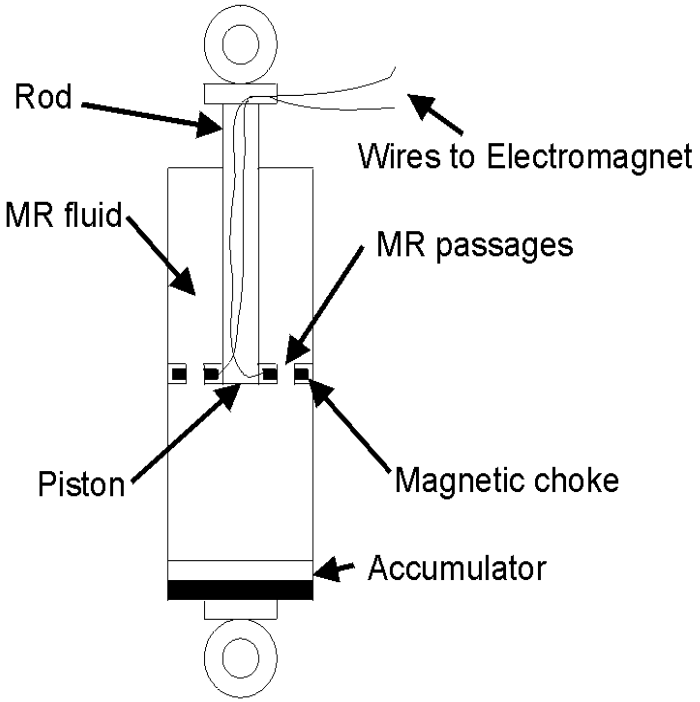
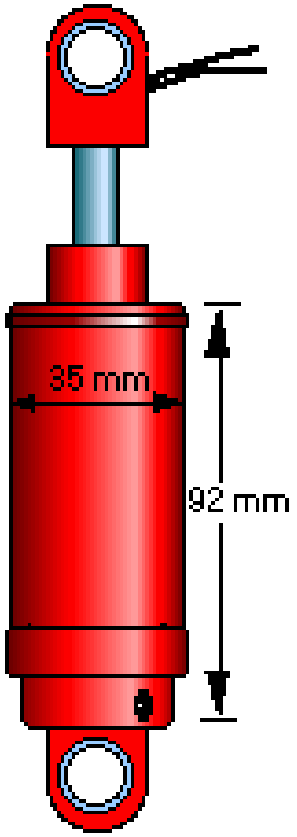
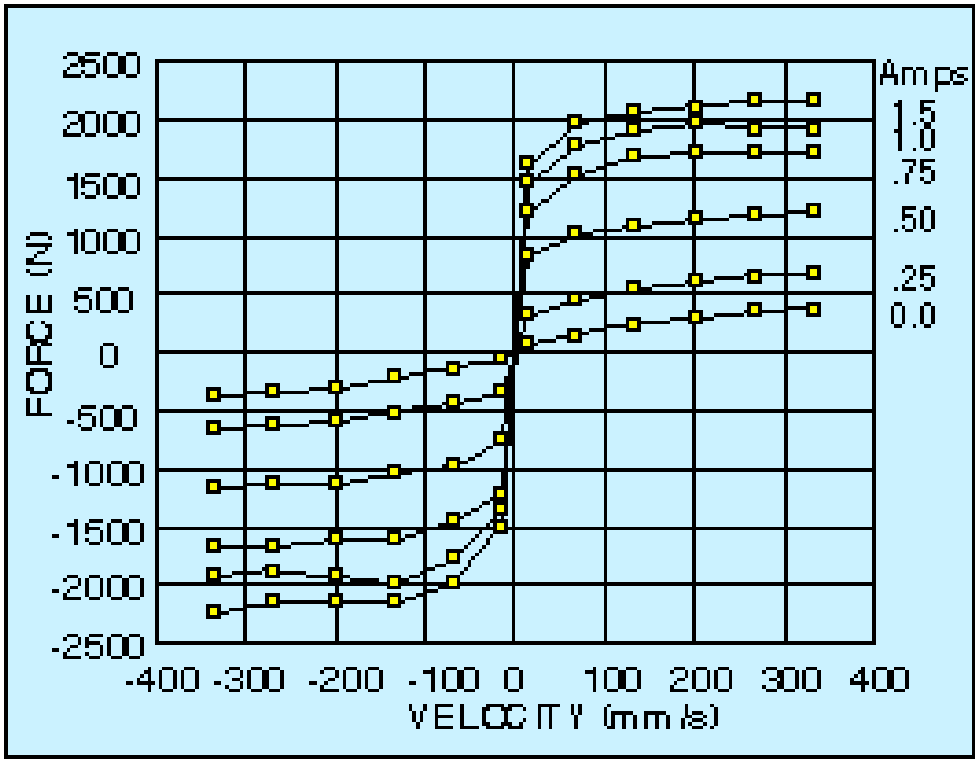
# MR Fluid Damper

- MR passage
  - Flow rate controlled by magnetic choke
- Accumulator
  - Bladder with nitrogen pressurized at 300 psi
  - Account for volume of fluid displaced by piston



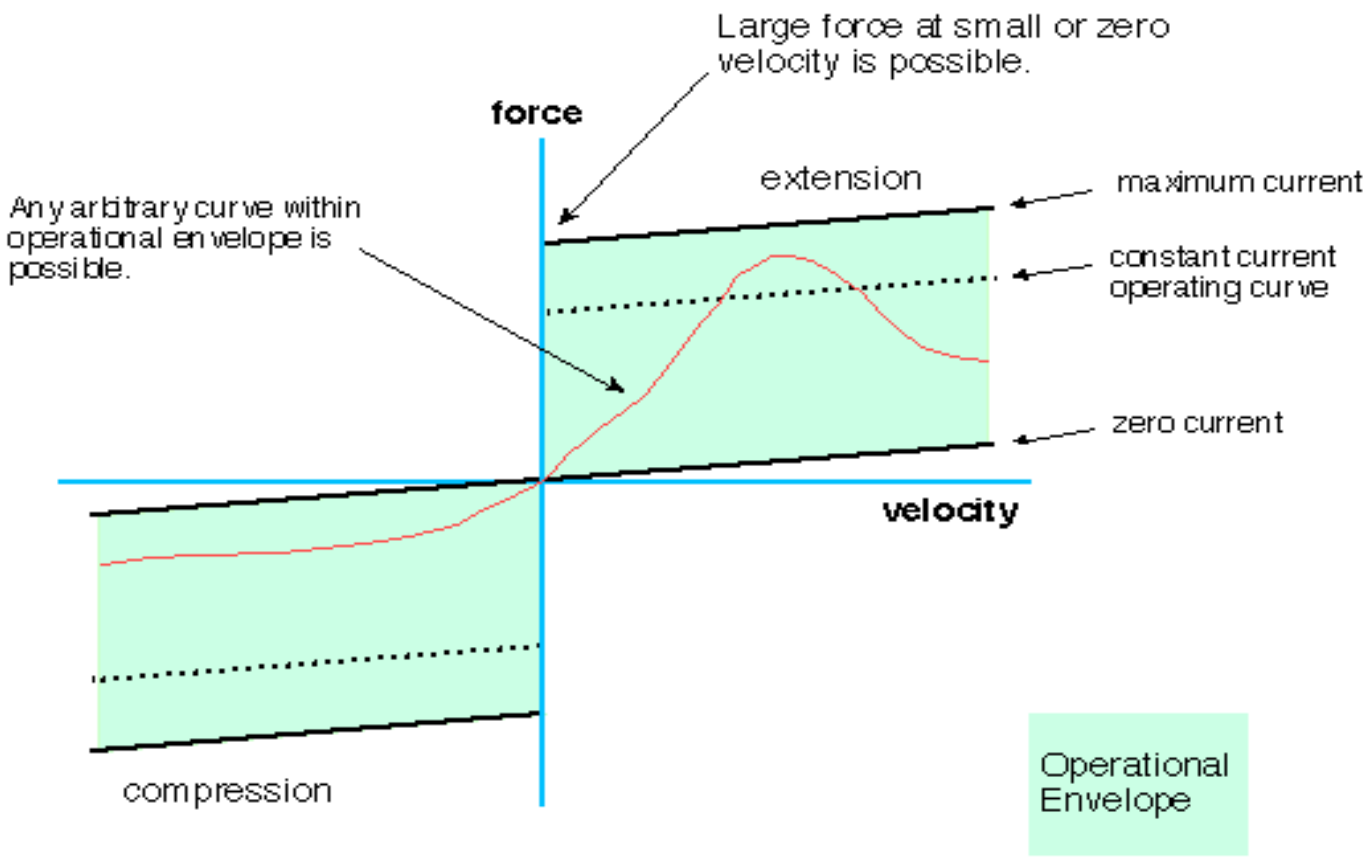
# Light Duty Damper (SD-1000-2) with Single Controllable Fluid Valve



# MR Fluid Damper

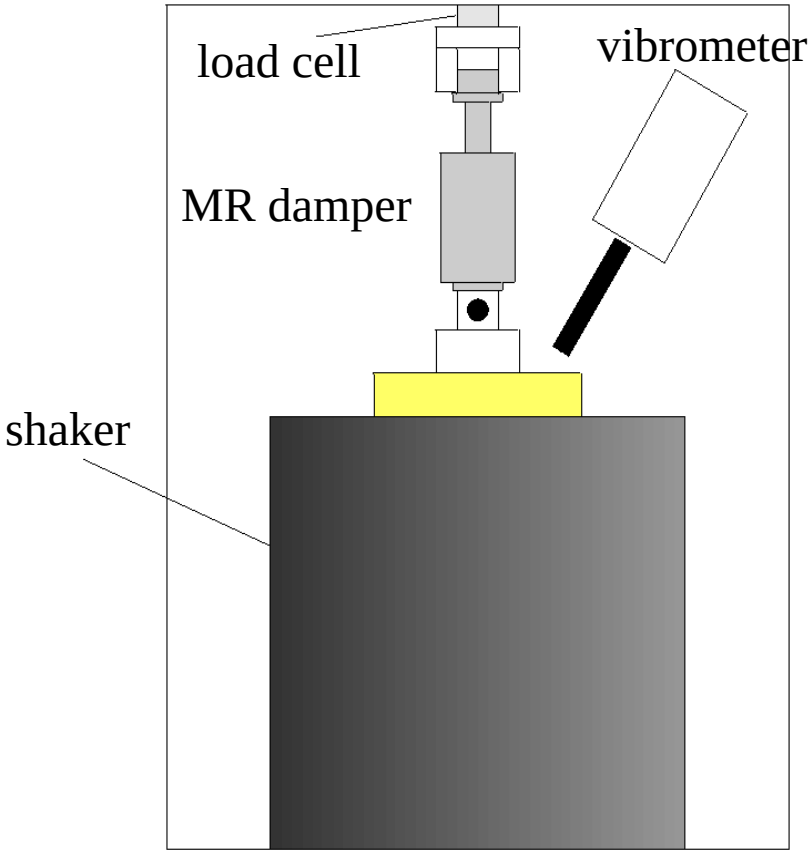
## Force versus Velocity Envelope for MR Fluid Damper



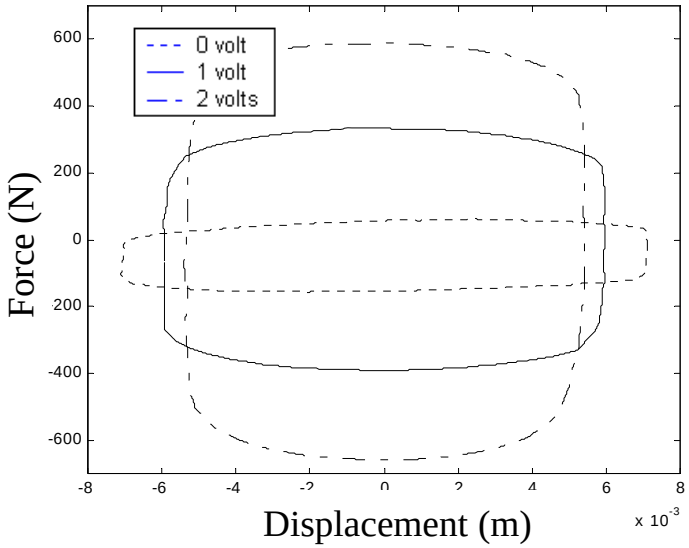

Damper may be controlled to produce a force that is any arbitrary function of displacement, velocity or acceleration.

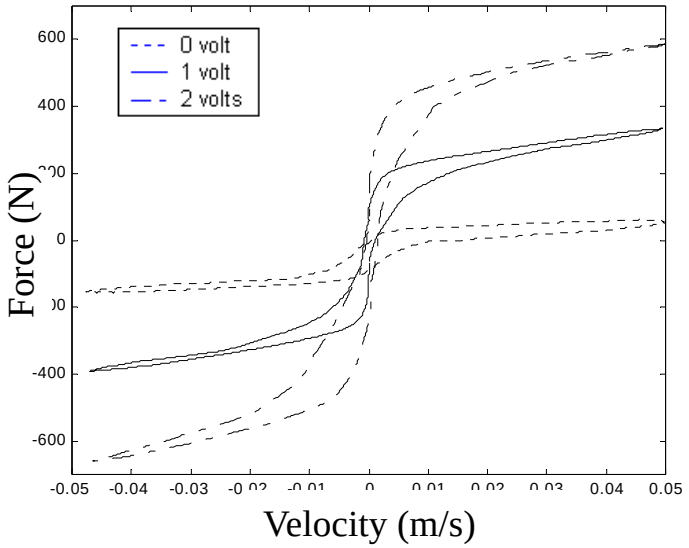
# Experimental Setup

- Obtain MR damper characteristics
- Shaker: produce excitation
- Load cell: measure damping force
- Laser vibrometer: measure displacement and velocity



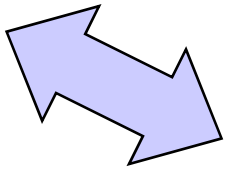
# MR Damper Characteristics

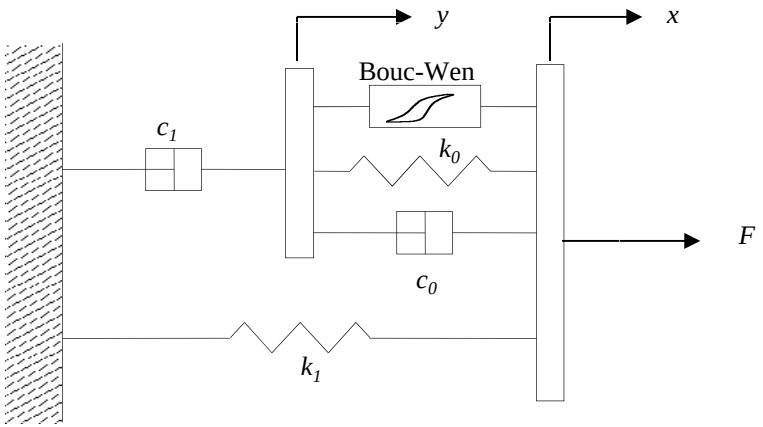



- Force vs. velocity & displacement for different voltages
- Offset in the damping force due to the accumulator
- Hysteretic looping

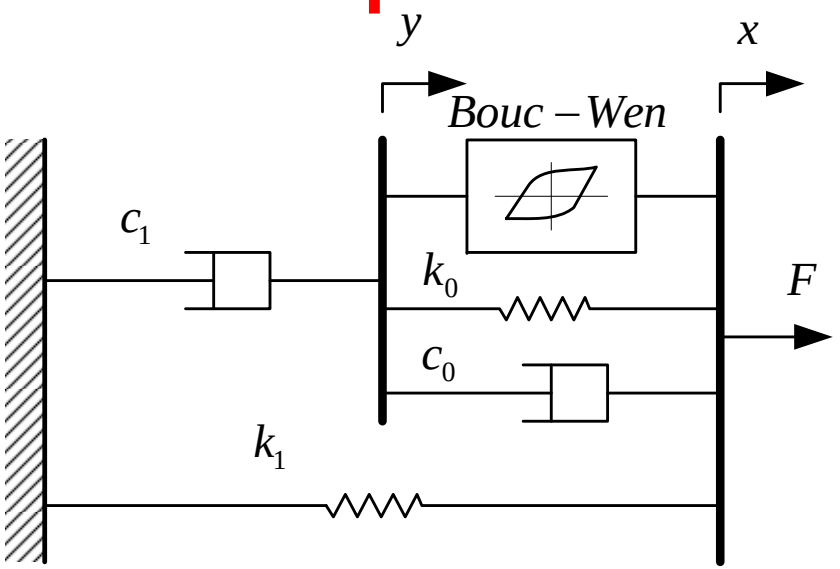
# MR Damper Model






- Relation between force and other parameters (displacement, velocity, voltage input)
- Bouc-Wen model: hysteretic modeling

# MR Damper Model




$$F = c_1\dot{y} + k_1\left(x - x_0\right)$$

$$c_1\dot{y} = \alpha z + k_0\left(x - y\right) + c_0\left(\dot{x} - \dot{y}\right)$$

$$\alpha = \alpha(u) = \alpha_a + \alpha_b u$$

$$c_1 = c_1(u) = c_{1a} + c_{1b}u$$

$$c_0 = c_0(u) = c_{0a} + c_{0b}u$$

Bouc-Wen model:

$$\dot{z} = -\gamma\left|\dot{x} - \dot{y}\right|\left|z\right|^{n-1} z - \mu\left(\dot{x} - \dot{y}\right)\left|z\right|^{n} + A\left(\dot{x} - \dot{y}\right)$$

Rheological equilibrium

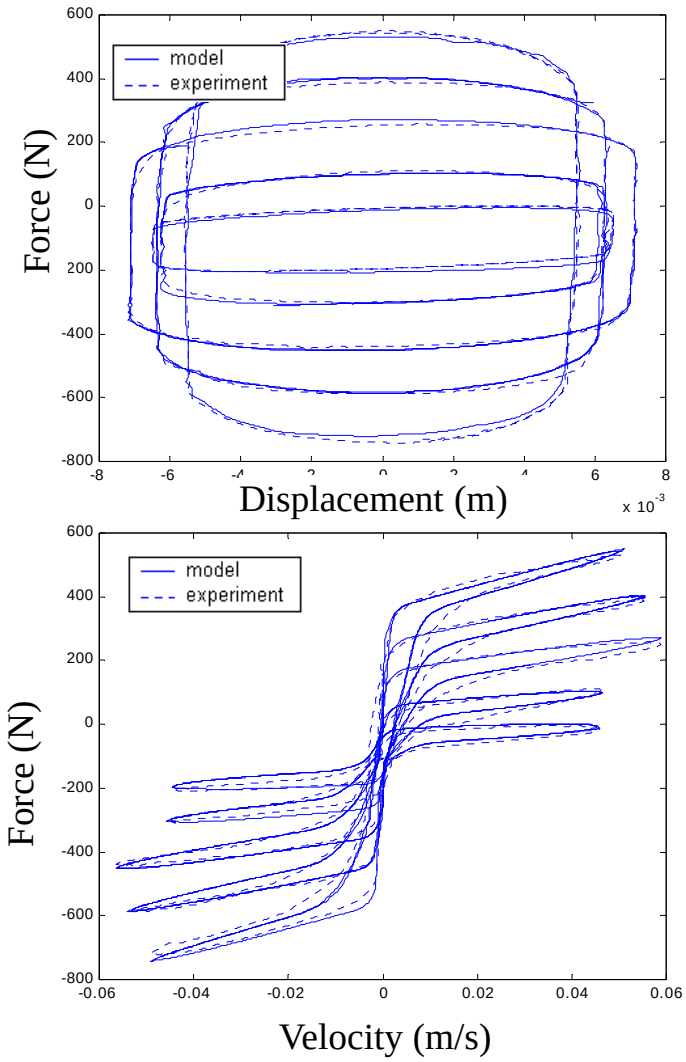
$$\dot{u} = -\eta\left(u - v\right)$$

# Model Parameters

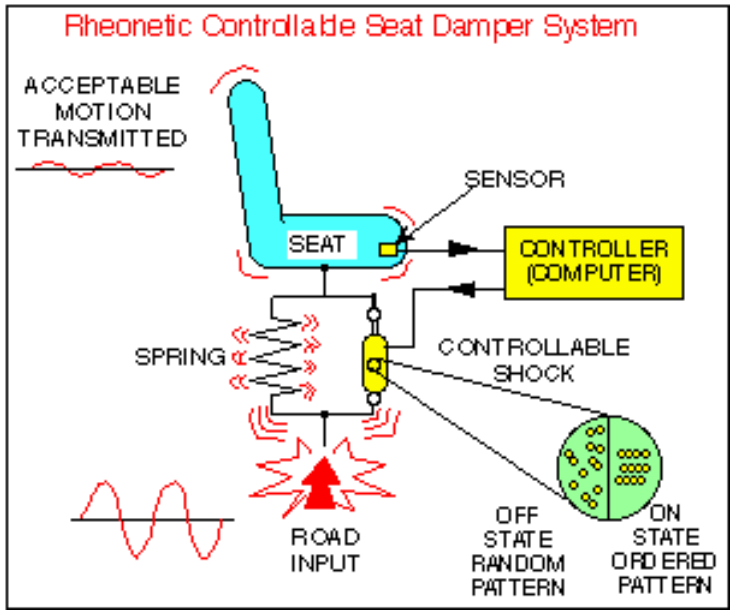
- Minimizing the error

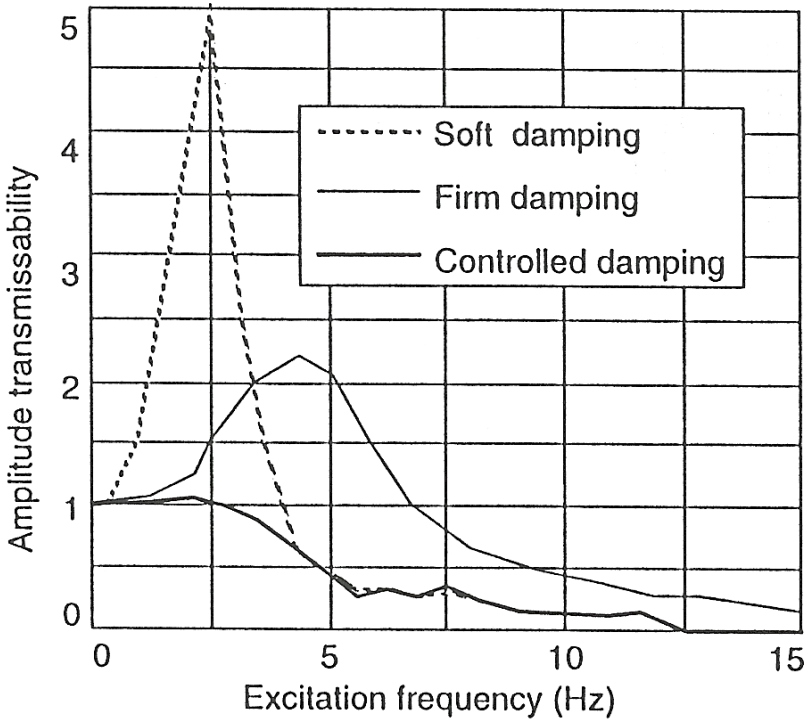
$$J = \sum \left( f_{\text{experiment}} - f_{\text{model}} \right)^2$$

- Accurately predicts the behavior of the damper



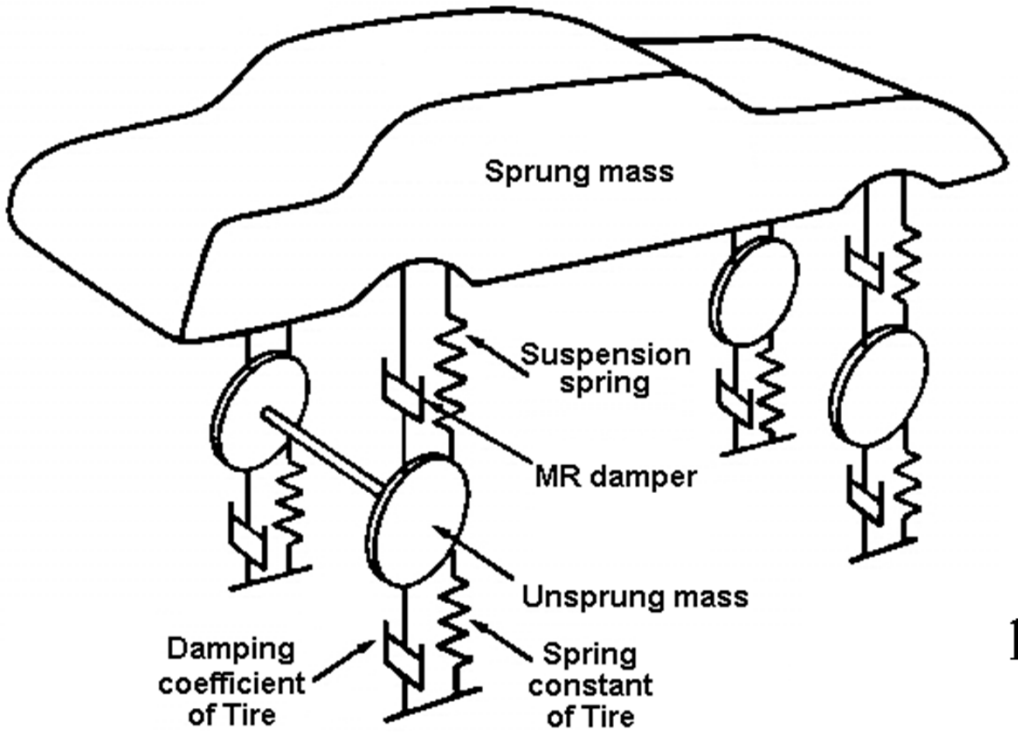
# MR Suspended Seat

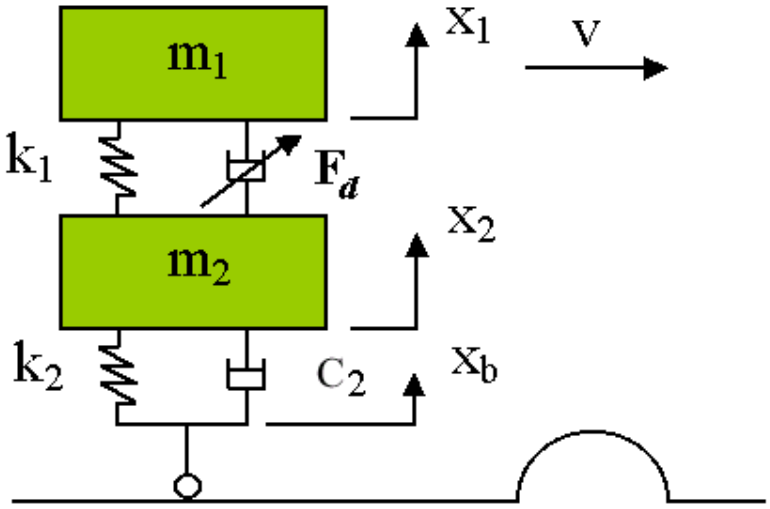


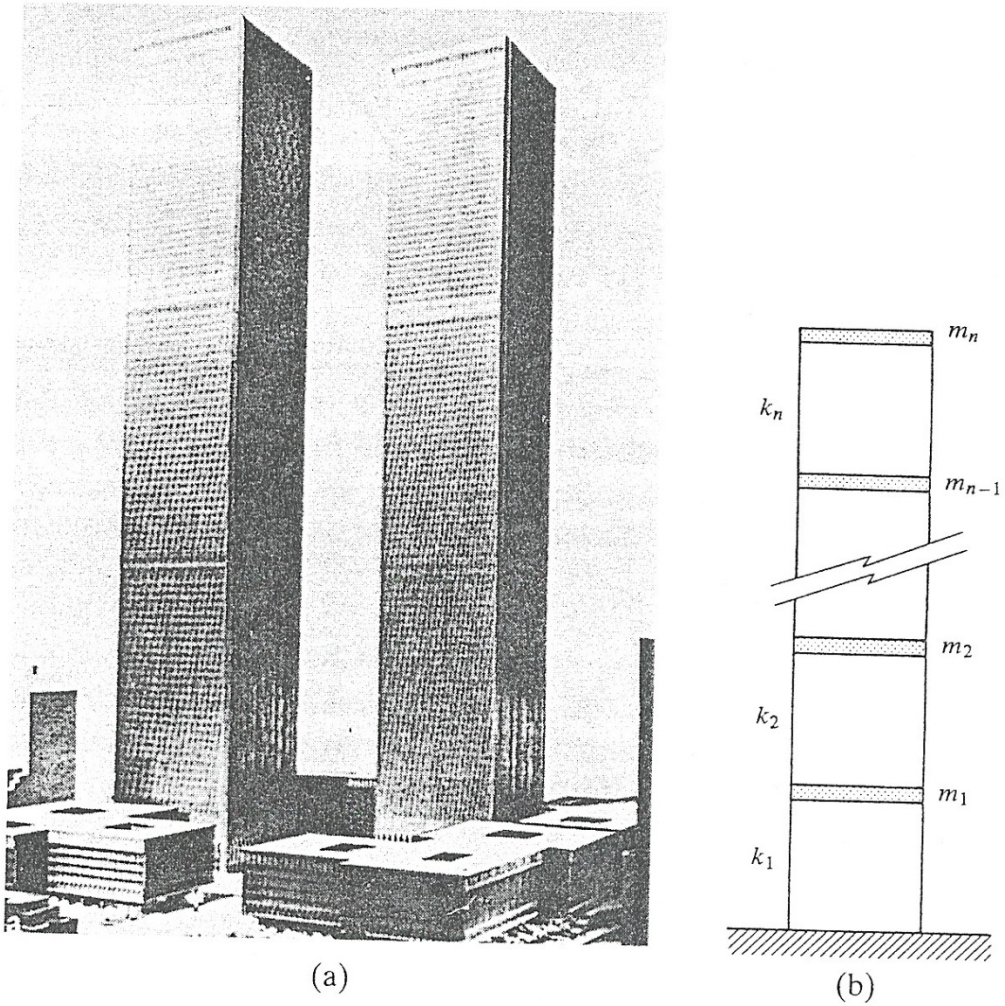




Performance for an MR semi-active controlled suspended seat

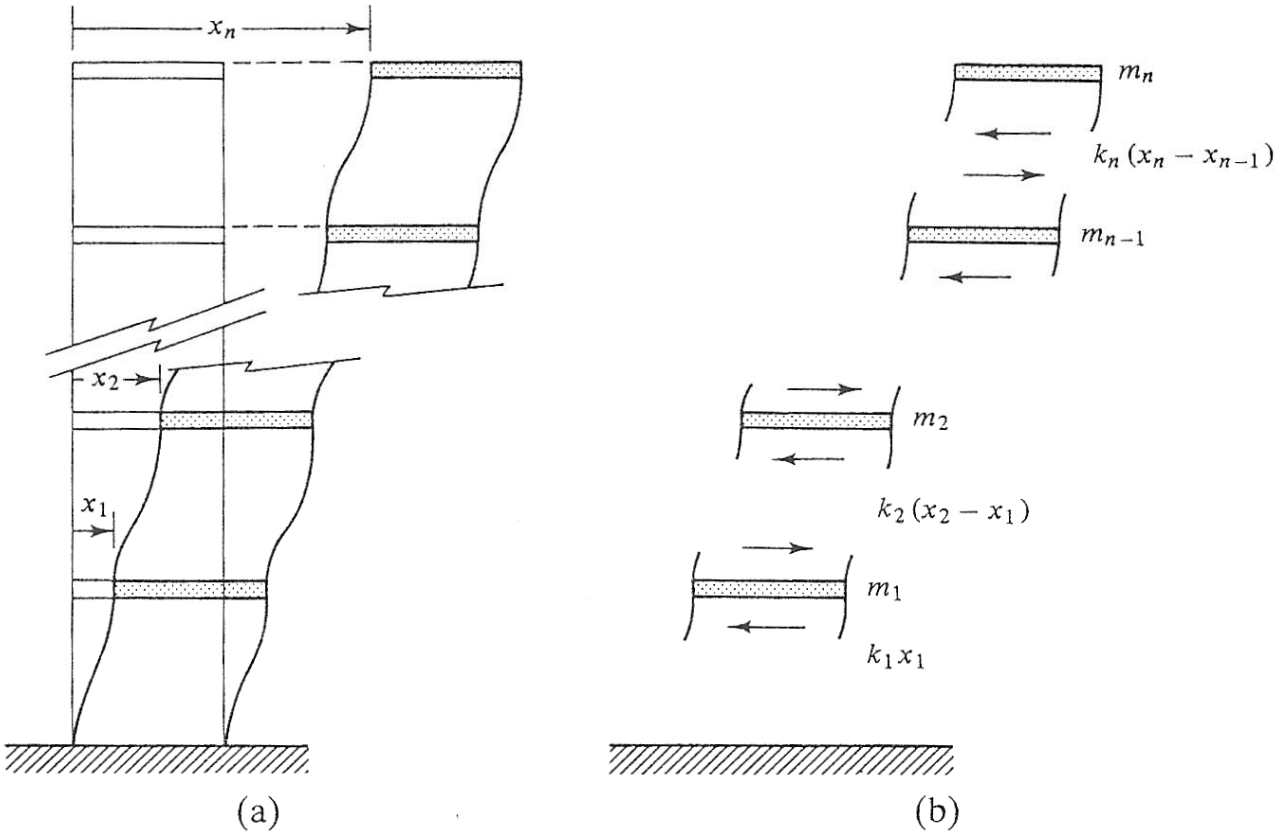
# Car Suspension System



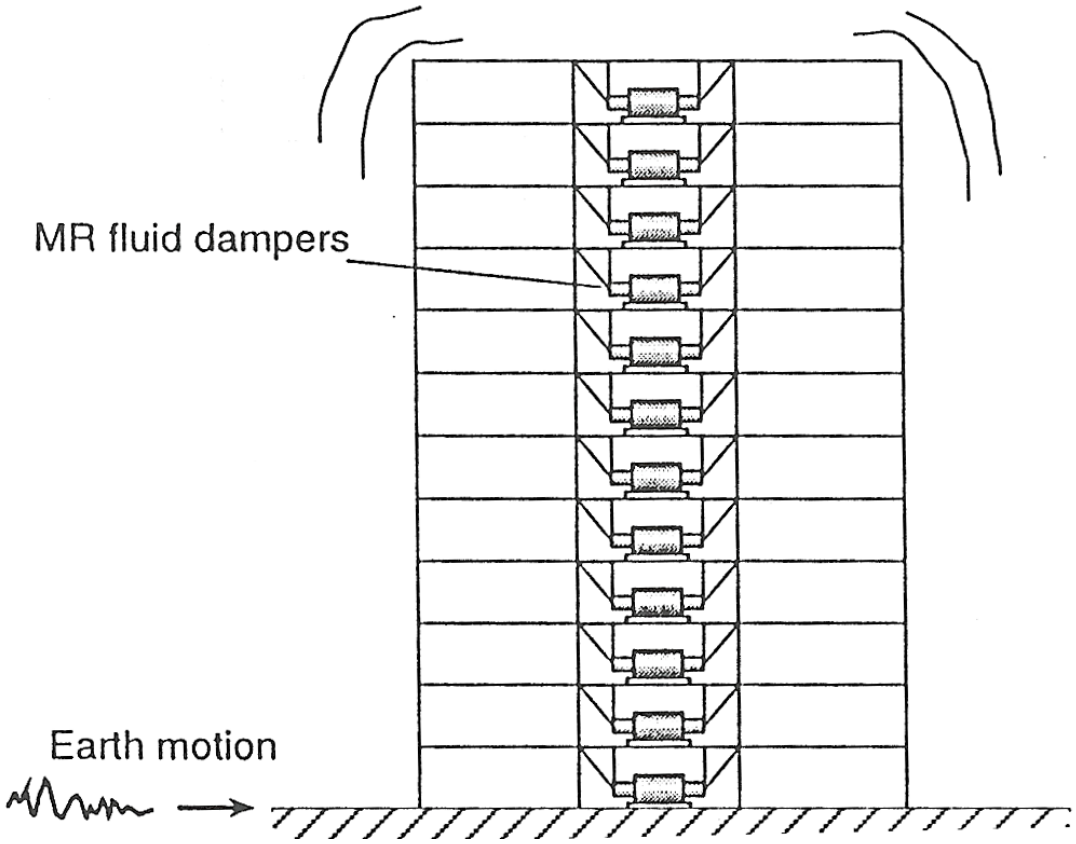





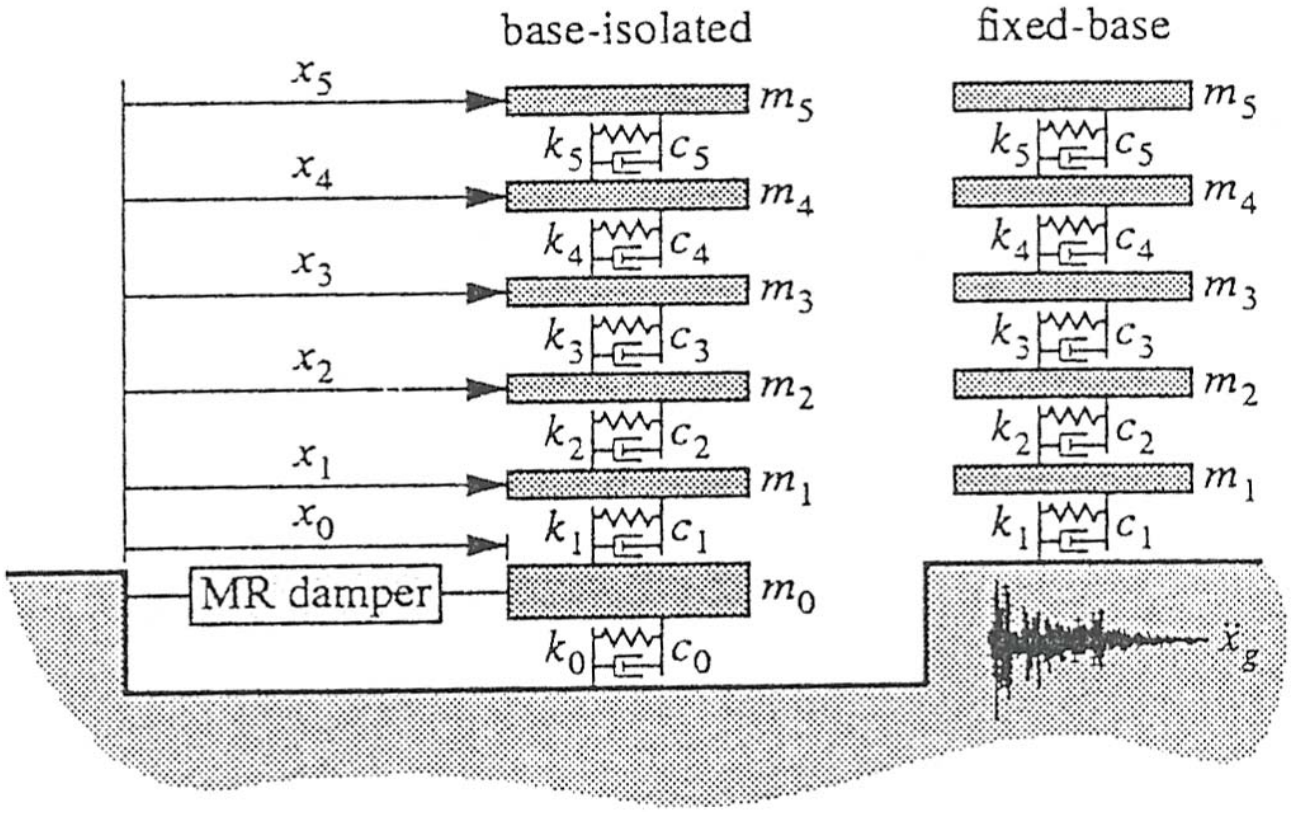

(a) Twin buildings of New York World Trade Center
(b) Model of a multistory building



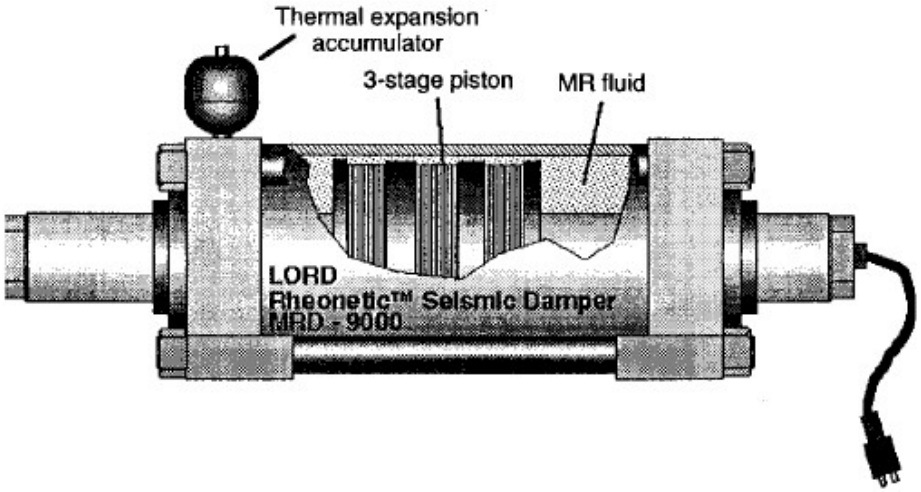

Free-body diagram for multistory building dynamics



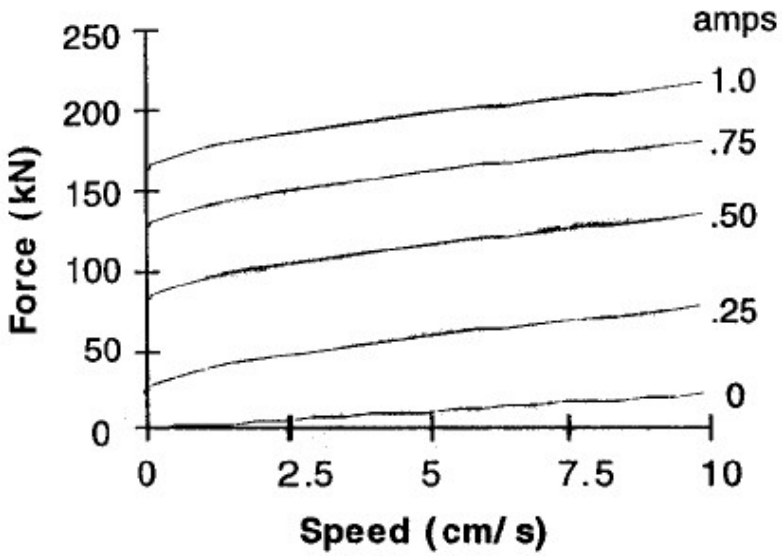

Distributed array of MR dampers as part of a civil engineering structure.
Seismic motion causes one floor to shear relative to next floor



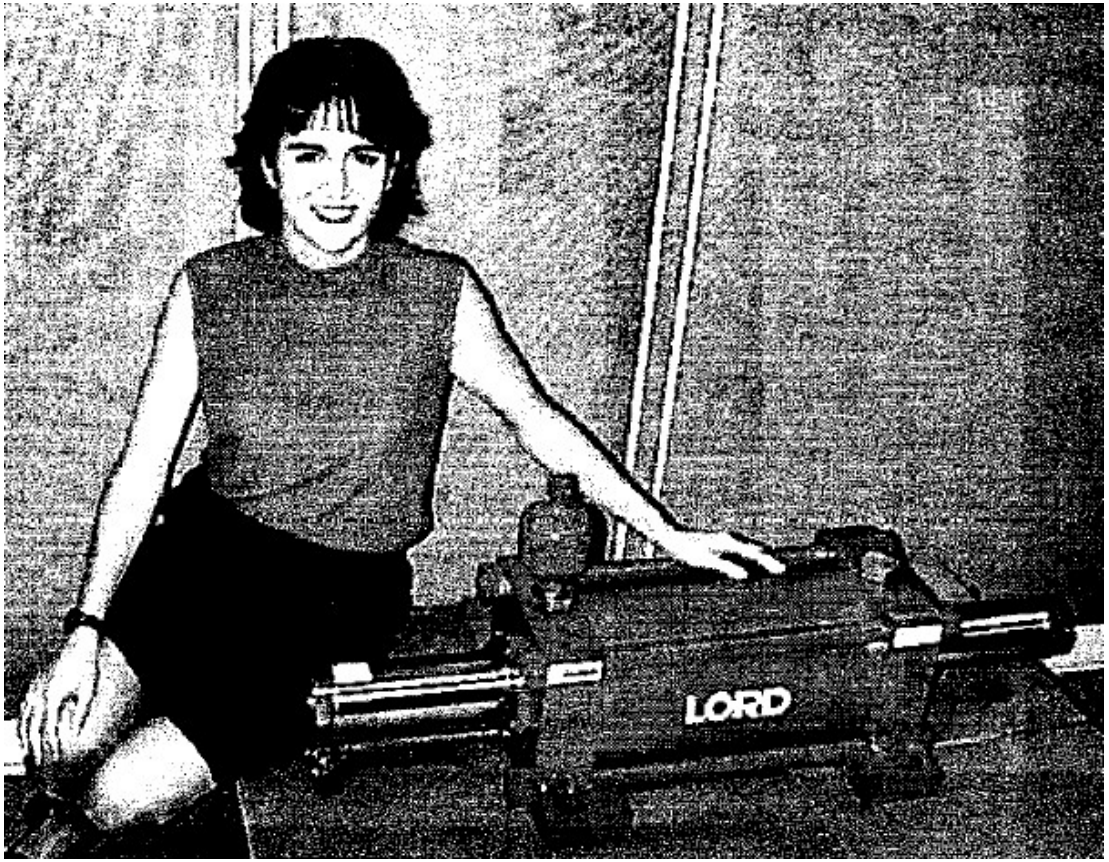

Linear, lumped-parameter model of the structure



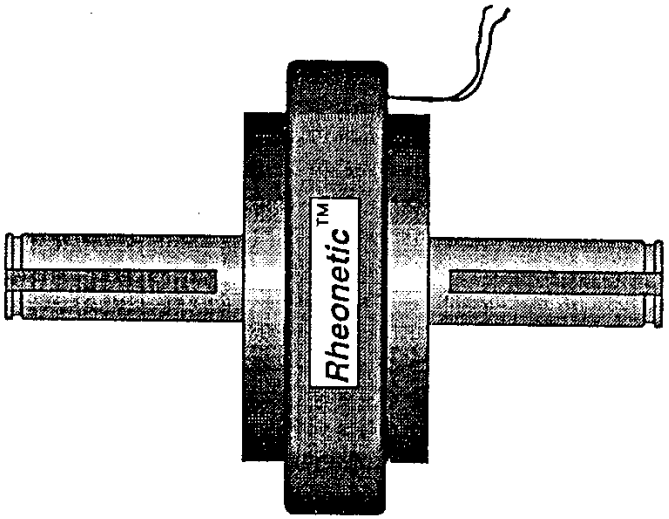

Schematic of MR fluid seismic damper



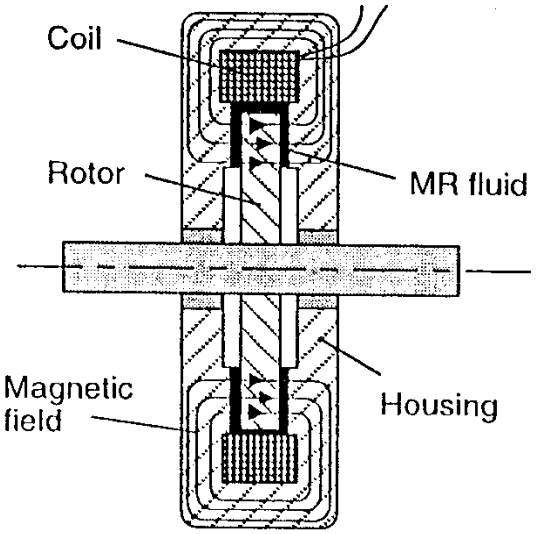

Performance for 20-ton MR damper



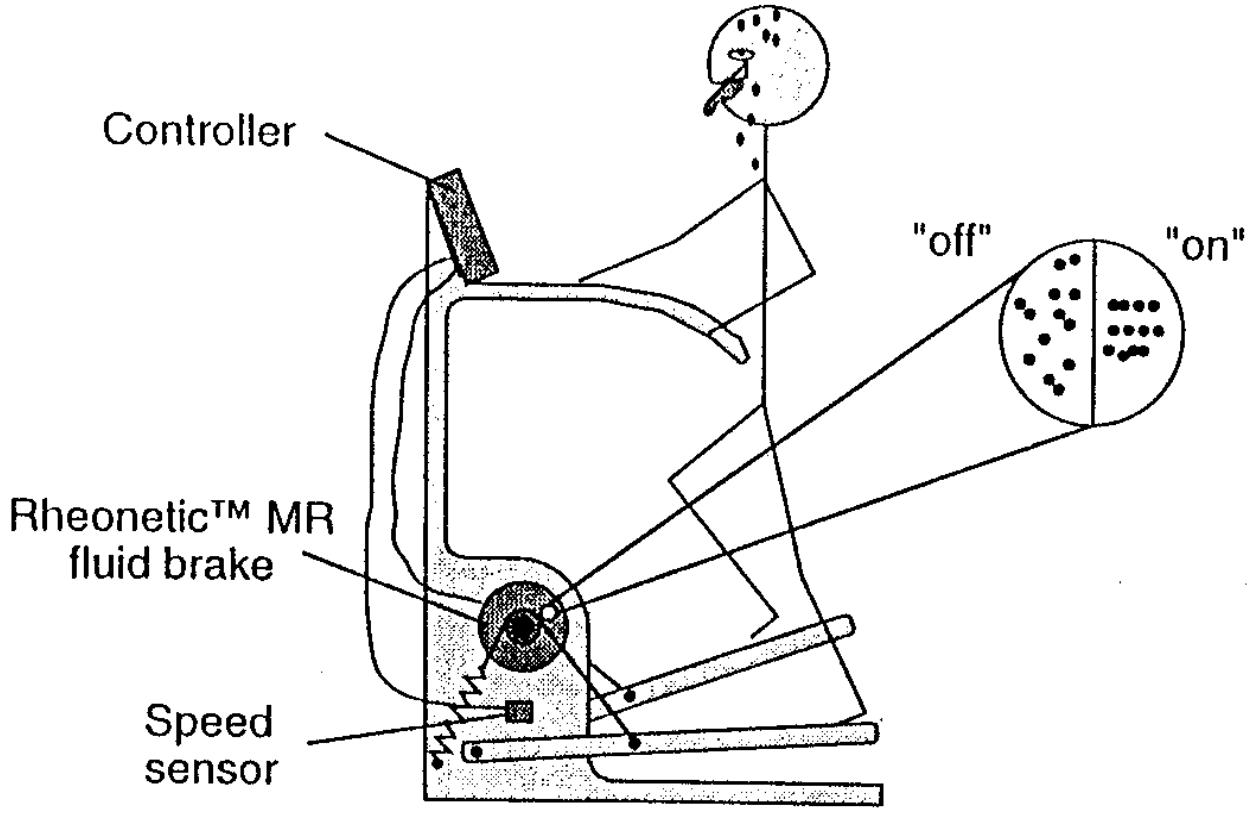

Completed 20-ton MR fluid damper




Commercial MR fluid rotary brake




Schematic of MR fluid rotary brake




Exercise machine with MR brake