chines, and staircase banisters over which the probe arm, or boom, will not roll without being retracted. The need to retract is sensed when the stanchion that supports the boom is deflected inboard from the vertical, thereby actuating a microswitch. Another switch signals the condition of the head, when it is caught behind a pipe or banister, by sensing the outboard tilt of the stanchion when it tries to retract the boom.

Signals from the several microswitches are fed to the logic control unit located in the upper half of the automaton body. This control includes all of the decision-making functions needed for the vehicle to exhibit a response appropriate to each set of input signals. The latter, representing the entire environment of the machine, are mostly in the form of on-off conditions of various microswitches and represent 17 different Boolean variables. The control section is a logical network that accepts these inputs and generates a set of outputs, comprising six Boolean variables that determine the entire behavior of the automaton.

The device has survived entirely on its own for as long as 21 hours. During this period of continuous movement around a closed path of two halls and two connecting corridors, it "fed" from four available electrical outlets about 25 times.

Plans have now been made to modify this model to give it a greater operational capability in the form of a higher "intelligence." Active acoustic guidance will be added to allow the automaton to move down the center of a hall, contacting the wall only when it is actively seeking a "feeding." A normal forward speed of twelve inches per second, which is twice the present speed, together with a slow speed of three inches per second for obstacle avoidance and the feeding phase, will be incorporated. Finally, provision will be made to allow the automaton to search vertically for electric outlets since, in the present model, only those few at a certain height can be used. Such other modifications as optical guidance and neuron analog devices are also anticipated in the future.

Polaris Fluid Magnetic Spring

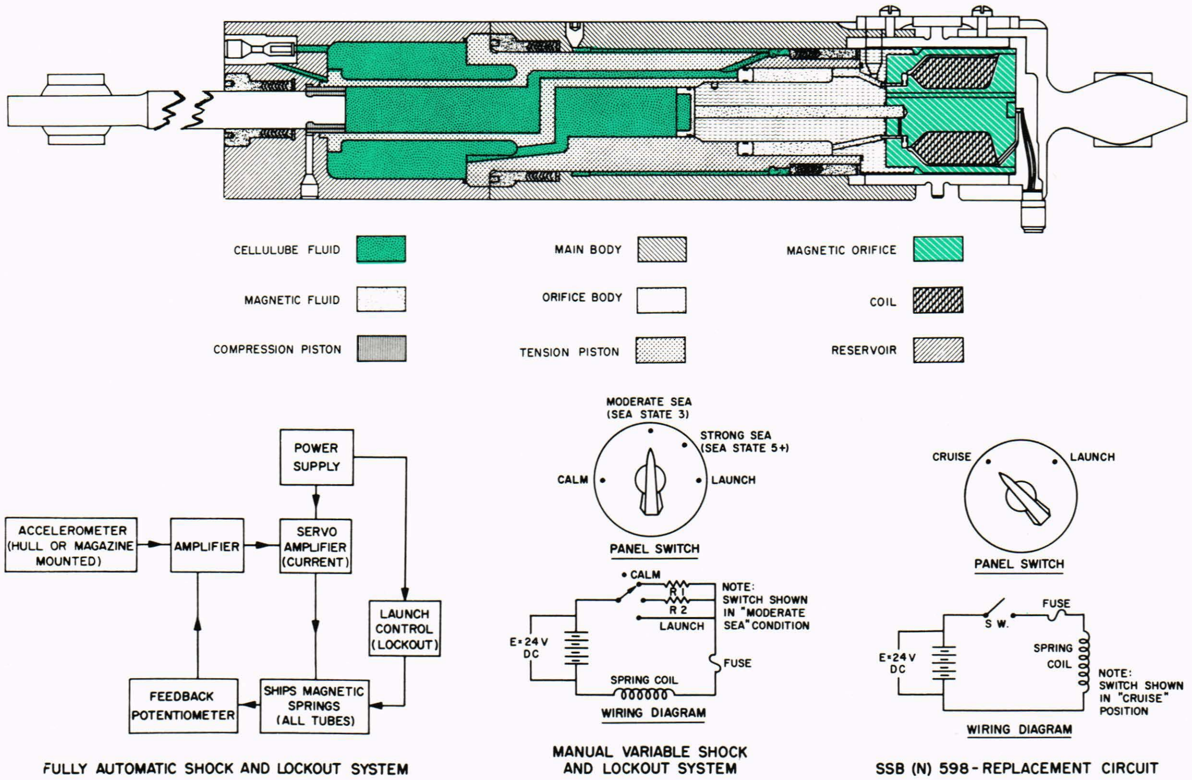
A fluid magnetic spring that provides suspension characteristics and acts as a variable damping and lockout device has been developed at APL for the Polaris missile and tube launching combination on Polaris submarines. The new spring is the work of R. E. Kemelhor.

The most common form of "liquid spring" is the conventional automobile shock absorber in which a hydraulic fluid is both compressed and metered through an orifice when the shock strut is subjected to suspension loads. In general, the force it transmits increases approximately as the square of the telescoping velocity; thus, when a fast-moving automobile travels over a bumpy road the shock absorber becomes very rigid. What was required in the Polaris program was a means of varying the "sponginess" (damping characteristics) of the liquid spring under shock conditions from "smooth" to "very rough."

The concept developed at APL is based on varying the viscosity of the working fluid by electrical control. The working fluid consists of a mixture of oil and iron particles rather than oil alone as in the case of the automobile shock absorber. When the mixture is passed through a magnetic field, the fluid can be changed through a range of viscosity from that characteristic of comparatively light oil to an almost rigid, mud-like consistency. Thus, by sensing the telescoping action of the shock absorber by means of a simple potentiometer mounted on the plunger, the viscosity of the unit can be automatically controlled. In addition, it is possible to control the electrical input manually so as to set the shock absorber to a desired stiffness.

The liquid spring illustrated shows the method of blocking the damper element by magnetically solidifying the fluid flowing through it. This isolates the most compressible fluid volume and renders the spring comparatively stiff when lockout is desired. Nonmagnetized operation of the spring is similar to that of a conventional liquid spring. When the spring is either extended or compressed, pressure in the Cellulube[1] volume is raised, forcing the magnetic fluid to flow through the

[1] Cellulube is a new non-petroleum-based, fire-resistant hydraulic fluid; it is a product of the Celanese Corporation.



Fluid magnetic spring, damper, and lockout. Design loadings for the unit shown are 18,000 lb at 4.0-in. compression and 21,000 lb at 4.0-in. extension strokes. Magnetic control is either manual or automatic, as shown by circuit diagrams.

orifice and compressing the Cellulube in the reservoir area. When the coil is energized the magnetic fluid is "solidified" in the magnetic orifice and the flow through the orifice is drastically reduced. Then when the spring is extended or compressed, only the fluid forward of the orifice and a portion of the magnetic fluid can be subject to stroking pressure. Since Cellulube is comparatively incompressible (8% at 30,000 psi), and since its volume is only 20% of the total, the spring is made stiffer.

There are other versions which permit greater control of damping; in such cases the only fluid used is the magnetic slurry. During both the tension and compression strokes the magnetic fluid is forced to flow through a long orifice pipe that is surrounded by a coil and then around the outside of the coil into the expansion chamber. By utilizing a long pipe orifice and a "wet" coil a large range of damping is obtained.

The present Polaris system contains 16 standard liquid springs, their reservoirs and replenishment lines, and six pneumatic lockout cylinders with their attendant lines and accumulators. The fluid magnetic spring will eliminate much of this hardware. This is particularly important for the future as missile weight, and consequently the number of springs and lockouts, increases.

The original research and development work on the fluid magnetic spring was conducted at APL. This program required fabrication of a scale model of such a device, while full-scale models for the Polaris launch tubes were subsequently developed and manufactured. Tests of the full-scale prototype conducted by APL and by Westinghouse Electric Corporation (the Polaris launcher prime contractor) have been successfully completed.

Future development of specific hardware for advanced Polaris submarines will probably be undertaken by Westinghouse, with APL acting as technical advisor. Possible future APL effort will be channeled into the development of shock and noise mitigation fluid magnetic mounts for shipboard auxiliary machinery and main turbines for the Navy Bureau of Ships.