slave tongs.

The three so-called lineal motions are accomplished by simply forming a U-shaped tubing structure, the free ends of which can be moved about. This is accomplished by supporting the closed part of the "U" in a support bracket counterbalanced with springs and so arranged that the entire "U" structure can move up and down in the Z motion, horizontally in the Y motion, and swing from side to side in the X motion. Thus the slave tongs and wrist joint assembly is suspended such that it can assume any position within a limited volume and the master handle and wrist joint can likewise assume any position in a similar volume displaced from the slave by 3 feet.

The three rotational motions of the master handle and slave tongs are synchronously linked together through gears, concentric tubing, drums and cables. The azimuth rotations are about the axes of the "U" and are driven synchronously by the azimuth drum and cable. The "U" legs, consisting of aluminum tubes, are mounted in ball bearings and carry the wrist joints of the master and slave ends in all three lineal motions and azimuth axis of rotation and the slave elevation axis is oriented parallel to the master elevation axis and driven synchronously by the azimuth drum and cable. The twist axis of rotation is always at right angles to the elevation axis of rotation and the slave twist axis is oriented parallel to the master twist axis, these being in the line of the slave tongs and master handle, respectively. The slave twist rotation and elevation rotation are synchronously driven by the master twist rotation and elevation rotation through differential gearing, concentric tubes and the elevation and twist drums and cables.

* Developed by members of the Remote Control Engineering Division under the leadership of R. C. Goertz.

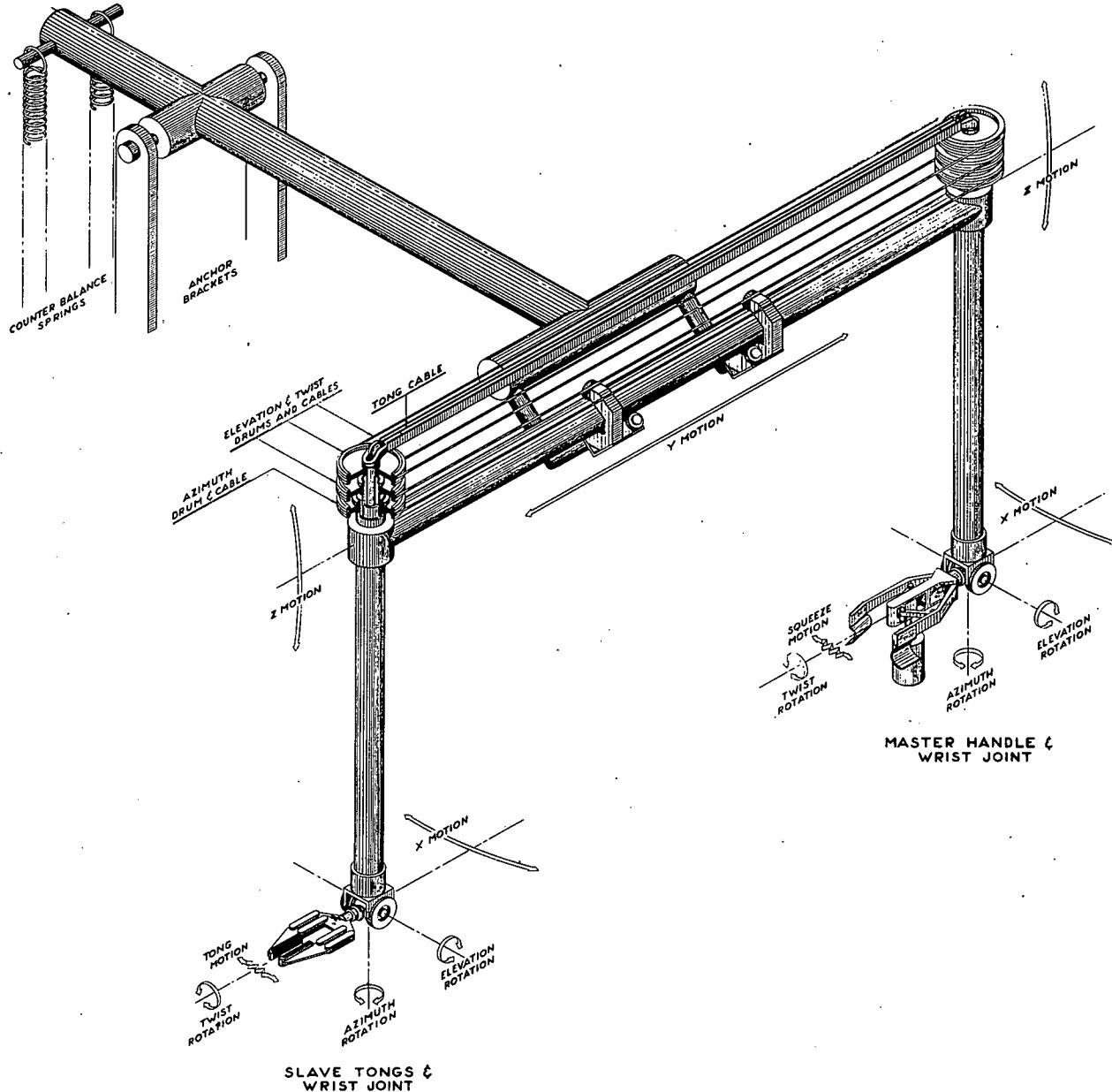
The tongs on the slave wrist joint are closed by closing the handles on the master squeeze handle by means of a cable running from the tongs to the master handle. A spring on the tongs opens them as the pressure is released on the master squeeze handles. The squeeze handles are closed by application of pressure through the thumb and forefinger of the operator's hand. In addition to the squeeze handles on the master handle there is a round handle extending at right angles to the twist axis which is grasped by the palm and last three fingers of the hand. This handle is used to move the manipulator to the desired position and orientation, and the squeeze handles are used only to close the slave tongs.

The entire assembly makes up a manipulating device, the slave end of which can be behind a barrier such as a lead glass window and which is operated by grasping the master handle and moving it about in displacement and rotation in the exact manner in which the slave tongs are desired to be moved. All the natural movements of the operator's hand are maintained and used in this method of manipulating except that the operator views his resulting motions from greater distance than that which he is normally accustomed to when using his hands directly or with a pair of ordinary tongs or tweezers.

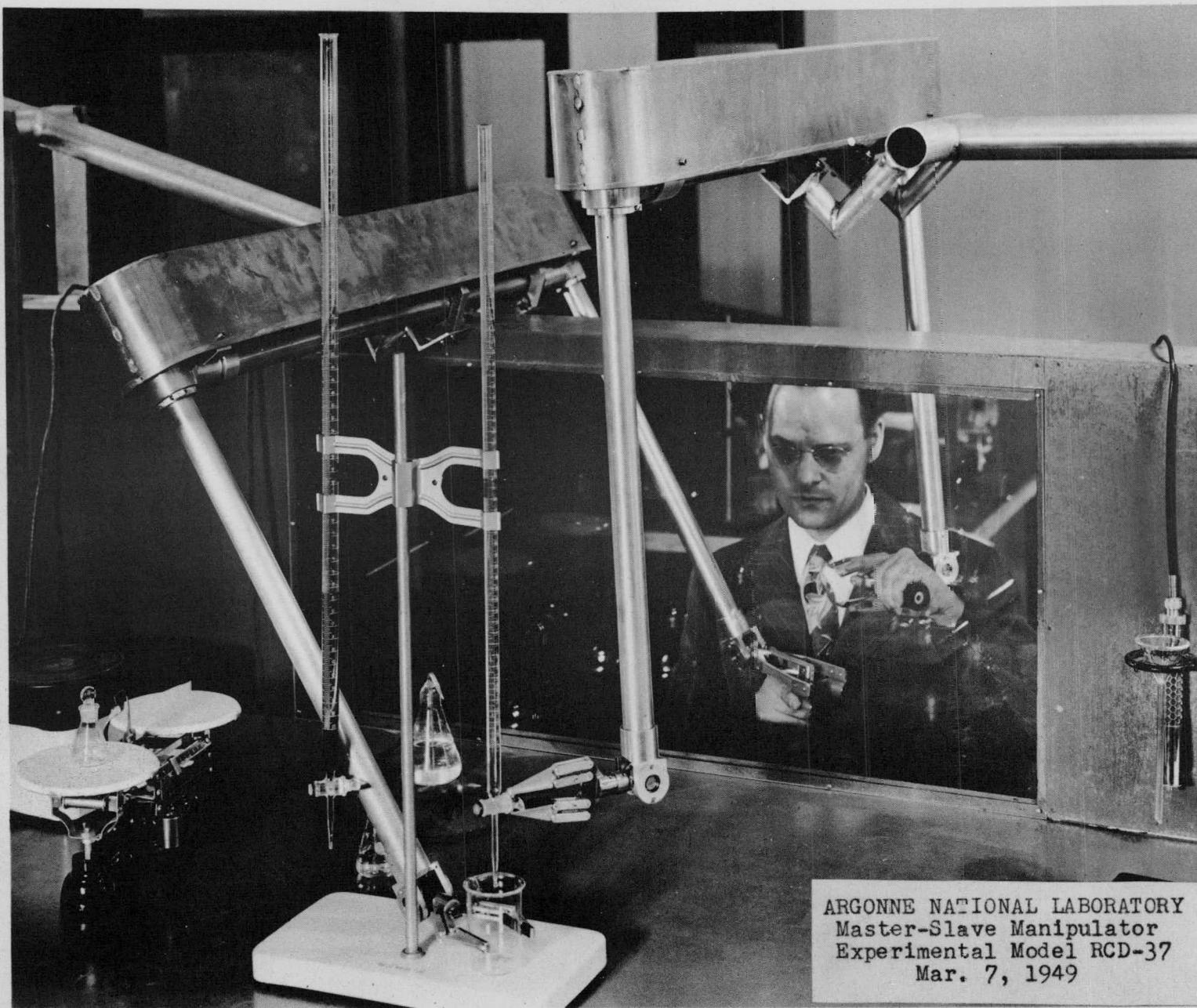
It has been found that the average person learns to operate the manipulator quite efficiently in from five to fifteen minutes of practice. A few people can operate the manipulator almost immediately with very few unintentional or hesitant motions and it has also been found that everyone can operate it fairly well within fifteen minutes if they have good eyesight. Operating with only one good eye is very difficult because of poor depth perception.

Tests show that the friction in all the seven motions must be kept very low and that the mass should be quite low. Backlash in some of the motions impairs operation, but a small amount can be tolerated.

This is the first completely master-slave manipulator known to exist and has proved that this type of manipulation is very successful when the unit is properly engineered and built. A great deal more work will be necessary in order to overcome difficulties of friction, mass, backlash, and to reduce the effective mass and at the same time increase the load-carrying capacity.



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