THE WORD STORAGE RELAY (WSR)

by Pat West, P.E. (W7EA)

One of the more complex systems developed during the cold war was the BOMARC missile system developed by Boeing and the University of Michigan. The BO in the acronym stands for Boeing and the MARC stands for Michigan Aeronautical Research Center. Boeing built two versions of the BOMARC, the first one designated "IM99A" and the second "IM99B". The "A" version used a liquid propellant boost system with a range of about 250 miles and the "B" used a solid propellant for boost and had a range of at least 400 miles. The BOMARC was a pilotless aircraft vehicle, developed and deployed to counter the Soviet massed bomber threat. An artist's version of a BOMARC missile is shown in Figure 1.

One of several electronic systems on the BOMARC was the command system. Figure 2 shows the major part of the command system, ready for installation in missile Section 41. The UHF receiver was mounted separately and is not shown in the figure. The command system responded to UHF radio commands, to control the launch, boost, cruise and terminal dive time phases of the missile. I believe the command system was an element of the first ever ground-to-air digital control system.

A brief summary of the role of the command system in a missile is as follows, please refer to Figure 3. A Semi-Automatic Ground Environment (SAGE) system used control centers at strategic locations in the USA. Each control center received radar target reports via a radar network. If hostile aircraft such as a bomber raid was identified by a control center, computers at the control center would generate digital control messages and would transmit them via land lines to a supporting BOMARC missile base. The control center would supply data to a selected missile that would include takeoff azimuth and dive timer setting. This information would be updated until such time that a launch command would be given. At the missile base, the flight control data would be transmitted to the missile by a low power UHF transmitter via a coaxial distribution system The UHF receiver in the missile would detect the data and pass the information on to the Word Storage Relay (WSR). Each command would ultimately reach the missile flight control system.

When the liquid propellant booster was activated, the missile would follow a boost phase as controlled by a transducer in the command system It would take off on the azimuth set by the control center computer. Commands from the control center during cruise phase would control the missile. These commands were transmitted to the missile from a high power UHF transmitter located on the missile base. When the dive timer was activated by the control center computer, the missile would dive on the target, the terminal guidance radar would lock on the target and control the remainder of the flight. At a certain distance from the target the fuse system would be activated to ultimately ignite the payload ordinance.

The digital data link from ground to air was a 14 bit system using a 4 bit address, a 9 bit position command for the addressed transducer and a 1 bit parity. Each bit took 10 ms and a complete word was 140 ms. A 460 ms period was allowed for transducer positioning before the next word was transmitted. Total cycle time was therefore 600ms. Real slow when compared to today's digital systems!

Each command system receiver on a missile contained a unique sub-channel module which was the technique used for missile selection. The leading edge of a transmitted word would trigger the WSR and the word would be stored for 460ms until the next cycle.

The brain of the command system was the Perkins-Reynolds Selector Relay, Patent No. 2795,773 as illustrated by Figure 4. This unit as used on the BOMARC "A" missile was referred to as Word Storage Relay (WSR). The WSR was conceived and developed in 1950/1951 by L. C. Perkins and F. D. Reynolds, engineering managers at Boeing. They developed the unit for a hobby, for the radio control of a complex model fire boat. The WSR was used only on the IM99A missile.

Figure 5 shows the principle of operation of the WSR. The figure shows 20 reeds as used on their model boat, whereas the BOMARC "A" WSR contained only 14. A non-ferrous metal disk with a slot in the edge of it is mounted on a ferrous shaft. Surrounding the edge of the disk are a number of spring steel reeds or fingers, whose outer ends are fixed to the frame of the device. The inner ends of the reeds are located so that they may pass through the slot, one at a time, from one side of the disk to the other when the slot is aligned with the reed. At all other times, each reed is trapped on one side or the other of the disk. A trapped reed supplies ground to its associated relay. Every 600ms as synchronized by the command system receiver, the WSR would be rotated a complete revolution in 140ms (Drive motor is not shown on the figure). Reeds would be synchronously activated or released.. The WSR would be idle for 460ms until the next cycle.

A magnet coil surrounds the shaft. An arm which is fixed to the shaft extends close to the slot in the disk. When the coil is energized, this arm concentrates the magnetic flux on the one reed which is at that time aligned with the slot, thereby pulling the end of the reed through the slot. In their free positions, the reeds are on the side of the disk away from the flux concentrator arm and do not touch the disk. When the reeds are attracted through the slot they become trapped on the concentrator-arm side of the disk, as a result of the rotation of the disk and make electrical contact with the disk.

It is therefore evident that once per revolution, we have the choice of closing any reed switch or a combination of them, leaving any or all closed that are already closed, opening any or all or leaving any or all open. At all times when the slot does not line up with a particular reed switch, the switch remains in the position it was left in the last time the slot passed it. Any configuration of open and closed switches representing any binary number may therefore be set up on the device in one revolution and retained as long as desired.

It is therefore obvious that the slotted disk must be rotated in a timed relationship with respect to the information pulses applied to the reed switching coil, in order that the proper reed switches will be closed. The rotation is controlled by a governed motor (not shown on Figure 5) so that the slot in the disk is aligned with each reed in turn at the exact time that the pulse intended for that reed actuates the magnet.

The command system included a box containing relays and a network of resistors. Certain relays would be activated depending on the transmitted word contents. A transducer would be selected and a transducer position would be derived by the relay/resistor bank. The existing transducer position would be represented by a 900 Hz voltage magnitude as picked off the transducer rheostat. This voltage and the 900 Hz voltage from the resister network would be fed to a servo amplifier. The voltages would be compared and the transducer would be repositioned to the commanded position.

The WSR was ultimately replaced with an all solid state unit as developed by Motorola. The BOMARC bases no longer exist and deployed missiles were used for other purposes including their employment as targets for other missile types.

There is an interesting story dealing with the invention of the Perkins-Reynolds Selector Relay. It appears that they, as Boeing employees, were required to advise Boeing of their patent. Boeing told them that the company had no requirements for a devise to control a toy boat and the patent was theirs. Ten years later, the inventors took the model boat to England and won a world championship with it. The model fire boat is illustrated in Figure 6.

In the meantime, back at Boeing, they were having trouble coming up with a good system for radio control of the BOMARC missile. The inventors made a pitch to Boeing management, they bought the idea and directed the Boeing patent staff to reacquire the rights to the model-boat control invention. The inventors signed a contract with Boeing and Mr. Reynolds became the manager in charge of the Boeing version of the devise. According to a study, the use of that “toy boat” invention in the guided missile saved 350 vacuum tubes per missile. (This was before the availability of transistors and integrated circuits.)

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CREDITS: 1. Photos- The Boeing Company, Seattle, WA

2. Description of WSR operation- F. D. Reynolds. Mr. Reynolds is the author of the book, "Crackpot or Genius", published in 1993, a complete guide to the uncommon art of inventing. Book is available from: Chicago Review Press, Inc., 814 North Franklin Street, Chicago, IL 60610.

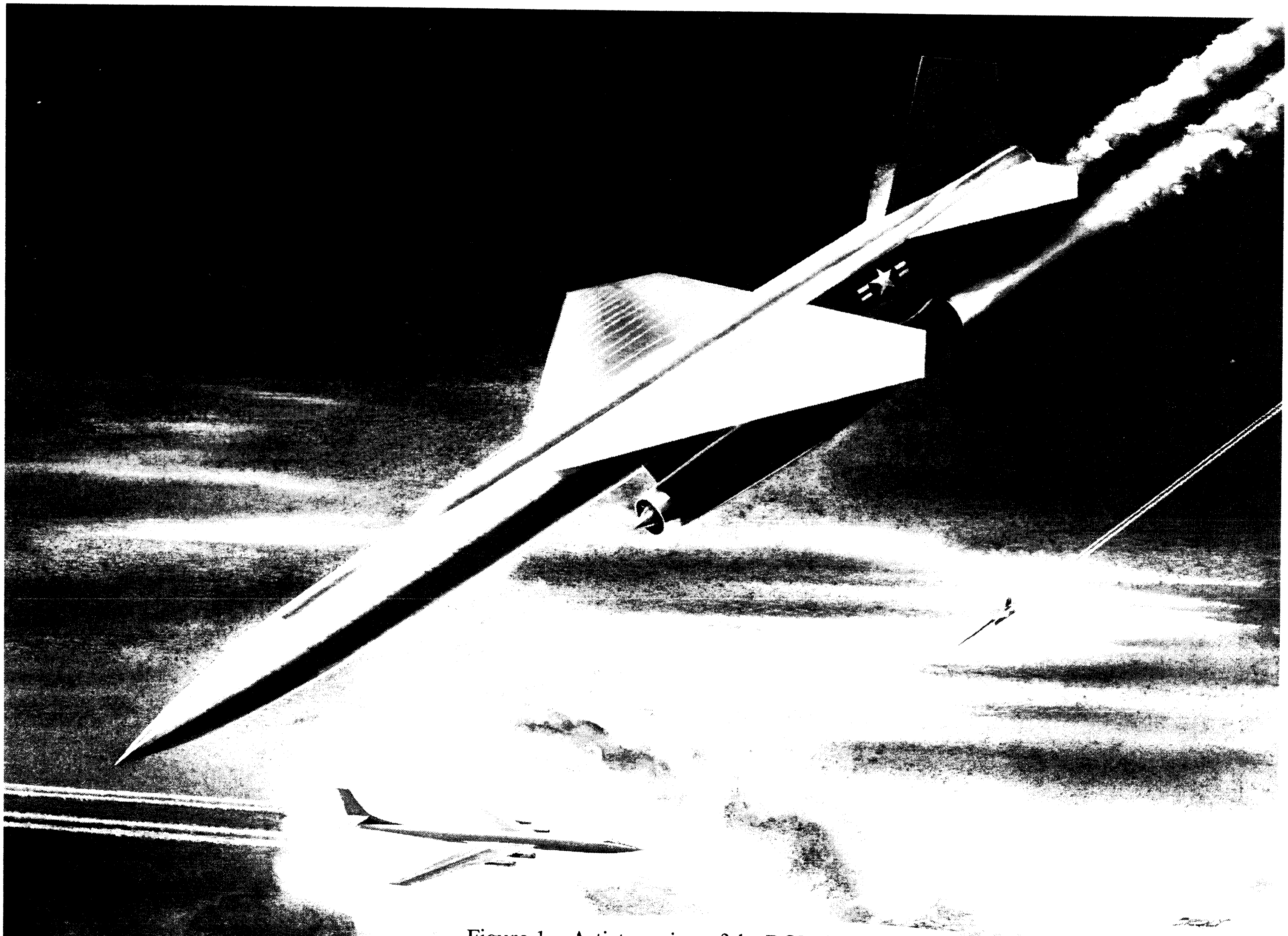

Figure 1—Artist version of the BOMARC missile.

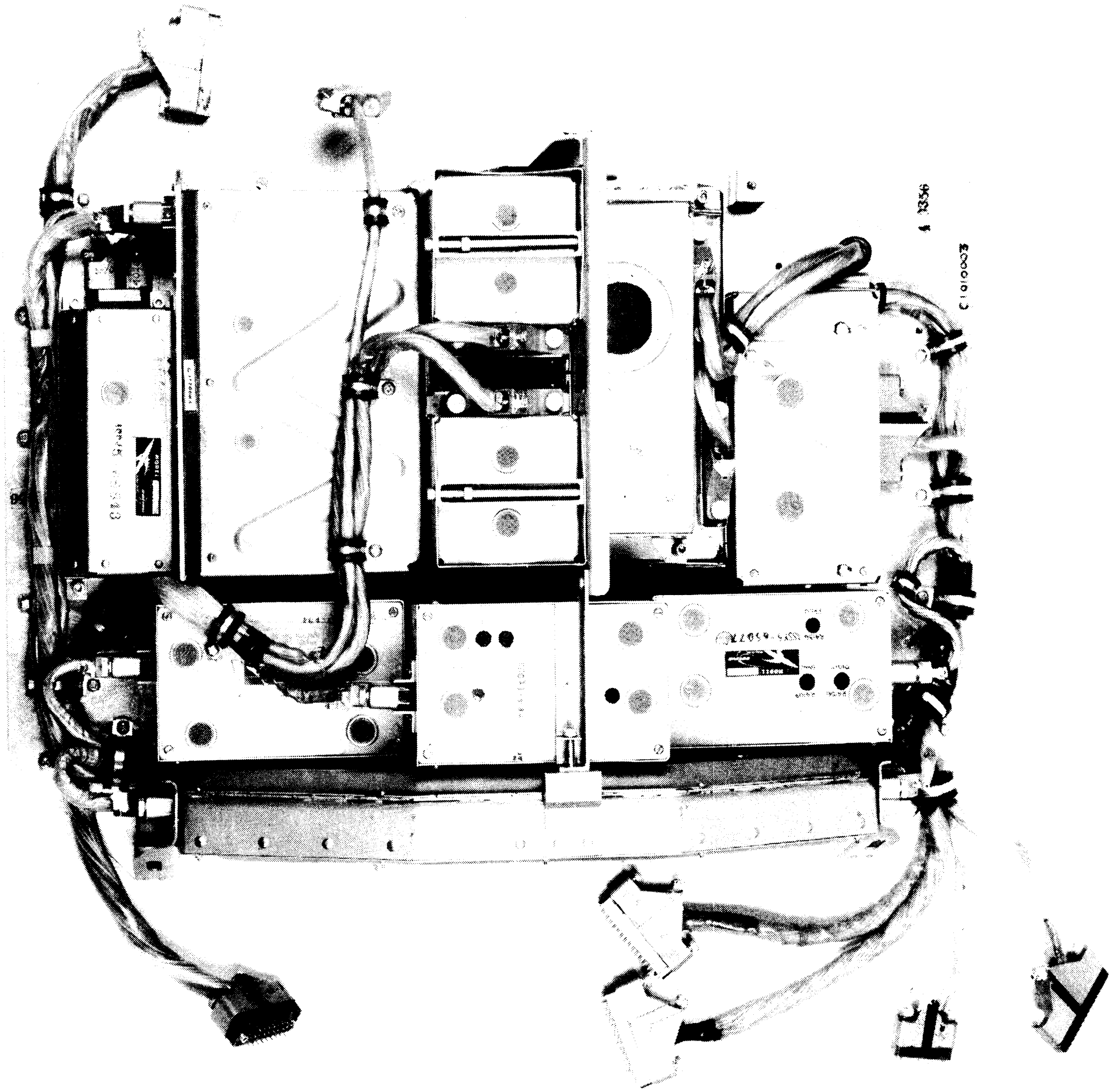

Figure 2-BOMARC Command System hardware.

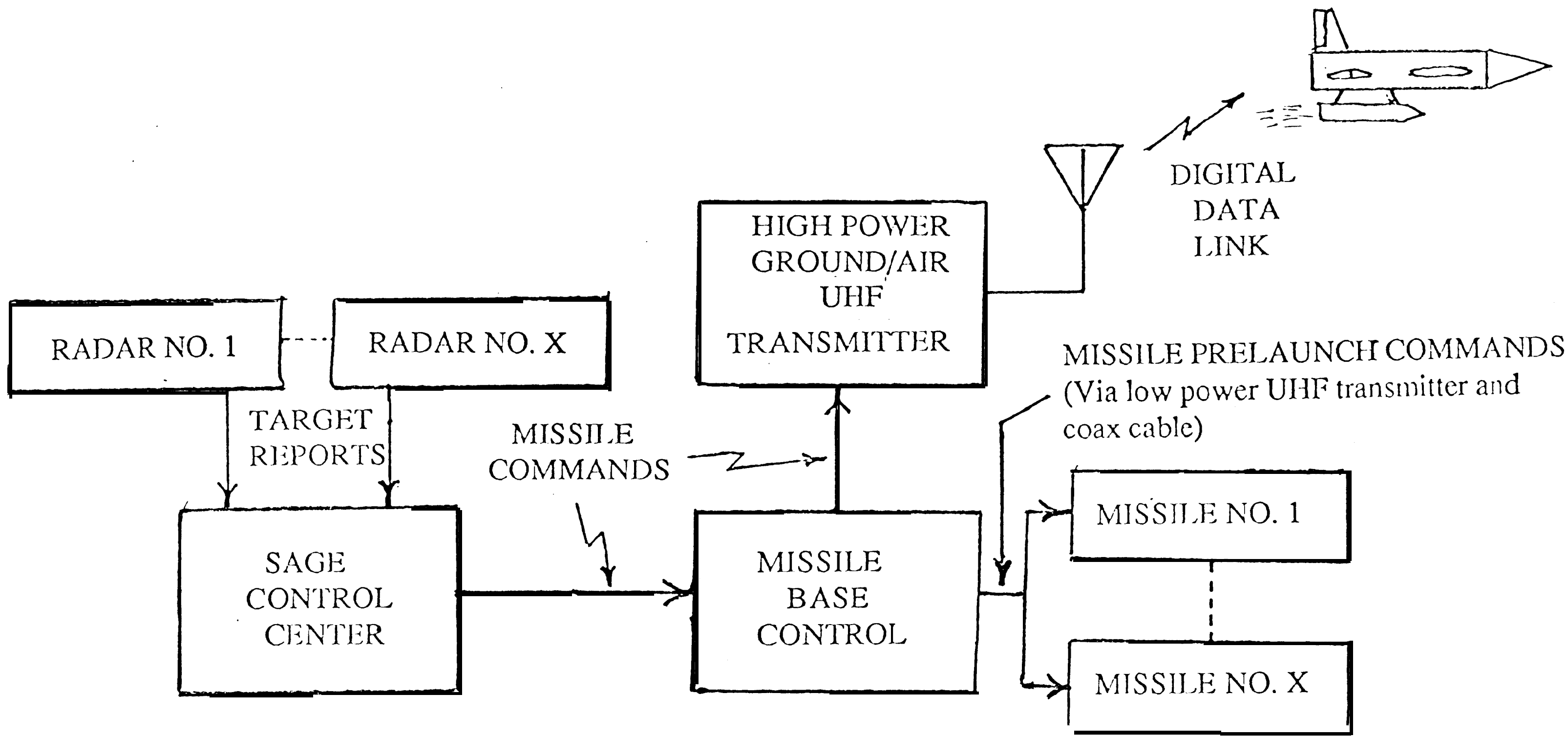

Fig. 3. SAGE control of BOMARC.

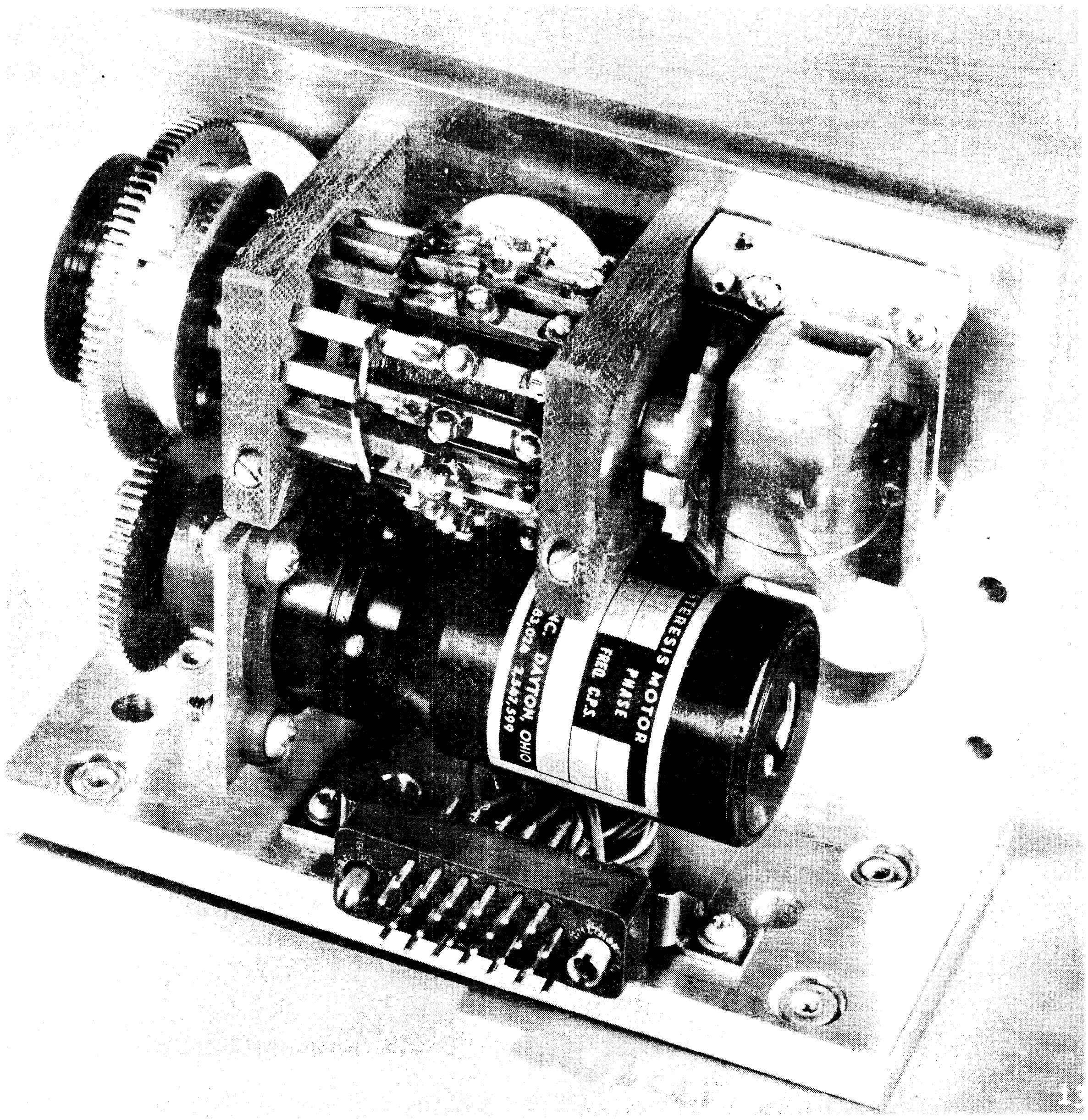

Figure 4-Perkins/Reynolds Selector Relay which was called word Storage Relay on the BOMARC Command System.

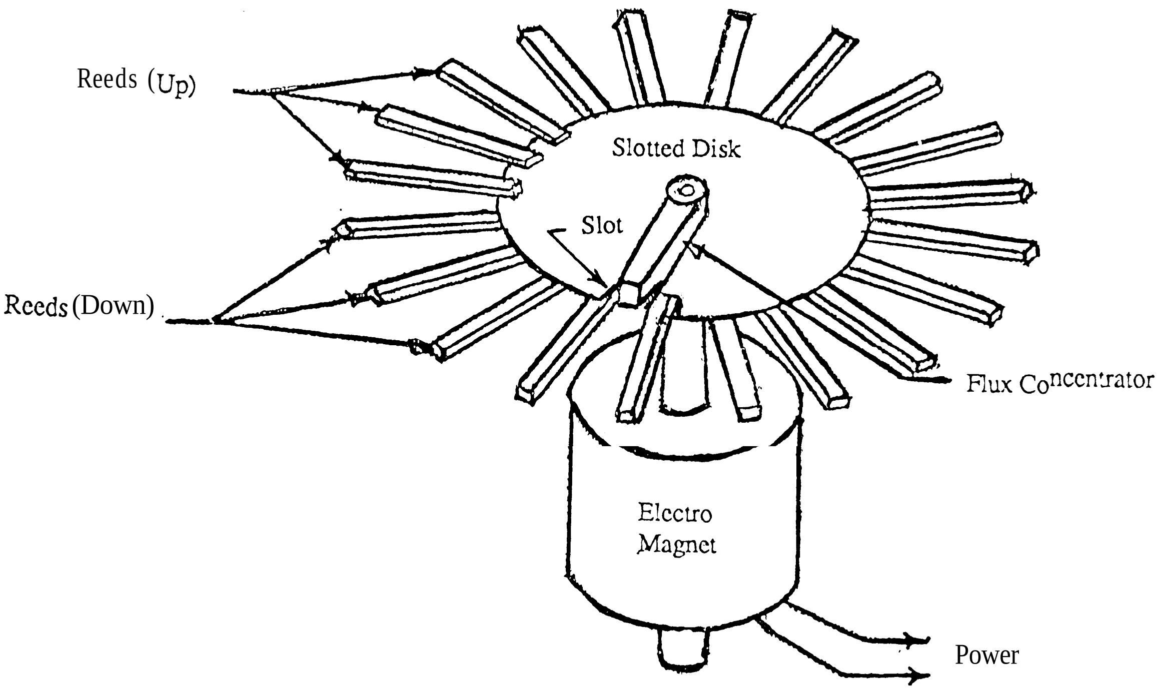

Fig. 5'. Illustration for explaining Word Storage Relay operation

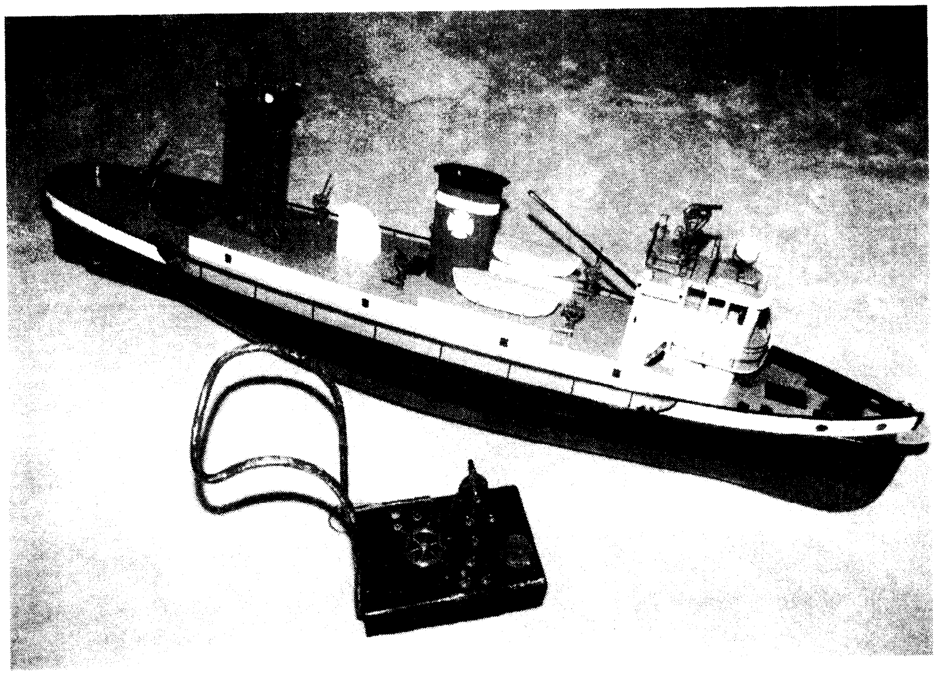

Figure GA-Model fireboat with controller.

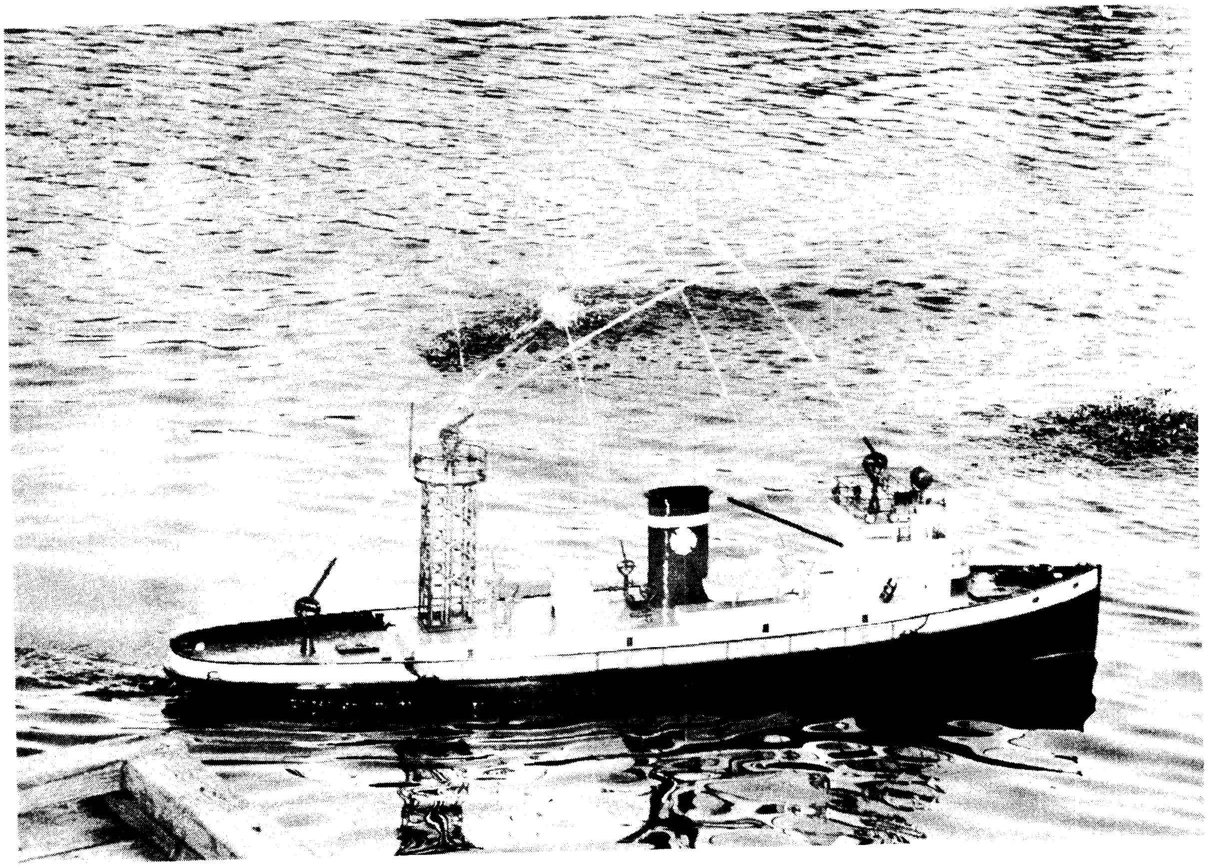

Figure 6B—Model fireboat with all hoses working and controlled by the WSR.