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REMOTE MAINTENANCE DEVELOPMENT
JULY 1975 – JULY 1976

Allied Chemical
IDAHO CHEMICAL PROGRAMS
IDAHO NATIONAL ENGINEERING LABORATORY
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Editor

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ABSTRACT

The results of the second year's efforts on remote handling development and studies for remote maintenance of failure-prone areas of the New Waste Calcining Facility (NWCF) are presented. Test arrangements and results for specific viewing situations and component remote installation and removal in the Remote Maintenance Development Facility (RMDF) and component material evaluations are discussed.

SUMMARY

For approximately 2 years Allied Chemical Corporation, Idaho Chemical Programs has maintained a program at the Idaho Chemical Processing Plant (ICPP) for developing remote handling techniques for the remote maintenance areas of the NWCF. This report covers the second year of this effort, primarily with full-sized mockups and equipment in the recently completed RMDF. Components tested and evaluated included several sizes of valves, pumps, airlifts, filter housing, liquid sampler, flanges, electrical connector, and the calciner nozzle.

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I. INTRODUCTION

With the ever-increasing effort to reduce both individual and total plant personnel radiation exposure to "as low as reasonably achievable" (ALARA) levels, the development and use of remote maintenance, as opposed to direct or contact maintenance, is becoming increasingly important. This report covers the second year's effort in developing new equipment and remote handling techniques for the NWCF at the ICPP. The first year's effort was reported by R. T. Jacobs in ICP-1081[1].

The RMDF was completed in the fall of 1975 and has been used extensively with full-scale mockups in the second year's effort.

II. OBJECTIVES

The primary objective of the NWCF remote maintenance development effort is to reduce both individual and total plant personnel radiation exposure to ALARA levels during repair or replacement of failed plant equipment. In most cases the failed equipment will be remotely replaced rather than repaired. The removed equipment will be decontaminated remotely and repaired by direct maintenance. Only the more failure-prone equipment items, as determined by Waste Calcining Facility (WCF) operating experience, will be designed for remote replacement. These include certain valve assemblies, pumps, motors, etc. In addition, a few "marginal" items are being installed with quick-release flanges to reduce the radiation exposure time if replacement should be required after a number of years of operation. Extensive decontamination would be anticipated in these cases before the quick-release flanges were opened and the item was removed and replaced.

III. TEST FACILITIES

The mockup and testing of all remote maintenance development items during the second year was carried out in the RMDF (Figures 1 and 2) located in the Materials Testing Reactor Building. The facility consists of two separate test areas--one equipped with master-slaves, an overhead bridge crane, and a bridge-mounted manipulator, and the other equipped with a wall-mounted manipulator and an overhead crane.

Figure 1 shows a view of the master-slave area which is designed to simulate a hot cell having an area about 15 ft long by 20 ft wide by 15 ft high. The three mocked-up wall sections each contain a pair of manipulators and a mock viewing window, and they are mounted on heavy-duty castors for flexibility of equipment arrangements. The bridge-mounted manipulator that has been purchased for this area will be installed on the support structure above the bridge crane. This area will be used to simulate all the NWCF cells where remote handling is done by master-slave manipulators, i.e., the calciner cell, flowmeter cubicle, off-gas cell, filter handling cell, and decontamination cell.

Figure 2 shows a view of the wall-mounted manipulator area. This area simulates the NWCF valve corridor and is approximately 40 ft high, 10 ft wide, and 60 ft long. The valves are located on the wall opposite the manipulator and are readily accessible for remote changeout studies and development. Two portable simulated viewing windows are also located on the manipulator side of the corridor and may be positioned at either of the two operating corridor elevations for viewing studies. TV units are also used as a part of the viewing and changeout studies and consist of both normal and three-dimensional TV. The 3-D camera has remote pan, tilt, and zoom capabilities for closeup viewing of specific operations. The normal TV camera will be used for area surveillance.

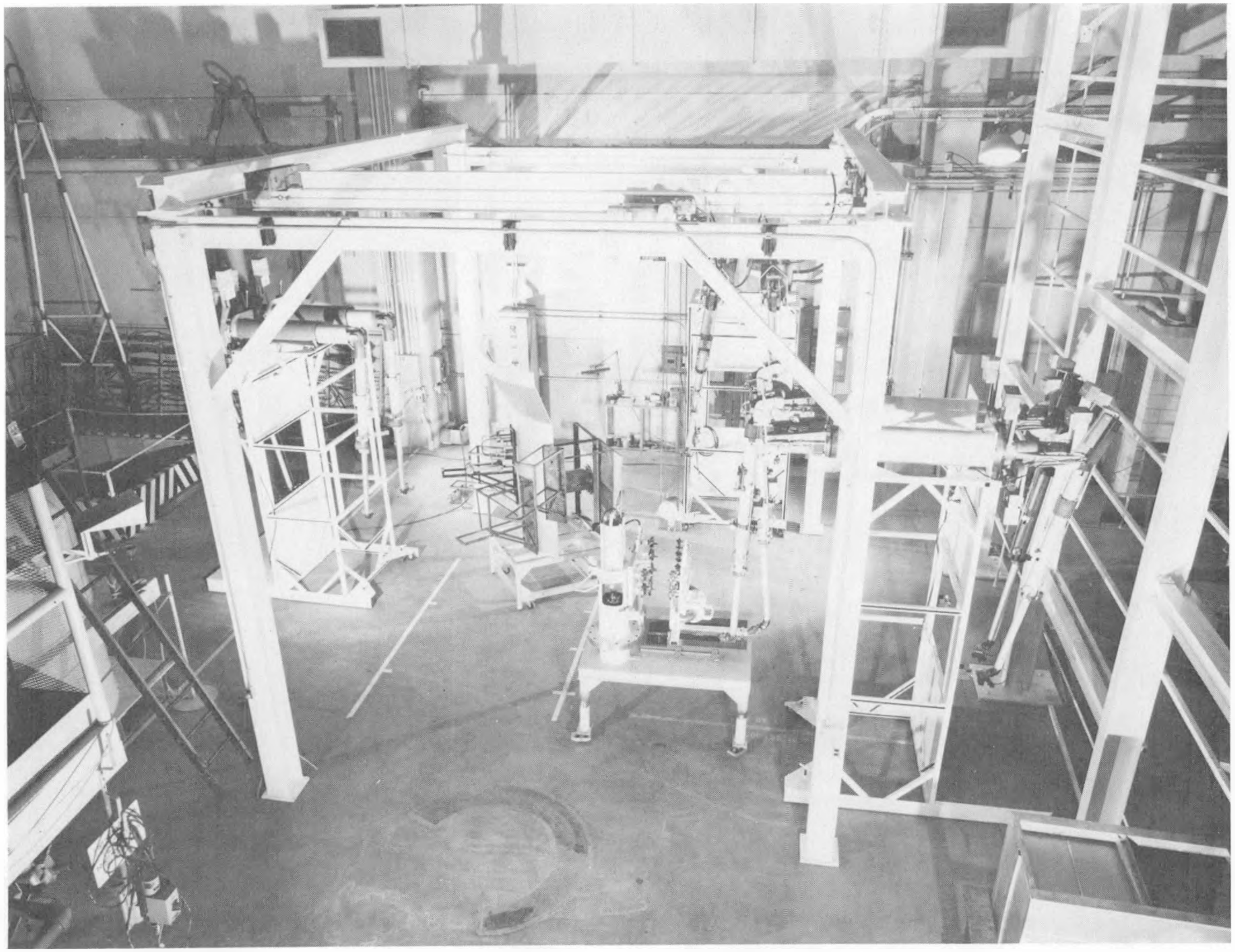


Fig. 1. Master-slave area.

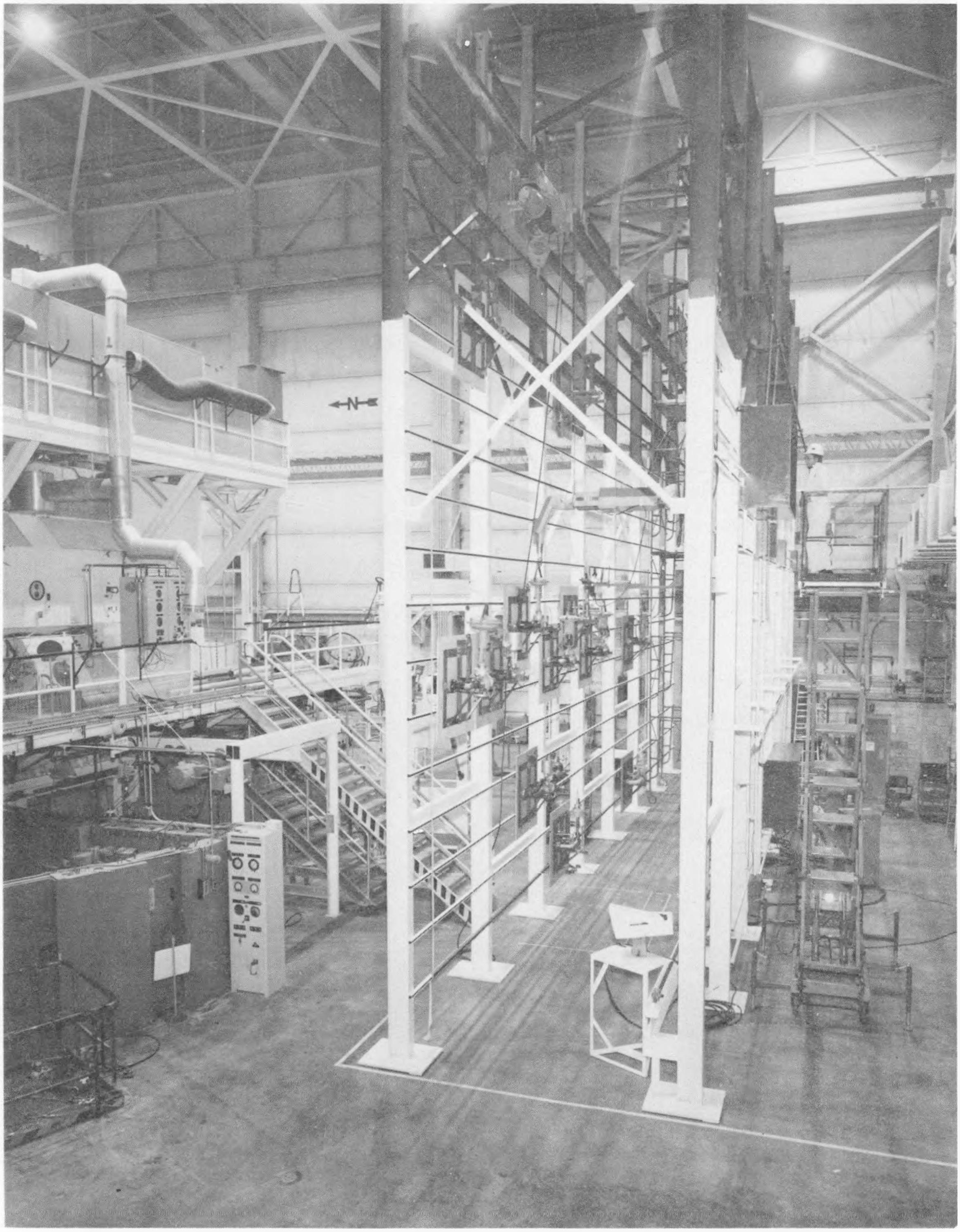


Fig. 2. Valve cubicle mockup.

IV. DEVELOPMENT

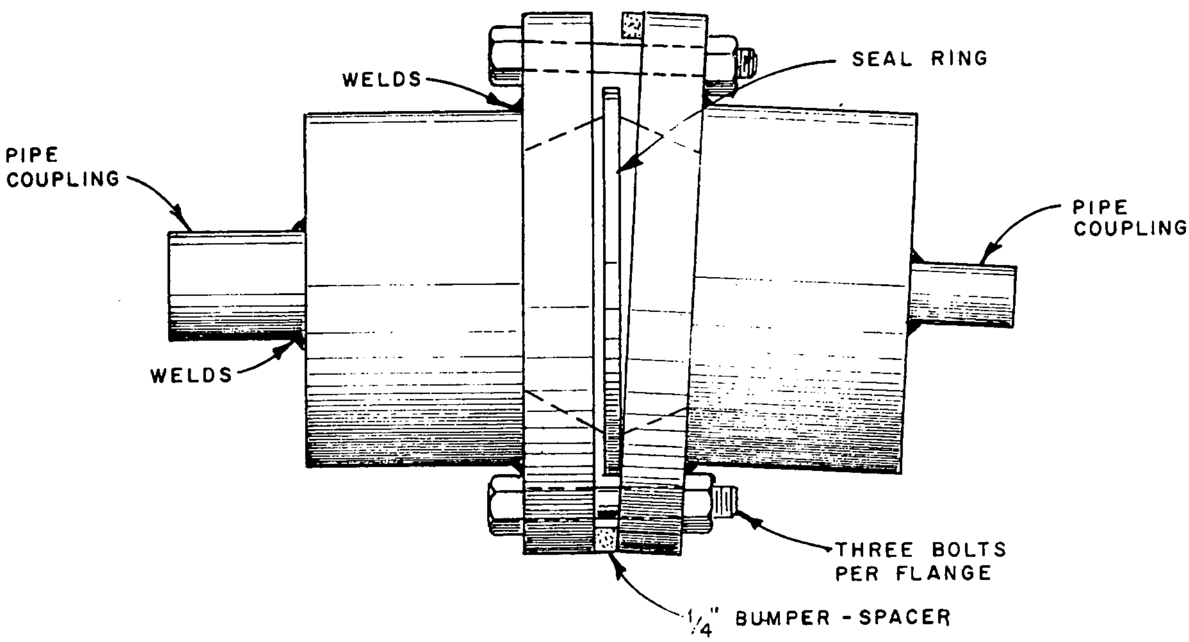
Developmental work continued on several items started during the first year, and a number of new items were added. The new items included a process off-gas filter housing, an airlift, and a liquid sampling system. This section presents a discussion of the tests, results, and progress.

1. KINEMATIC-GRAYLOC FLANGE

Leak tests were performed with 1-1/2- and 3-in. Kinematic-Grayloc flanges, using a Grayloc seal ring between the flanges, and 110-psi water pressure. Tests were made with the flanges in the parallel position and the "fully cocked" position. To effect the "fully cocked" position, one flange bolt was tightened until the "bumper" spacer touched; then the other two bolts were tightened (see Figure 3). Neither flange position (parallel or cocked) leaked at an internal pressure of 110 psi, even though extremely low bolt torques were applied (the 1-1/2-in. flange bolts were torqued to 10 ft-lb, the 3-in. flange bolts to 15 ft-lb). Because the pressures anticipated in the NWCF process lines will be considerably less than the 110-psi test pressure, these units proved entirely satisfactory from a pressure standpoint. However, further evaluation of the Grayloc seal indicated that it was designed to seal by deflection of the seal lip and that each seal ring size required a certain minimum loading to deflect the lip. For example, according to Gray Tool Company data, the minimum force required for the 1-1/2-in. flange was 13,410 lb and for the 3-in. flange, 30,000 lb. Lower compressive loads on the seals result in a line (or narrow edge) seal rather than an area seal, which is not compatible with the NWCF corrosion requirement of 1/8 in. in 20 years. To achieve the required forces, the torque required for each of the three 3/4-in. bolts was 56 ft-lb for the 1-1/2-in. flange and 130 ft-lb for the 3-in. flange.

Using these forces, the following comparison was made:

(1) The stresses in the flanges and bolts were calculated in accordance with Section VIII, Division 2 of the ASME Boiler and Pressure Vessel Code[2].



NOTE: In the cocked position, the two flanges come together so that one bumper-spacer is touching before the other two bolts are torqued.

Fig. 3. Kinematic-Grayloc flange pressure test setup with flanges in cocked position.

(2) These stresses were compared with stresses in 150- and 300-lb weld neck flanges meeting the requirements of ANSI Standard B16.5[3], with the stress allowances calculated in accordance with Section VIII, Division 1 of the ASME Code[4] for a design temperature of 300°F.

The results of the analyses indicated that when the minimum force required to energize the seal ring was applied, the flange and bolt stresses in all of the flanges larger than 1-1/2-in. pipe size exceeded those allowed by the ASME Code. The three-bolt flanges were then redesigned to meet the necessary stress requirements, but this resulted in flange designs which were too large and heavy to meet the remote handling requirements. For example, a flange for a 4-in. pipe size had an estimated weight of 40 lb per flange, while a 6-in. flange was estimated at 97 lb and would have required six 1-1/8-in. bolts rather than the three 3/4-in. bolts previously used.

A final problem with metal-to-metal seals that became apparent during these tests was the need to be able to remotely refurbish the seal surface. This ability to refurbish remotely has not been developed or proven to date.

These developments indicated that other sealing methods (elastomers, etc.) should be investigated to reduce the seal pressure requirements. Three elastomers (Royalene, Nordel, and Viton[a]) which are noted for their comparatively high radiation resistance were investigated, examined, and chemically tested.

Royalene was rejected due to leaching and swelling. Slight leaching was noted in 5 M HNO_3 at 20°C and would be expected to continue and perhaps accelerate after long periods of time. The material also became very sticky in boiling 5 M HNO_3. Nordel was rejected due to chemical degradation. After 48 hr in boiling 5 M HNO_3, the material left a very sticky matrix. Viton showed good to excellent resistance to boiling 5 M HNO_3 with only slight swelling and might have been an acceptable gasketing material. However, one other material (Grafoil[b]) was also tested in a 5 M HNO_3 solution and appeared to be impervious to this solution. Based on this encouraging information, Grafoil was then tested in the following solutions, all of which are typical of NWCF solutions: 0.55 M oxalic acid, 2 M nitric acid - 0.03 M potassium permanganate, and 1 M nitric acid - 0.3 M hydroxylamine sulfate.

For these tests, Grafoil washers were placed between stainless steel washers on a nut and bolt assembly that was then torqued to 60 ft-lb. Four such assemblies were prepared, and one assembly was immersed and boiled for 30 days in each of the above solutions. As can be seen in Figure 4, which shows the disassembled assemblies at the end of the test, there were no discernible corrosion or chemical effects on the Grafoil. However, as shown in column B of Figure 4 (the oxalic acid test), the Grafoil delaminated on disassembly. This is presumed to be because chrome oxalate bonded the gasket to the washer.

[a] Royalene - the registered trademark of Universal Chemical's ethylene propylene terpolymer.
Nordel - the registered trademark of du Pont's ethylene propylene.
Viton - the registered trademark of du Pont's fluorelastomer.

[b] Grafoil - the registered trademark of Union Carbide Company's 100% graphite.

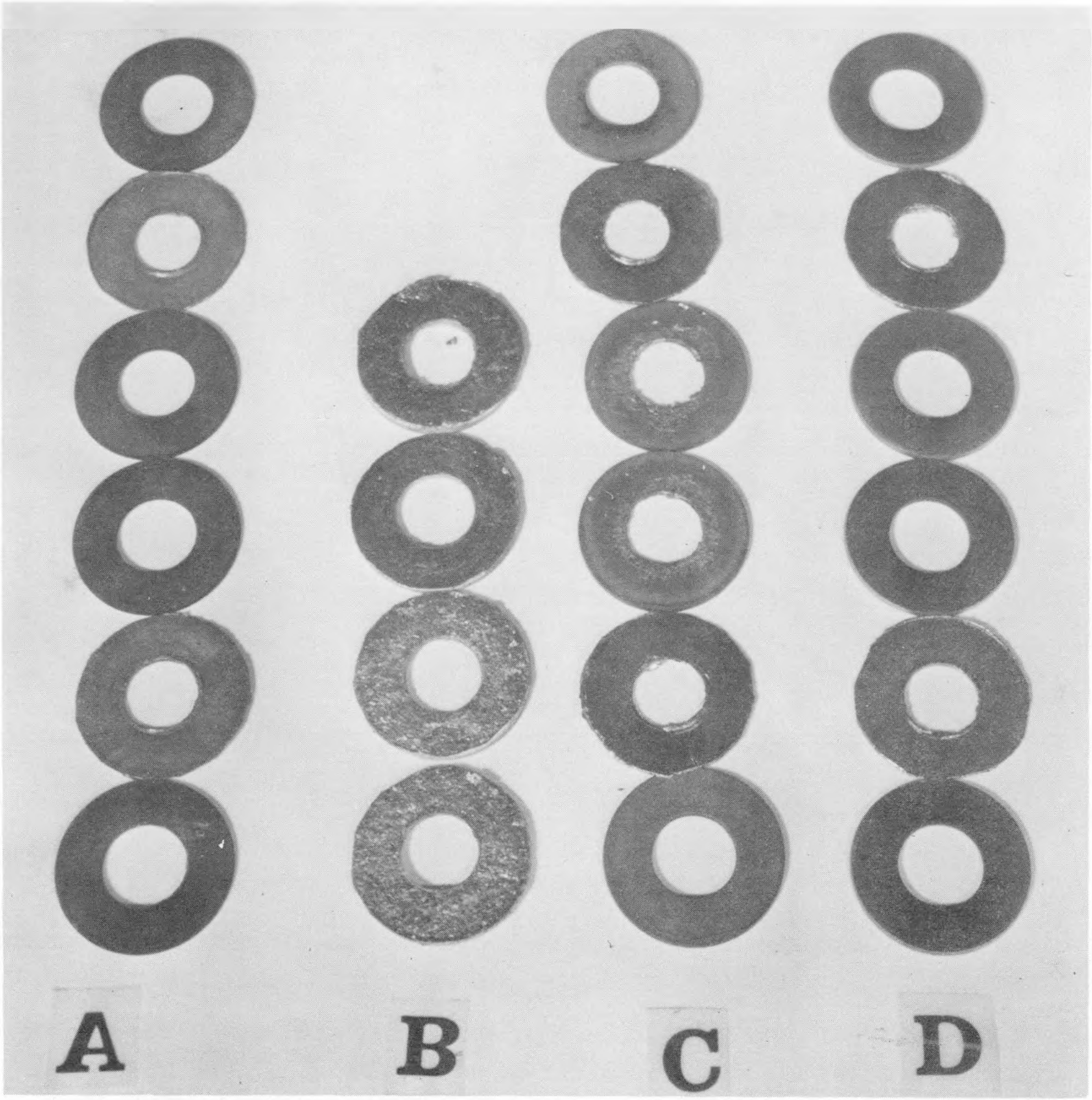


Fig. 4. Grafoil and stainless steel washers after 1 month of boiling.

Vendor data also indicate that Grafoil is impervious to almost all chemicals except strong solutions of oxidizing acids such as nitric and sulfuric. Based on this information, the decision was made to convert the liquid Kinematic-Grayloc flanges to Kinematic-Grafoil flanges with full-face gaskets. An additional step in designing the NWCF fluid connectors concerned the materials of construction for the nuts and bolts. These were examined for galling potential, which is important because of the possible difficulty in remotely repairing or replacing a galled assembly.

The following table summarizes the results of the galling tests made with unlubricated 3/4-in.-NC nuts and bolts.

Material Combination			
Bolt	Nut	Torque (ft-lb)	Galling Observed (yes - no)
Type 17-4 PH stainless steel	Type 17-4 stainless steel	150-200	yes
Carbon steel Grade 5	Carbon steel Grade 5	200	no
Type 316 stainless steel	Type 316 stainless steel	200	no
Nitronic 60 stainless steel	Nitronic 50 stainless steel	200	no
Type 440C stainless steel	Type 440C stainless steel	200	no

NOTES

1. The above set of tests was repeated twice with the same results, except that the Type 17-4 PH galled at 150 ft-lb the first time and at 200 ft-lb the second time.
2. The test consisted of torquing the bolt and nut 10 times and then inspecting the threads for signs of galling.
3. Both the Type 17-4 PH and the Type 440C stainless steels were hardened by heat treating.
4. The carbon steel was high-strength Grade 5.
5. The Type 316 stainless steel nuts and bolts were commercial grade.
6. The Nitronic metals are not hardenable by heat treating and were used as fabricated.
7. The nuts were of different thicknesses as tabulated below:

1/2 in. thick - Type 17-4 PH stainless steel
Type 440C stainless steel
Nitronic 50 stainless steel
5/8 in. thick - Type 316 stainless steel
3/4 in. thick - carbon steel

The Armco Steel Corporation has also made galling tests on similar materials; the results are available in Product Data Bulletin S-56A[5]. Table 1 includes data from the pamphlet and additional data from personal contacts at Armco. The Armco tests were made with a Brinell hardness tester by applying a deadweight load on two flat polished surfaces and slowly rotating the surfaces 360°. The surface was then inspected for galling streaks.

TABLE 1

ARMCO GALLING TESTS

Stainless Steel Couple (Hardness - BHN)		Galling Pressure (psi)	Wear Factor[a]
Nitronic 60 (213)	vs. Type 17-4 PH (313)	50,000+	4.3
Nitronic 60 (205)	vs. Type 316 (150)	50,000+	
Nitronic 60[b]	vs. Type 316 (150)	38,000	
Nitronic 60 (205)	vs. Nitronic 50 (205)	50,000+	3.5
Nitronic 60 (205)	vs. Type 440C (560)	50,000+	
Nitronic 60 (205)	vs. Nitronic 60 (216)	50,000+	2.8
Nitronic 60 (205)	vs. Type 304 (140)	50,000+	
Type 304 (140)	vs. Type 316 (150)	2,000	10.5
Type 17-4 PH (311)	vs. Type 304 (140)	2,000	
Type 17-4 PH (415)	vs. Type 316 (150)	2,000	18.5
Type 440C (560)	vs. Type 440C (604)	11,000	3.8
Type 301 (169)	vs. Type 440C (560)	3,000	
Type 410 (352)	vs. Type 316 (150)	2,000	
Type 17-4 PH	vs. Type 17-4 PH	2,000	52.8

[a] The wear factors are weight loss in mg after 1,000 cycles on a Taber metal abrader machine.
[b] Data obtained from Armco Product Data Bulletin S-56A.

The data show that using Nitronic 60 with almost any other type of stainless steel improves galling resistance. The corrosion resistance of Nitronic 60 is reported to be comparable to Type 304 stainless steel, and yield strength is almost twice the yield strength of Type 304. Consequently, the recommendation has been made that Nitronic 60 stainless steel bolts be coupled with either Type 304 or Nitronic 50 stainless steel nuts for NWCF fluid flange connections.

As an additional precaution, the nut on the facility flanges will be placed in a cage (Figure 5) rather than tack-welded. The nut cage will be open so that should a nut gall or cross-thread, it could be removed and replaced. Each nut will have a wire tack-welded to the top side with a loop in the end to facilitate remote removal and replacement.

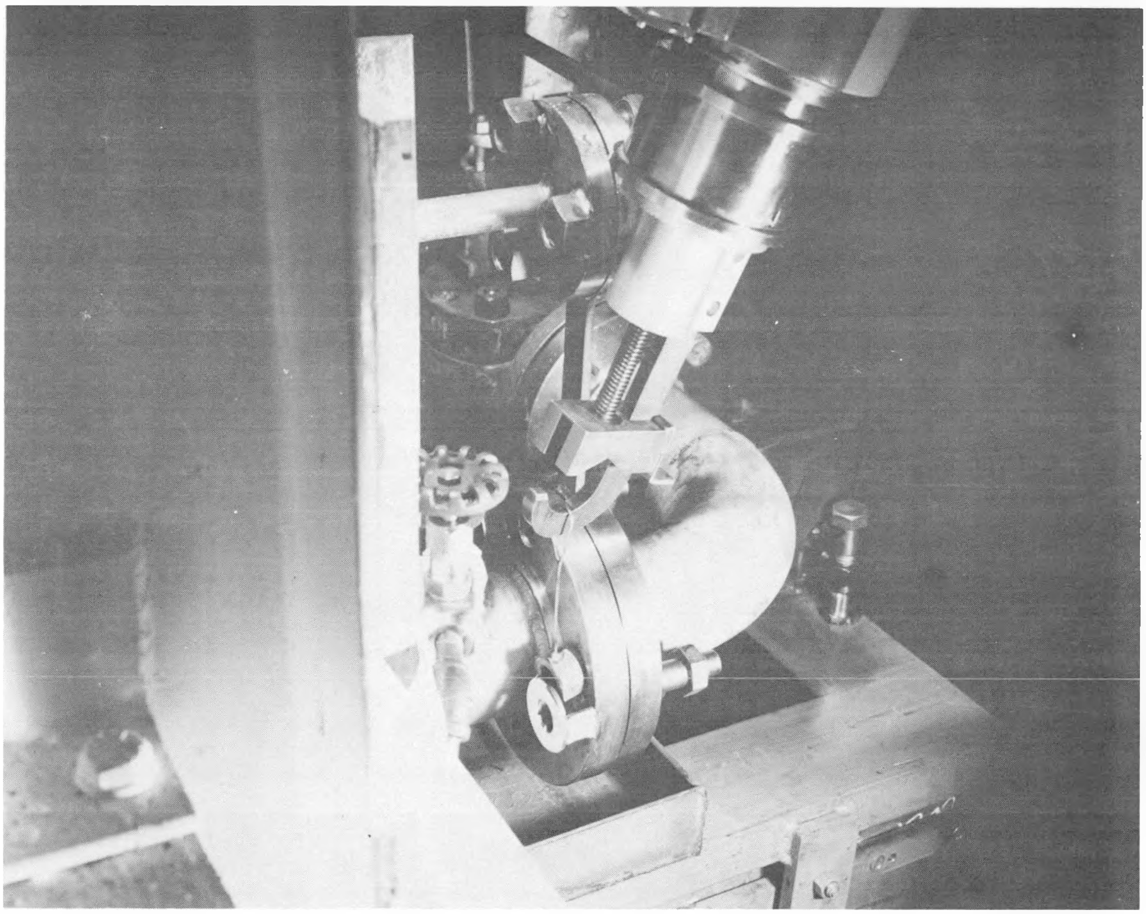


Fig. 5. Caged nut.

The final step in the NWCF fluid connector test program was designing the face of the two flanges.

The part of the flange face in the bolt circle area was undercut to reduce the seal area where the Grafoil gasket is compressed. This increases the load pressure (psi) on the seal area, which in turn increases the pressure necessary to cause leakage. A small raised-face rim was left on the flange edge so the two flange faces will be self-flattening. This is a desirable feature, especially with remote handling where the operator has no feel and close visual inspection is impossible. The Grafoil gasket is held in place both by the bolts which penetrate the gasket and by silicone rubber cement placed in the recessed part of the removable flange between the boltholes. In addition, Grafoil with an adhesive backing is available.

As part of the test program, a Kinematic-Grayloc-Grafoil flange with a Grafoil-covered Grayloc seal ring was also considered, but it was rejected as being much more complicated than the modified raised-face flange described above.

Based on these series of tests, the following recommendations concerning the NWCF fluid connector design have been given to the architect-engineer (A-E), Fluor Engineers and Constructors, Inc., to assist them in their design efforts:

(1) A standard-OD-size flange should be used for all 1/4- to 1-in. nominal pipe size connections, and a second standard-OD-size flange should be used for all 1- to 3-in. nominal pipe size connections--thus allowing valve assemblies of several sizes to be fabricated from the same pattern or welding assembly fixture.

(2) All bolts for both flanges should be standardized to minimize impact wrench socket changes, or as a minimum, the boltheads should be made the same size.

(3) All flanges should be full-face with flat Grafoil gaskets.

2. QUENCH TANK PUMP DISCONNECT

Figures 6 and 7 show the quench tank pump direct maintenance arrangement in the WCF. The six fluid connections, the two thermocouple connections, and the electrical power connector to each of the two pump motors require manual unbolting prior to removal of the pump for repair or replacement.

The purpose of the quench tank pump disconnect mockup was to develop an arrangement by which the pump could be disconnected and removed remotely without exposing personnel to radiation. This mockup was fabricated and tested

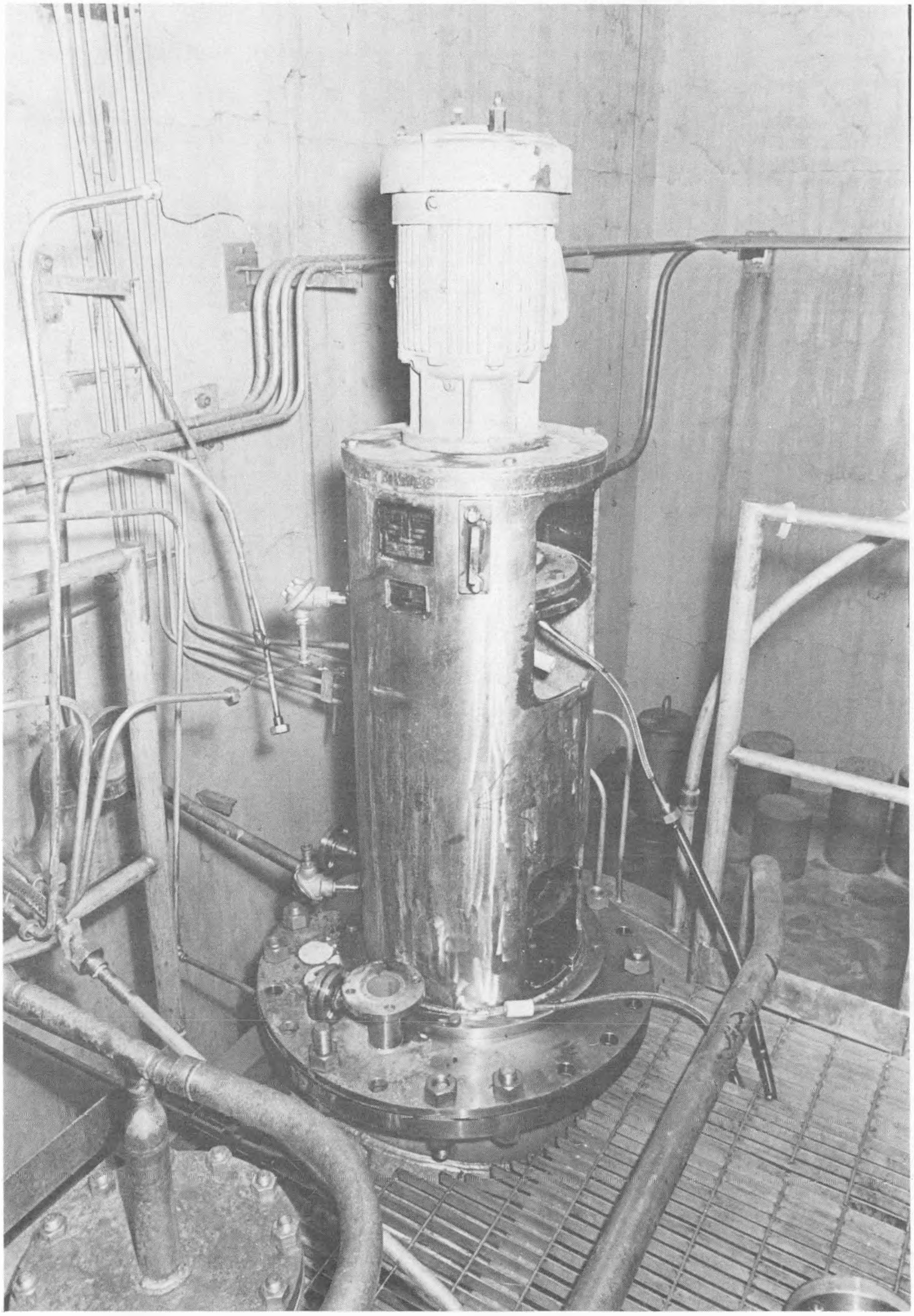


Fig. 6. WCF quench tank pump.

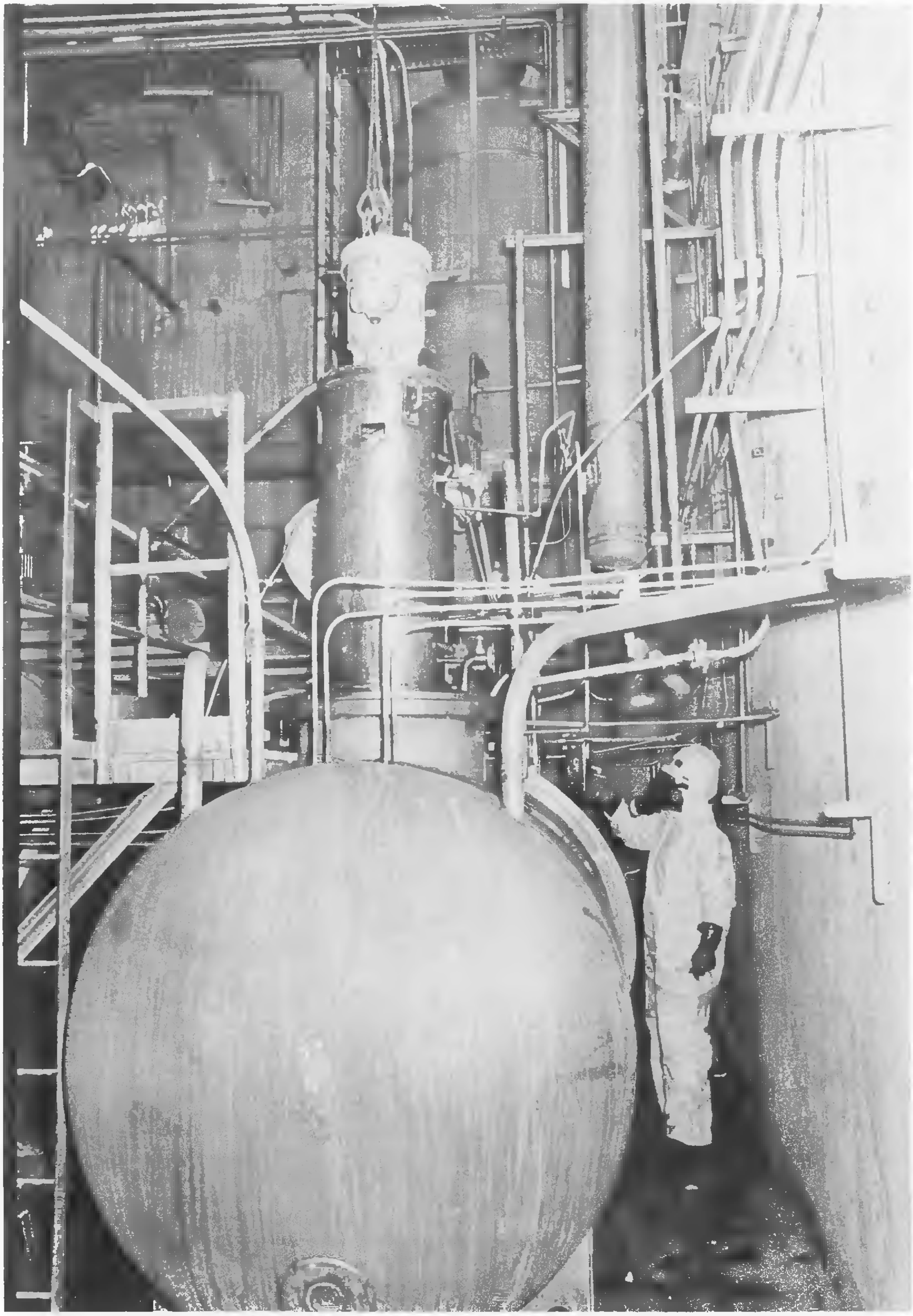


Fig. 7. WCF quench tank.

several times, with improvement being incorporated into each model. The final mockup is shown in Figure 8, where the top of the table represents the top of the 5-ft-diameter quench tank. The fluid connections are Kinematic-Grafoil flanges (see Section 1) in the form of jumpers. The complete jumper assembly is guided into place by a cam follower-mounted support platform. The jumper assembly is aligned on the support platform by three self-centering points made of tapered-end bolts which fit into cone-shaped support blocks welded to the support platform. The remote electrical power connector for the pump motor is equipped with a flexible pigtail and a lifting bail (Figure 8). As a result of testing, the lifting bail for the remote electrical power connector was changed from the rigid bail shown in Figure 9 to a flexible cable. This prevented binding on the guide pins during connector removal.

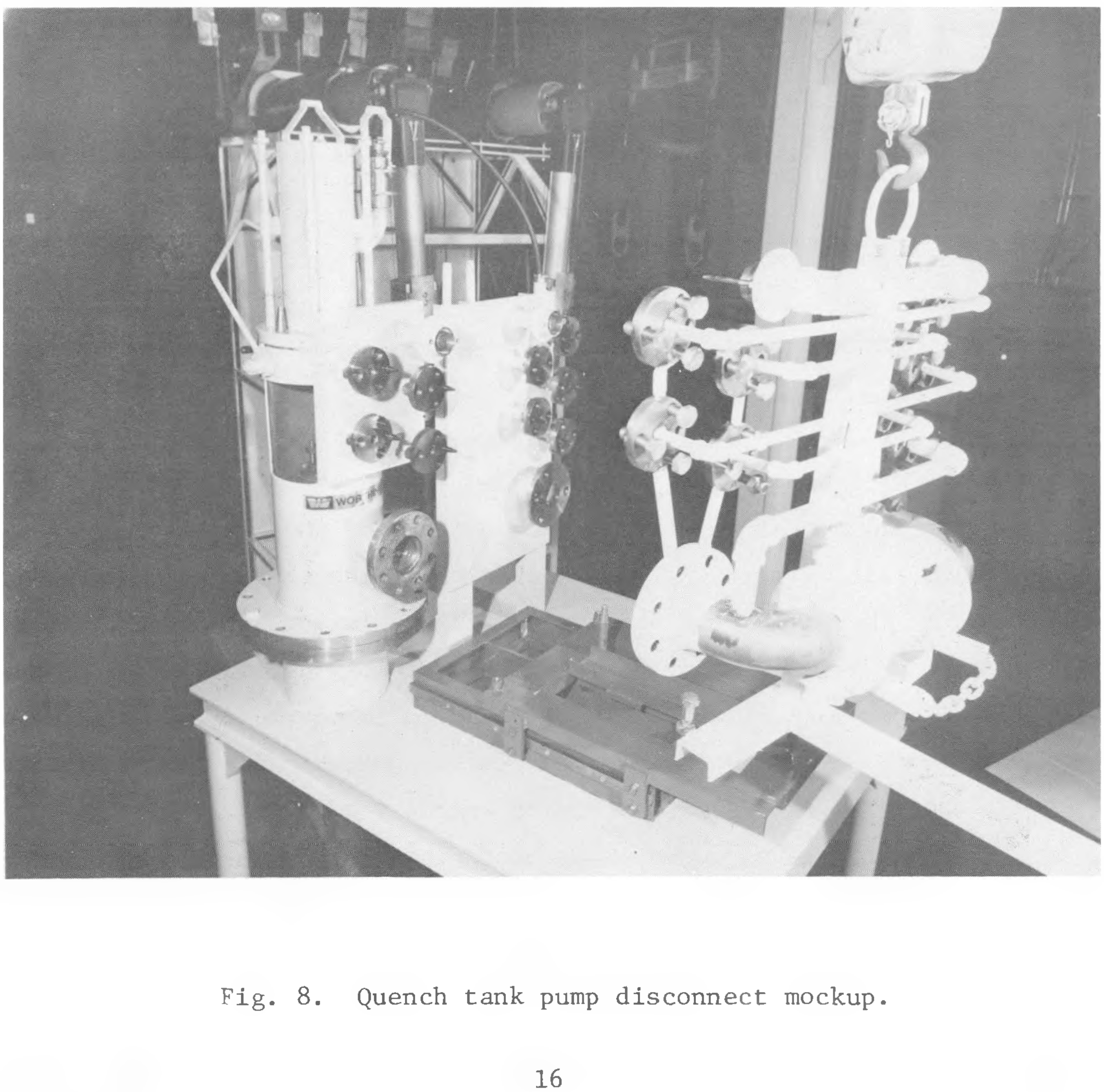


Fig. 8. Quench tank pump disconnect mockup.

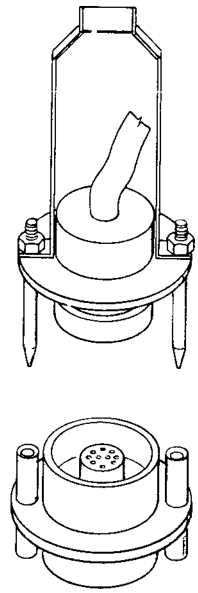


Fig. 9. Electrical connector.

With information from the mockup, Fluor was able to negotiate a subcontract with a pump manufacturer to design a remotely removable pump. When this design is complete, the pump will again be mocked up and tested for remote maintenance and replacement capabilities.

3. SUPPORT AND ALIGNMENT PLATFORMS

Although it is possible to remotely remove and replace a pipe jumper using only a bridge crane and manipulator(s), in doing so there is a risk of damaging the flange seal surfaces or other parts of the jumper by misaligning and/or bumping during handling. To reduce this risk, a platform or other support device should be provided upon which the jumper assembly can be positioned. Such an assembly provides positive assembly positioning during removal and replacement operations and also supports the weight of the assembly while it is in place. Consequently, a support and alignment fixture having two fixed slide rails and alignment pins (primary and secondary) was developed (Figure 10). The secondary alignment pins provide preliminary alignment of the entire jumper assembly prior to engaging the primary (flange) alignment pins with the permanent facility flange holes. The two fixed slide rails provide vertical alignment and overall support. This system worked well for

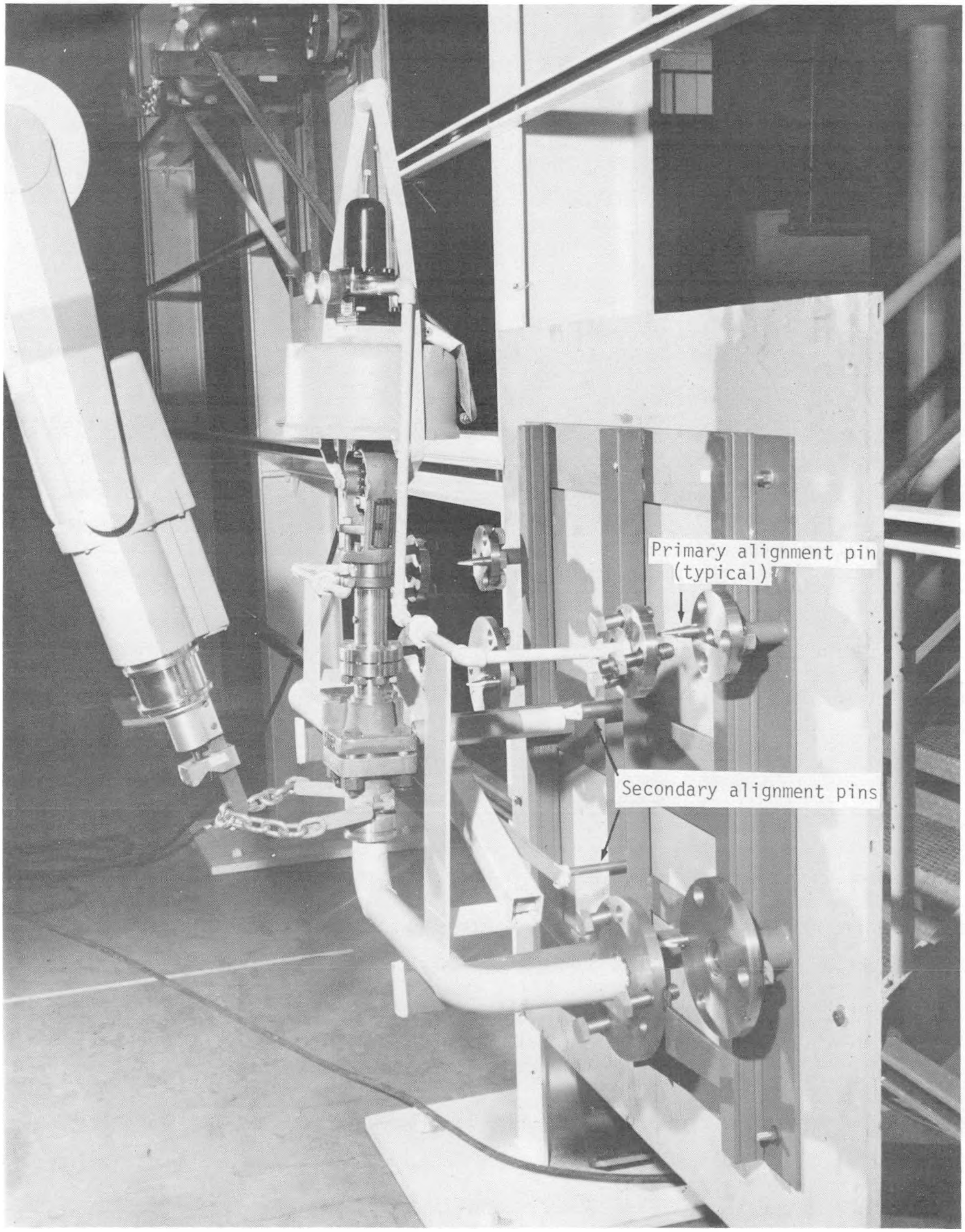


Fig. 10. Pipe jumper.

jumpers up to 2-in. pipe size, including a control or shutoff valve; above 3-in. pipe size, however, the assembly became heavy and difficult to slide. Also, although the flange alignment worked very well, slightly better alignment was needed for engaging the electrical connectors associated with the valves.

To correct these two problems, a support platform was developed which rolled on cam followers and also had cam followers to limit side movement (Figure 11). Figure 12 shows a test platform with a pump, two valves, and a liquidtight electrical connector mounted on it, while Figure 13 shows the pump and valve assembly removed from the platform. Figure 14 shows a second generation of the support platform which has been modified to provide a more compact and simplified construction. This platform has also been provided

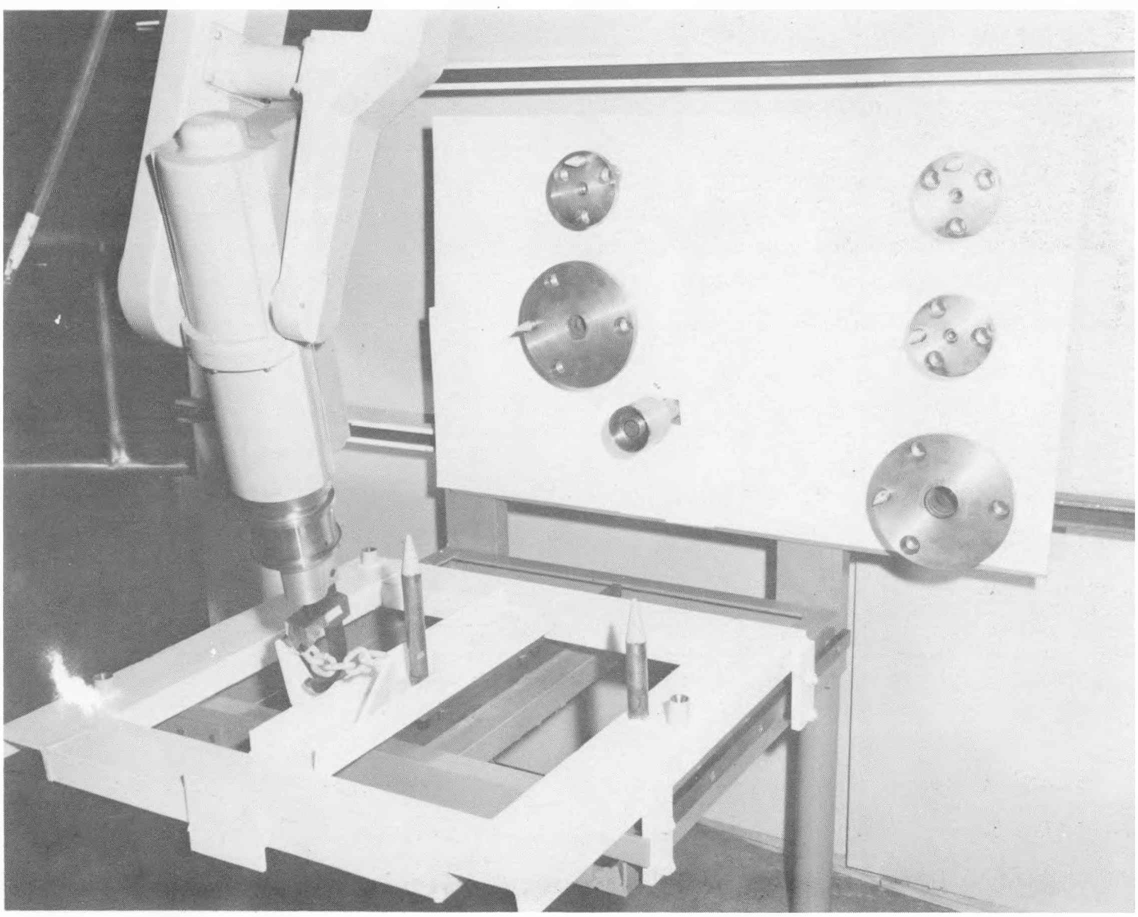


Fig. 11. Support platform.

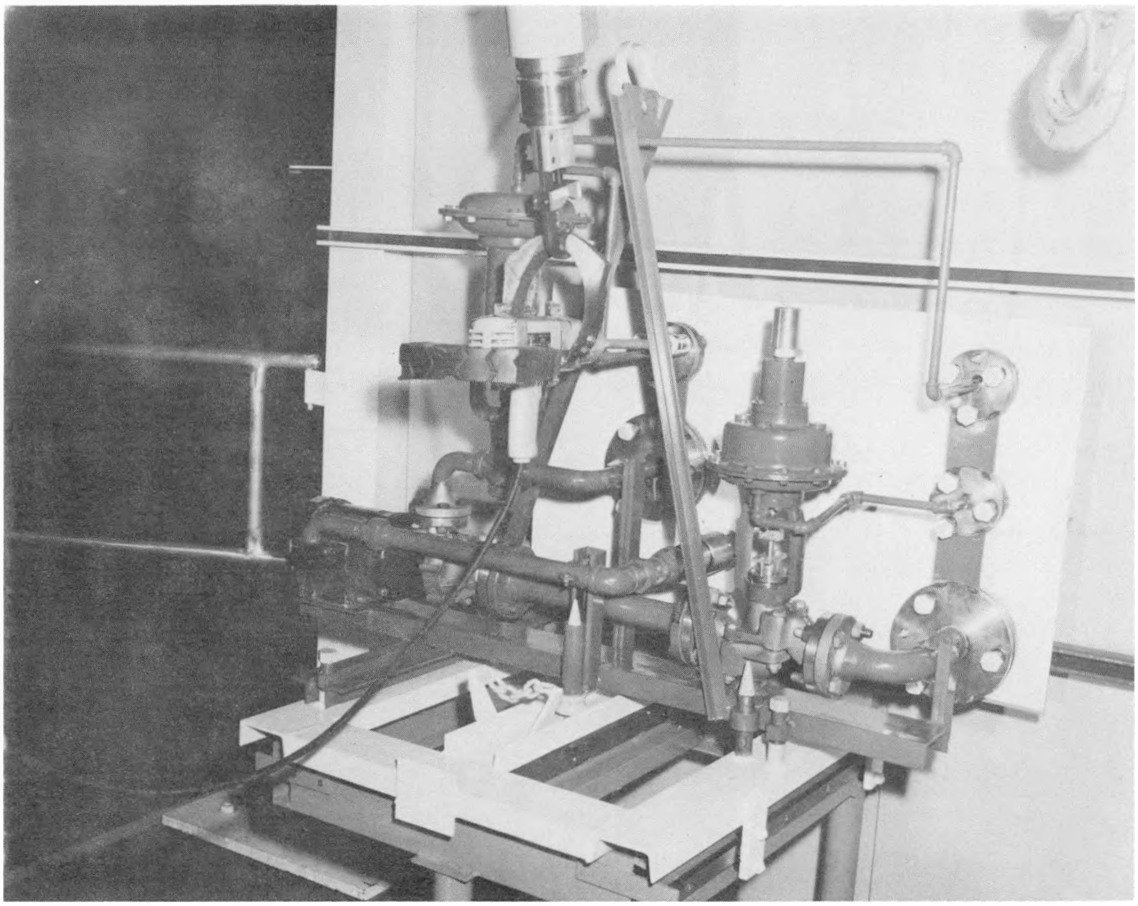


Fig. 12. Support platform with pump and jumper.

with drip trays for any residual liquid present when the flanges are separated. Work is continuing on the cam follower-mounted support platform to achieve a "standard unit".

4. OFF-GAS FILTER HOUSING

Final cleanup of the NWCF process off-gas will be accomplished in four parallel filter units. There will be six filters in each unit, two prefilters and four high-efficiency particulate air (HEPA) filters--arranged so the off-gas passes through three filters in series, a prefilter and then two HEPA filters. The filter units are designed so each of the filters can be isolated and remotely replaced through the use of viewing windows, a wall-mounted

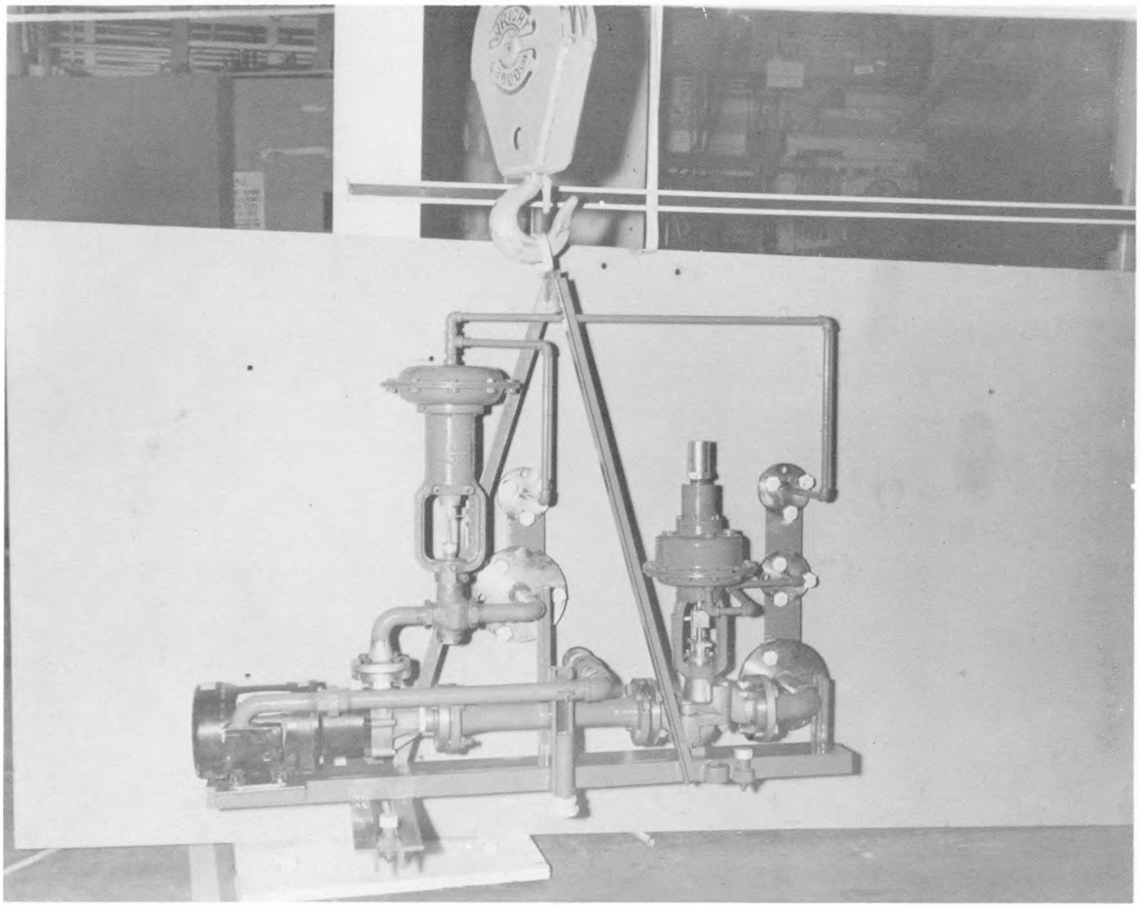


Fig. 13. Pump and valve assembly removed.

manipulator, and an impact wrench. The filters can also be DOP-tested in place.

To eliminate the possibility of off-gas bypassing the filters and to allow for quick changeout, a fluid seal is incorporated into the filter design. The fluid medium is a silicone grease which will not relax or separate but which will flow around and over imperfections. The filter-to-frame seal is effected by a knife edge permanently mounted on the filter housing so that it inserts into a continuous perimeter channel on the face of the filter. The channel is filled with the silicone grease. To change the filters, it is necessary to open the housing, release the filters from the seal, and pull the filters forward so they can be removed for disposal.

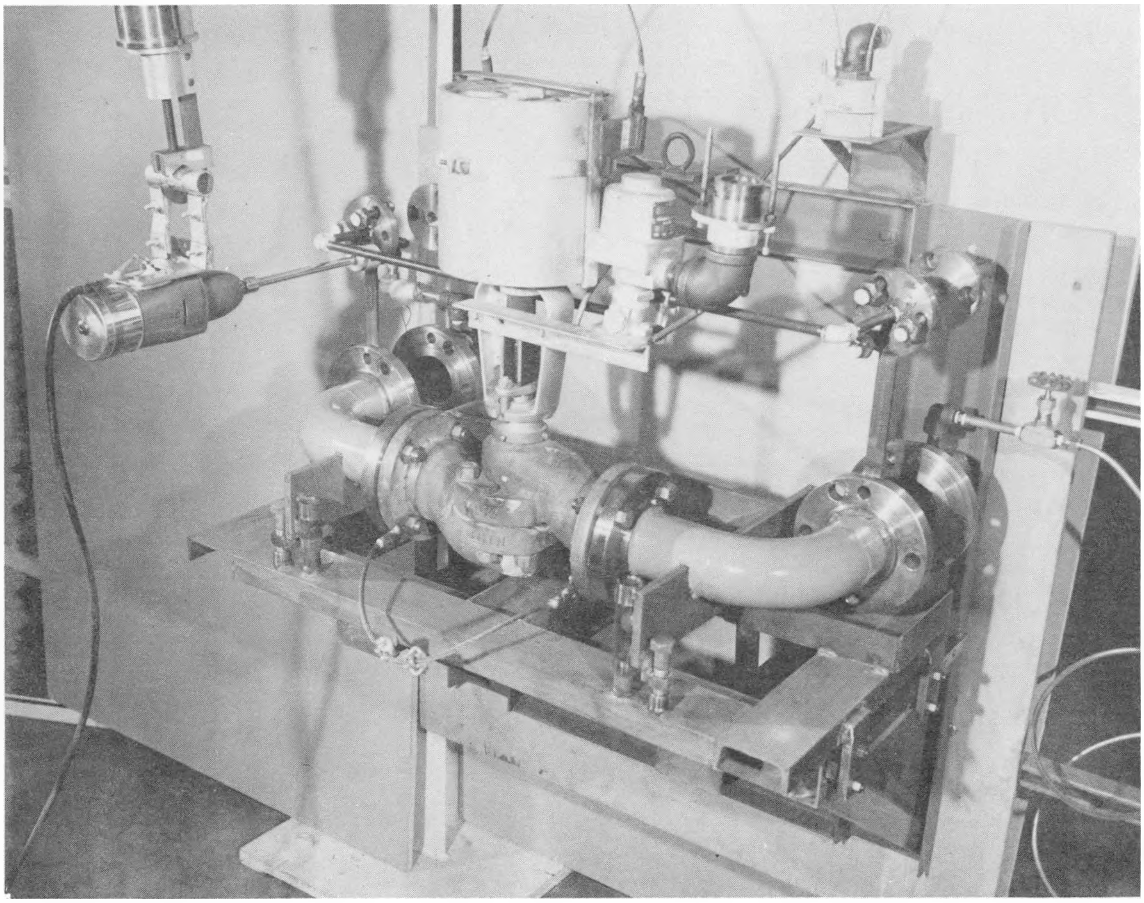


Fig. 14. Revised support platform.

Because of the uniqueness of this system, Flanders Filters, Inc., was asked to assist in the design and fabrication of a prototype unit that could be used to test designs and procedures.

Several modifications and interactions were required to make the unit remotely operable and provide for remote removal and replacement of filters and internal parts. After completion of the modification, which included redesigning the door and hinges so the door could be removed remotely, and fabrication of a filter housing fixture, the equipment shown in Figure 15 was developed. This system and arrangement has proven to be workable, and a full-scale reproduction of one-third of a filter housing (including all appurtenances) is now being fabricated for additional testing. The filter

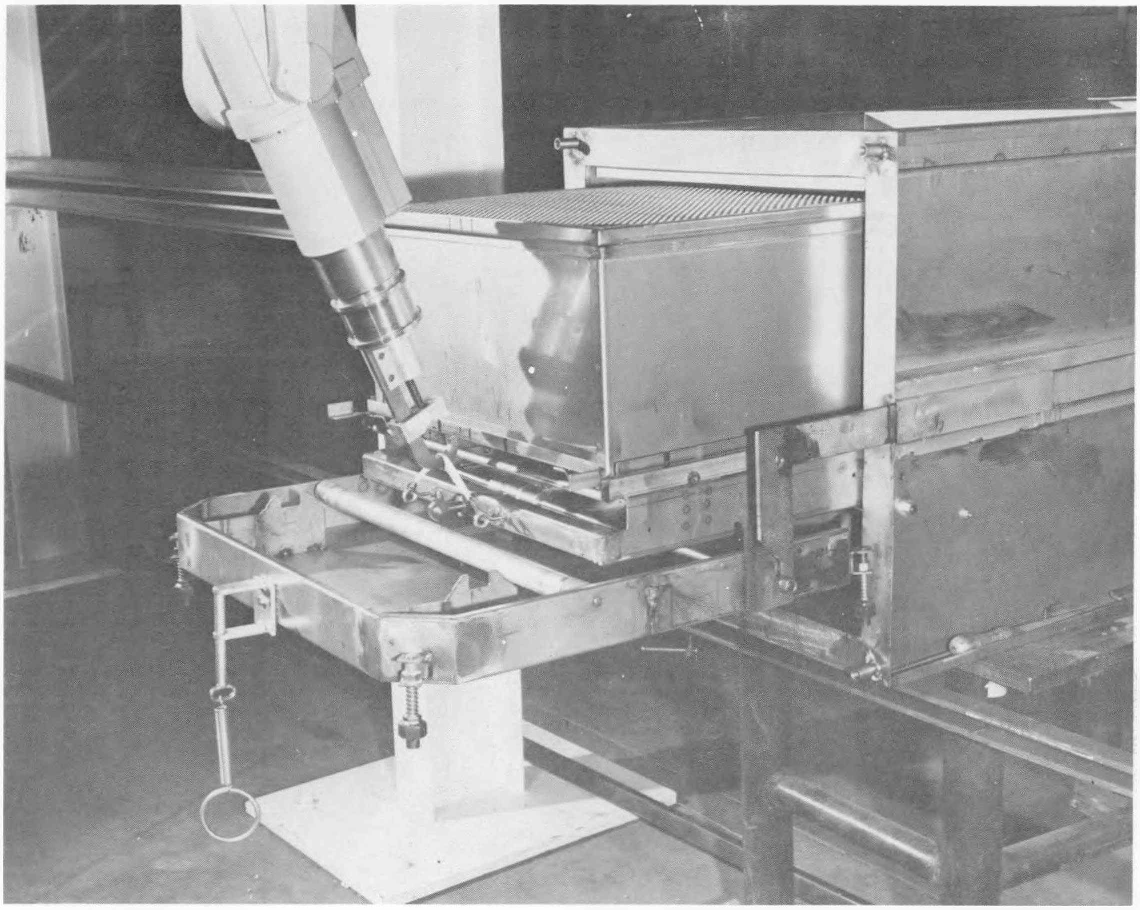


Fig. 15. Filter being removed from housing.

handling fixture developed to remove, replace, and transport the filters is shown in Figure 16. As can be seen, this unit is an ice-tong arrangement with two handles. When one handle is vertical, the fixture is released; when the other handle is vertical, the fixture is closed to carry the filter.

5. CALCINER NOZZLE

Fuel and feed nozzles on the existing calciner have proven to be high-maintenance items, and development of a remotely replaceable unit was given high priority. The criteria for design of these units were as follows:

(1) Remotely removable by impact wrench and master-slave manipulators

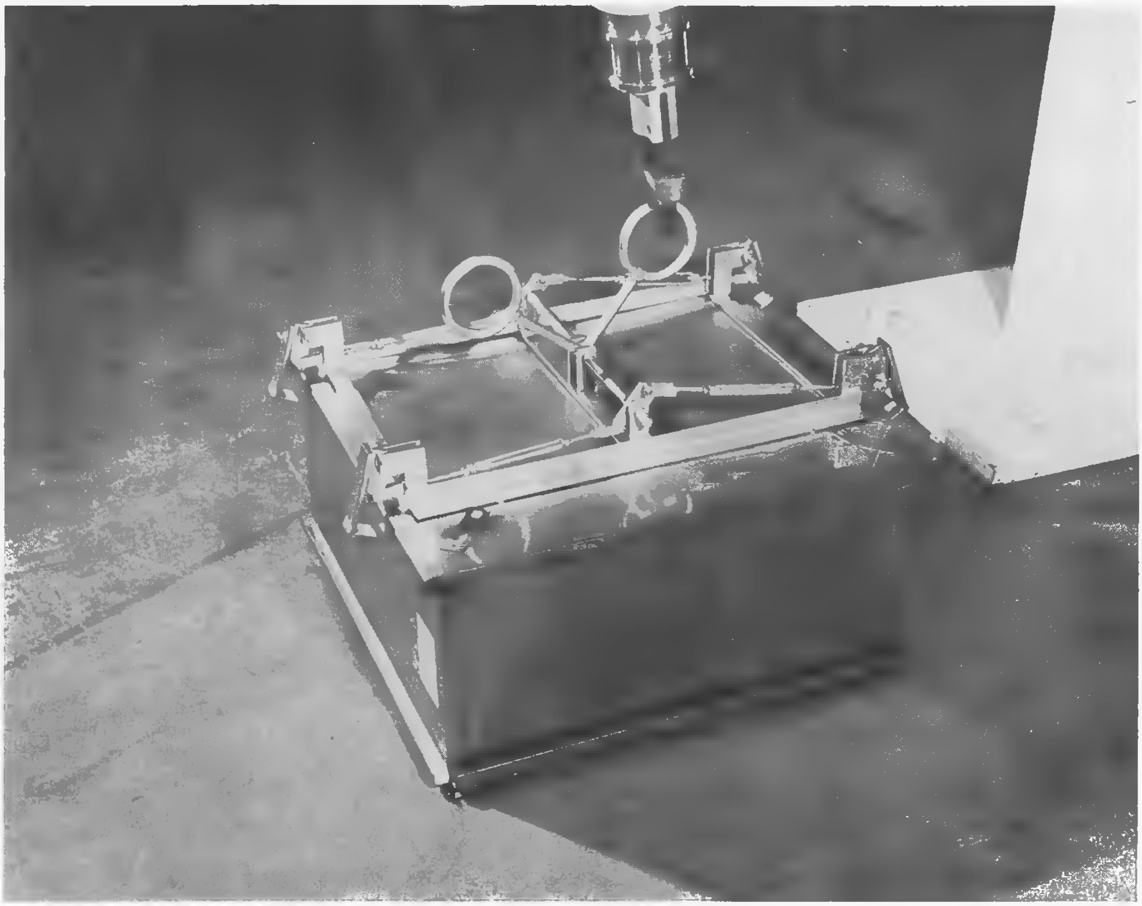


Fig. 16. Filter handling fixture.

(2) Metal-to-metal seal between the nozzle and the calciner vessel

(3) A 2-in. minimum nozzle diameter at the calciner end because of erosion

(4) Internal fuel nozzle design based on the present WCF Type B fuel nozzle

(5) Internal feed nozzle design based on the present WCF modified Spraying Systems Company nozzle

(6) A tapered design to preclude sticking and binding during removal

(7) Feedlines having smooth bends and continuous downward slopes to preclude particle plugging

The basic external design for both the feed and fuel nozzles started with a 2-in.-diameter unit at the calciner vessel end and increased to 2-1/2 in. in diameter 2-1/2 in. from the calciner vessel. The 2-1/2-in. diameter was selected to permit using a 2-1/2-in. Grayloc connector and thus provide the required metal-to-metal seal between the nozzle and the vessel.

The original piping arrangement was similar to the mockup shown in Figure 17, where two three-bolt flanges were used for the liquid and gas lines. However, because of the possibility of having to introduce new (replacement) nozzles into the calciner cell on a routine basis through a 6-in.-diameter tool port, it became necessary to reduce the size of the nozzle assembly. For this reason, a second Grayloc connector was added to the nozzle to allow separation of the nozzle from the "extractable piping". The extractable piping consists of two 180° pipe bends connecting the back of the nozzles to the fuel-oxygen or the feed-air piping. Since plugging normally occurs in the nozzles and not in the piping, the piping did not have to be sized to pass through the tool port. A Grayloc connector was also added at the upper end of the extractable piping for ease of remote operation and alignment. The second and third Grayloc connectors are 2 in., dual port, with two seal rings in each connector--one for the liquid and one for the gas. To reduce the weight of the nozzle, the Grayloc connector was reduced from 2-1/2 to 2 in., and the body of the nozzle between the two Grayloc connectors was reduced from 4 to 2-7/8 in. in diameter. The diameter reduction also provided better handling with the manipulator. The nozzle support cart was equipped with a pivot pin so the nozzle assembly could be rotated to permit more direct access by the manipulators. The final nozzle arrangement resulting from remote testing and modification is shown in Figure 18.

Based on the remote work, a prototype fuel nozzle was fabricated and satisfactorily test-fired in the open air on a test stand (Figure 19). The unit was also tested in the pilot plant 12-in. calciner (see Section V.2). Testing confirmed the operating characteristics of the nozzle design and the Grayloc seal integrity following thermal cycling.

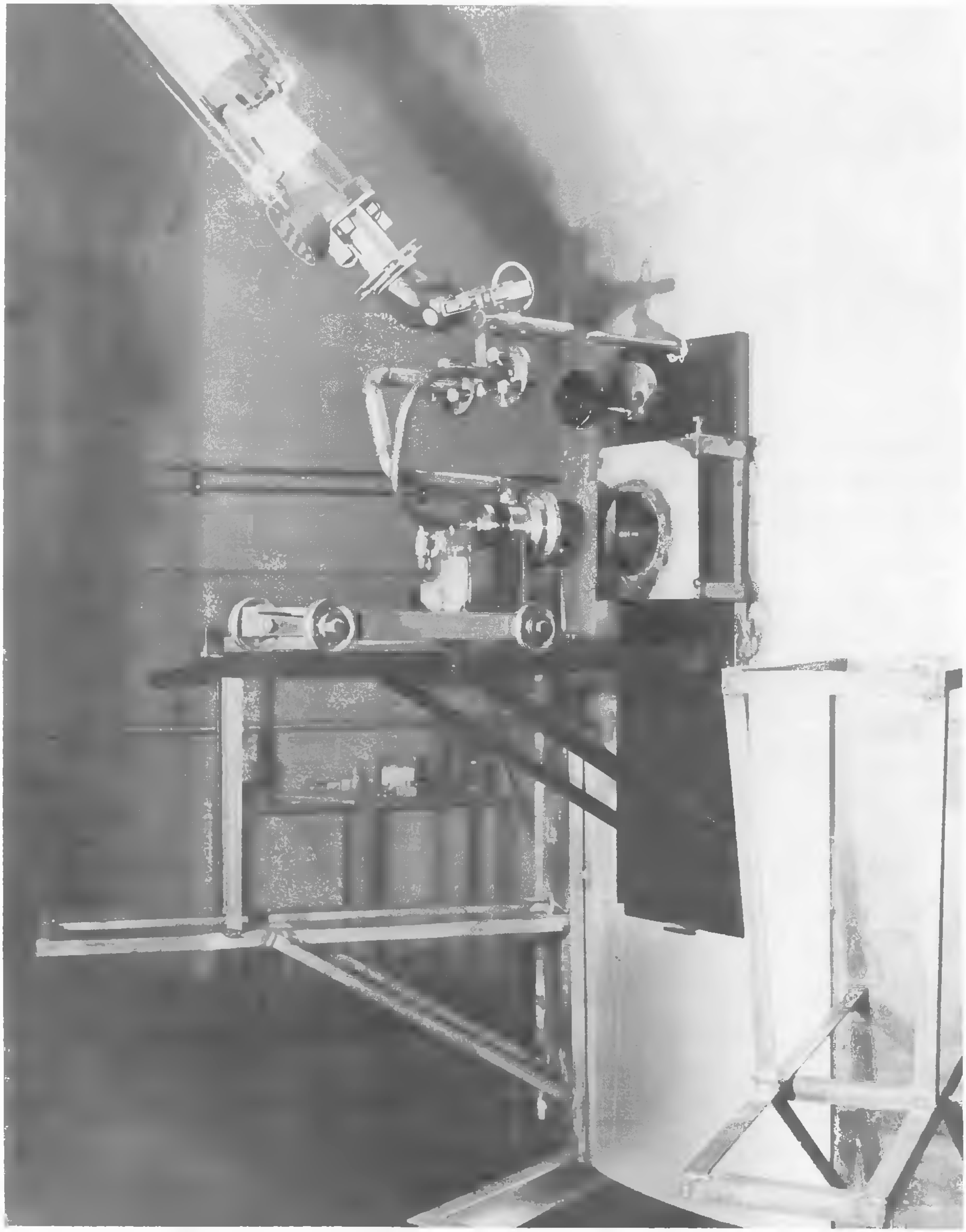


Fig. 17. Original nozzle and piping arrangement.

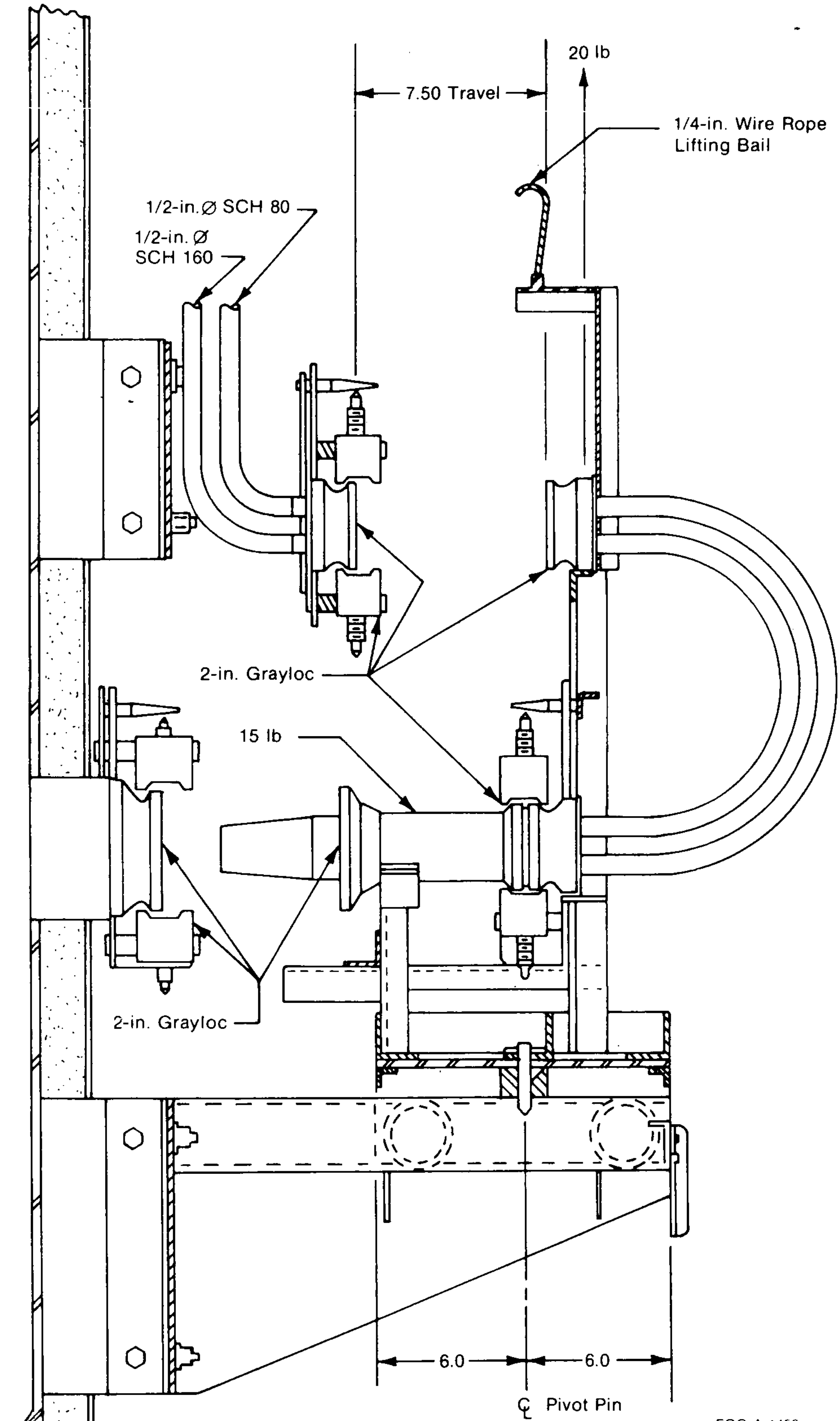


Fig. 18. Final nozzle and piping arrangement.

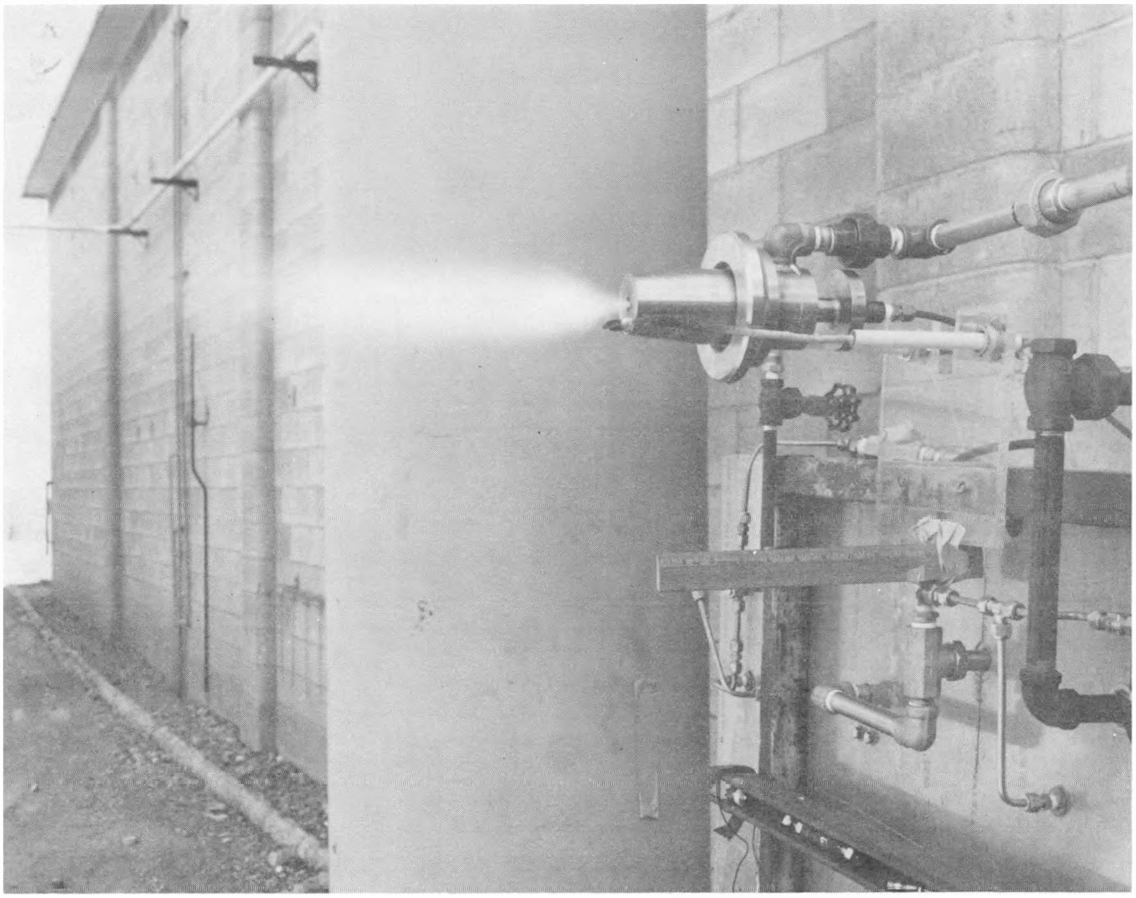


Fig. 19. Prototype nozzle in test stand.

6. AIRLIFT

Three airlifts will be located in a pit in the valve cubicle floor of the NWCF. They will be used to transfer feed solutions from the blend tank to the waste hold tanks and from the hold tanks to the calciner feed tank. Although plugging occurs infrequently, airlifts can become plugged with solids, and the airlift design had to permit remote removal and replacement of the lower section. The removable section is approximately 14 ft long, weighs approximately 350 lb, and will be connected to the process piping by three flanges. Two of the airlifts will be constructed of 3-in. pipe, the other of 2-in. pipe. The air line to both will be 1/2 in. All three units must be remotely replaceable using an overhead bridge crane, a wall-mounted manipulator, and an impact wrench.

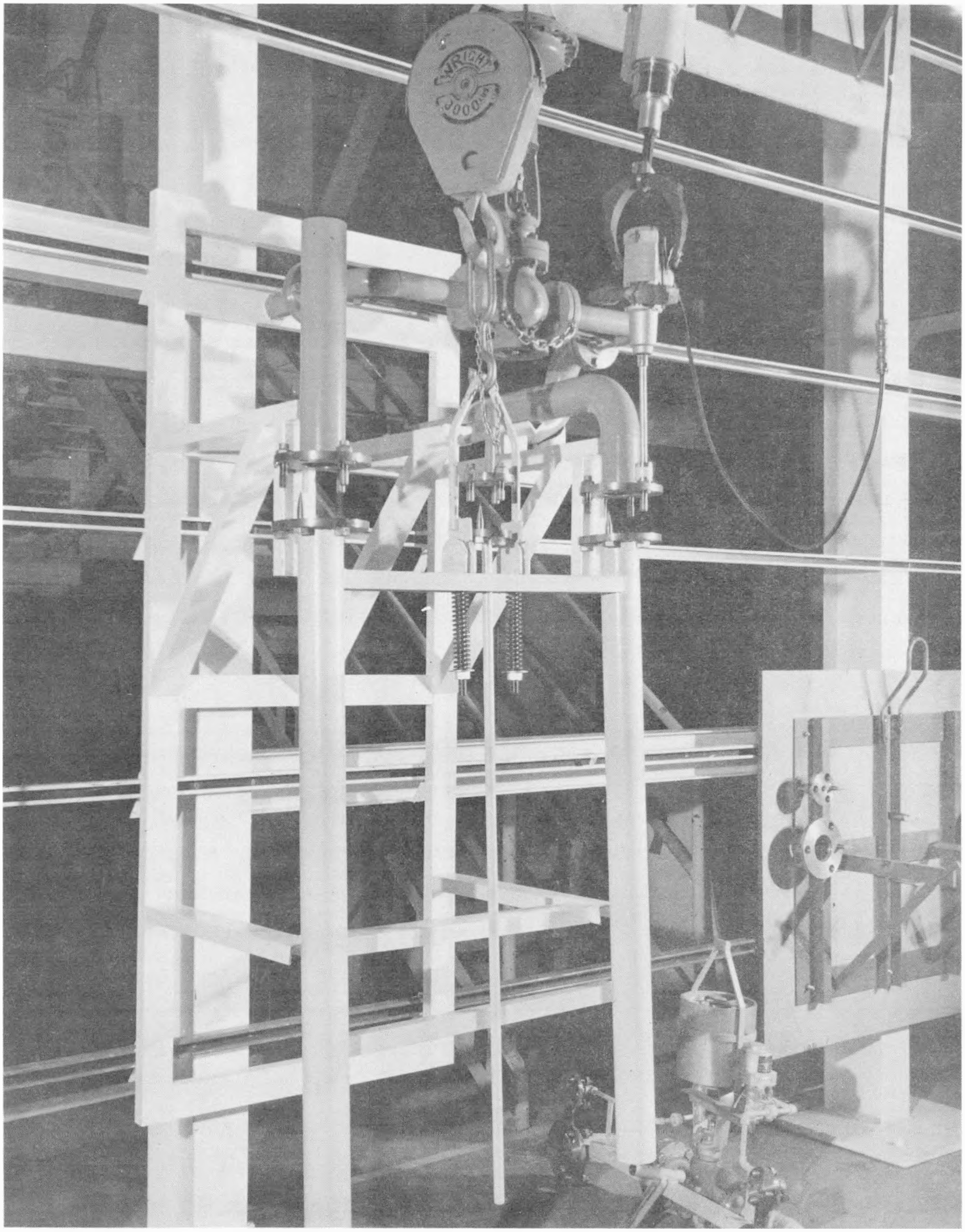


Fig. 20. Airlift mockup.

The mockup airlift which was constructed for the remote tests is true size (3 in.) at the connections and 7 ft long (Figure 20). Springs on the lifting bail carry the weight of the airlift, and the bail is hinged to provide access to the air line flange bolts. After the air line flange bolts are disconnected, the lifting bail is engaged by the crane and raised until the springs are depressed 1/4 in., taking the weight from the flanges. The other flange bolts are then disconnected, and the airlift is removed for decontamination and repair.

On the mockup, the only positioners used to guide the airlift into place were tapered pins on the flanges and the framework that supports the facility piping. Replacement was accomplished by positioning the removable section directly below the connection flanges and just touching the U-channel support frame. As the unit was elevated, it was guided into place by the guide pins and matching holes in the flanges. The bolts on the process line flanges were then engaged with the impact wrench. To complete the replacement, the lifting bail was released from the crane and the air line flange bolts were engaged. This design, which proved both effective and easily remotely replaceable, has been incorporated into the facility design.

7. ELECTRICAL CONNECTOR

The first development work on the remotely operated electrical connector was previously reported in ICP-1081[1]. Testing of the first unit, which is shown in Figure 21, indicated some minor problems in handling and alignment visibility. No attempt was made to design this unit as a liquidtight connector.

The second-generation connector (Figure 22) consisted of an enclosed Amphenol plug with an O-ring to provide a liquidtight seal. In use, the two parts of the connector are each mounted rigidly to the support platform and the wall penetration as described in Section 3 and shown in Figure 12. The third-generation connector, shown in Figure 8 and described in Section 3, was incorporated into the jumper unit on the revised support platform (Figure 14). The basic connector was identical to Unit 2 except that the connection to the jumper was made by flexible cable rather than rigid conduit.

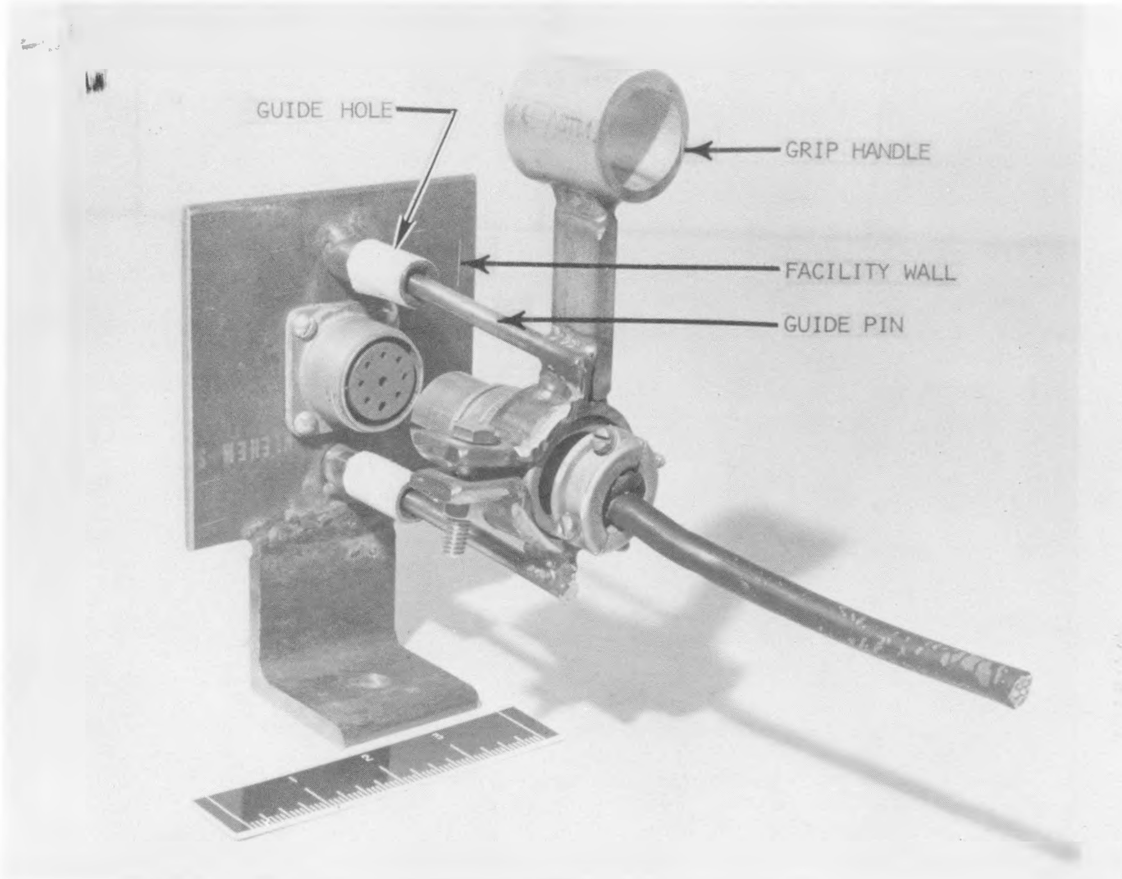


Fig. 21. Modified Amphenol plug for remote electrical connections.

This change reduced the alignment requirements of the support platform, since alignment requirements for flanges are considerably less than for pins of an electrical connector. The lifting bail for the connector shown in Figure 9 was a rigid loop, which caused some difficulty in aligning the two parts of the connector using a manipulator. The lifting bail was therefore changed to a flexible cable, as shown in Figure 23, which has proven to be much more satisfactory for remote handling and alignment.

Fig. 22. Remote electrical connector.

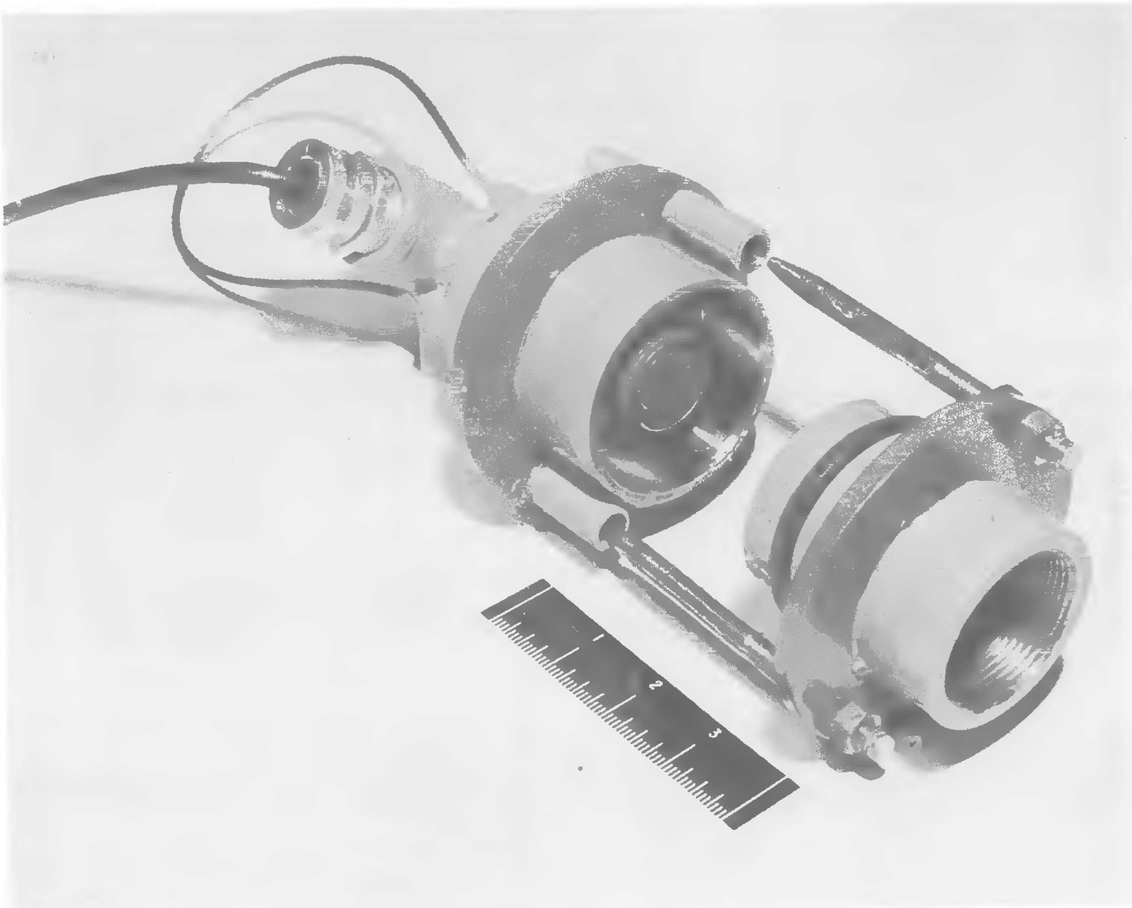


Fig. 23. Remote electrical connector with lifting bail.

V. REMOTE HANDLING TEST RESULTS

The remote handling tests--which include both manipulating and viewing to prove accessibility, visibility, maintainability, compatibility, and equipment capability--were carried out in both the master-slave manipulator area and the wall-mounted manipulator area of the RMDF.

1. VALVE CUBICLE LAYOUT

Mockup tests for the valve cubicle included positioning of the shielding windows and related valves and airlifts. These are shown in Figures 2 and 20.

1.1 Window Layout. To perform the viewing tests, two shielding windows were mocked up according to the size recommendations of a shielding window manufacturer. The windows were also mocked up in such a manner that through geometric design they provided a view identical to one that would have been provided by a 3-ft-thick, wide-angle, oil-filled shielding window. The windows were positioned to represent preliminary window locations, as selected by the A-E, at both the operating corridor level elevation and the access corridor elevation of the NWCF. As each window position was tested, the visible area in the valve access corridor was identified by colored ribbons. The mockup tests of the several window positions indicated that all valves and airlifts (see 1.2 below) were visible from at least two windows and that the maximum viewing from the different window locations overlapped each other by several feet. The locations of the windows, valves, and airlifts are being further refined.

1.2 Valve and Airlift Position Layout. All the valves and airlifts in the valve cubicle were mocked up and positioned in accordance with the preliminary layouts prepared by the A-E. These items were then checked for visibility from the window locations described in Section 1.1 for access with remote equipment, for cost of removal and replacement, and for interference with surrounding equipment during replacement tests. These tests proved that all valves and airlifts were visible from at least two windows, that they could be reached and handled with the remote equipment, and that interferences were minimal. The test results have been communicated to the A-E for use in additional design layouts.

As piping layouts and design progresses and changes in size or location are made because of operating or process restrictions or needs, these series of tests will be repeated. As design is completed, one final series of tests will be run for confirmation of location.

1.3 Valve Cubicle Width. The original valve cubicle width, as envisioned by the A-E and simulated in the RMDF, was 10 ft 10 in. This dimension was based on the PaR Model 2000 manipulator being used in the RMDF mockup and was entirely adequate. As the NWCF design progressed and equipment weights, sizes, and locations became firm, however, a PaR Model 3000 manipulator was recommended because of its greater capability and longer reach, viz., 5 ft 9 in. vs. 7 ft 7 in. Following equipment selection, the valve corridor mockup was used to assist the A-E in selecting optimum corridor width to maximize equipment capability, available space, and visibility. Based on test results, the cubicle width was increased to 11 ft 6 in. These changes now make it possible for an operator to position the manipulator bridge out of his line of sight while performing a task directly opposite a viewing window. The wider corridor also makes the remote operations safer by providing more room for equipment that is being transferred the length of the valve corridor.

2. CALCINER NOZZLE

The prototype calciner fuel nozzle described in Section IV.5 was tested on a stand in the open air and also in the 12-in.-diameter pilot plant calciner. Figure 19 shows the full-scale prototype being successfully fired on the test stand at the normal flow rate (6 gph) with a free flame approximately 18 in. long and 46 in. wide. The tests in the 12-in. calciner were conducted to determine operating characteristics in a calciner bed and the integrity of the Grayloc seal following thermal cycling. For those tests, the calciner and nozzle assembly was cycled from ambient to 640°C five times and to 420°C four times. Following thermal cycling, the nozzle and backplate were removed from the calciner (keeping the Grayloc seal intact), and the assembly was submerged in water and tested for leaks with 50-psig air. No leaks were detected. With these encouraging results, the assembly was taken to the RMDF for remote disassembly and handling tests. Initially, the tapered nozzle body was stuck in the Grayloc hub and could not be removed using master-slave manipulators. A small remotely handled air vibrator was used against the side of the nozzle for 2 to 3 sec to loosen the nozzle body. When the nozzle was removed, the nozzle body and the hub were prevented from separating by approximately 22 cm^3 of calcine material that had lodged in the annular space between them.

Viewing and handling tests of the calciner nozzle and the associated piping were carried out on a mock 90° section of the calciner vessel. This section (Figure 24) contained two fuel and two feed nozzles. The support platform with two tracks accommodates the rolling carrier upon which the prototype fuel nozzle and the pipe jumper ride. The carrier provides about a 6-in. horizontal motion to the nozzle and permits inserting the nozzle body through the calciner vessel wall. The adjacent steel frameworks, which represent the space occupied by the three other nozzles and supports, are provided for checking manipulator clearances and operator viewing. All four proposed nozzle locations proved to be within the working range of the manipulators. However, in order to reach the outside feed nozzle (the nozzle most distant from the manipulator), the manipulator "Y" motion had to be indexed at approximately 45° and the "X" motion at approximately 20°. Such an arrangement transmitted a considerable backward and side thrust to the manipulator operator when the full weight of the nozzle was taken by the manipulator and proved to be very undesirable. Therefore, this nozzle support carrier was modified to pivot so that as this nozzle is disengaged from the vessel, the assembly can be rotated approximately 90° to improve viewing, decrease side and backward thrust, and improve operator confidence in the entire operation.

3. AIRLIFT

The airlift mockup (3-in. pipe size) described in Section IV.6 and shown in Figure 20 was removed and replaced several times without difficulty using

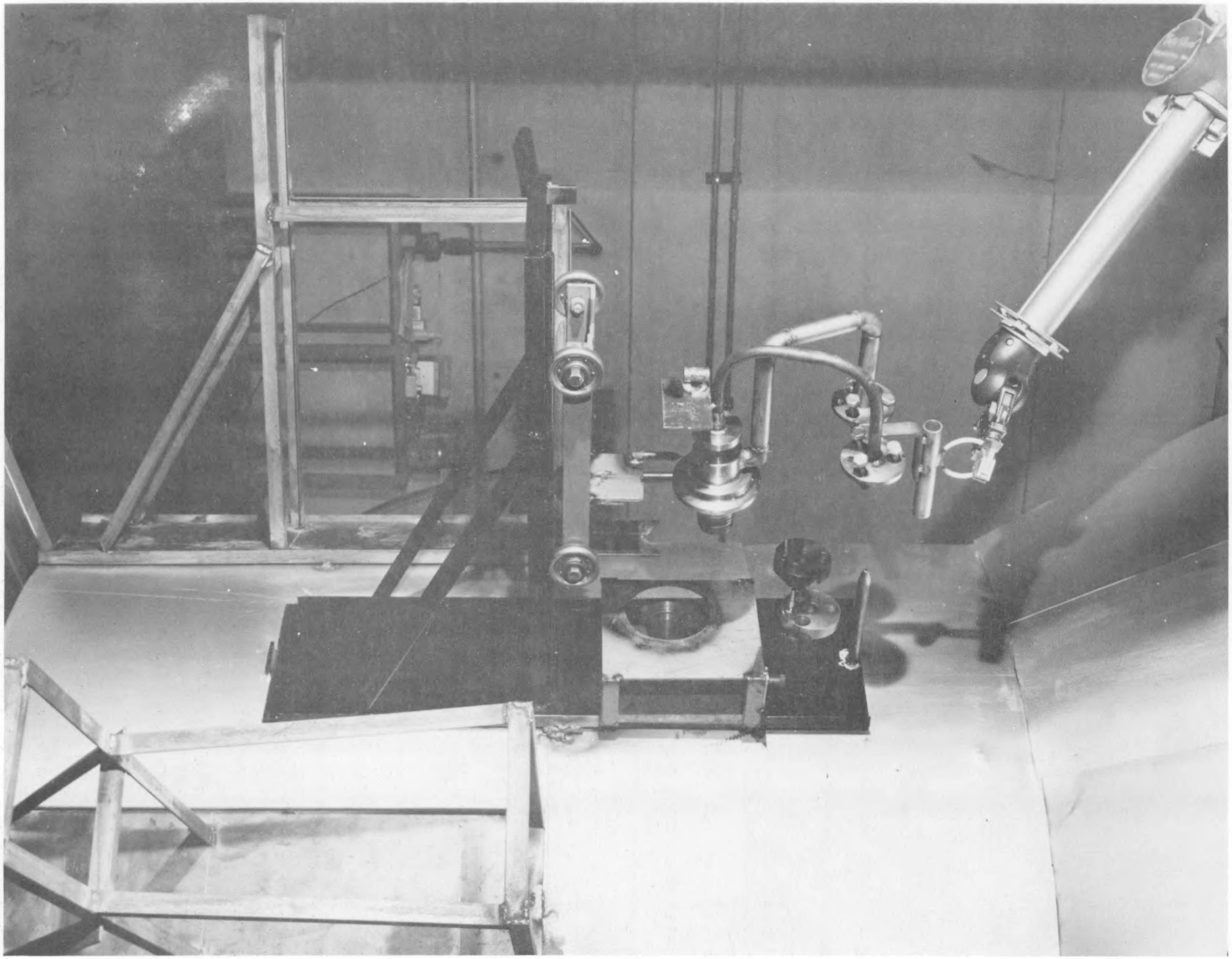


Fig. 24. Calciner nozzle mockup.

the PaR Model 2000 manipulator, an impact wrench, and the overhead bridge crane. A slight difficulty in viewing some of the flange bolts was encountered, but this can be overcome through the use of TV or an assistant operator stationed at an adjacent window. Because of the anticipated infrequency of this operation, such an arrangement is acceptable.

4. LIQUID SAMPLER

The NWCF liquid samplers are located in a sampling cell that is provided with a shielding window and a pair of master-slave manipulators for sample collection, sample bottle handling, and equipment repair or replacement. One liquid sampler section, containing three sample lines and a decontamination line, was mocked up (Figure 25) to determine the suitability of using Swagelok fittings on the lines and the accessibility of the fittings and valves for remote maintenance. Although the Swagelok fittings proved to be relatively easy to handle remotely, testing showed that the tubing and fittings should be designed so that gravity assists in holding the fitting nut in place during assembly. Also, each valve assembly and its associated tubing should be mounted on an individual alignment plate to provide precise positioning during assembly and replacement.

5. FEED FLOW CONTROL VALVE

The feed flow control valves regulate the flow of feed to the four calciner feed nozzles. The four feed valves will be located in the flowmeter cubicle and will be remotely replaceable. To prove the remote concepts including removability and replacement, the valves were mocked up as shown in Figure 26. The results indicated that the outlet flanges should be relocated to the side of the assembly centerline, primarily for access by the master-slave manipulators and the impact wrench and to improve visibility. The mockup also indicated that the flowmeter assembly guide-in support should be relocated either at or above the assembly's center of gravity and that the disengaging travel distance for the supports should be approximately 4 to 5 in. These changes are being incorporated into the NWCF design.

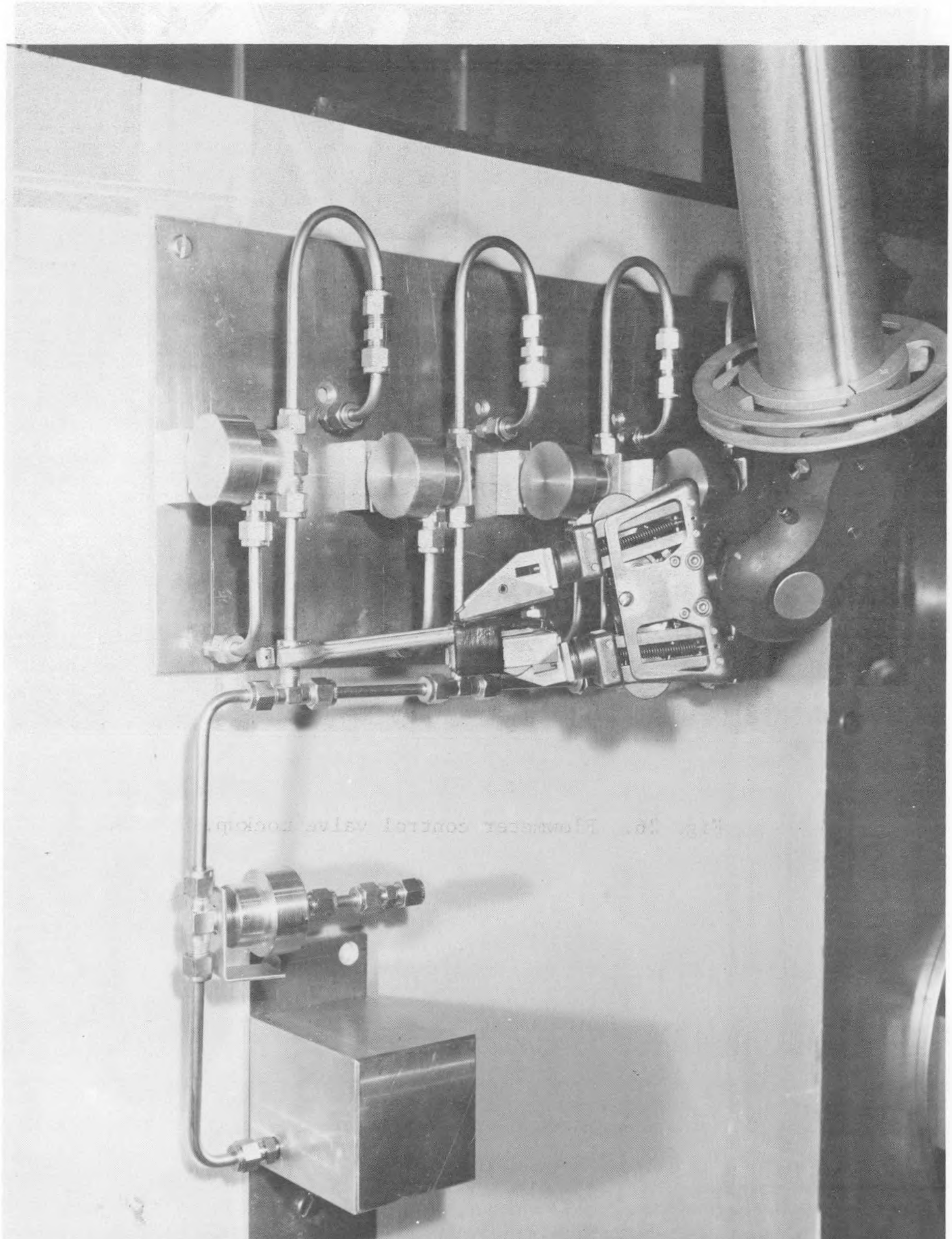


Fig. 25. Liquid sampler mockup.

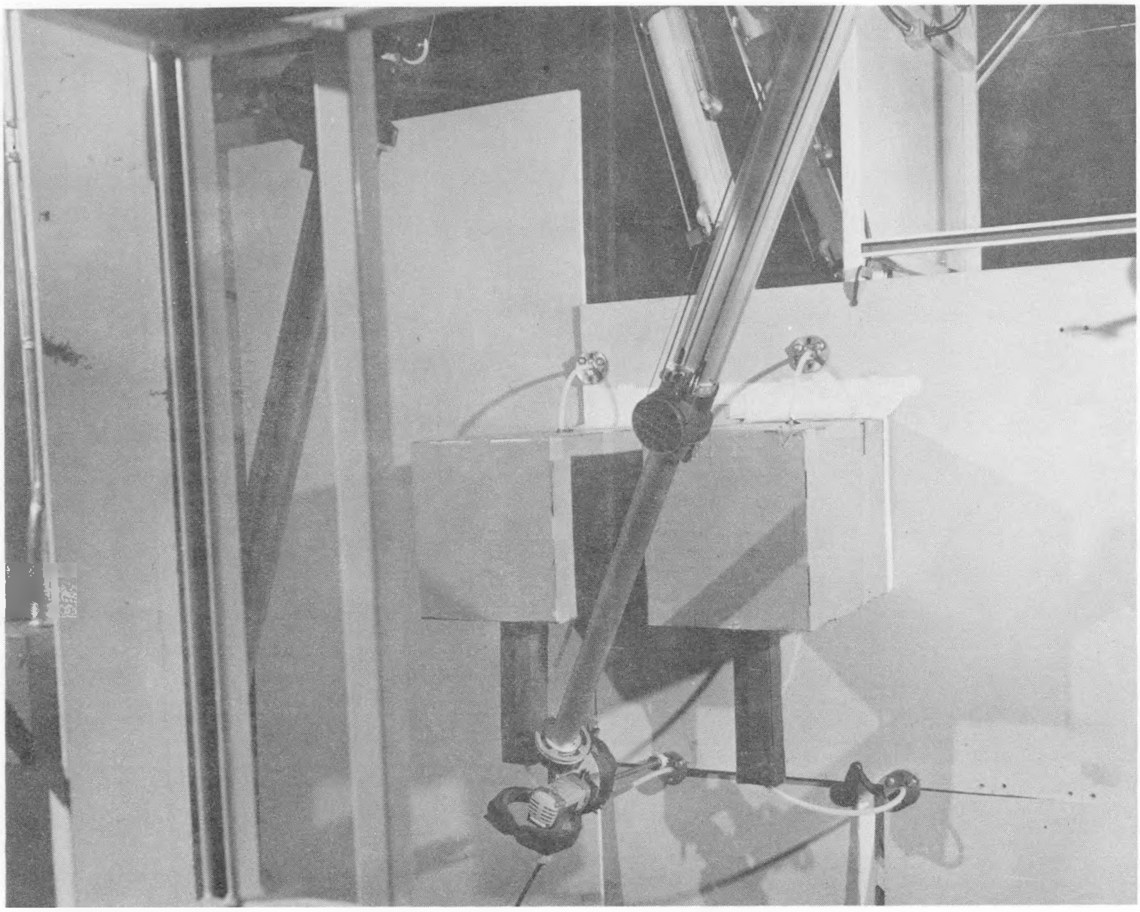


Fig. 26. Flowmeter control valve mockup.

VI. FUTURE PLANS

Initial mockup and testing efforts have been directed toward proving the conceptual design of the NWCF remote handling requirements. As design progresses to detailed layout, equipment selection and sizing, and space allocation, mockup and testing will be refined to identify and resolve problem areas. Items included in this continuing effort include the following:

(1) Testing of three-bolt flanges in sizes greater than 3-in. pipe size to determine the pressure range in which they may be used

(2) Developing and demonstrating the use of electrical connectors having protective covers

(3) Testing the integrity of commercial HEPA filter seals that have been made up by remote equipment

(4) Demonstrating liquid, gas, and solid sampling equipment handling techniques

(5) Demonstrating (a) transfer of samples and sampling equipment and (b) sample transfer through a double-seal transfer system

(6) Reviewing and demonstrating NWCF in-cell transfer methods system

(7) Testing and evaluating remote viewing methods including windows, TV, and mirror systems

(8) Developing methods of vessel inspection using TV

Plans also include supporting the Fluorinel Process remote handling design by testing in the area of fuel charging, dip tube replacement, condenser tube replacement, solids packing and transfer, valve replacement, and system sampling.

VII. REFERENCES

1. R. T. Jacobs, Remote Maintenance Development, June 1974 - July 1975, ICP-1081 (October 1975).

2. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section VIII, "Pressure Vessels - Division 2 Alternative Rules" (1974).

3. American National Standards Institute, Standard B16.5-1973, "Steel Pipe Flanges, Flanged Valves, and Fittings".

4. ASME Code, Section VIII, "Pressure Vessels - Division 1" (1974).

5. Armco Steel Corp., Product Data Bulletin S-56A.