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DEVELOPMENT AND TESTING OF A CONNECTOR FOR REMOTE HANDLING OF HIGH-LEVEL WASTE CONTAINERS

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OAK RIDGE NATIONAL LABORATORY
OPERATED BY UNION CARBIDE CORPORATION • FOR THE U.S. ATOMIC ENERGY COMMISSION

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Abstract

The design for a connector that can be used in the remote handling of high-level waste containers at spent-fuel reprocessing plants and a repository was developed at Oak Ridge National Laboratory. A prototype connector was fabricated and has been subjected to preliminary cyclic and strength tests. These tests were conducted for 4000 cycles with no load and approximately 16,000 cycles with load, and the results indicate that the connector exceeds the basic safety and load criteria. Future testing of the connector is planned to further evaluate its remote operating capabilities, its underwater operation, and the effects of heat on its performance.

1. INTRODUCTION

Current plans for the disposal of solidified radioactive waste from spent-fuel reprocessing plants call for the transport of this material to either an engineered surface storage facility or to a federal repository in a salt mine for storage. The high-level radioactive waste will be transported in containers within shielded casks. Of necessity, all handling of individual waste containers must be performed remotely. Typical of these handling operations are those envisioned for the proposed pilot plant repository in a salt mine where the waste containers will be taken out of a shipping cask and placed in a mine shaft cage, transferred from the cage to a shielded cask for transport into the mined area, removed from the cask and lowered into a previously prepared hole in the mine floor. To facilitate such typical remote handling operations at a repository or an engineered surface storage facility as well as a reprocessing plant, a program was undertaken at Oak Ridge National Laboratory (ORNL) to develop and test a suitable hooking device or connector for lifting and moving individual high-level waste containers.

The criteria established for the remote connector at the beginning of the development program are outlined in Section 3 of this document. The design for the connector that was developed to meet the criteria and the fabrication of the prototype connector are discussed in Section 4. The initial tests performed on this prototype included both no-load and load tests, and these are described in Section 5. The results of these tests reported herein reflect work done through April 1972. Future tests are planned to further evaluate various performance aspects of the connector, and these tests are discussed in Section 6. The information contained in these sections is summarized in Section 2.

2. SUMMARY

The criteria established for the connector included reliable operation with the capability for remote installation and removal, an initial load handling capacity of 4000 lb and an ultimate capacity of 8000 lb, physical size limitations, the ability to withstand exposure to thermal heat and nuclear radiation, and the capability for underwater operation. The connector is designed to be operated with compressed air or other gases, and it employs a detent coupling device which locks onto a stepped lifting pin attached to the top of the waste container. Some simple tools and a holding fixture were also designed and fabricated to facilitate disassembly and reassembly of the connector. These accessories are readily adaptable for use in a glove box should this become desirable.

A test stand was built and controls were devised to cycle the connector automatically through sequential operational steps. The test stand and controls were used to test the connector for over 20,000 cycles of operation with loads varying from zero to 6000 lb. The connector was disassembled for inspection at various intervals during the testing. Minor modifications to the locking pins of the detent device were made as a result of some signs of wear observed during the no-load phase of the testing. No other difficulties were observed during the remainder of the no-load tests or throughout the load tests. The results of these tests indicate that the connector exceeds the basic criteria for safety and load capacity.

Additional testing of the connector is planned to further demonstrate and evaluate its remote operational capabilities, determine its underwater operability, and determine the effects of high temperature on its performance.

3. CRITERIA

The waste container connector was designed to meet criteria established at the beginning of the development program. These criteria were based on available information on a proposed repository and on experience gained during the Project Salt Vault (PSV) experiment.[1] The criteria were also established so that the connector developed would be compatible with the existing PSV transporter. The criteria established for the connector are outlined as follows.

1. The connector must have the capability for remote attachment to and removal from cell cranes and transporter cable.

2. The connector must have the capability to be remotely attached to or released from a waste container without radial orientation.

3. The connector must be capable of handling a load of 4000 lb when used with the PSV transporter and a load of 8000 lb when used with future transporters.

4. The load must be transmitted from the pin on the waste container to the lifting hook without being transmitted through any additional clevises, threaded joints, or bolted assemblies within the connector.

5. The actuating power of the connector may be supplied by electrical current or by hydraulic or gas pressure.

6. The waste container must not be released upon inadvertent loss of power or inadvertent hang-up of the container during placement in or removal from various transfer devices at either a fuel reprocessing plant or a repository.

7. The connector must be compact and small. The outside diameter of the connector must not exceed 6 in. (the outside diameter of the smallest proposed waste container), and the height of the connector from its base to the center line of the cable attachment must not exceed 10 in.

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[1]R. L. Bradshaw and W. C. McClain, "Project Salt Vault: A Demonstration of the Disposal of High-Activity Solidified Wastes in Underground Salt Mines," USAEC Report ORNL-4555, Oak Ridge National Laboratory, April 1971.

This latter restriction is dictated by the existing PSV transporter, and it may be relaxed somewhat for future transporters.

8. The connector must be capable of withstanding damage from the nuclear radiation and thermal heat of waste containers for a reasonable length of time or number of operational cycles.

9. The connector must be easily maintained and repaired, possibly from within a glove box.

10. The connector must be capable of underwater operation.

4. DESIGN AND FABRICATION

The connector for high-level waste containers that was designed to meet the criteria outlined in Section 3 is illustrated in Fig. 4.1. This connector is comprised of an air-operated spring-return cylinder which actuates a detent coupling device that locks onto the stepped lifting pin illustrated in Fig. 4.2. It is proposed that this pin be used on the top

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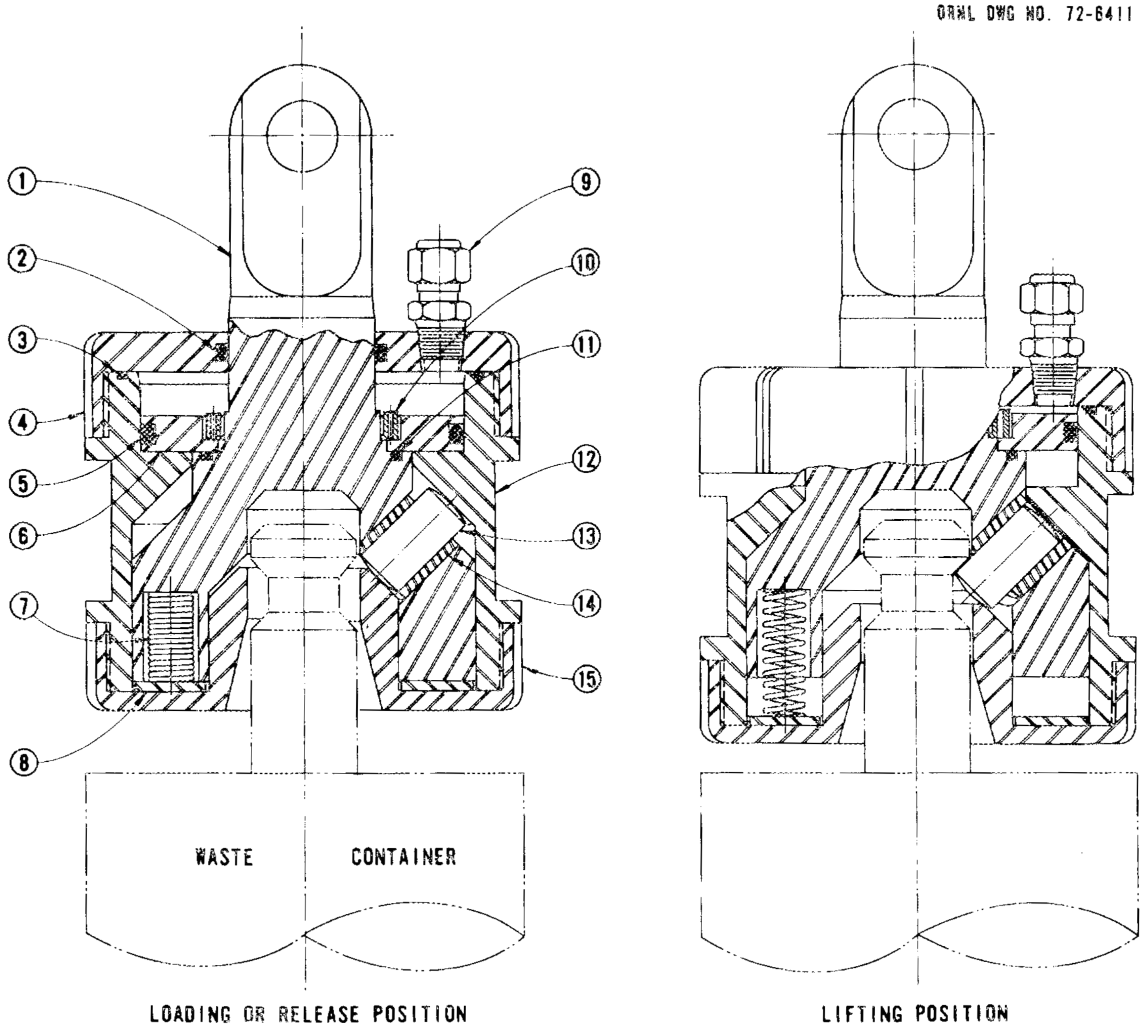

① LIFTING YOKE
② O-RING
③ O-RING
④ TOP NUT
⑤ O-RING
⑥ PISTON
⑦ COMPRESSION SPRINGS
⑧ SPRING PLATE
⑨ QUICK SOCKET
⑩ PISTON RETAINER
⑪ O-RING
⑫ CYLINDER
⑬ LOCKING PINS
⑭ PIN BUSHINGS
⑮ BOTTOM NUT

Fig. 4.1. Connector for High-Level Waste Containers in Loading and Lifting Positions.

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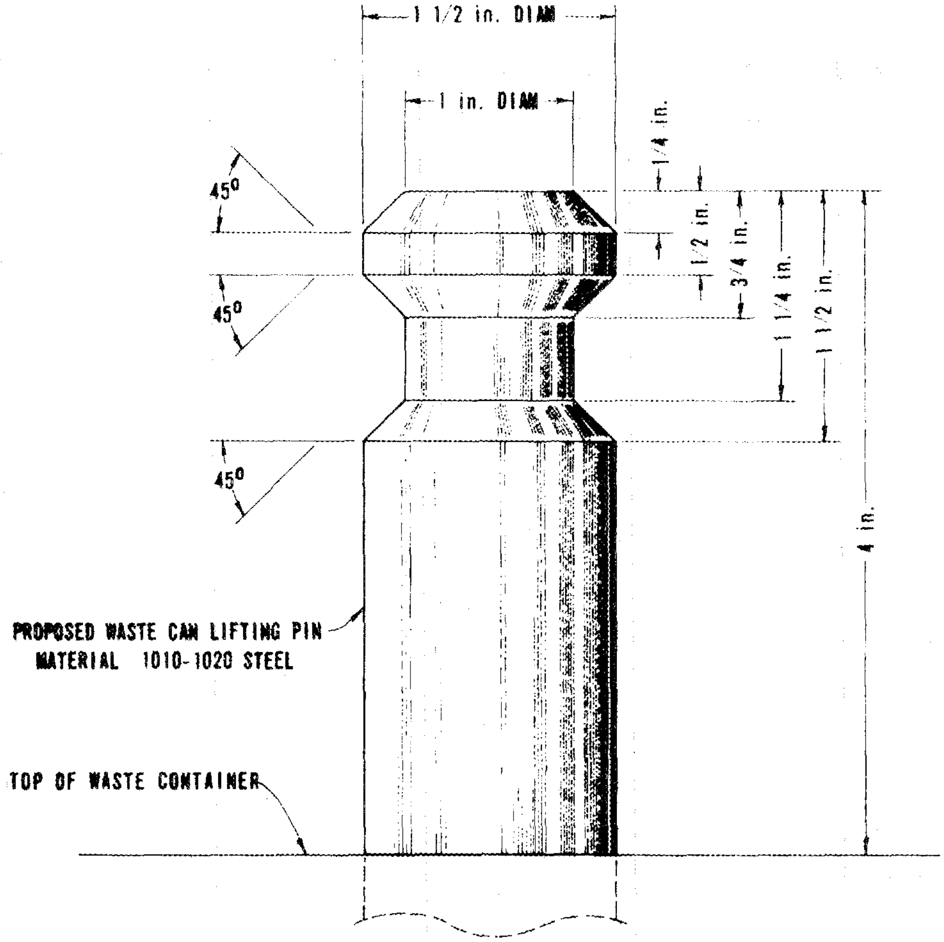

Fig. 4.2. Proposed Lifting Pin for High-Level Waste Containers.

of all the high-level waste containers. Locking of the detent device onto the pin is mechanical, and release of the detent device is actuated by air pressure. Therefore, a loss of electrical power, a ruptured air line, or a hang-up of the waste container during the time the container is being lifted, transported, or lowered will not cause the connector detent device to release the container. However, inadvertent application of air pressure to the connector cylinder would cause release of the container, and the air control system will be designed to render this impossible.

Equipment used in hot cells, contaminated areas, or in reactor storage pools is normally fabricated from stainless steel to minimize corrosion and permit decontamination with acid solutions. However, to reduce the cost of fabrication, the selection of the materials of construction for the prototype connector was based on availability in ORNL Stores, ease of machining, and heat treatment capability to achieve the surface toughness and strength required for the anticipated loads. Parts 1, 4, 6, 10, and 15 (illustrated in Fig. 4.1) were fabricated from ASTM A-108, Grade 1020, cold-rolled mild-steel bar with diameters of 5 and 6 1/2 in. General-purpose tool steel, SAE Class 01, was used to fabricate the pin bushings (part 14). Since they would not require heat treatment or grinding, commercially available dowel pins were used for the locking pins (part 13). The four compression springs (part 7) were fabricated from music wire, and the four O-rings (parts 2, 3, 5, and 11) used initially were neoprene, available from ORNL Stores stock. Viton O-rings, which had to be purchased, were used later.

The prototype connector was fabricated without difficulty in the ORNL shops during September and early October of 1971. Some minor design changes were made during fabrication to facilitate and expedite the work. The most significant change was one involving the fabrication of hardened pin bushings (part 14) to be shrunk into the lifting yoke in lieu of case hardening of the holes in which the detent locking pins (part 13) work. The compression springs (part 7) were fabricated from a heavier gauge wire than was originally selected, and a black oxide finish was put on all parts to protect them from rust.

Future connectors to be fabricated for development and testing or for use at a fuel reprocessing plant, repository, or an engineered surface storage facility will be fabricated from stainless steel whose complete physical and chemical properties will be recorded as part of the quality assurance program. The strength of the base metal selected will be equal to or greater than that of the material used for the prototype unit now being testing. The lifting pins for production waste containers will be fabricated from a material compatible with that of the containers to which they will be secured and with the corrosive environment anticipated in their use. The material will also have strength properties at least equal to those of the SAE 1020 carbon steel from which the test model was fabricated.

5. INITIAL TESTING

Tests were conducted under no-load and load conditions to check the operability and performance of the connector. The test stand devised for these tests, illustrated in Fig. 5.1, consisted of a structural steel

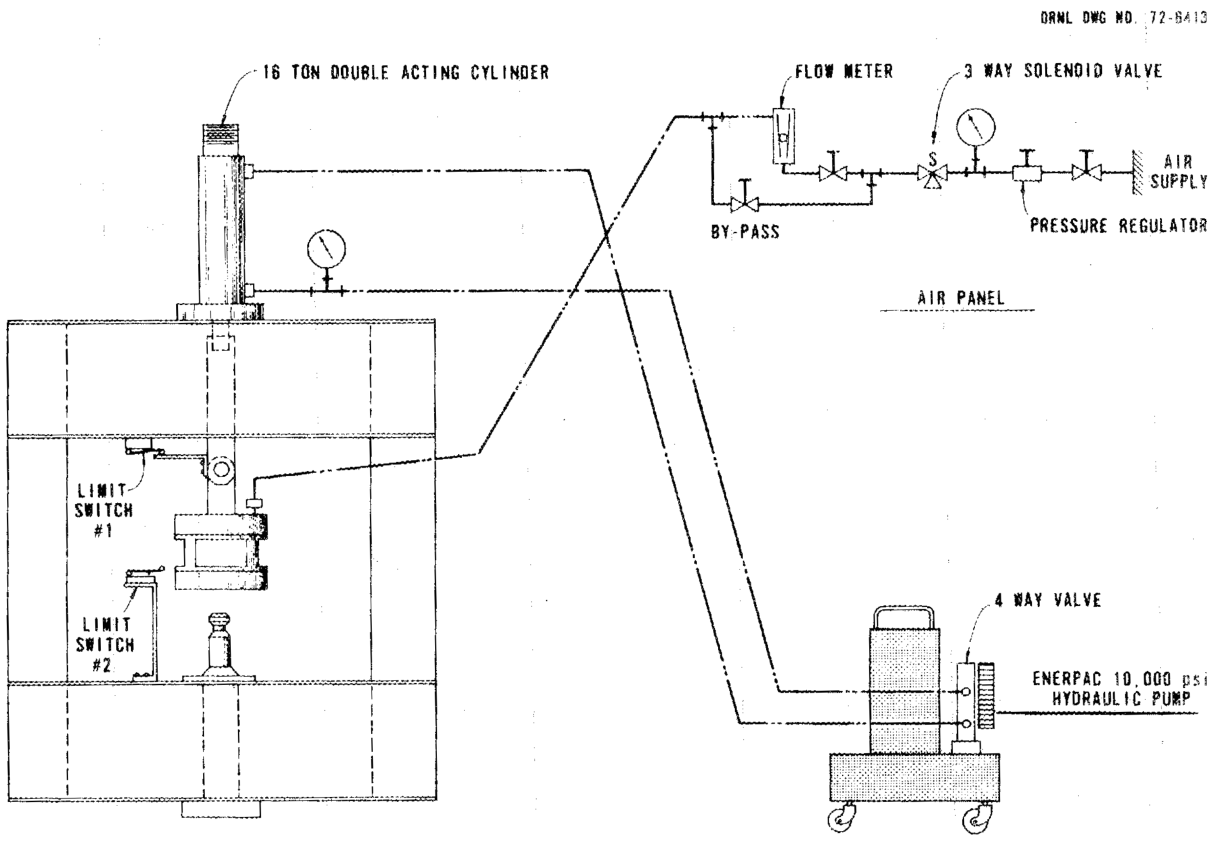

Fig. 5.1. Schematic Diagram of Connector Test Stand and Controls for No-Load Tests.

frame and a 16-ton double-acting hydraulic cylinder powered by an electrically driven pump with a capacity of 10,000 psi. Two separate electric control units were assembled to permit automatic cycling of the connector through sequential operational steps without requiring the constant attention of an individual.

5.1 No-Load Tests

The no-load testing of the connector involved cycling of the air cylinder that, in turn, retracted and extended the four locking pins (part 13 in Fig. 4.1 on page 6) of the detent device. This test was performed to assure that the moving parts, adjacent surfaces, and O-rings in the connector functioned as intended and to determine whether there were any points of wear when the connector was operated without a load.

The controls for this test consisted of the air panel illustrated in Fig. 5.1 and two time-delay relays to actuate the three-way solenoid valve. An air supply with a maximum pressure of 40 psig was required for actuation of the connector, but plant air was not available at the test site and bottled N_2 was substituted.

The cycle set up for this test consisted of pressure on for 15 sec and pressure off for 15 sec. The connector cylinder was cycled in this manner for an accumulated total of approximately 4000 cycles. During this period, the connector was disassembled and inspected six times.

The inspections performed during the no-load testing indicated two areas of wear. These were between the four locking pins of the detent device (part 13 in Fig. 4.1) and the 45° sloped surfaces of the cylinder (part 12) and the sloped surfaces of the bottom nut (part 15). The four locking pins were originally designed with flat ends, and the wear observed during this phase of the testing was caused by the flat end meeting the sloped surface in a point contact. The edges of the pins cut into the sloped surfaces during actuation. Wear was also observed on the brass spring plate (part 8). This was caused by the springs during assembly and disassembly operations, but this wear was expected and was the reason the plate was installed. All other parts performed satisfactorily. The four neoprene O-rings had a total leak rate of only 0.6 $\pm$ 0.1 scfh, and this rate did not change during the no-load testing of the connector. The O-rings exhibited no signs of wear or damage.

Modifications to some parts of the connector were required as a result of the wear observed during the no-load testing. To eliminate gouging of the sloped surfaces of the bottom nut (part 15 in Fig. 4.1) and the cylinder (part 12), the locking pins of the detent device (part 13) were modified by grinding the ends to a 1 1/2-in. spherical radius. This permitted smoother travel of the radiused ends of the pins over the sloped surfaces. More travel of the connector over the lifting pin on top of the waste container was also provided by increasing the depth of the recess in the lifting yoke (part 1) 3/16 in.

During the no-load testing period, three tools were fabricated to aid in the disassembly and reassembly of the connector after each portion of the testing. These included a holding and turning fixture and two spanner wrenches. The connector holding and turning fixture is clamped around the 5 1/4-in. square section of the cylinder (part 12 in Fig. 4.1) to provide convenient working access to either end of the connector by permitting the entire assembly to be inverted. One spanner wrench was designed to remove the top nut (part 4) and the bottom nut (part 15), and the other was designed to remove the piston retainer (part 10). These tools will be suitable for use in a glove box maintenance station with some minor modifications. These modifications include bolting of the holding and turning fixture to the floor of the glove box and removal of any shart edges on the tools that might rip or cut a glove.

5.2 Load Tests

To test the performance of the connector under load, a series of tests was set up to simulate a lifting operation in a repository transfer cell. The test stand illustrated in Fig. 5.1 and the electrical controls schematically illustrated in Fig. 5.2 were used for the load tests.

For the load testing, a test cycle is begun with the connector in the up position and the limit switch striker plate contacting limit switch No. 1, which applies pressure to the connector air cylinder. The hydraulic cylinder on the test stand lowers the connector over the waste container lifting pin (secured to the bottom of the test stand) until limit switch No. 2 is actuated. Actuation of limit switch No. 2 stops the lowering action of the hydraulic cylinder and releases the air pressure on the connector, whereupon the connector detent device is locked to the

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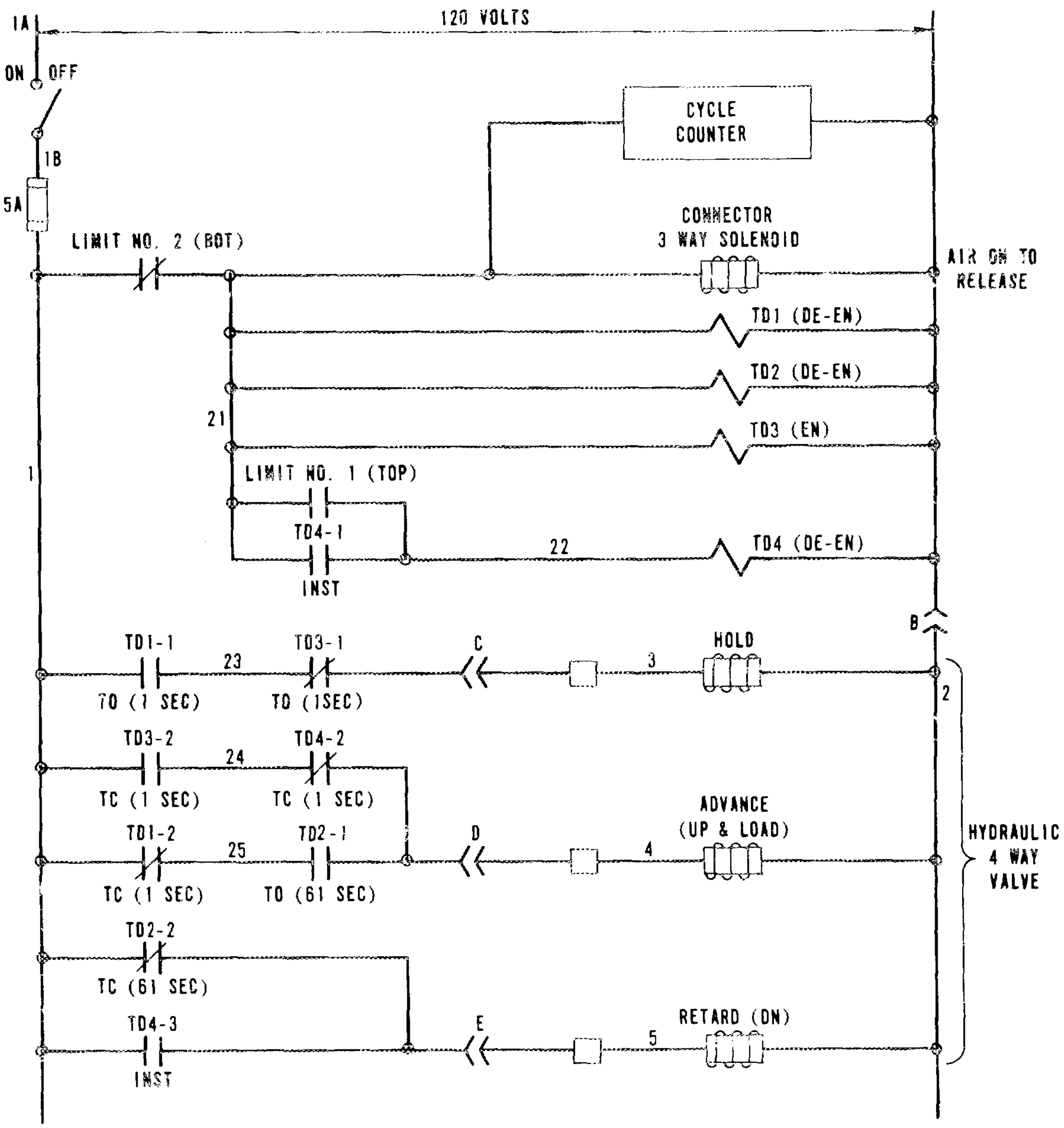

Fig. 5.2. Schematic Diagram of Electrical Controls for Load Tests.

container lifting pin and the connector is in the lifting mode. The hydraulic cylinder raises the connector against the shoulder of the container lifting pin, applying a preset load to the connector for 15 sec. The hydraulic cylinder then lowers the connector until limit switch No. 2 is again contacted to stop the action of the cylinder and pressurize the connector air cylinder, releasing the detent device locking pins from the container lifting pin. The connector is then raised by the hydraulic cylinder until limit switch No. 1 is contacted. Actuation of limit switch No. 1 stops the lifting action of the cylinder and starts the test cycle over again. The completion of one complete test cycle requires approximately 30 sec.

The load testing was performed in two phases. During the first phase, the load was increased from 500 to 6000 lb in 500-lb increments and the test was conducted for approximately 500 cycles for each increment of load. The connector was disassembled and all parts were cleaned and inspected for wear or damage after each load increment stage of testing. The second phase of the load testing consisted of two uninterrupted tests conducted with a load of 4000 lb for approximately 5000 cycles. The first 5000 cycles of testing were conducted with the same neoprene O-rings in the connector that had been used since the beginning of the no-load tests, while the second 5000 cycles of testing were conducted with Viton O-rings in the connector. Viton is the material that will be used for the repository connector because of its greater resistance to radiation damage and high temperature (500°F). Cyclic and load data for both the no-load and the load tests performed on the connector are summarized in Table 5.1.

The results of the load tests were very favorable. Approximately 17,000 cycles (including 1000 with no load) were run after the modifications to the connector (discussed in Subsection 5.1) were made, and none of the components showed any signs of wear, surface fatigue, or damage. The same four springs were used throughout all of the tests, and their spring rate decreased from 21 to 19 lb/in. This decreased value is higher than the original design load of the connector.

Table 5.1. Data on No-Load and Load Tests Conducted on Connector for High-Level Waste Containers

Test Number	Number of Cycles	Accumulated Number of Cycles	Load (lb)	Remarks
1a	740	740	0	Disassembled for inspection
1b	260	1,000	0	↓
1c	600	1,600	0	↓
1d	500	2,100	0	↓
1e	900	3,000	0	Minor modifications made
1f	1000	4,000	0	Disassembled for inspection
2a	514	4,514	500	Disassembled for inspection
2b	554	5,068	1000	↓
2c	510	5,578	1500	↓
2d	520	6,098	2000	↓
2e	585	6,683	2500	↓
2f	560	7,243	3000	↓
2g	555	7,798	3500	↓
2h	534	8,332	4000	↓
2i	500	8,832	4500	↓
2j	600	9,432	5000	↓
2k	510	9,942	5500	↓
2ℓ	515	10,457	6000	Disassembled for inspection
3a	5050	15,507	4000	Disassembled for inspection
3b	5225	20,732	4000	O-rings changed to Viton

6. FUTURE TESTS

Additional tests are planned to further evaluate the performance of the connector for high-level waste containers. These include remote testing, blind grappling, pool testing, and heat testing.

Remote tests of the connector will be conducted in an existing ORNL hot cell, and the existing cell crane, manipulators, and viewing facilities will be used in these tests. The tests will be conducted to check out the remote operation of the connector, attachment and removal of the connector to and from the cell crane, configuration of the air line, removal of the connector from a waste container when the air line is damaged, and the general handling of a waste container mock-up from a cask to a hoist cage. Performance of these tests will require that the existing hot cell be mocked up to closely resemble the transfer cell now envisioned for a repository and a mock-up of a waste container with the desired weight. Designs will be developed for attachment of the connector and air supply line to the cell crane and for removal of a connector with a damaged air line.

Blind grappling tests will be conducted to develop procedures and check out concepts for waste retrieval. Operation of the connector will be evaluated for removal of the waste container mock-up from a hole 7 to 8 ft deep. These tests will probably be performed in the existing hot cell used for the remote tests in order to have access to the hoist.

Pool tests will be performed on the connector to evaluate its underwater operability in spent-fuel reprocessing plants. Heat tests will also be performed on the connector to determine the effects of heat radiated and transmitted from high-level waste containers to the connector. These tests will be performed by attaching the connector to the lifting pin of a waste container mock-up that contains a heat source.