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PHASE II
PRIMARY HEATER MODULE

FINAL REPORT
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FEBRUARY 1980 - NOVEMBER 1983

VOLUME VI

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FOREWORD

This program was conducted by the Rocketdyne Division of Rockwell International under Contract DE-AC21-80-ET15020 for the Department of Energy (DOE) during the period February 1980 through November 1983. Major subcontractors were the Battelle Columbus Laboratories and Burns and Roe Pacific, Inc. The DOE manager who initiated the program was Carey A. Kinney, Fossil Energy Division. The program was then transferred to the Morgantown Energy Technology Center in 1982 and the DOE manager was Larry K. Carptenter. Jerry M. Friefeld was the program manager at Rocketdyne. This final report is presented in several volumes.

RI/RD83-213 Executive Summary

RI/RD83-213A

- SECTION 1: Phase II Program
- SECTION 2: Summary
- SECTION 3: Program Organization

RI/RD83-213B

- SECTION 4: AFB Heat Exchanger Technology

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- SECTION 5: PC Heat Exchanger Technology

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- SECTION 6: Series Bed Heat Exchanger Technology
- SECTION 7: Working Fluid Corrosion Technology
- SECTION 8: Planning for Phase III
- SECTION 9: Interpretation of Program Results, Conclusions, and Recommendations

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- APPENDIX A: 6' x 6' AFB Combustor/Heater Drawings
- APPENDIX B: CCGT Cogeneration System Performance

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- APPENDIX C: 6' x 6' AFB Installation Photographs

ABSTRACT

Research was conducted on components and subassemblies of coal-fired heaters suitable to supply the heat input to closed-cycle gas turbine-based cogeneration systems of 25 to 50 MWe electrical output.

Three concepts were researched: (1) a dry bottom, pulverized coal-fired radiant furnace heater for 1450 to 1550 F turbine inlet temperature, (2) an atmospheric pressure fluidized bed fired heater for 1450 to 1550 F, and (3) a heater employing atmospheric pressure fluidized beds in series, for 1750 F turbine inlet temperature. The series beds concept employs ceramic heating surface in its high-temperature bed.

Both laboratory and field testing was conducted on heating surface materials durability in the pulverized coal and fluidized bed environments. Burner and furnace designs were researched for pulverized coal heaters employing large quantities of flue gas recirculation to moderate the furnace heat flux. A 6' by 6' fluidized bed was assembled and tested for materials and operational research on the 1450 to 1550 F heater concept. A ceramic-to-metal joint concept was devised, fabricated and made ready for test. The conceptual commercial heater concepts were refined.

The program results indicate that each of the three heater concepts is technically feasible. The fluidized bed concepts are judged most likely to be both technically and commercially feasible. Their continued development is recommended.

APPENDIX C

6' X 6' AFB INSTALLATION PHOTOGRAPHS

Throughout this program, photographs have been used to document the fabrication, installation, and hardware condition. Since photographs can quickly convey such information, this section was created to provide a convenient overview of the 6' x 6' AFB experimental facility through the use of photographs, particularly the test systems and equipment. The following figures represent a few of the photographs selected to show key elements of the combustor/heater component, installation, and completed facilitly. These figures are presented without text, although comments were often included on the individual figures.

The overall view of the facility is presented in Fig. C-1 through C-4. The combustor/heater component is well documented by detailed design drawings (Appendix A), and a few photographs of the completed assembly sections have been selected (Fig. C-5 through C-13). The combustor/heater sections were delivered to the facility and installed in the main platform in a single day, and Fig. C-14 through C-20 show the installation process. The material specimen probe components and their installation are shown in Fig. C-21 through C-27, and the oxygen partial pressure probe is shown in Fig. C-28 as used in the testing. Views of the installed specimen probes taken from inside of the combustor/heater are shown in Fig. C-29 through 31. Finally, various details of the facility system and control room are presented in Fig. C-32 through C-64.

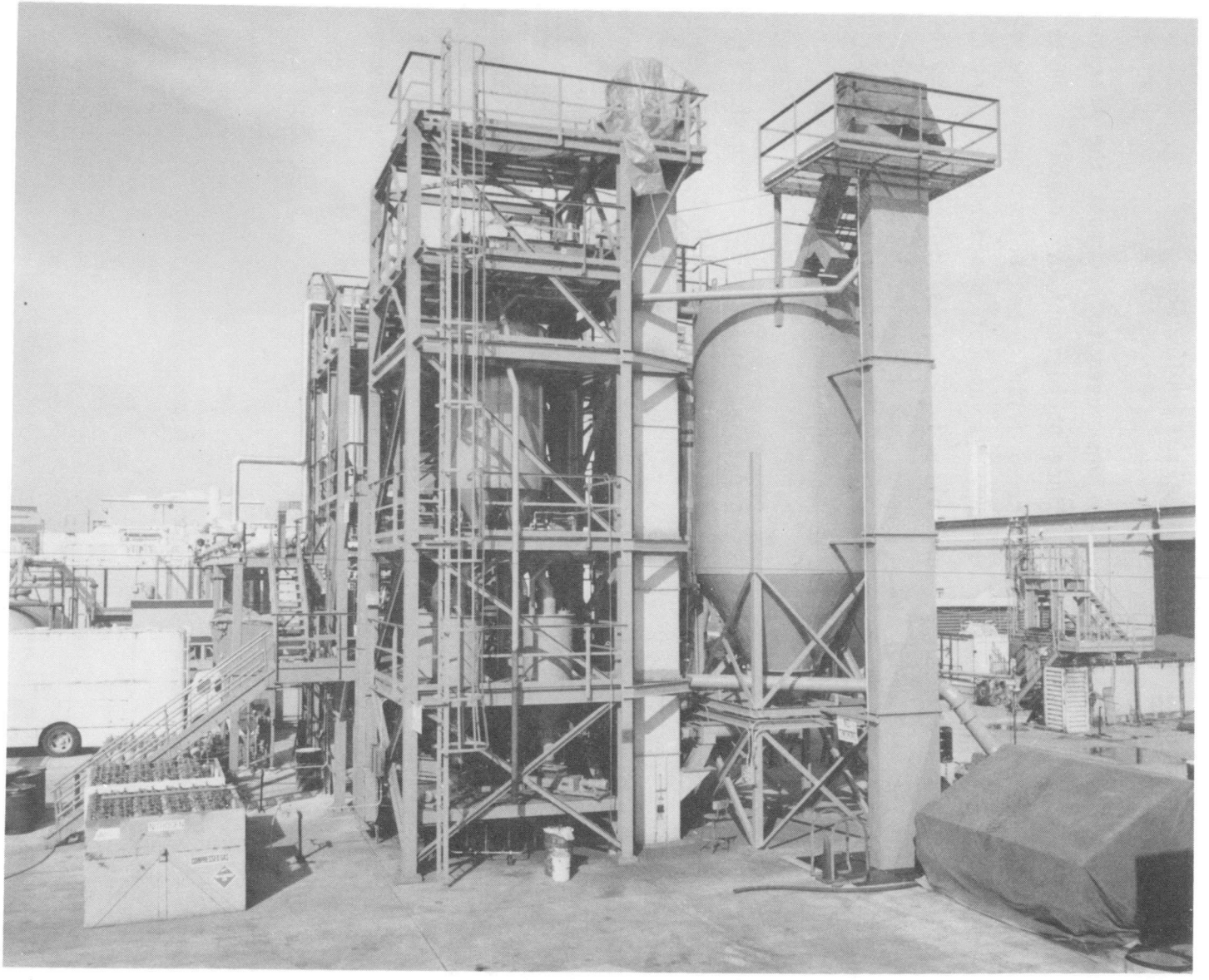

Figure C-1. Overall Facility - South Elevation (in the foreground are the coal tower, coal silo, and coal receiving pit)

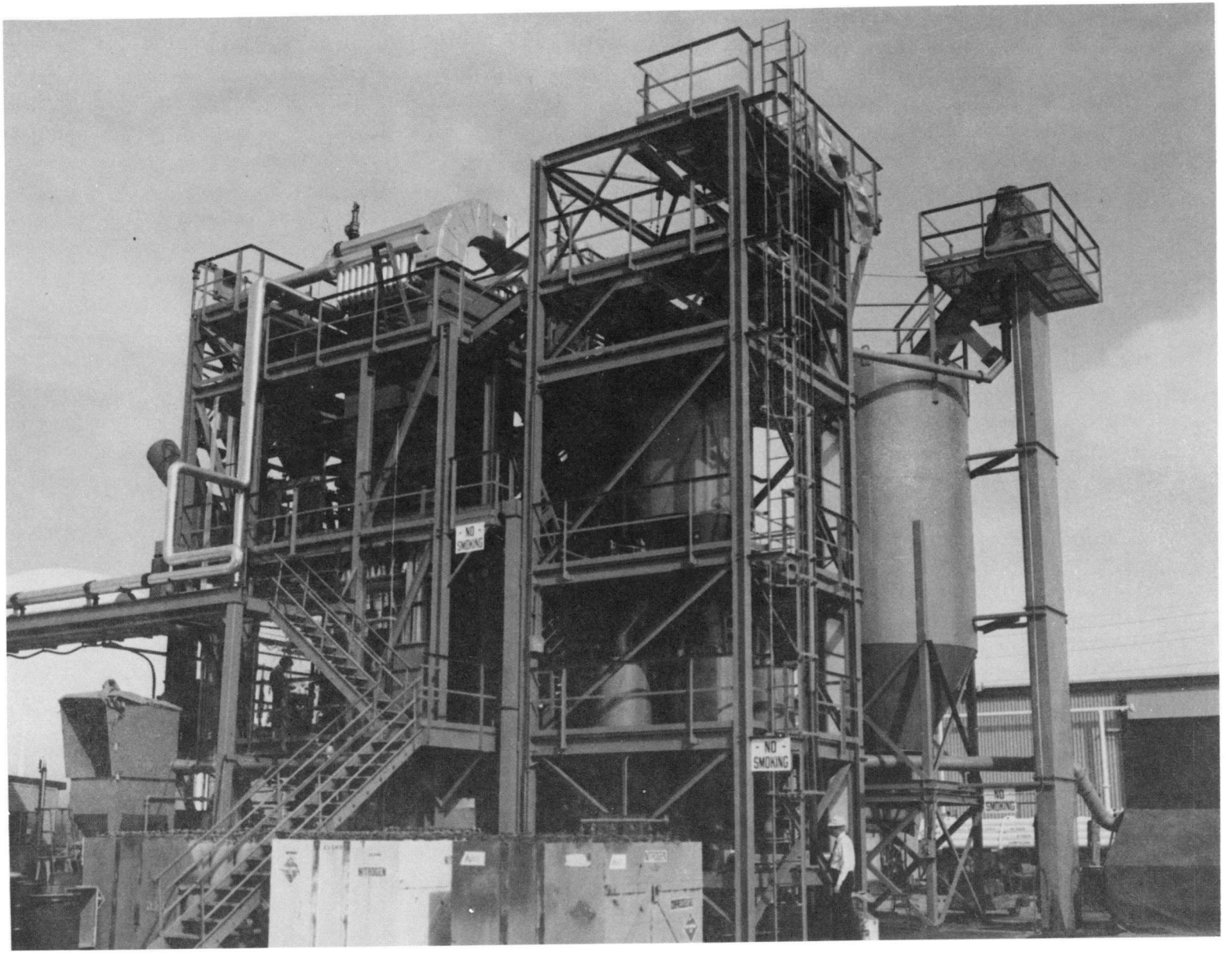

Figure C-2. Overall Facility - West Elevation (main platform and coal tower; working fluid air supply tressel at middle left, limestone fill station at lower left)

Figure C-3. Overall Facility - North and East Elevations (left to right, baghouse, exhaust stack, air preheater, ash recycle bins, and combustor/heater in main platform; upper right of platform are the limestone and spent bed material bins, and the working fluid mufflers)

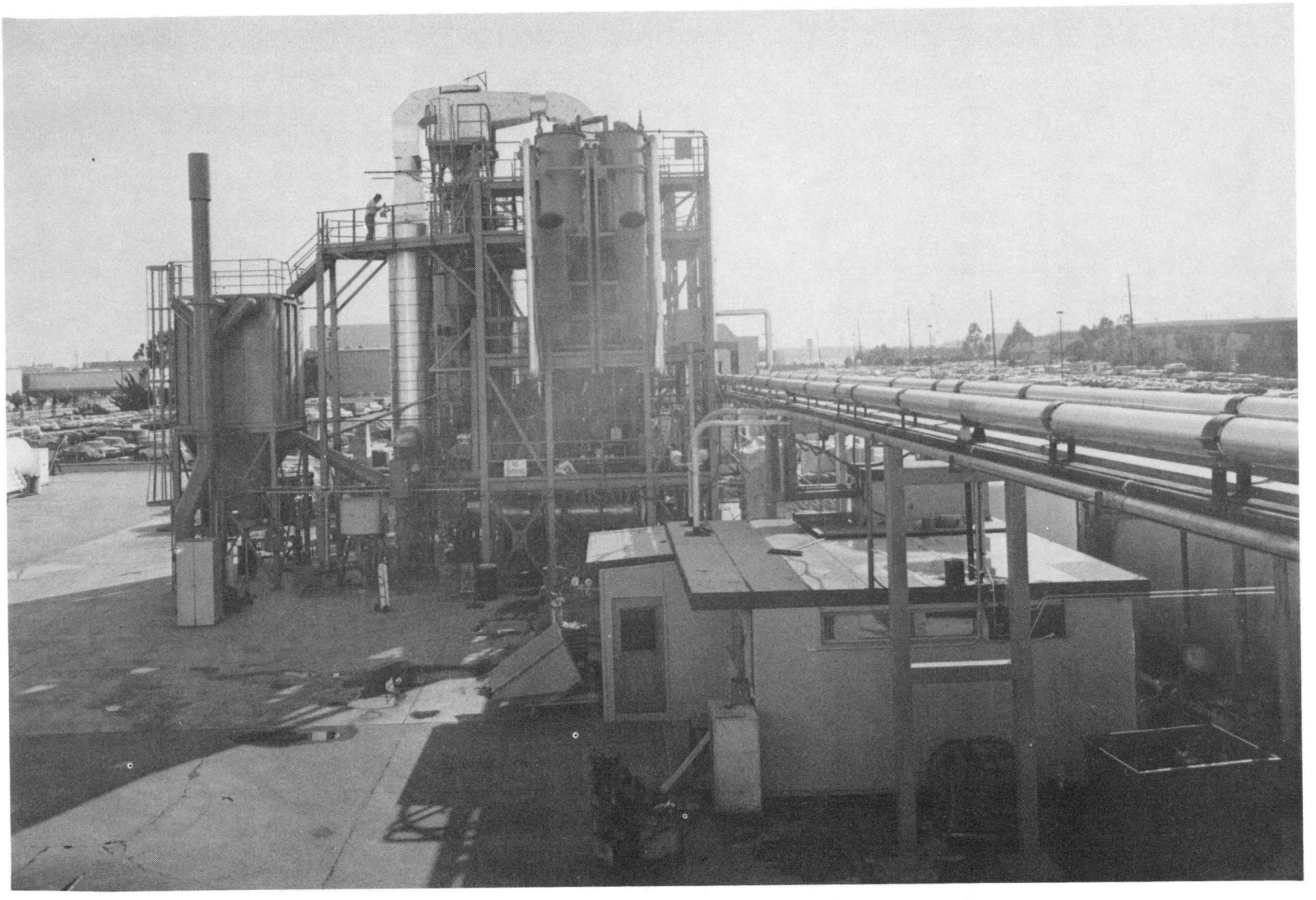

Figure C-4. Overall Facility - North Elevation (in the foreground are the control center and working fluid air supply tressel)

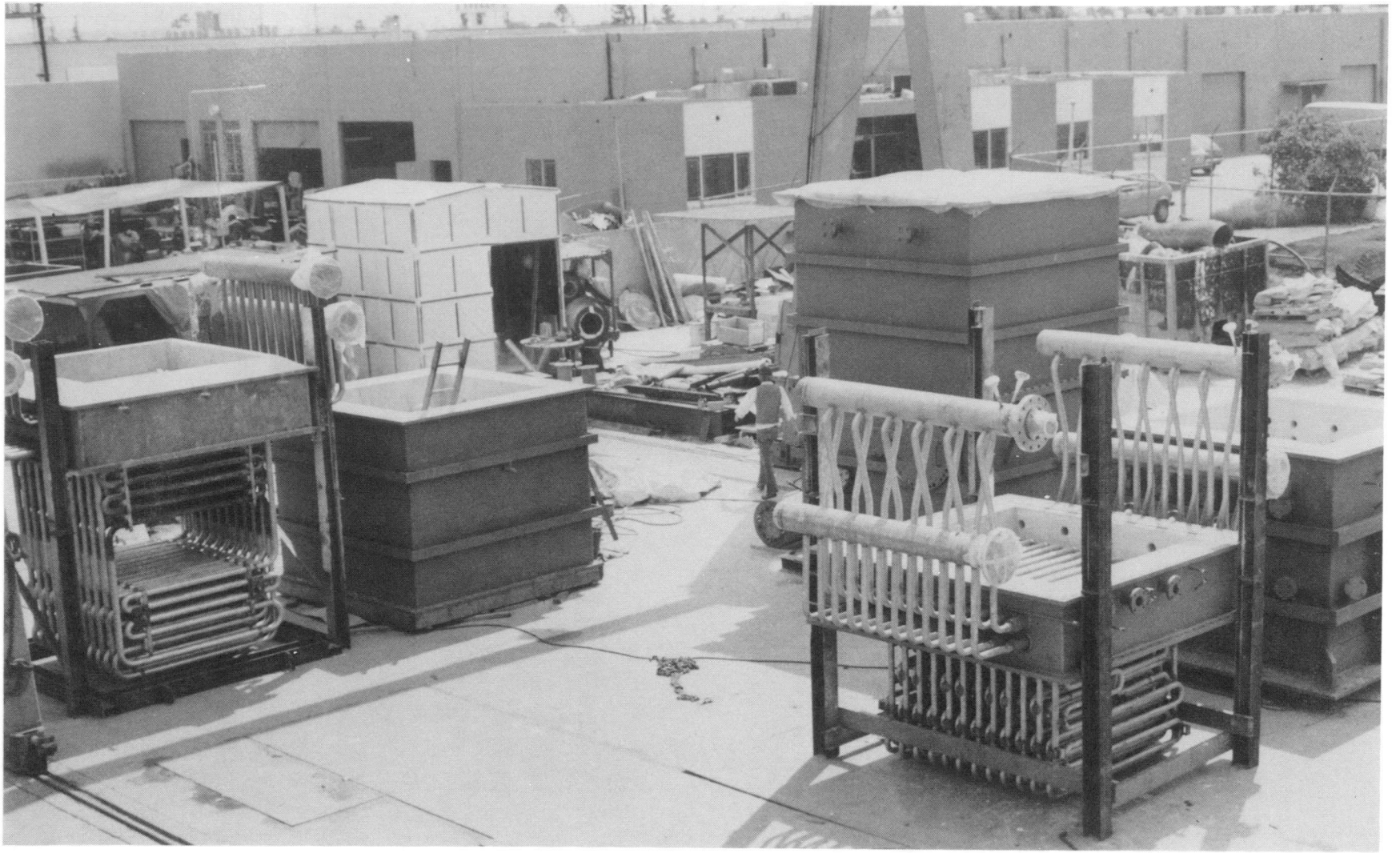

Figure C-5. Combustor/Heater Sections (convection heat exchanger on left and bed heat exchanger on right, both are next to the mating sections; freeboard section is in the background)

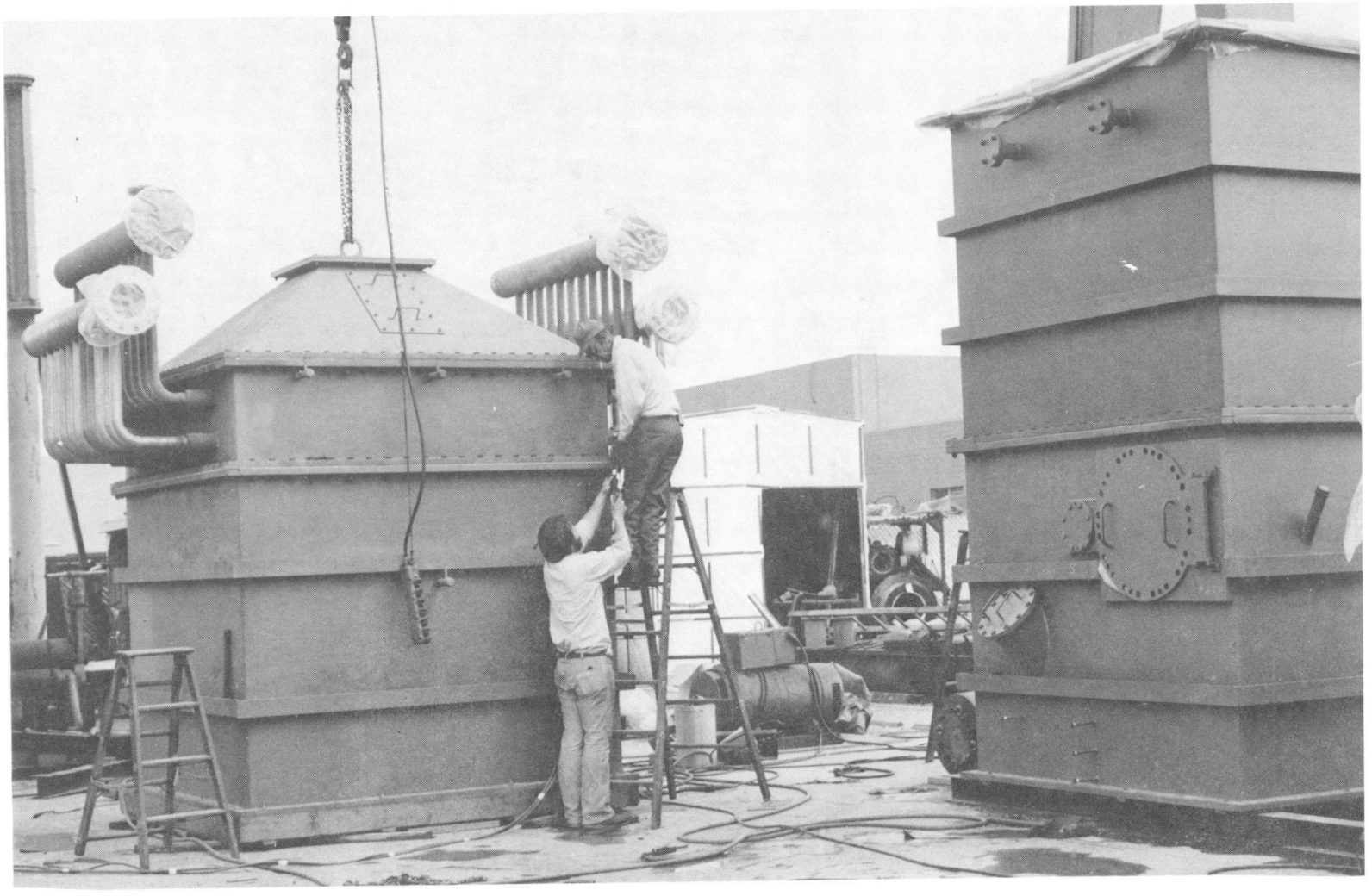

Figure C-6. Combustor/Heater Sections Ready for Transportation (convection heat exchanger on left and freeboard on right; note the manway door and observation window on the freeboard section)

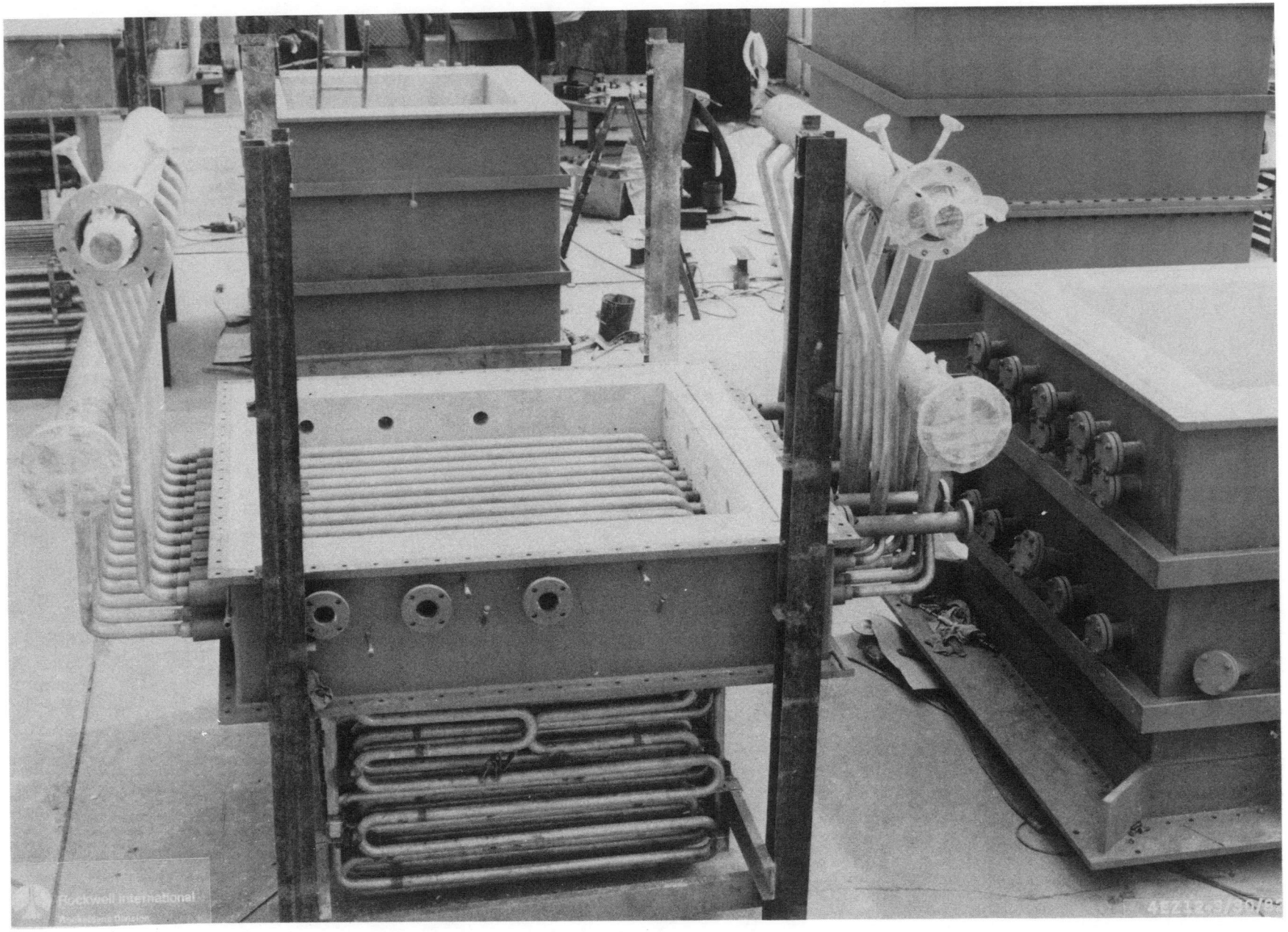

Figure C-7. Bed Heat Exchanger (note the shortened tube on the first platen to provide space for a material specimen or diagnostic probe)

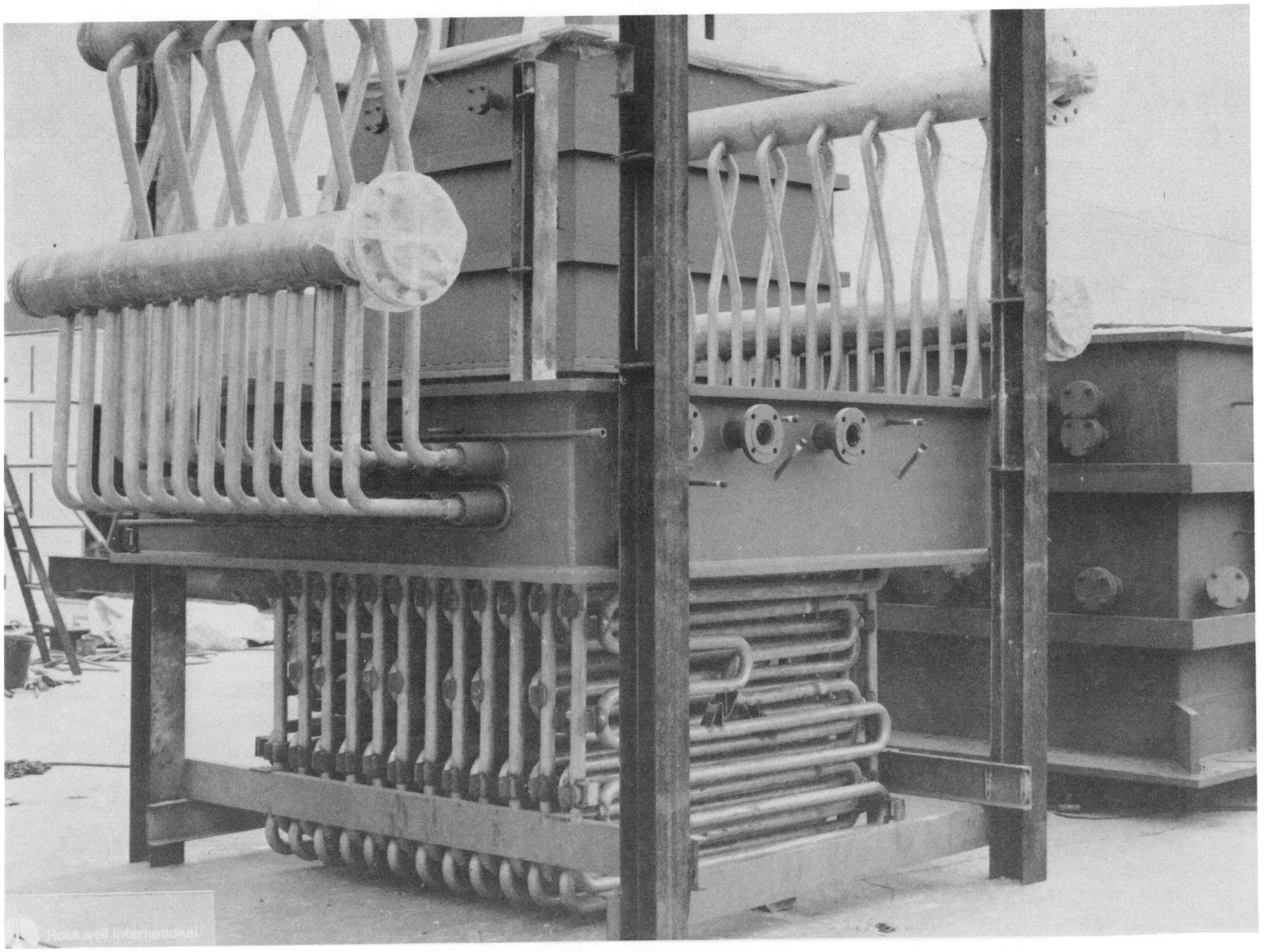

Figure C-8. Bed Heat Exchanger (the upper manifolds are the outlets and the lower manifolds are the inlets)

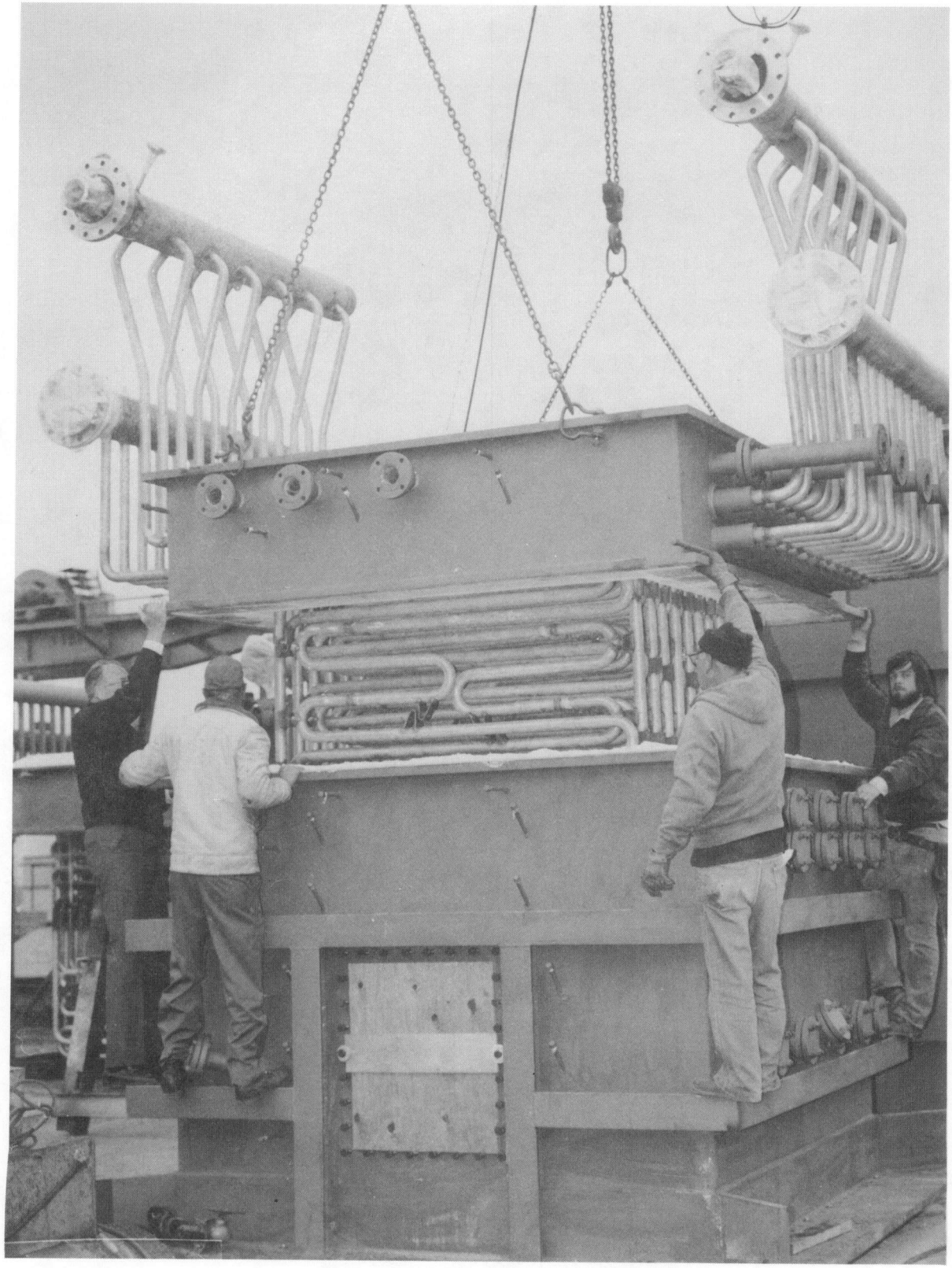

Figure C-9. Bed Heat Exchanger Section Being Readied for Transportation

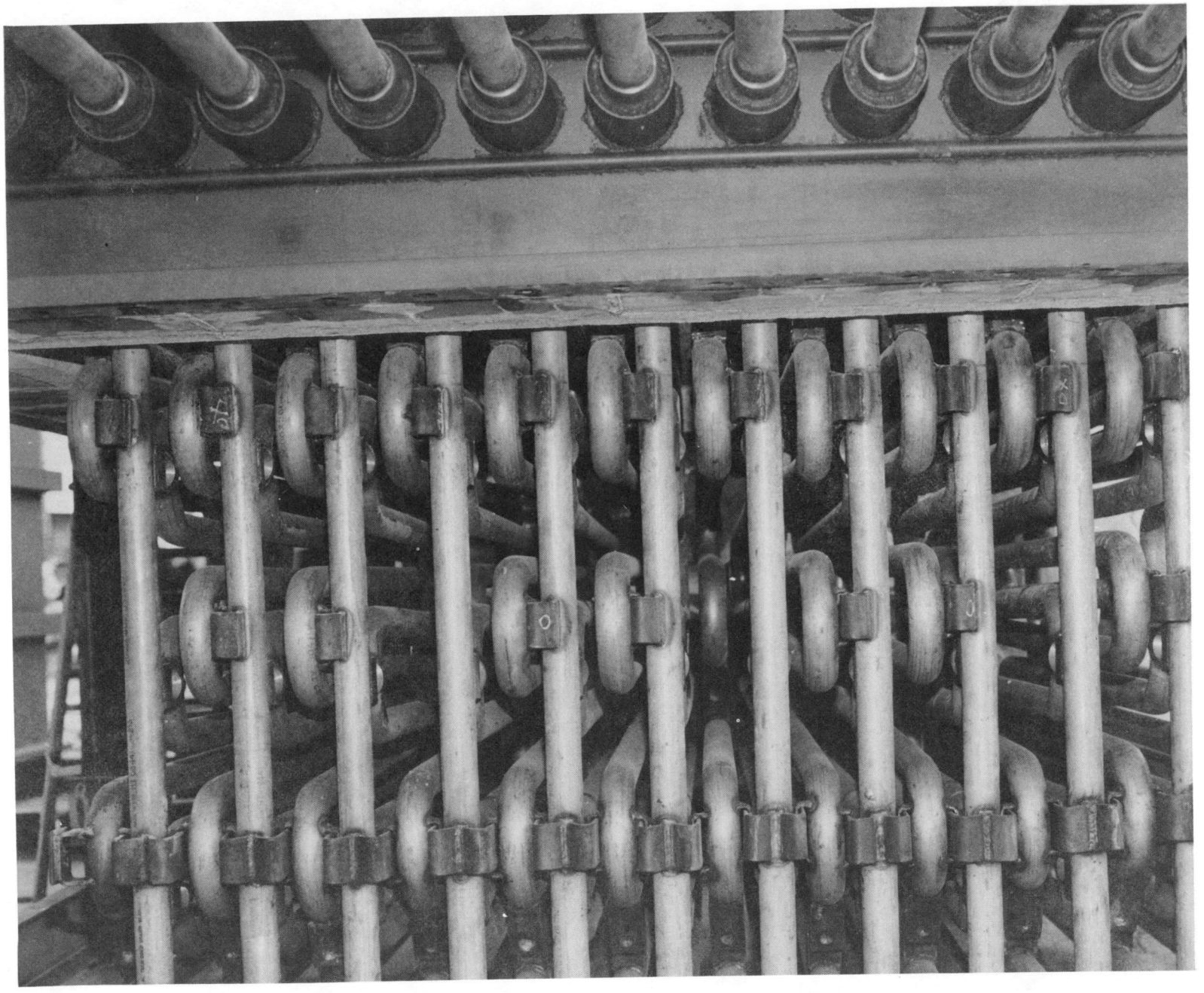

Figure C-10. Close View of Bed Heat Exchanger (note the tube hangers and attachments)

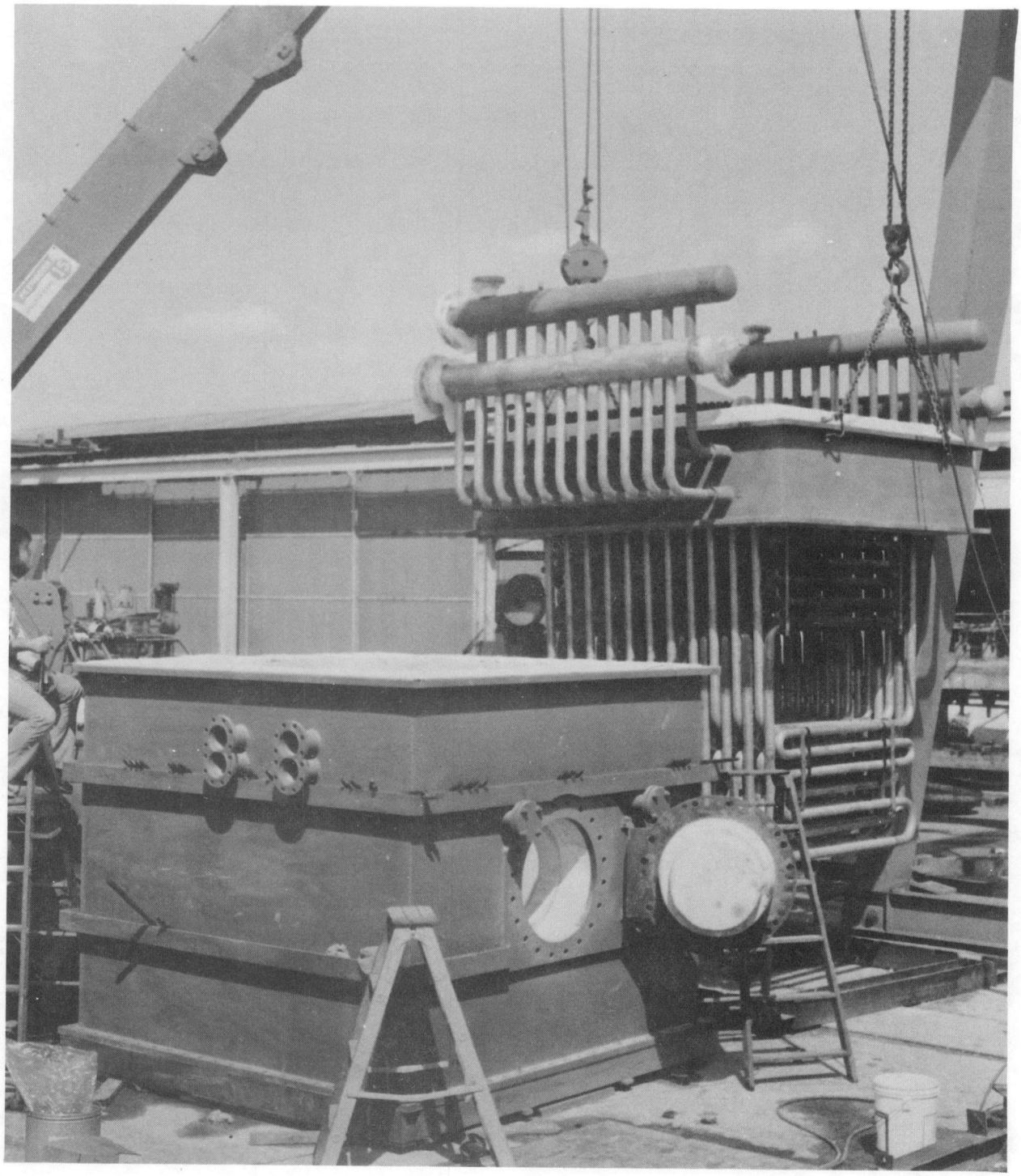

Figure C-11. Convection Heat Exchanger Being Readied for Transportation

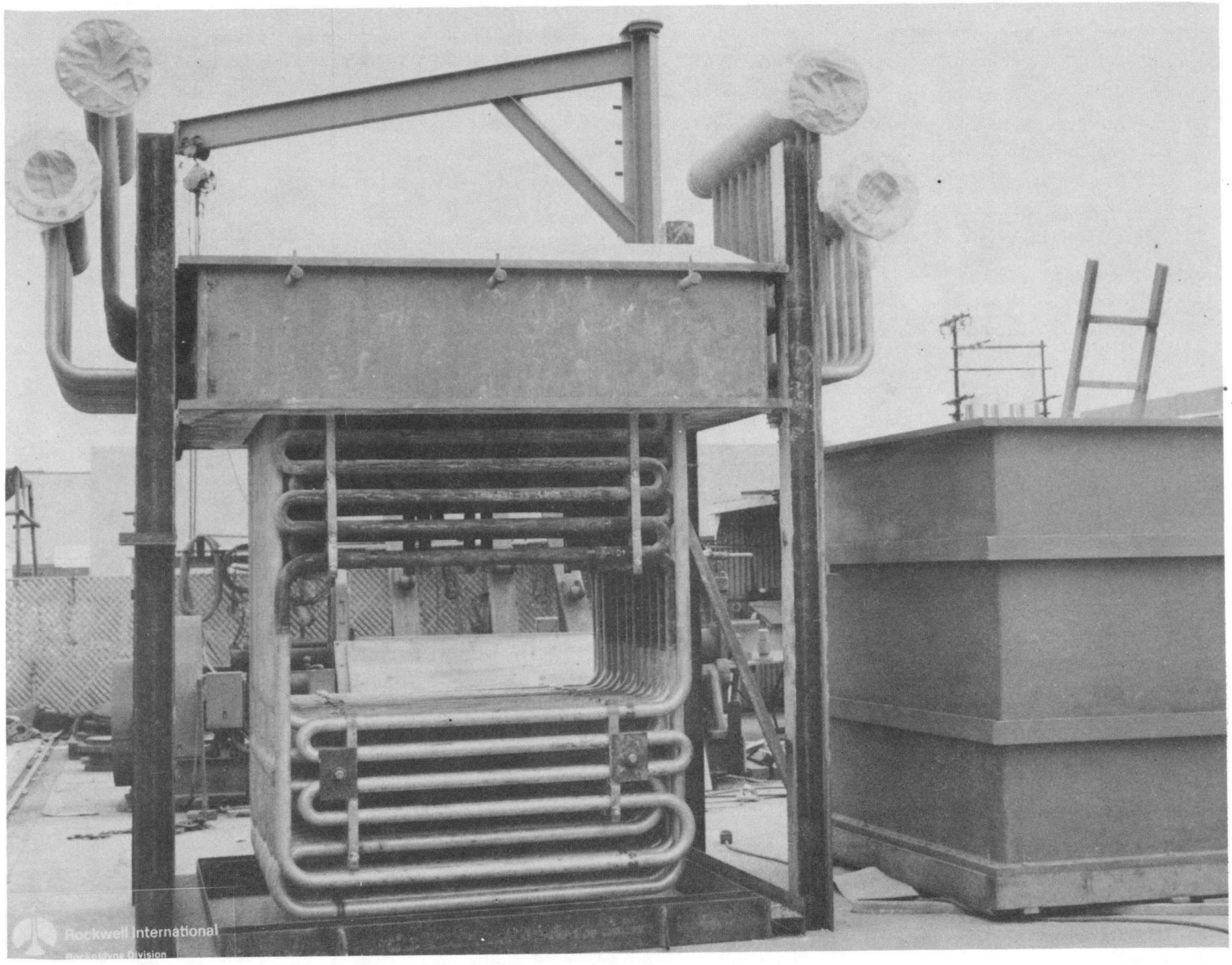

Figure C-12. Close View of Convection Heat Exchanger

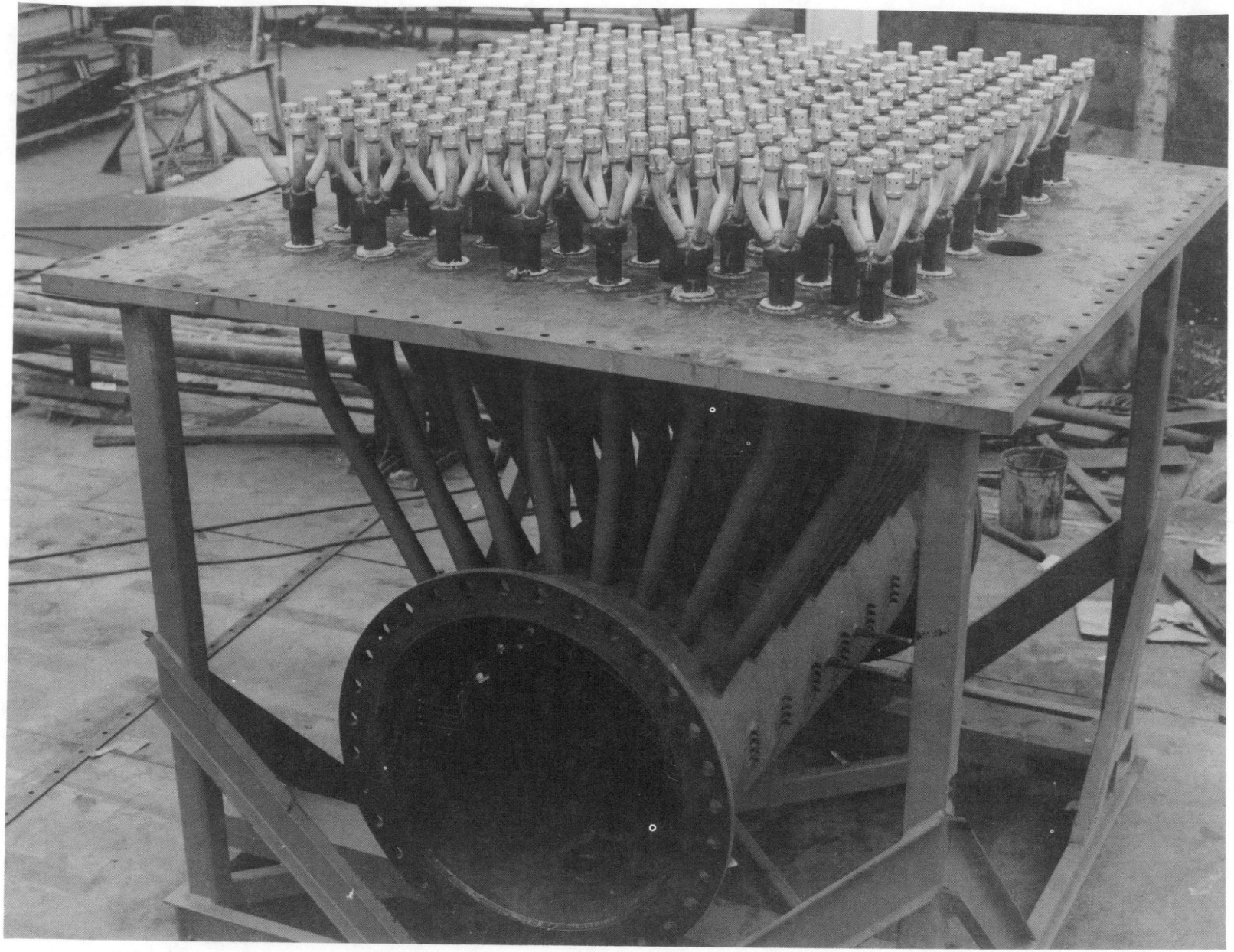

Figure C-13. Distributor Section During Fabrication (small lines in the windbox are for measuring flow in each feedline)

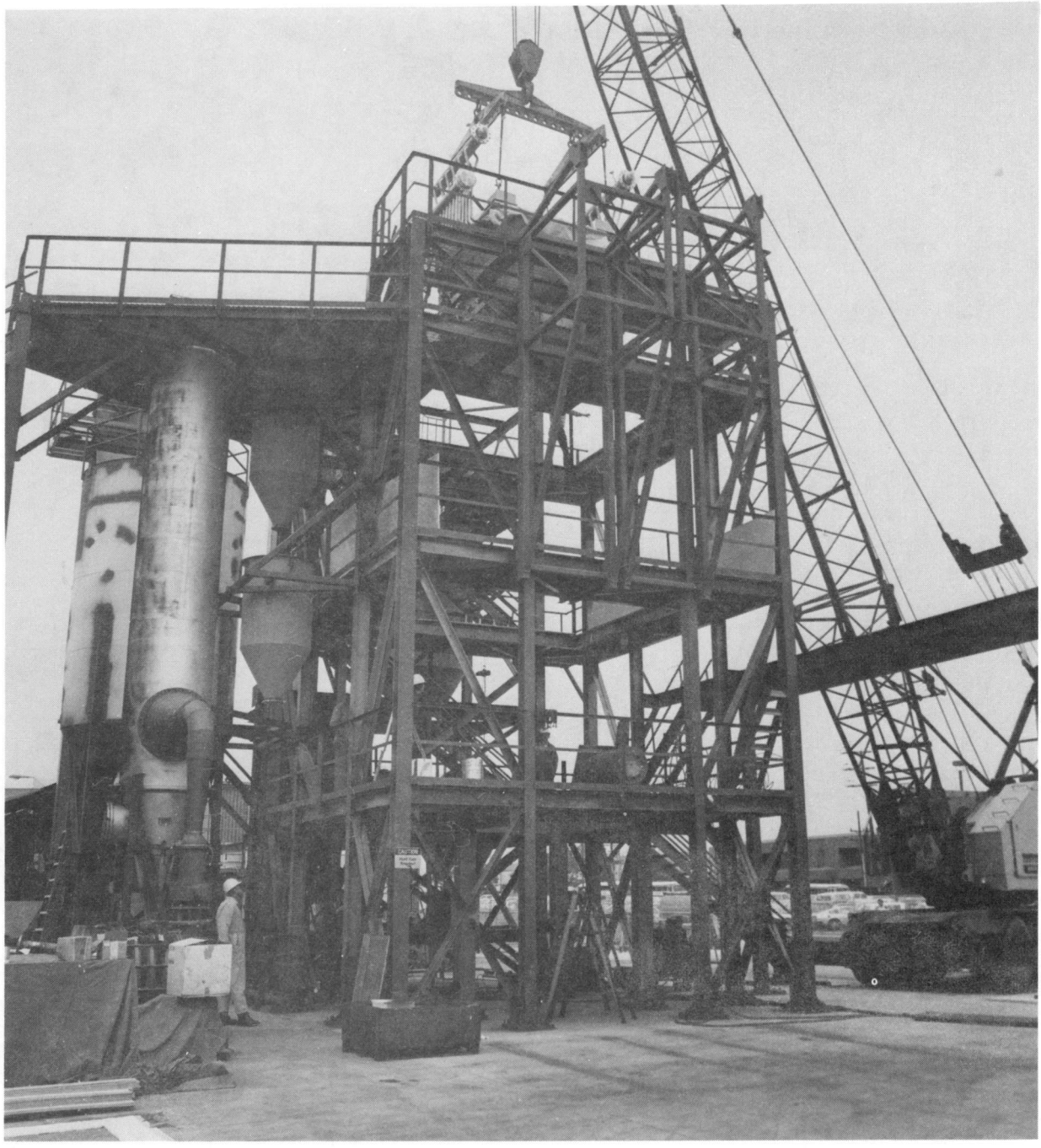

Figure C-14. Lower Section Being Installed

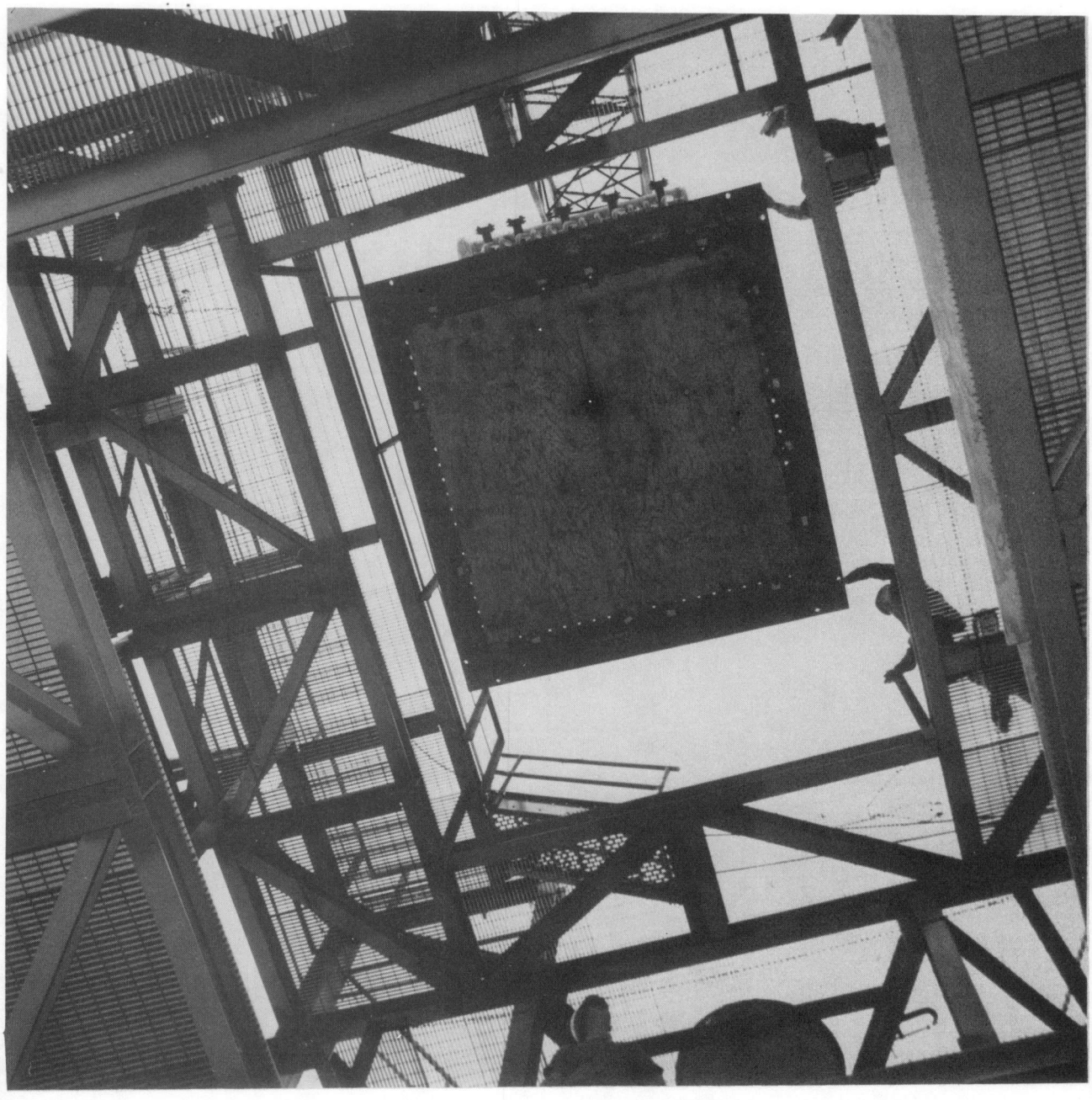

Figure C-15. Lower Section During Installation into Test Platform

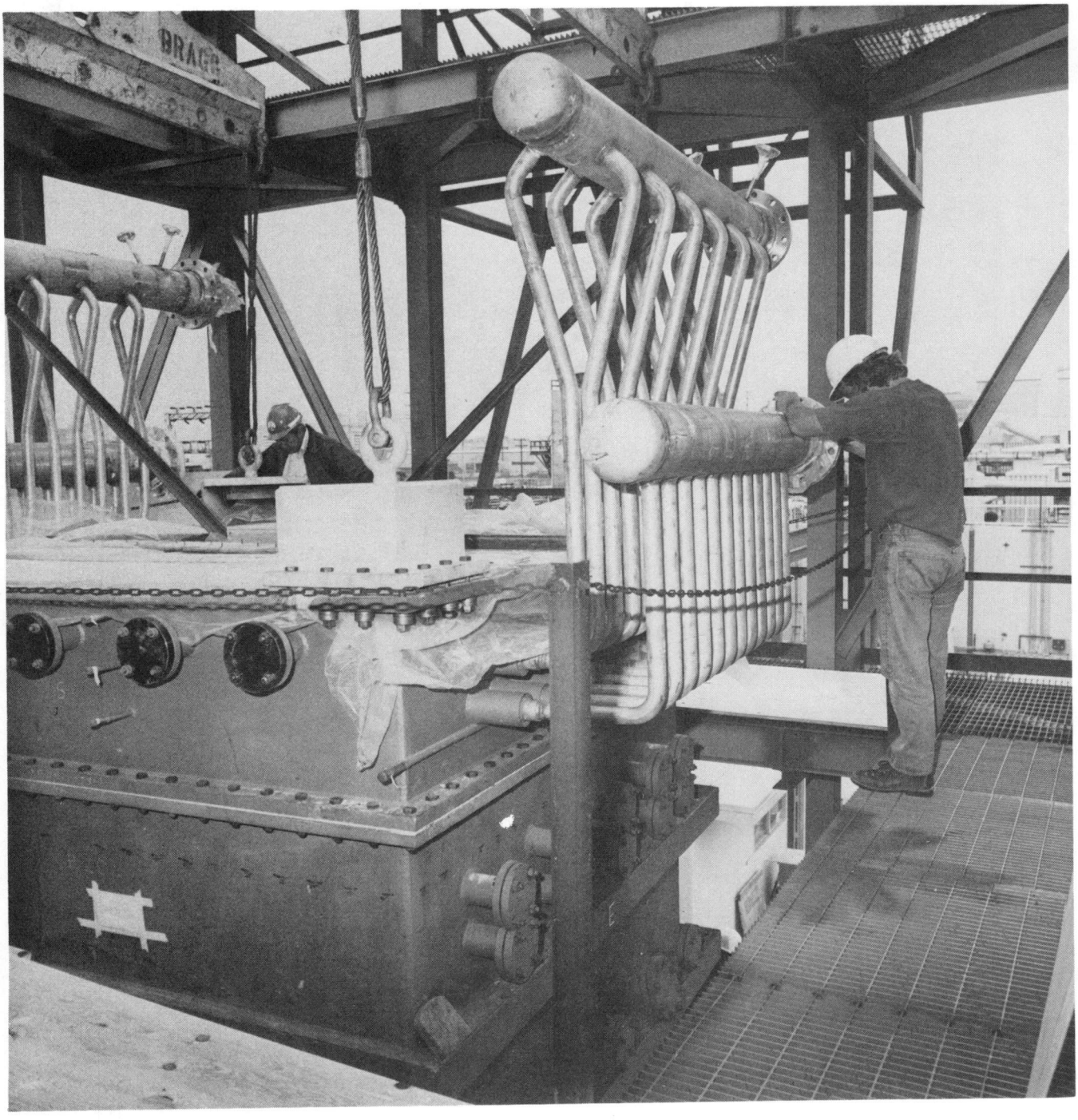

Figure C-16. Lower Section Being Eased into Place

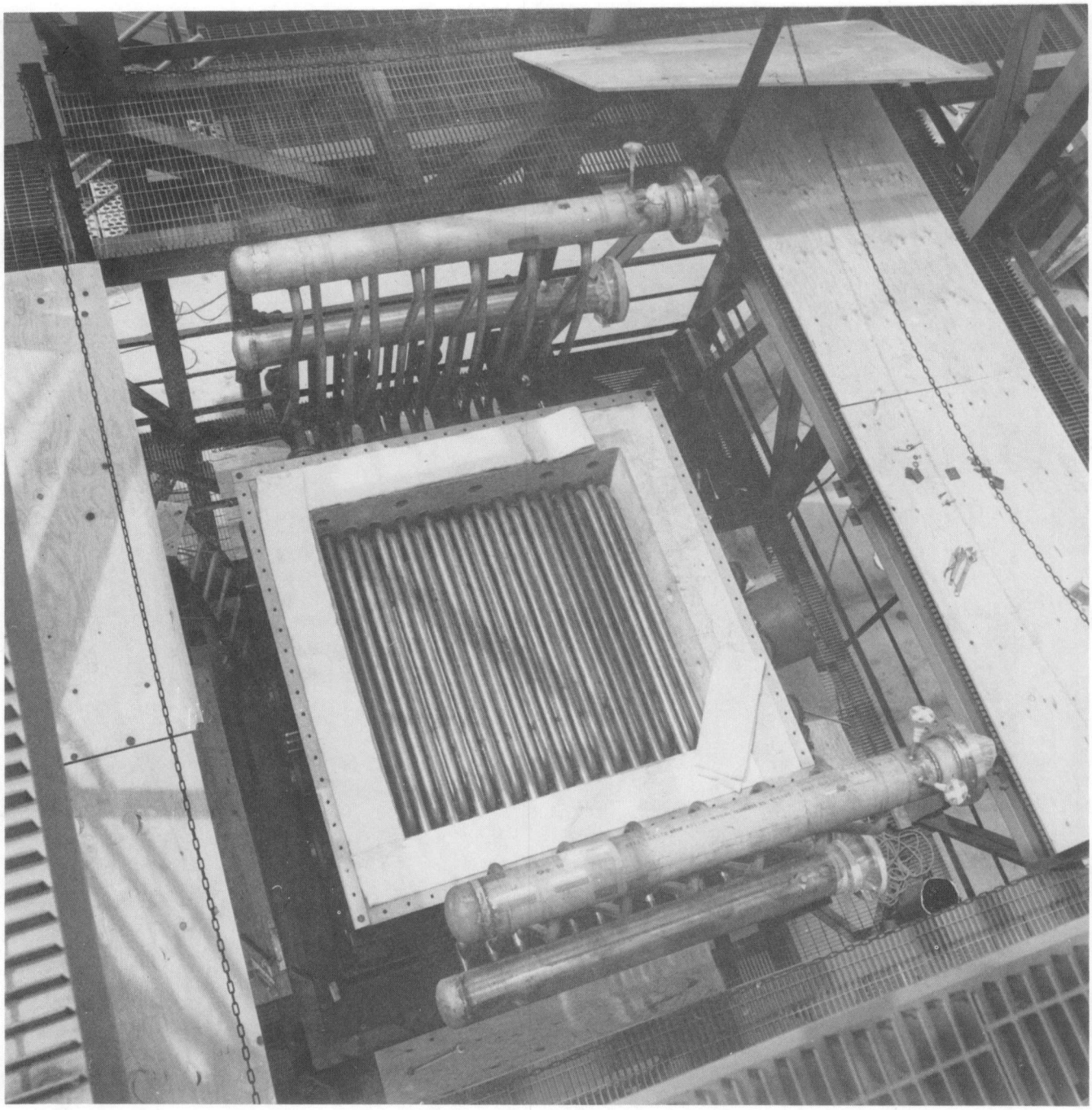

Figure C-17. Top View of Lower Section Installed in Platform (gasket material is shown partially installed)

Figure C-18. Freeboard Section Being Installed

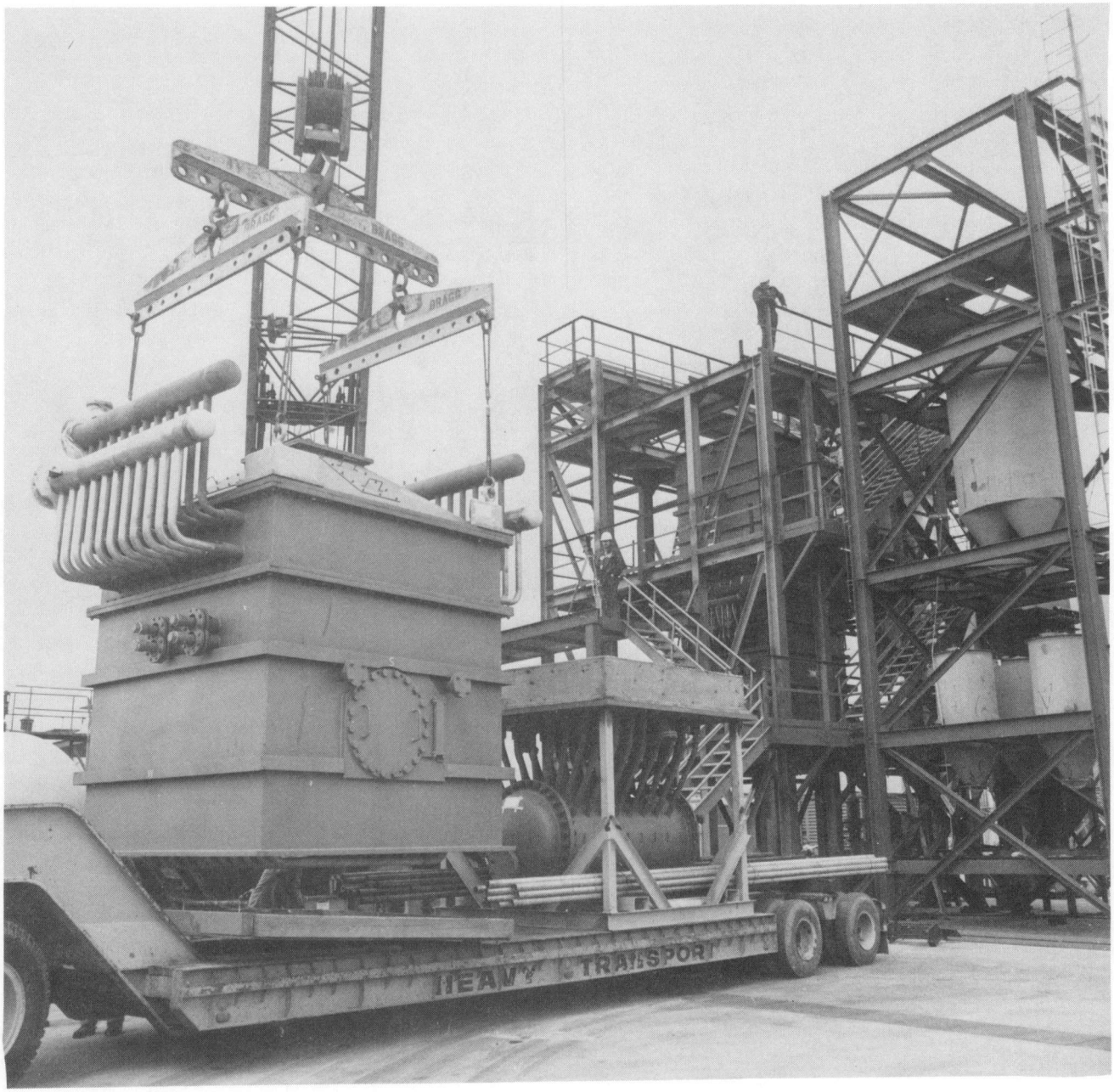

Figure C-19. Convection Heat Exchanger and Distributor Sections at Facility

Figure C-20. Convection Section Being Installed in Platform

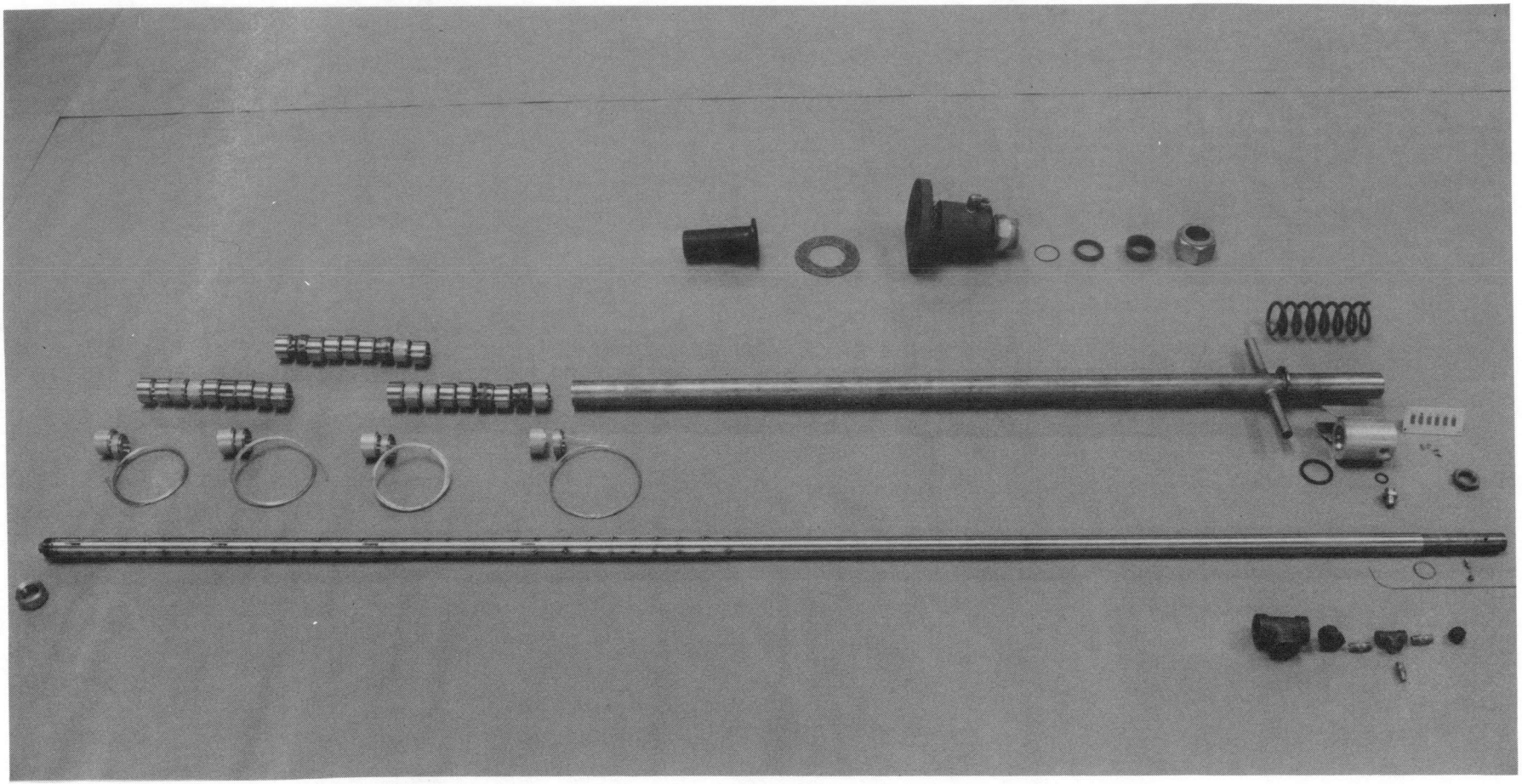

Figure C-21. Components of a Material Specimen Probe (typical arrangement of ring specimens and thermocouple rings shown at upper left)

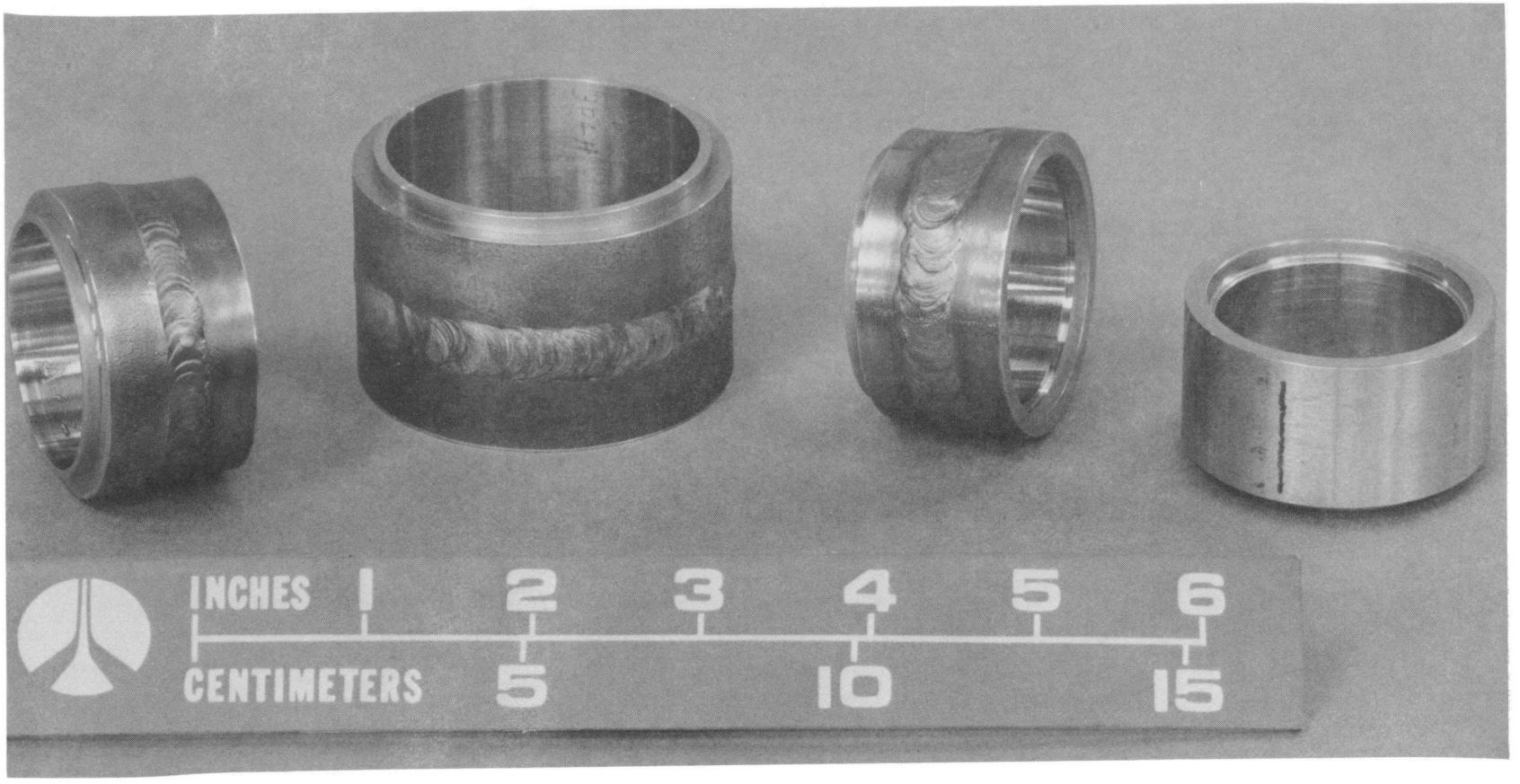

Figure C-22. Close View of Typical Ring Specimens (weld joint specimens are toward the left)

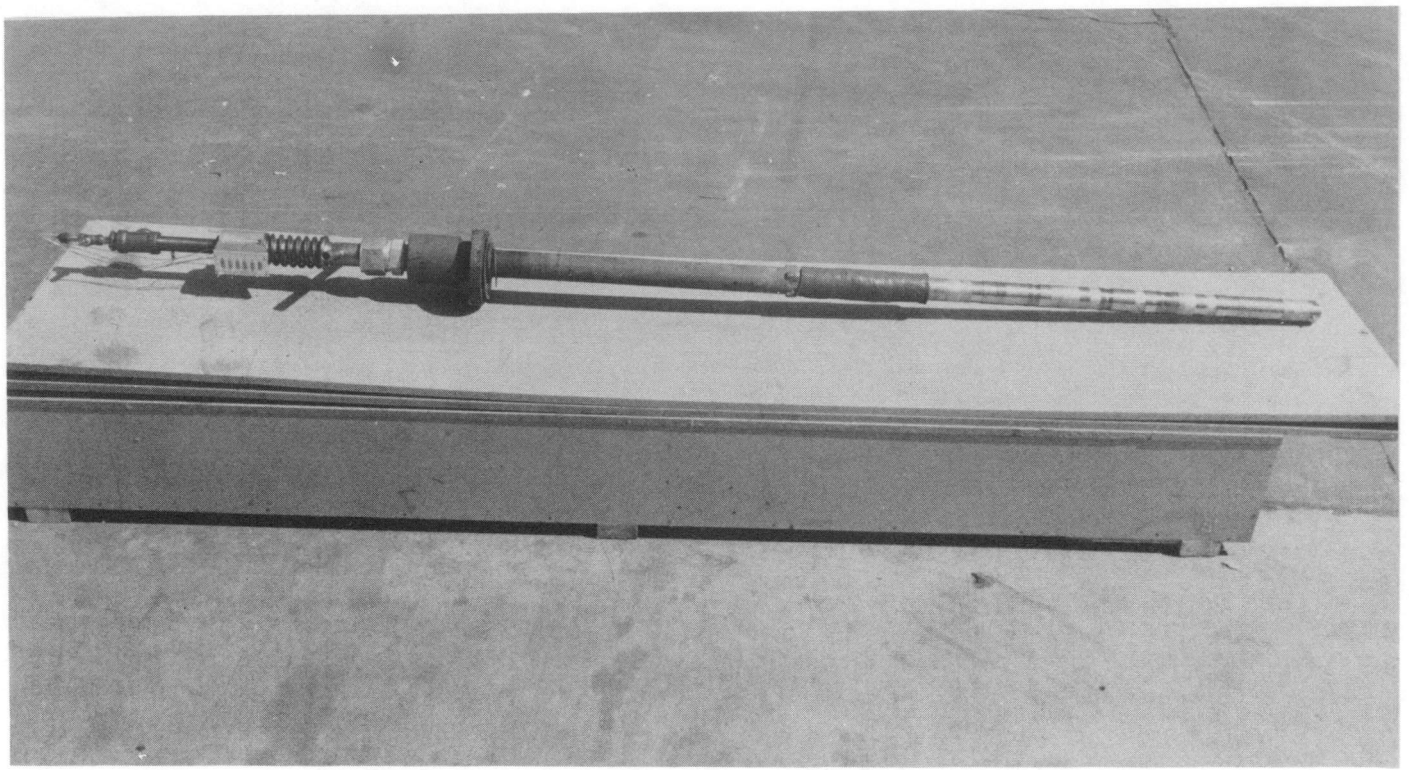

Figure C-23. Complete Material Specimen Probe Assembly

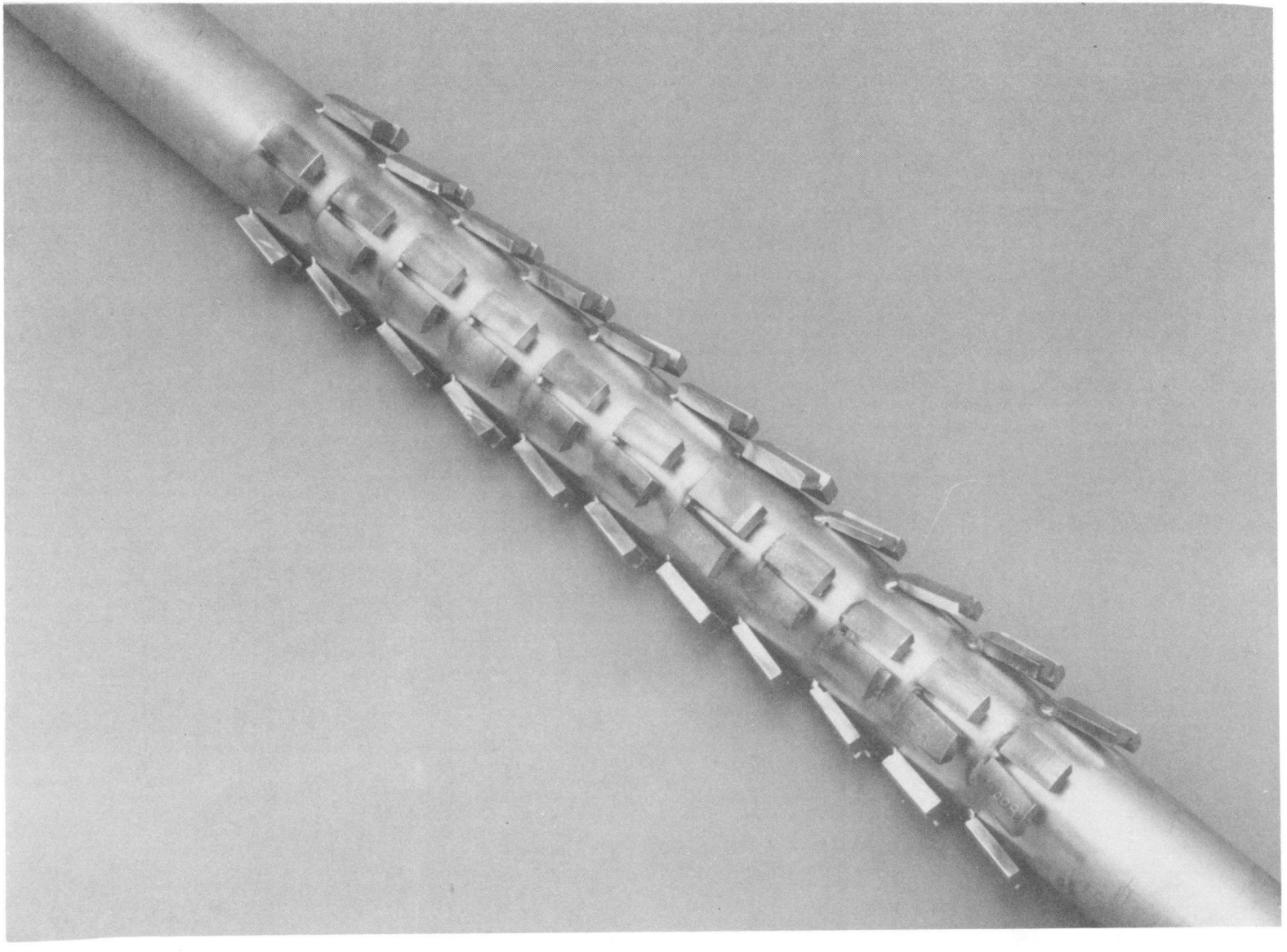

Figure C-24. Typical Hanger Material (Uncooled) Specimen Probe

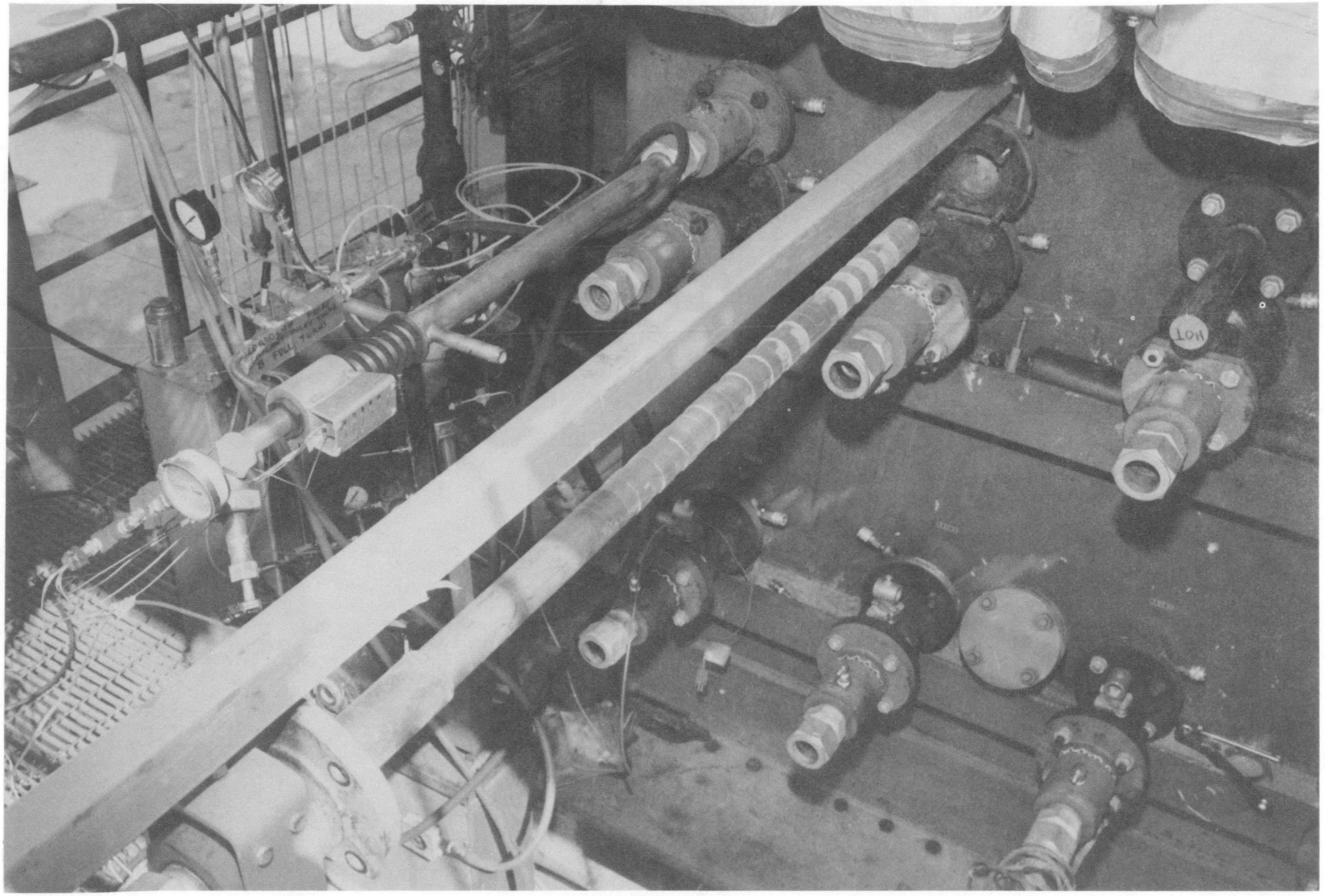

Figure C-25. Material Specimen Probe Being Removed After a Run (dummy probe labeled "hot" is shown at the right)

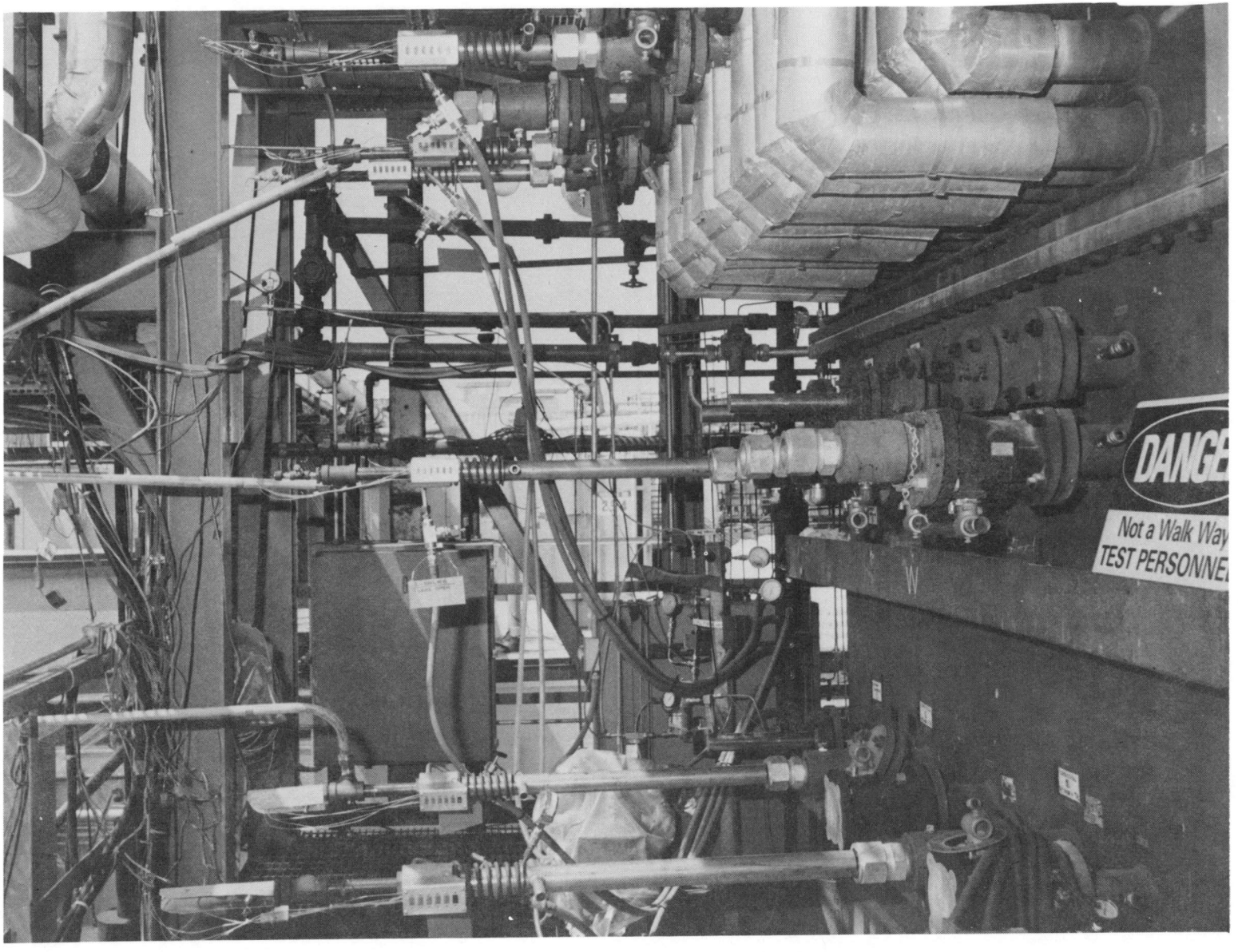

Figure C-26. View of Material Specimen Probes Installed for Exposure Test Series

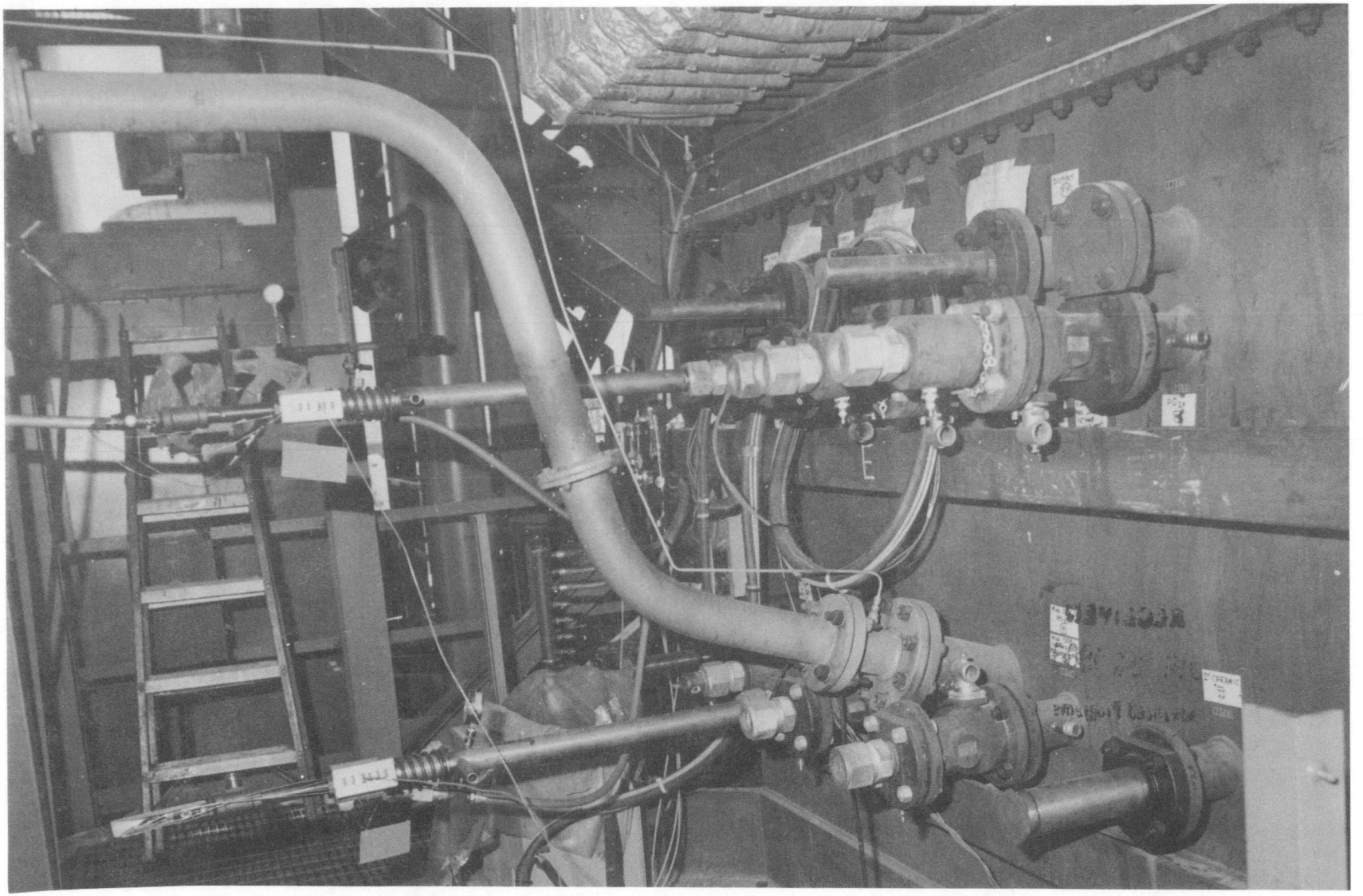

Figure C-27. View of Material Specimen Probe Installation and Ash Recycle Injection Line

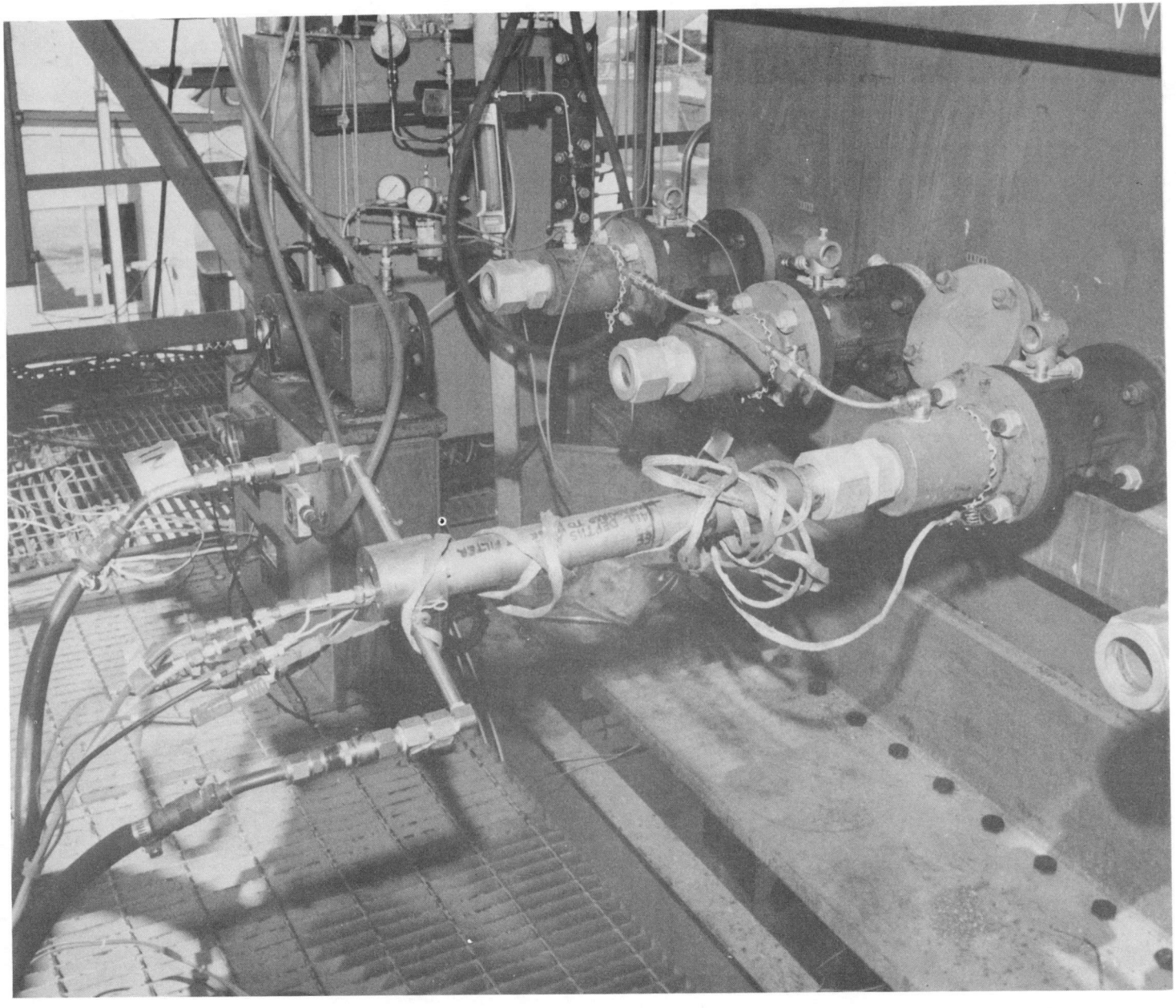

Figure C-28. Installation of Oxygen Partial Pressure Probe

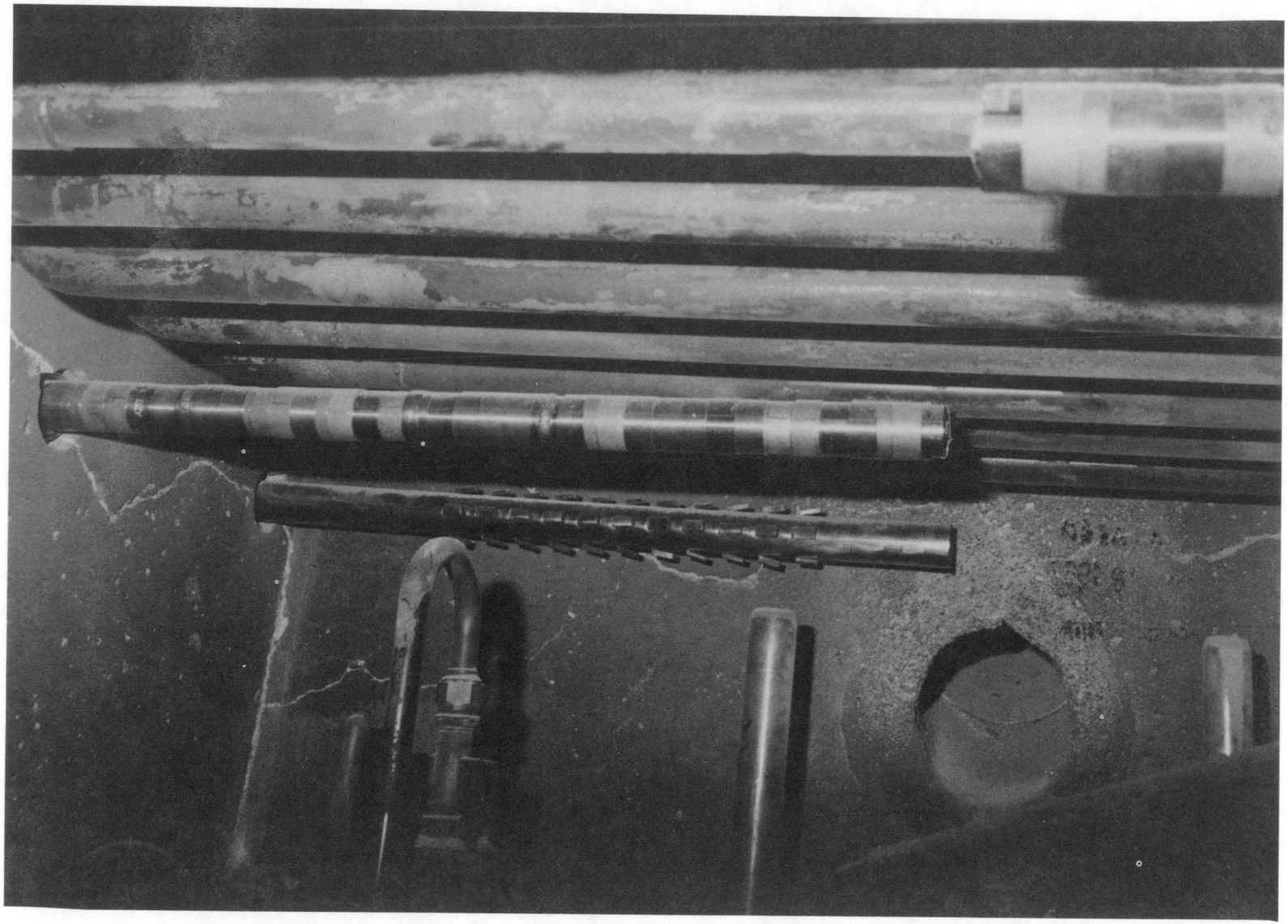

Figure C-29. Material Specimen Probes Installed Below Bed Heat Exchanger (prerun photo)

Figure C-30. Post-Run View of Material Specimen Probes Installed Above the Bed Heat Exchanger (uncooled surface penetration probes partially visible at top of photograph)

Figure C-31. View Looking Up at Material Specimen Probes Installed Below Convection Heat Exchanger (shown is a cooled ring probe, uncooled hanger specimen probe, and two temperature rake probes)

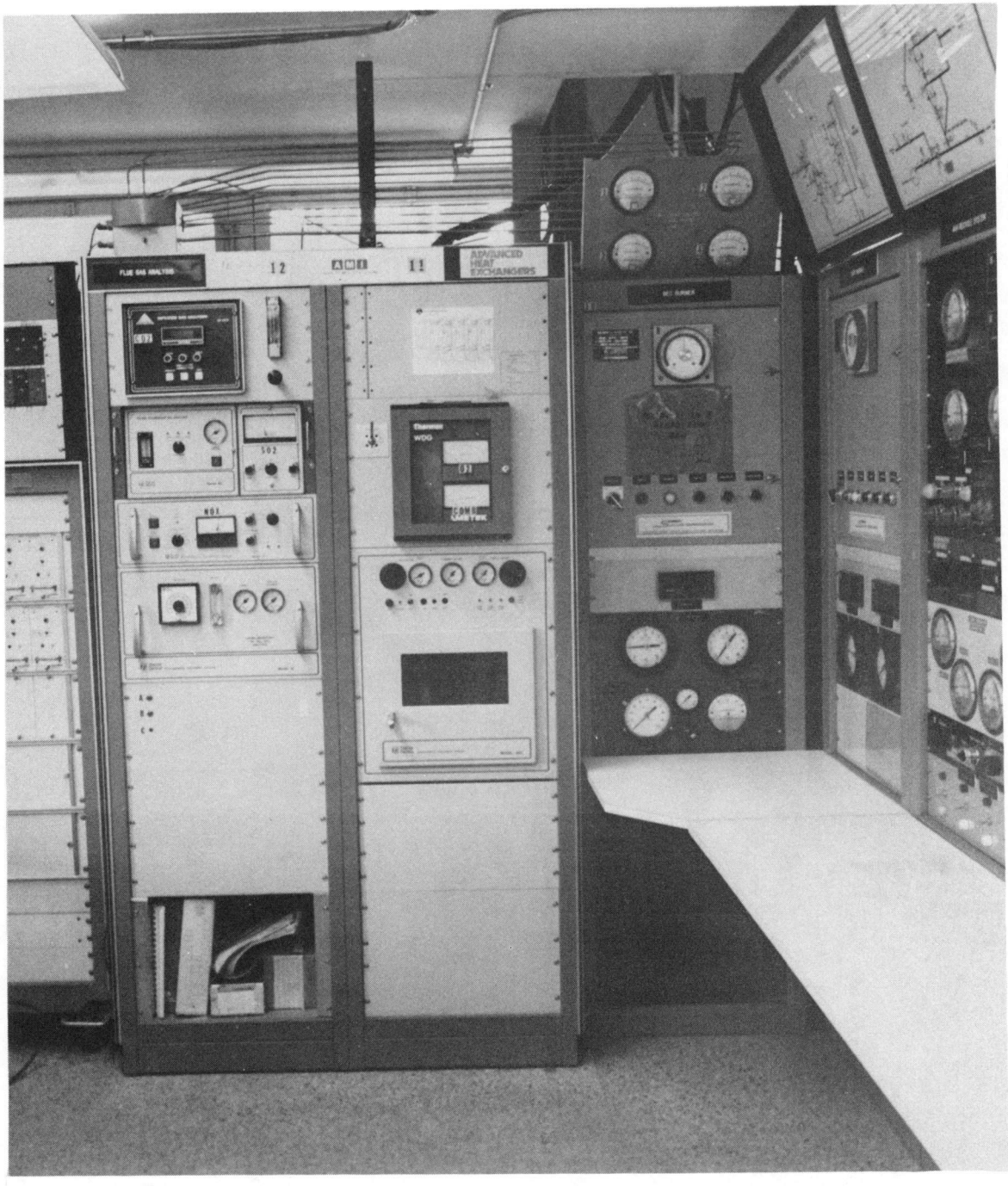

Figure C-32. Control Room (flue gas analysis console is in the center; the two panels in the corner are the control panels for the two ignition burners; the gages on top of the panel are to detect plugging in the four coal ports per quadrant splitter feedlines)

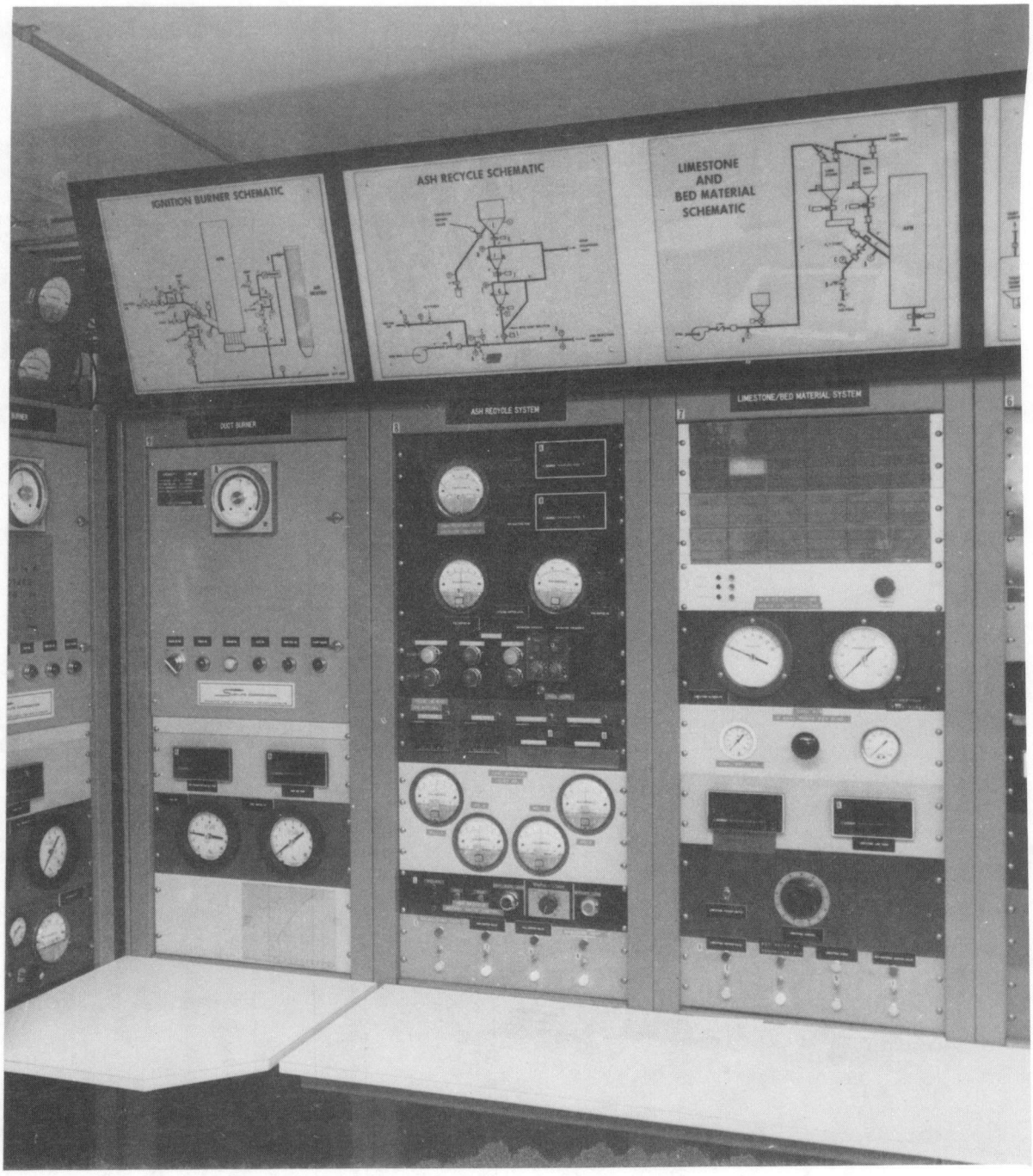

Figure C-33. Control Room Panels (panels for the duct burner, ash recycle system, and limestone system; annunciator is the upper portion of the right panel, most of the controls of each system tend to be under the appropriate schematic)

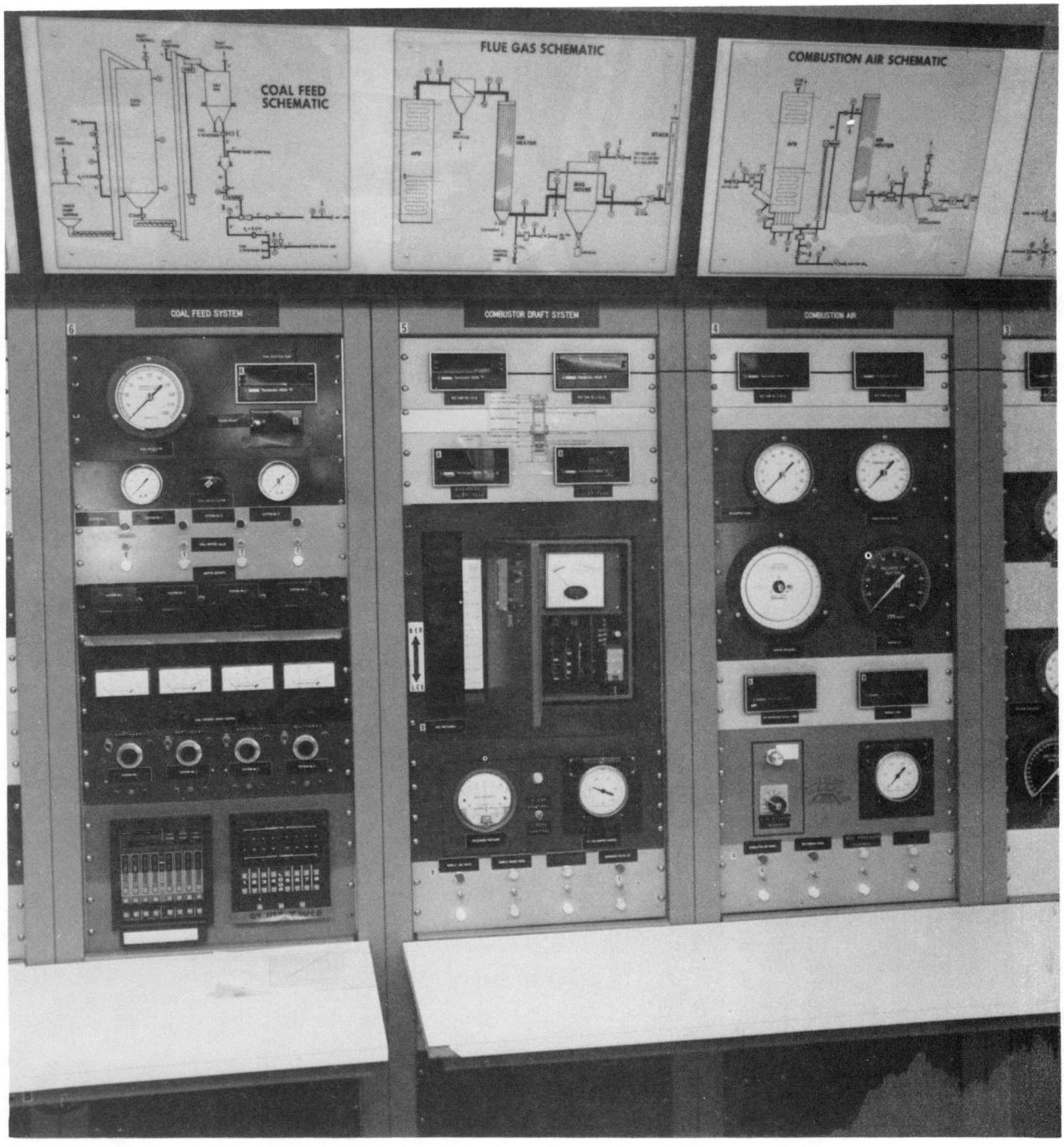

Figure C-34. Control Room Panels (left panel is the coal feed system with the process controller at the bottom; center panel contains the induced draft fan controls at the bottom; in the middle are the in situ oxygen meter and bed level gage; the right panel has the force draft blower controls; indicators at the top of the right panels display bed temperatures)

Figure C-35. Control Room Panels (left and center panels have the two working fluid systems; right panel has another in situ oxygen meter in the middle while the Autodata recorder is at the bottom.

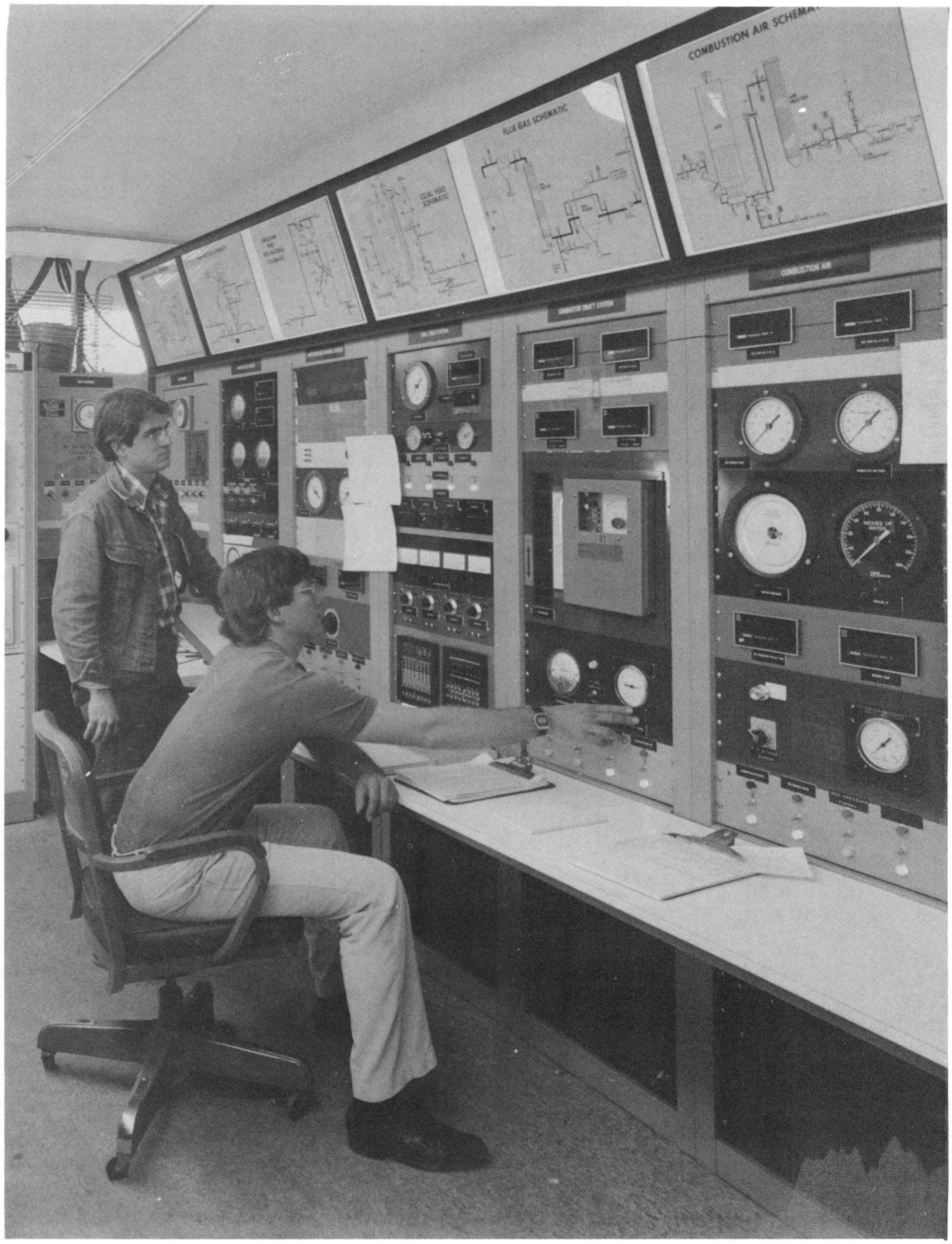

Figure C-36. Overall View of Control Room Panel

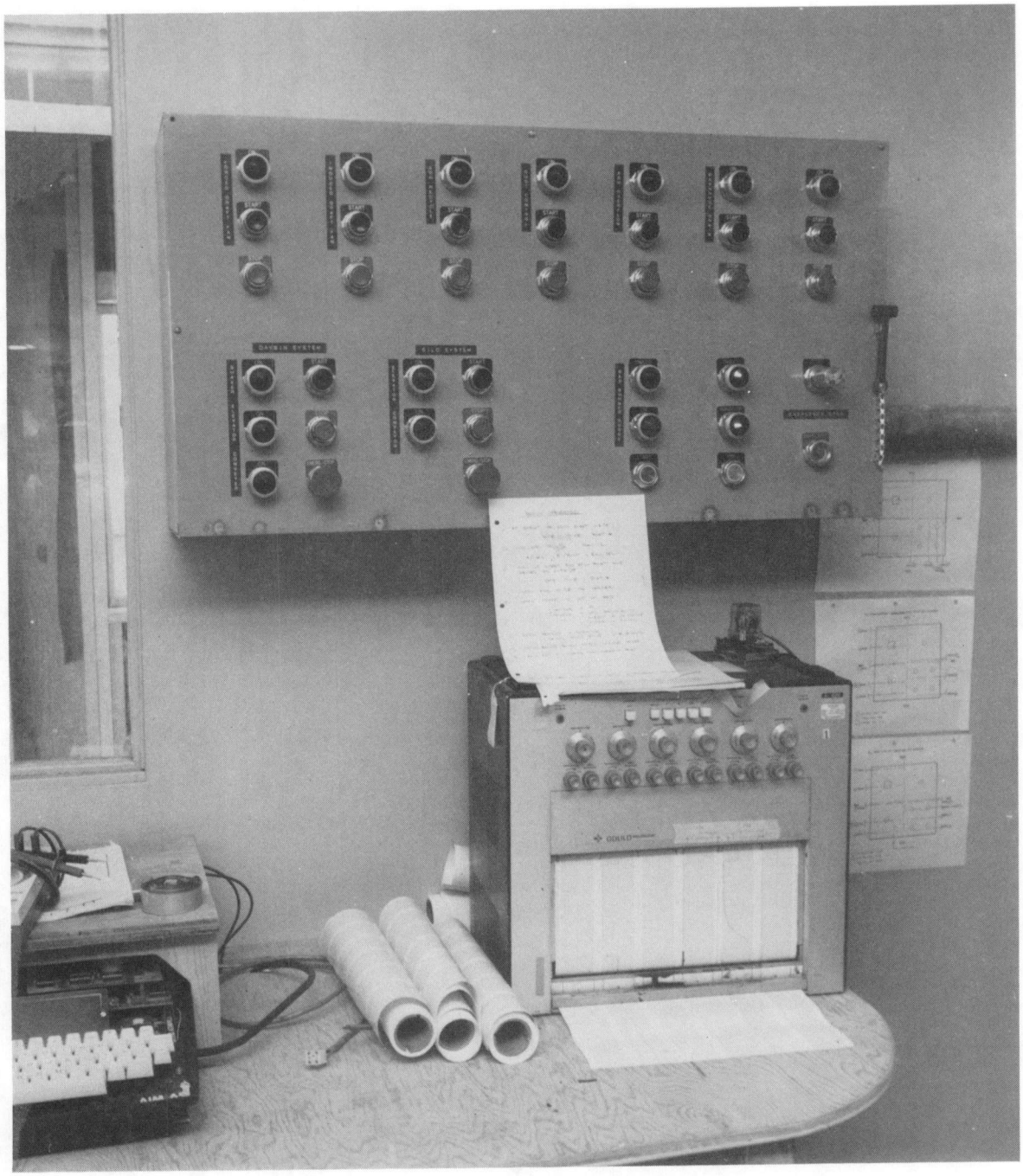

Figure C-37. Auxiliary Motor Control Panel in Control Room

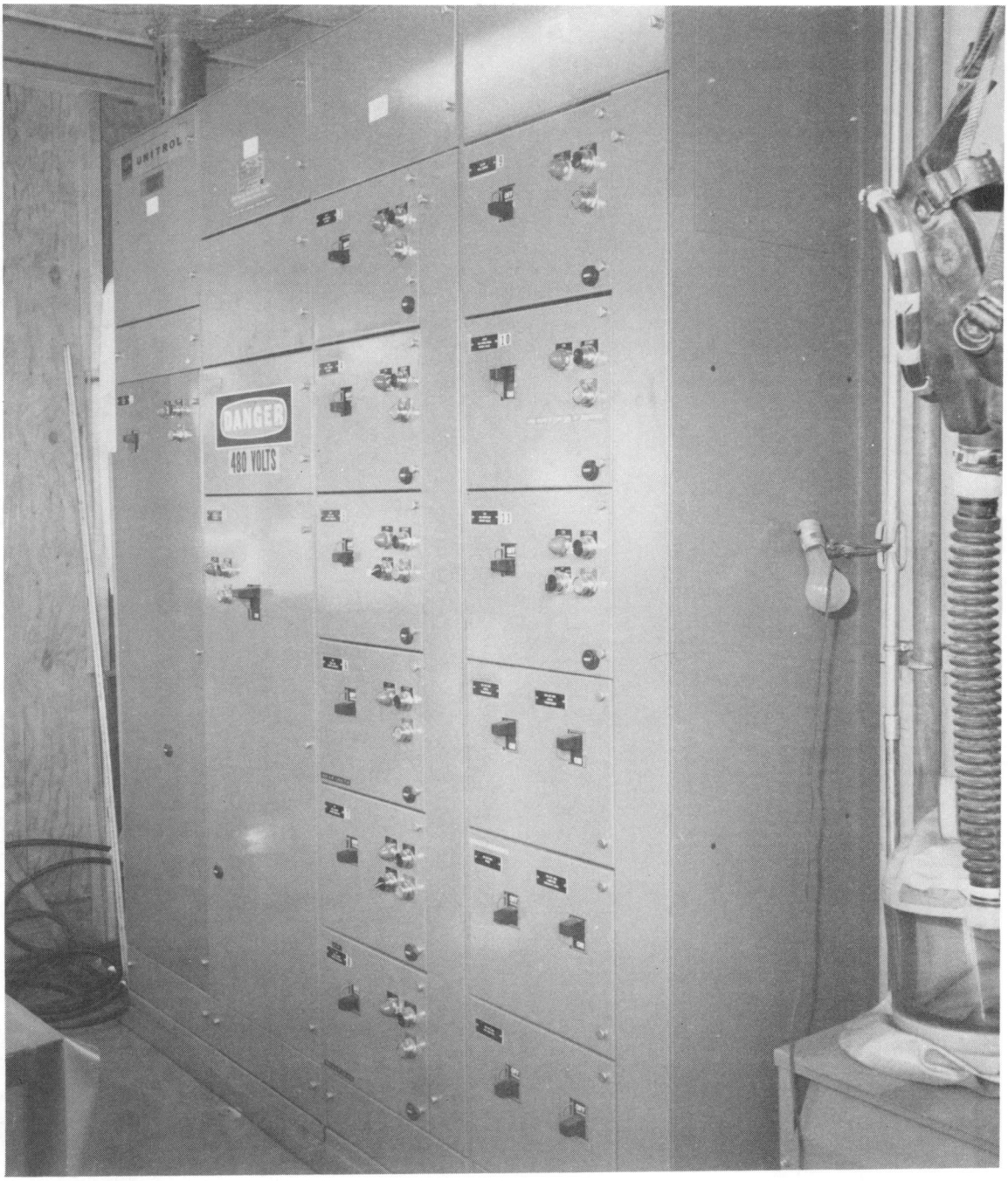

Figure C-38. Motor Control Panel

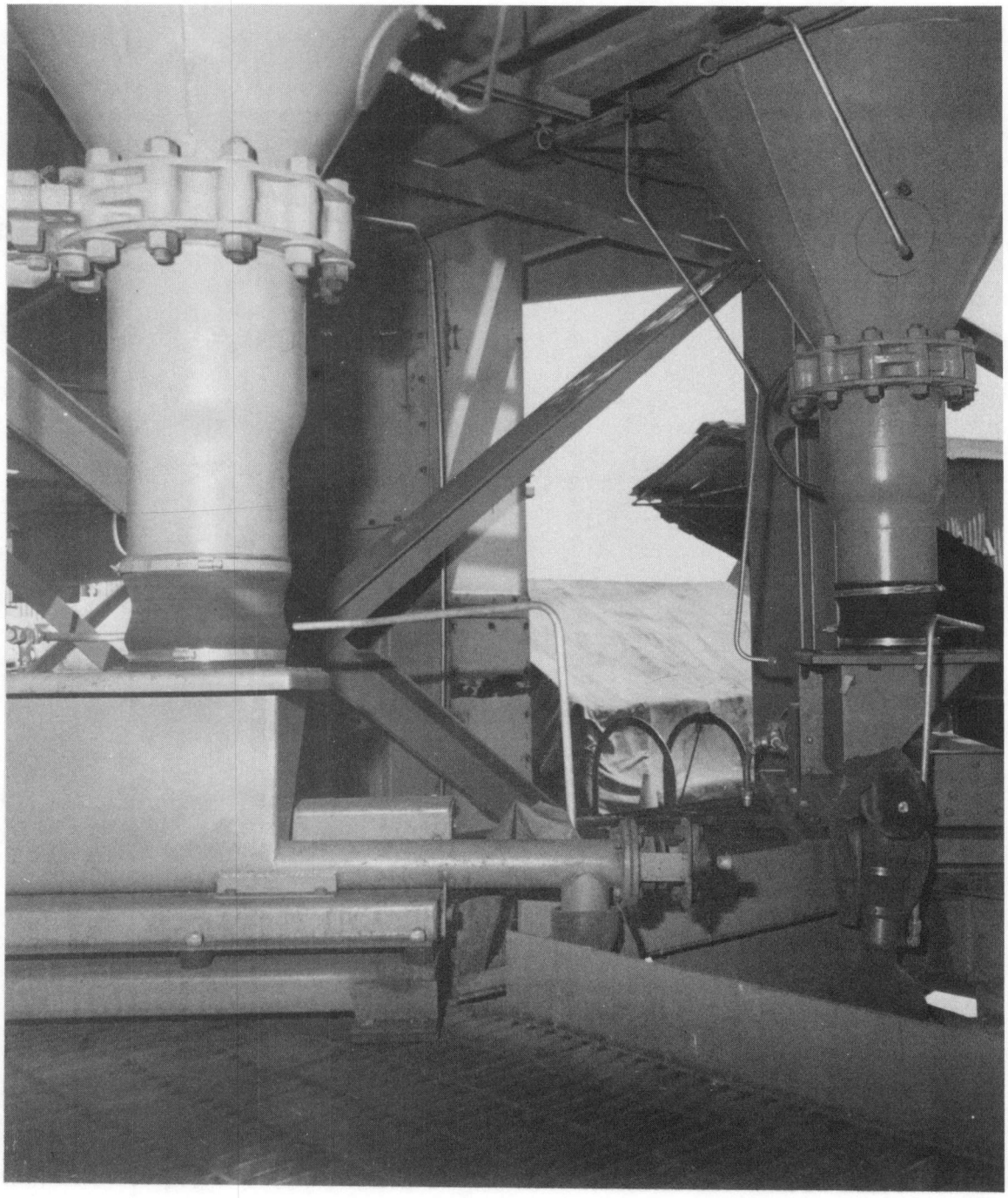

Figure C-39. Vibrascrew Coal Feeders (located on lowest deck of coal tower)

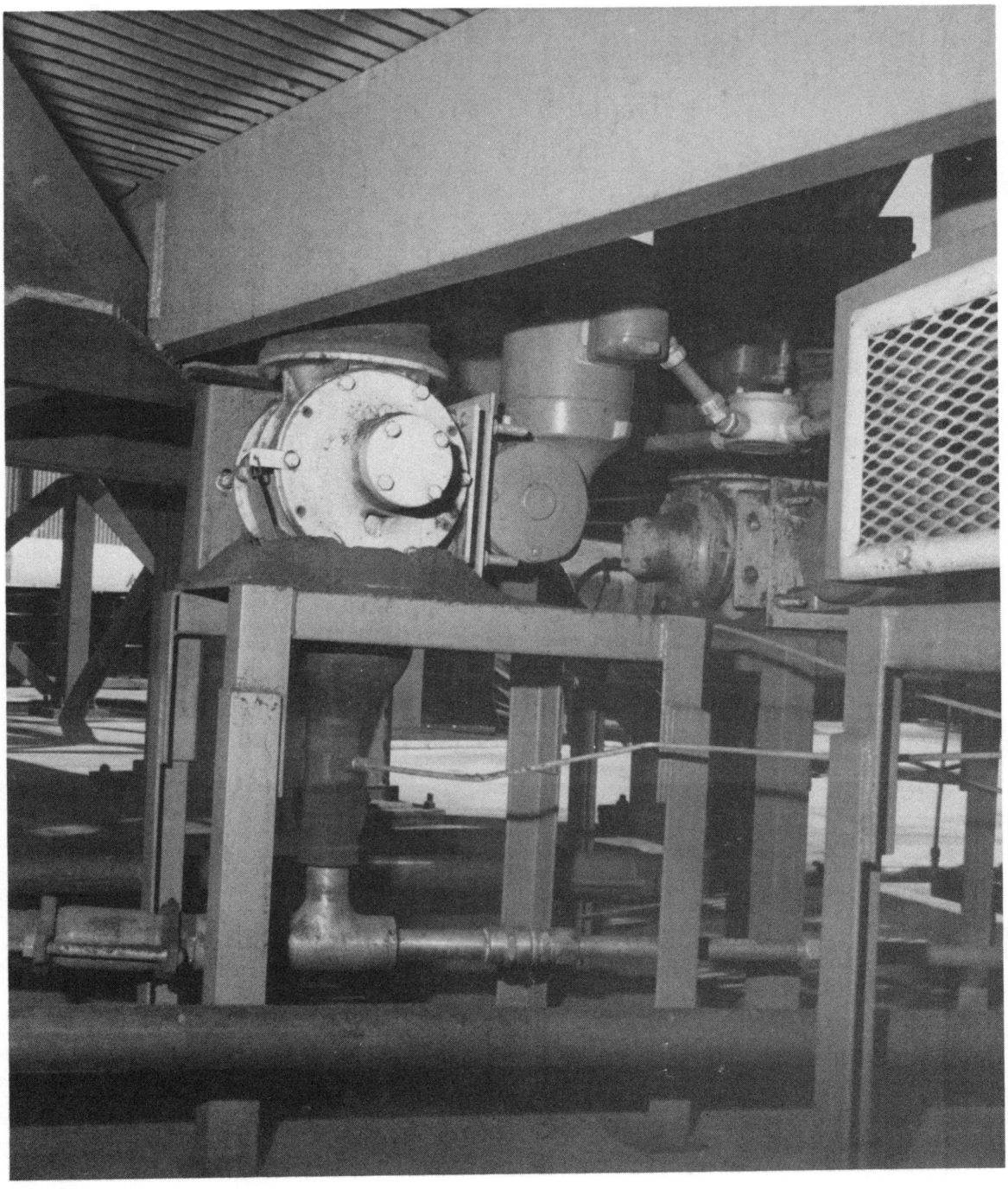

Figure C-40. Coal Feed System and Eductors (coal passes through the rotary air lock shown into the eductor; air flows from the right into the eductor)

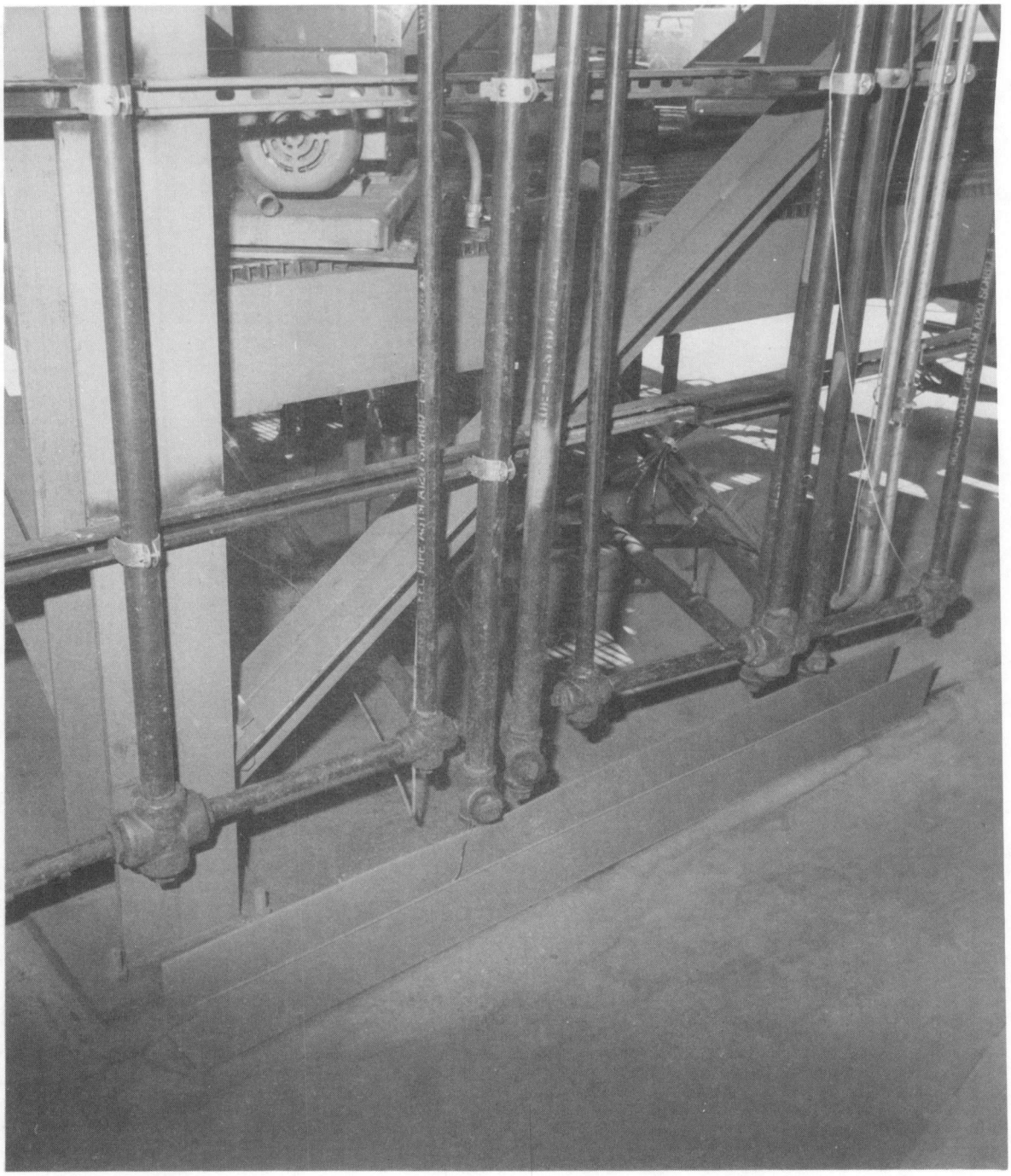

Figure C-41. Coal Feedlines (typical arrangement of the coal lines using straight pipe and plugged crosses; this view shows the lower portion of the splitter used in the four ports per quadrant system)

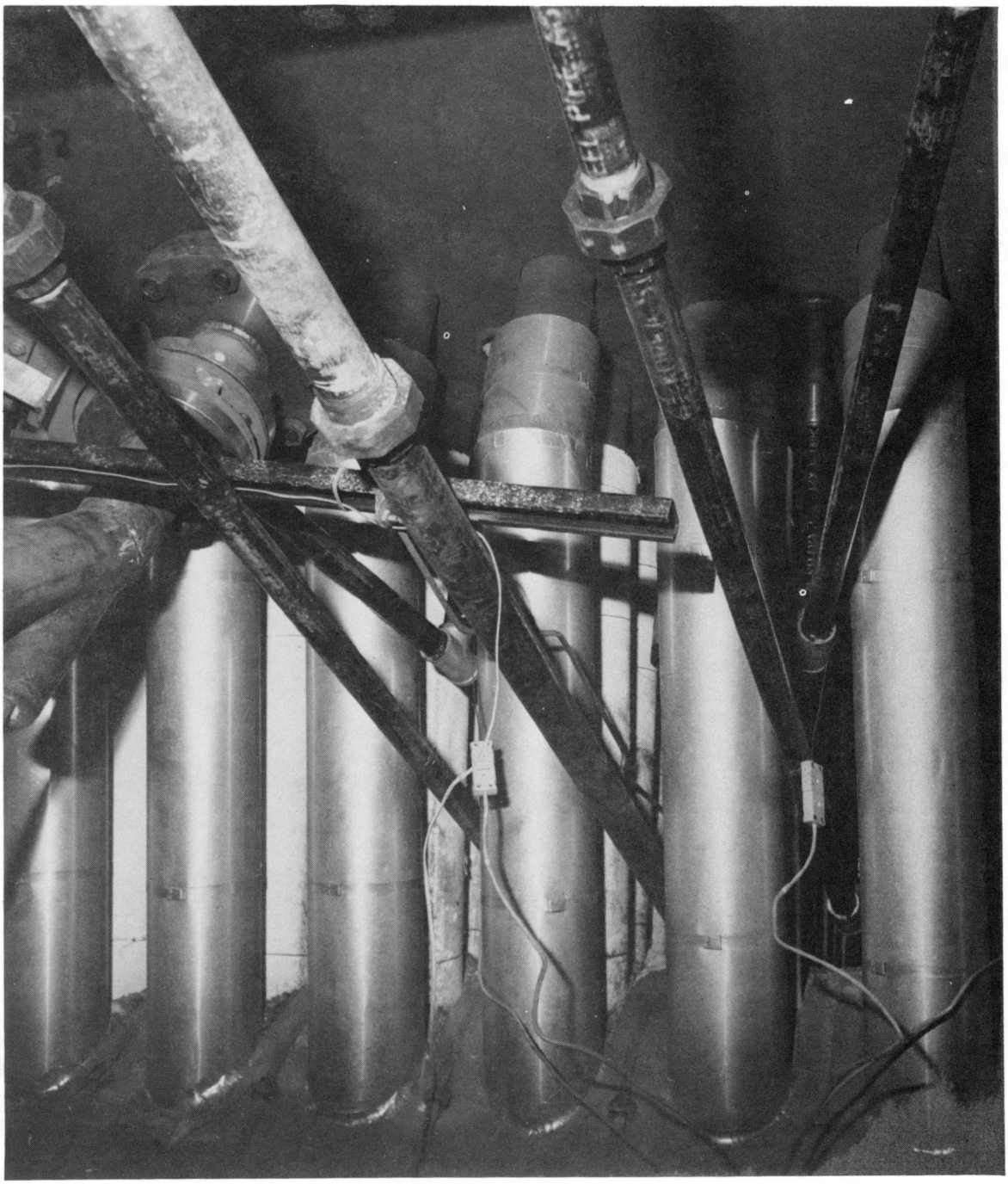

Figure C-42. Coal Feedlines Under the Distributor (windbox is at bottom; coal lines pass through the tuyere feedlines)

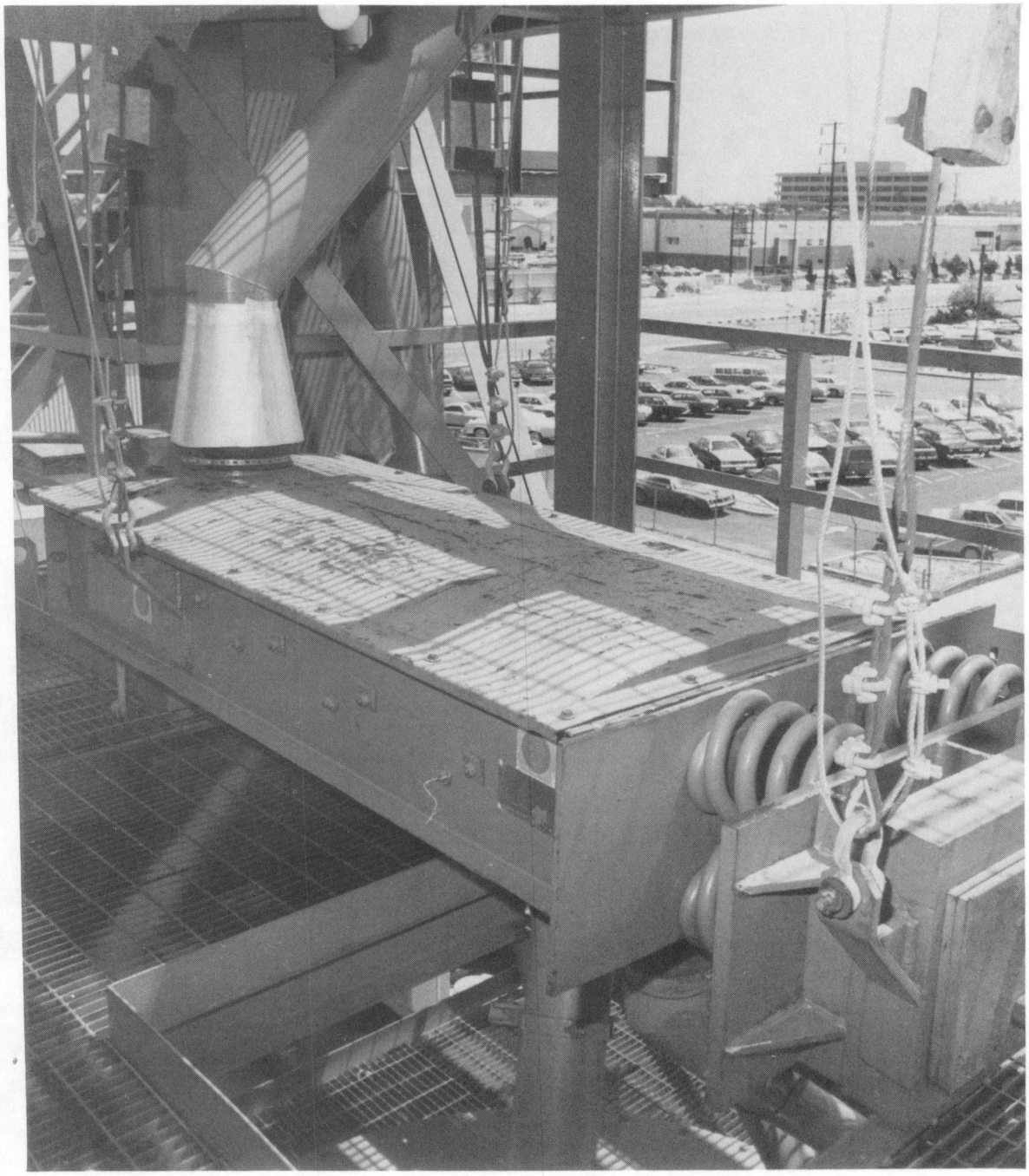

Figure C-43. Coal Screen (located at the top of the coal tower and used to remove oversize particles from the coal)

Figure C-44. Forced Draft Blower (the air flow path is through the filter/silencer, control damper, blower, and blowoff valve section; in the left background are the blowoff valve control panel as well as the bottom of the baghouse)

Figure C-45. Combustion Air Venturi (shown are the blowoff valve/silencer, venturi, and air preheater inlet)

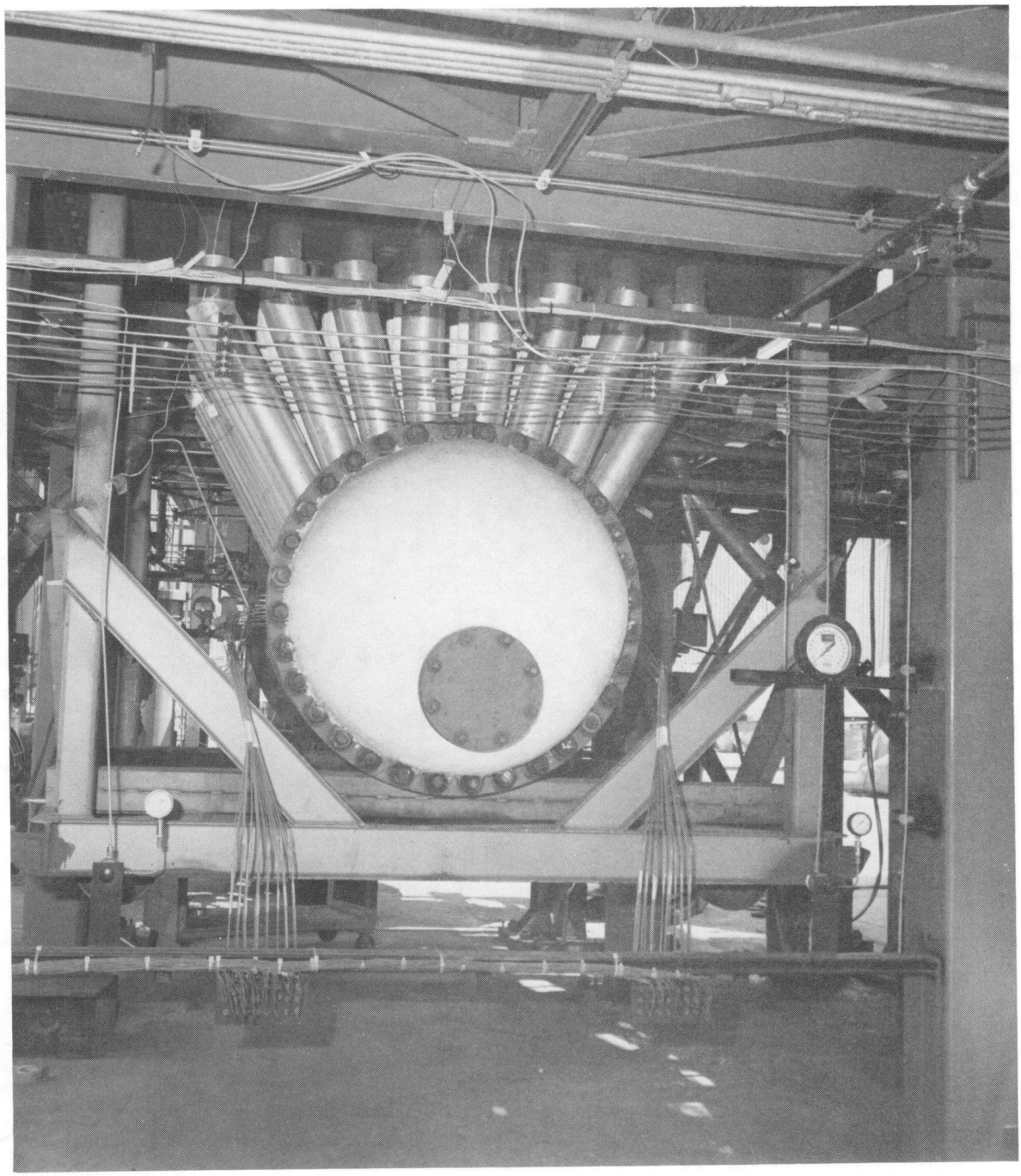

Figure C-46. Distributor and Windbox (shown is the end view of the windbox with the access plate)

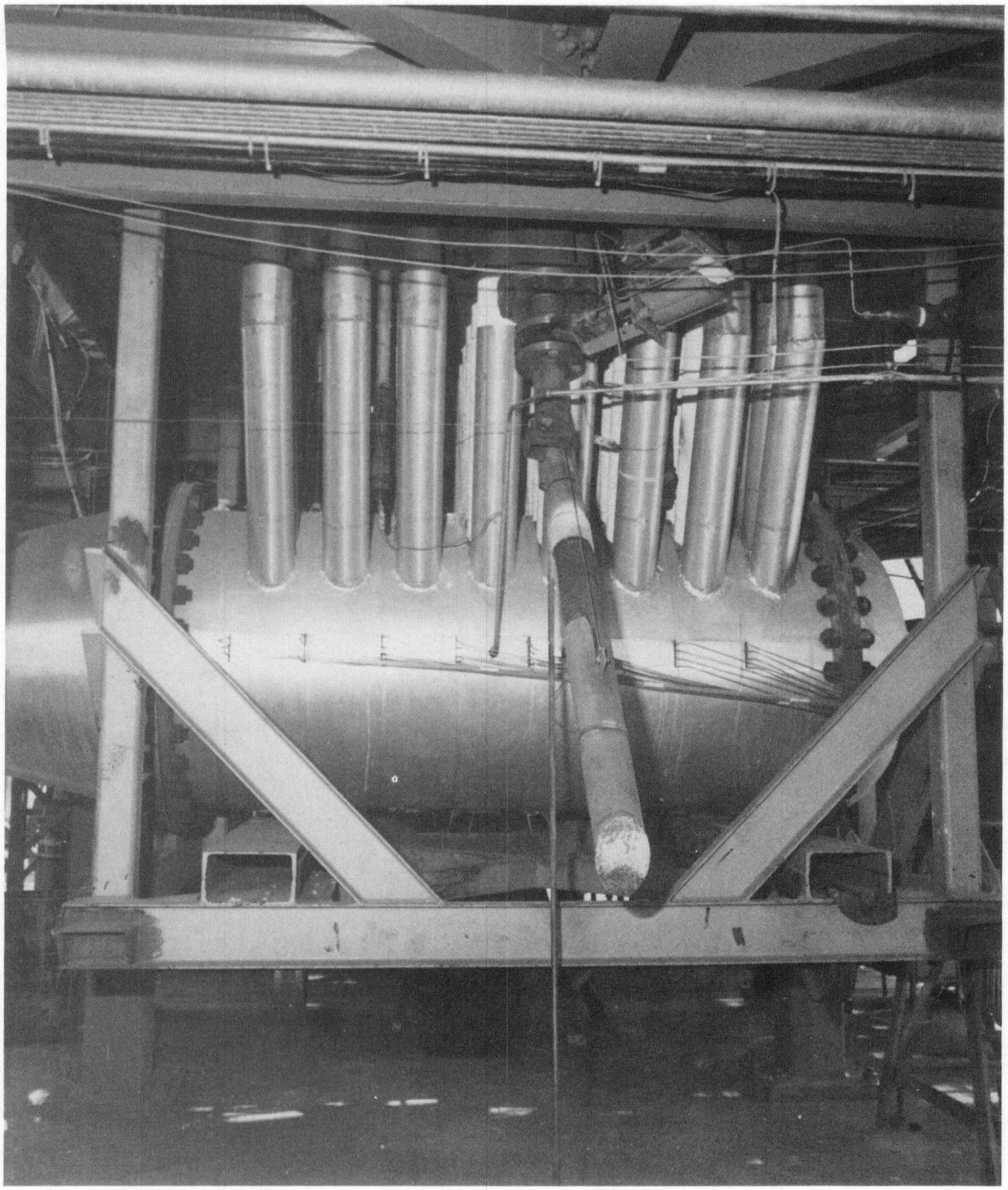

Figure C-47. Windbox and Bed Drain (bed drain valve and line shown in the center)

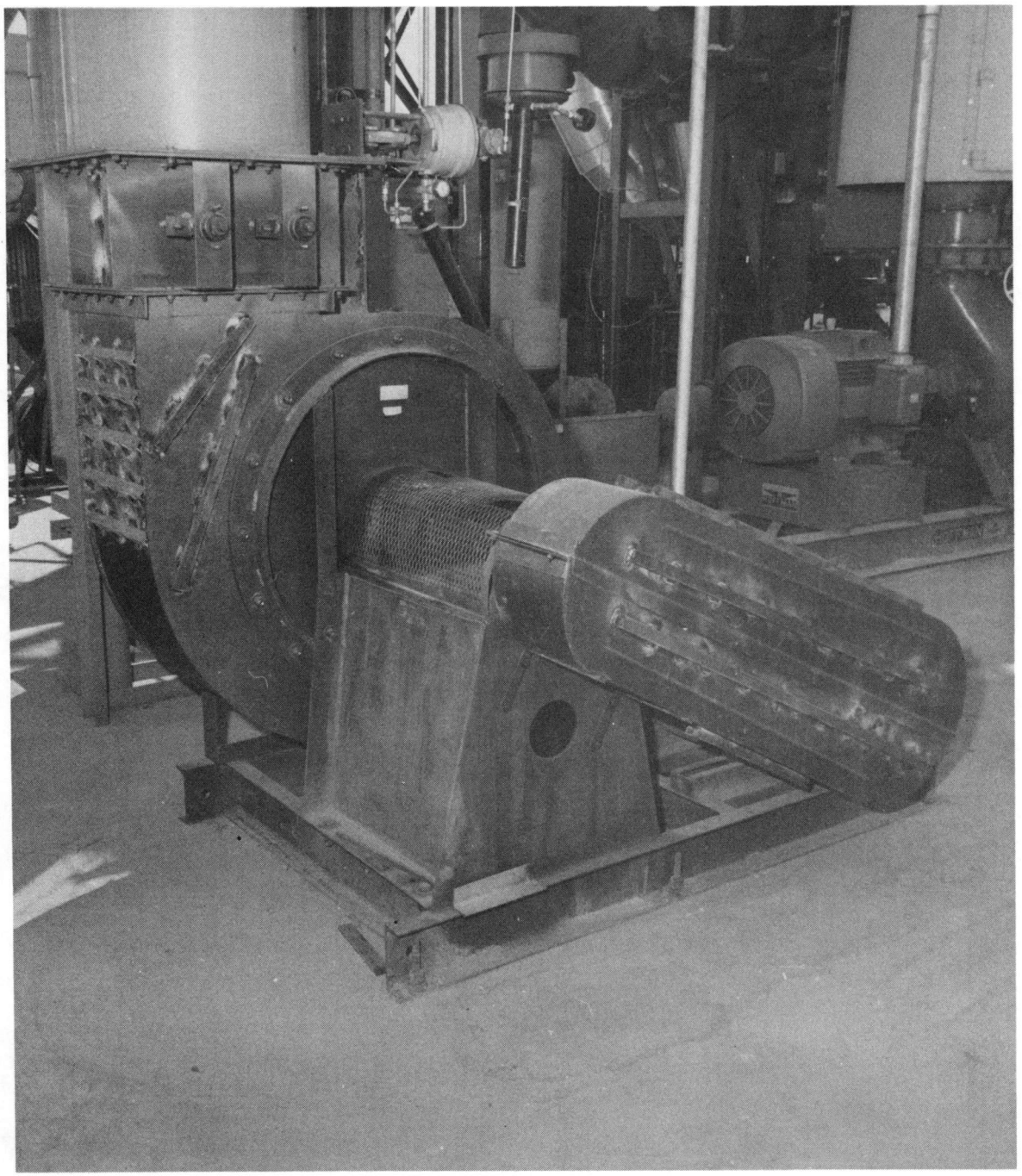

Figure C-48. Induced Draft Fan (bottom of the exhaust stack is shown where it connects the fan outlet)

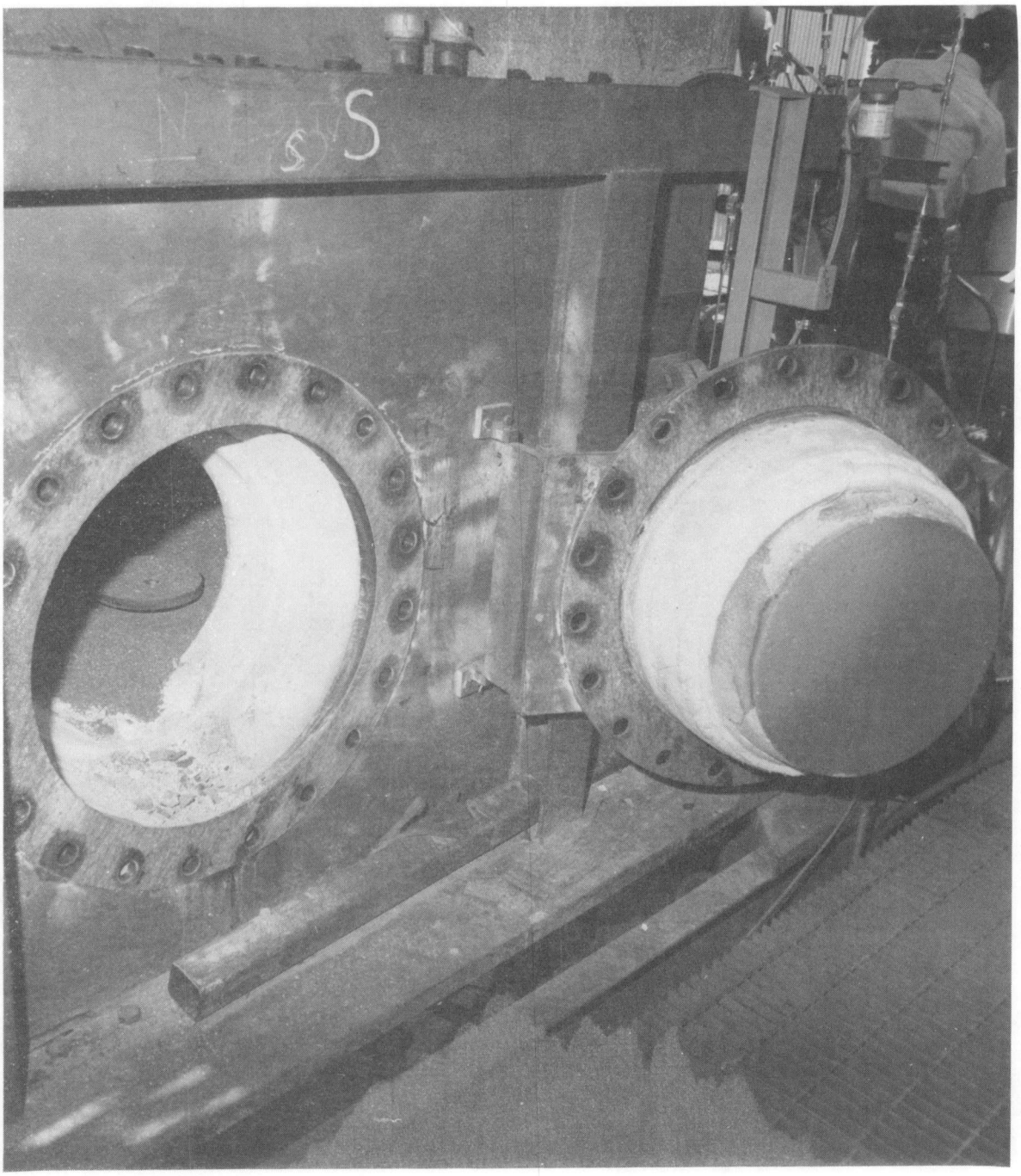

Figure C-49. Access Door to Bottom of the Fluidized Bed

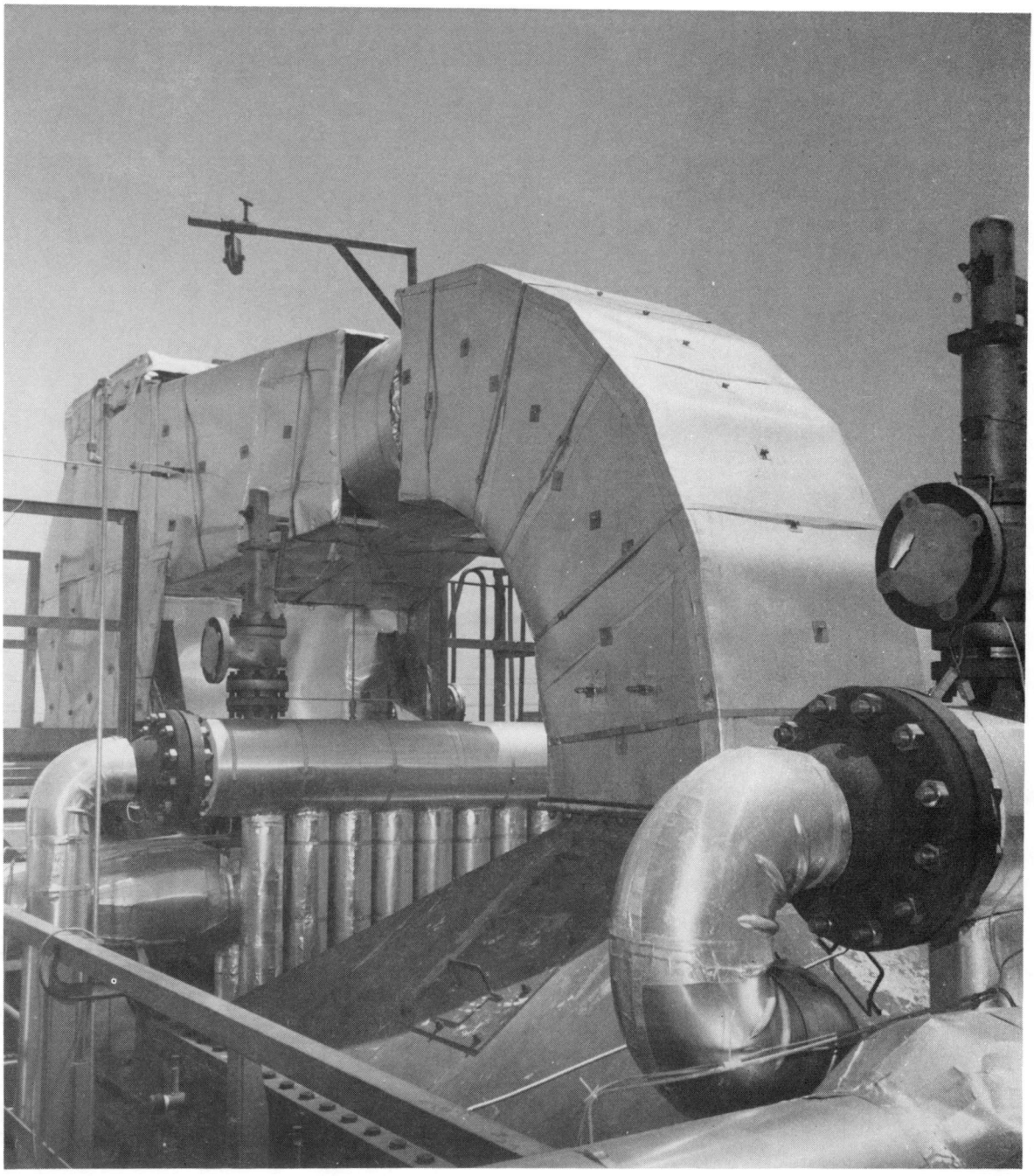

Figure C-50. Flue Gas Ducting at Top of Combustor/Heater (this view shows the ducting with the gas going to the cyclone unit; expansion joint is in the center of the ducting; the working fluid air inlet lines and manifolds are shown)

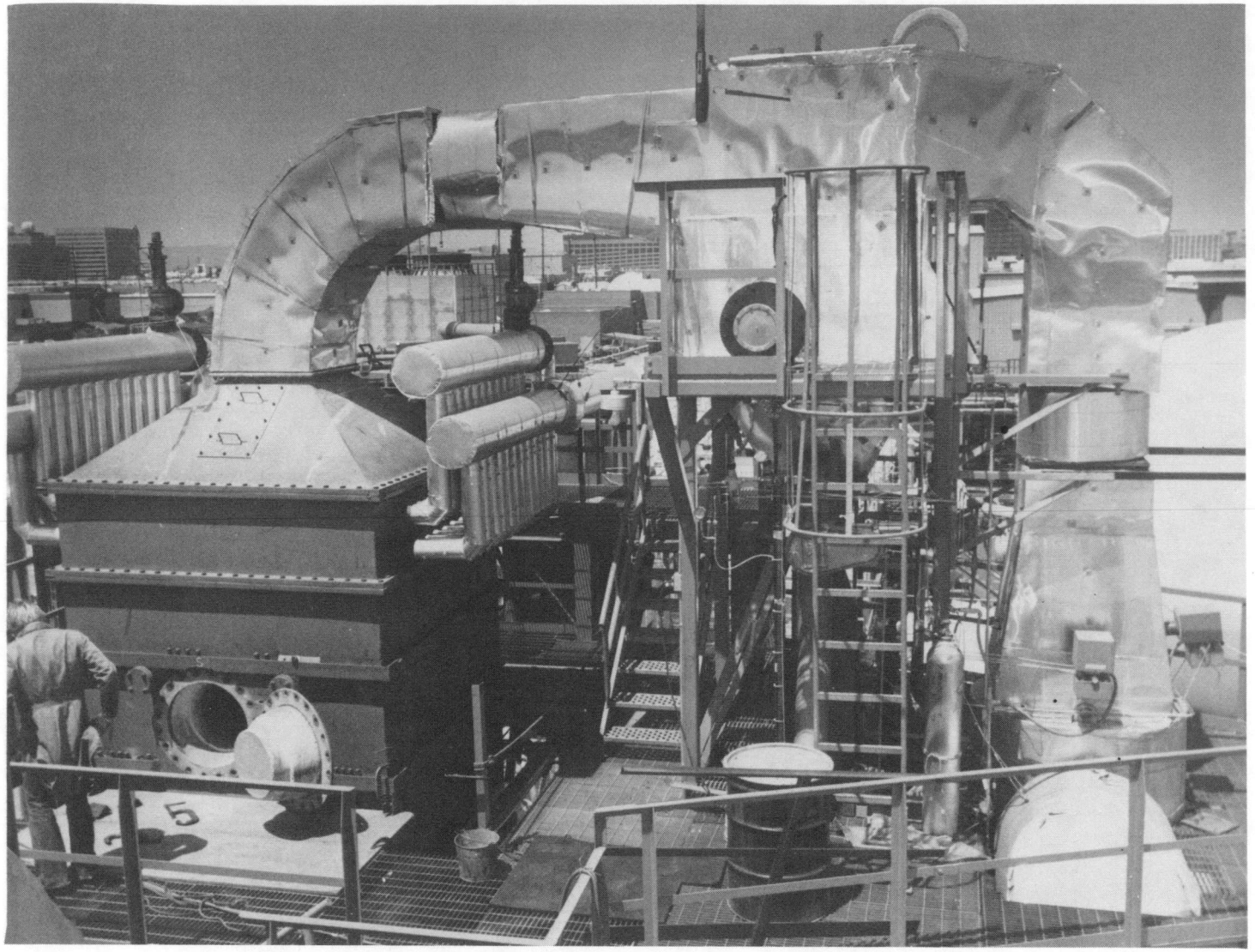

Figure C-51. Flue Gas Ducting (shown is the top of the combustor/heater, cyclone unit, and top of the air preheater; access door to the soot blower cavity of the convection heat exchanger; the acoustic soot blower appears as the circle on the cyclone unit; two in situ oxygen analyzers are located at the top of the air preheater)

Figure C-52. View Toward the Baghouse Walkway (top of the air preheater is shown on right with the heated combustion air ducting on the left)

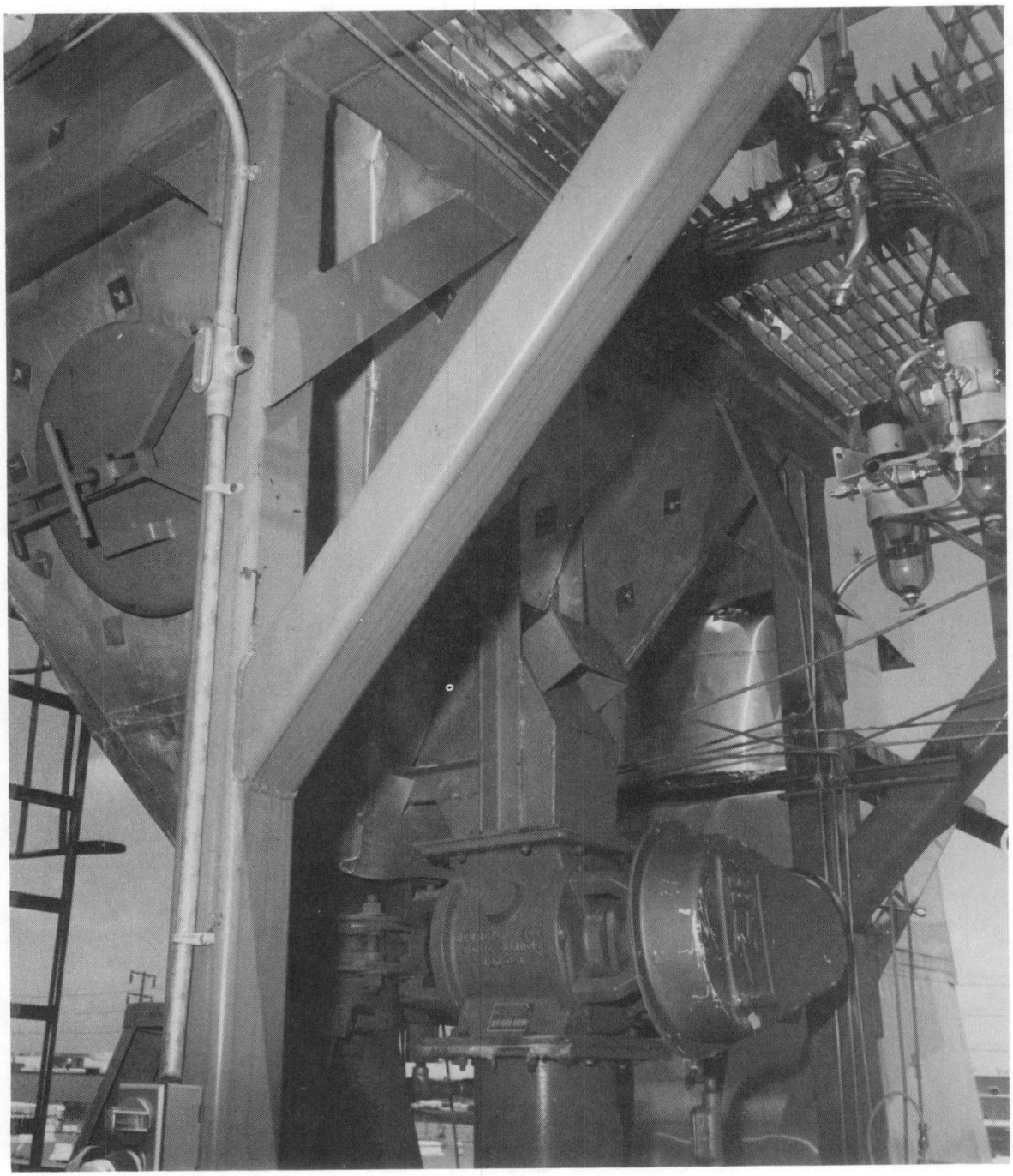

Figure C-53. Bottom of Cyclone Unit (shown is the cyclone hopper with the access door; in the middle and bottom are shown the ash overflow line and rotary valve)

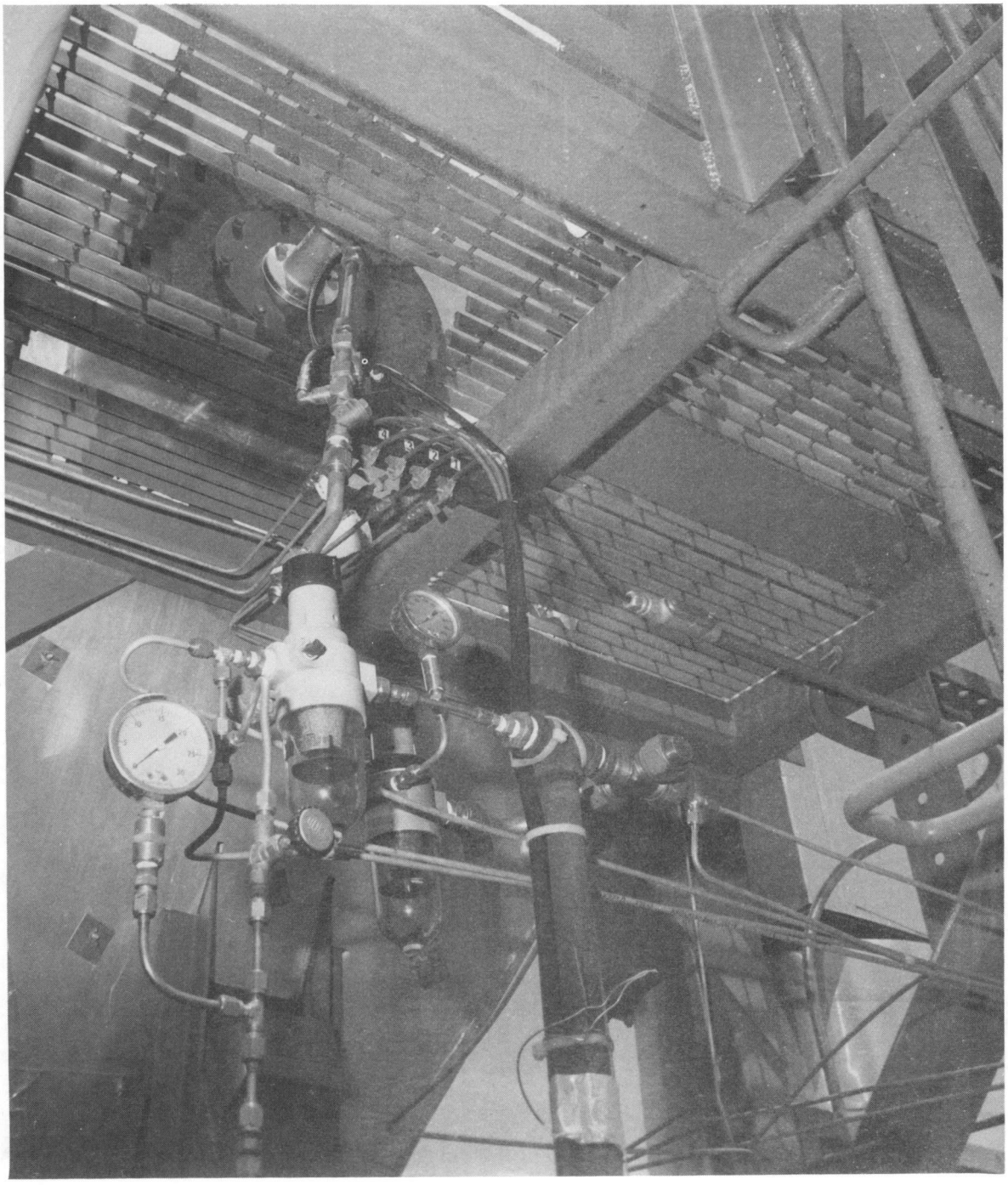

Figure C-54. Cyclone Hopper (the acoustic soot blower is shown in the top left)

Figure C-55. Ash Recycle Rotary Valve (located under the two ash recycle hoppers; ash is conveyed from right to left, and ash injection line is shown on left)

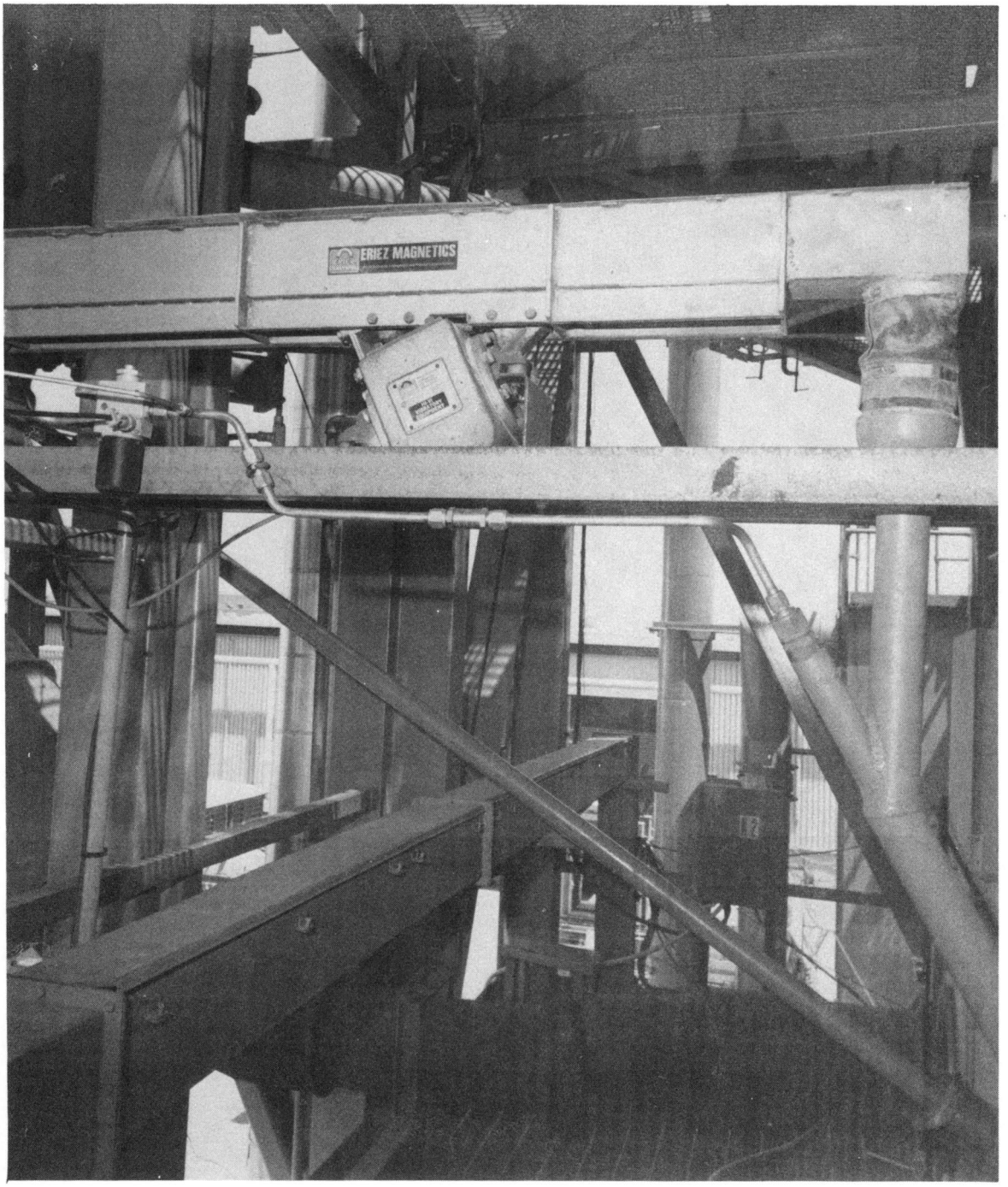

Figure C-56. Limestone Vibrating Feeder (feeder is shown at the top, and limestone is gravity fed into the combustor/heater with line on right; sloping line in background is spent bed material feedline)

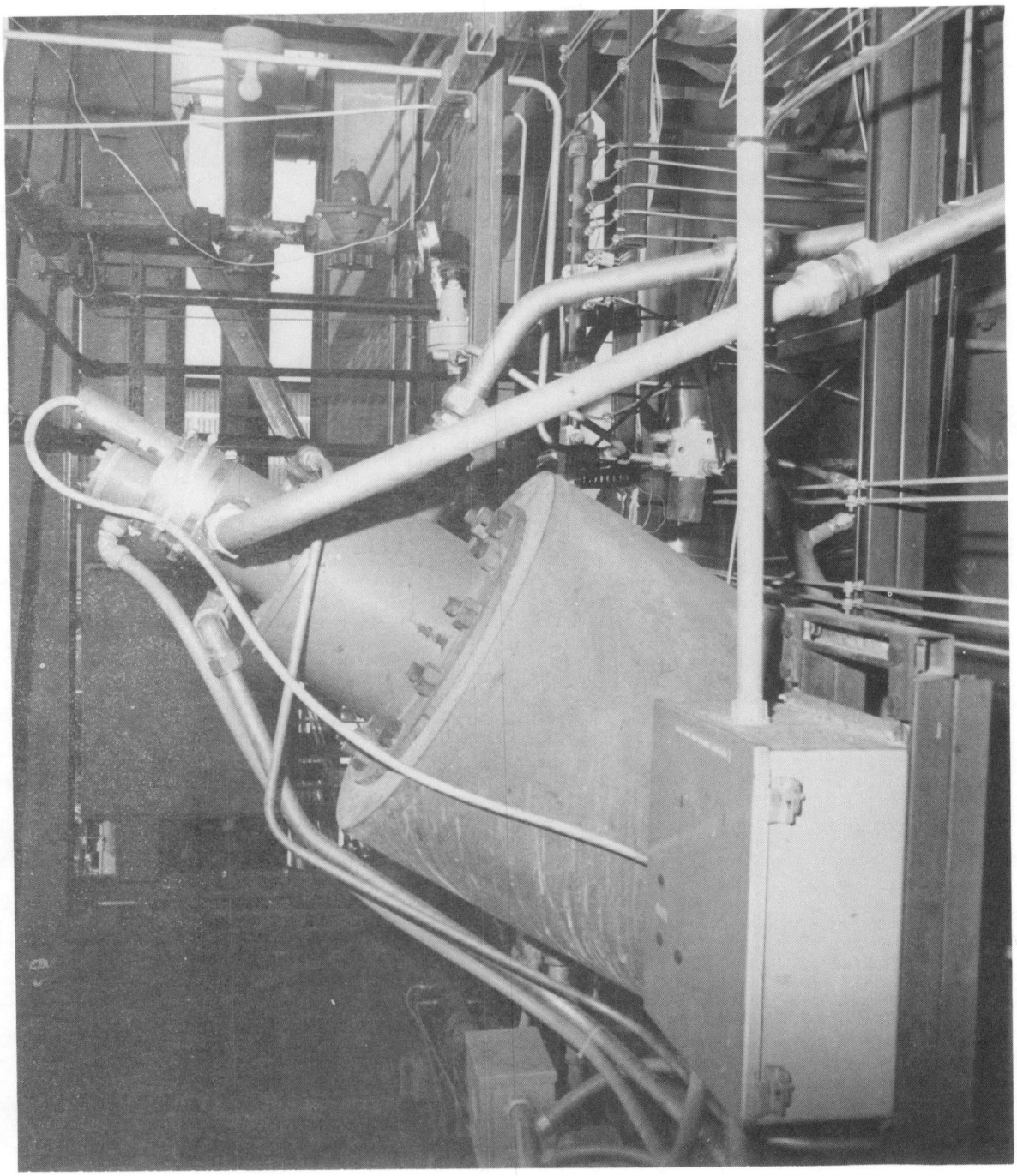

Figure C-57. Bed Ignition Burner (unit is mounted on a refractory line duct directing the combustion gases downward at the bottom of the bed)

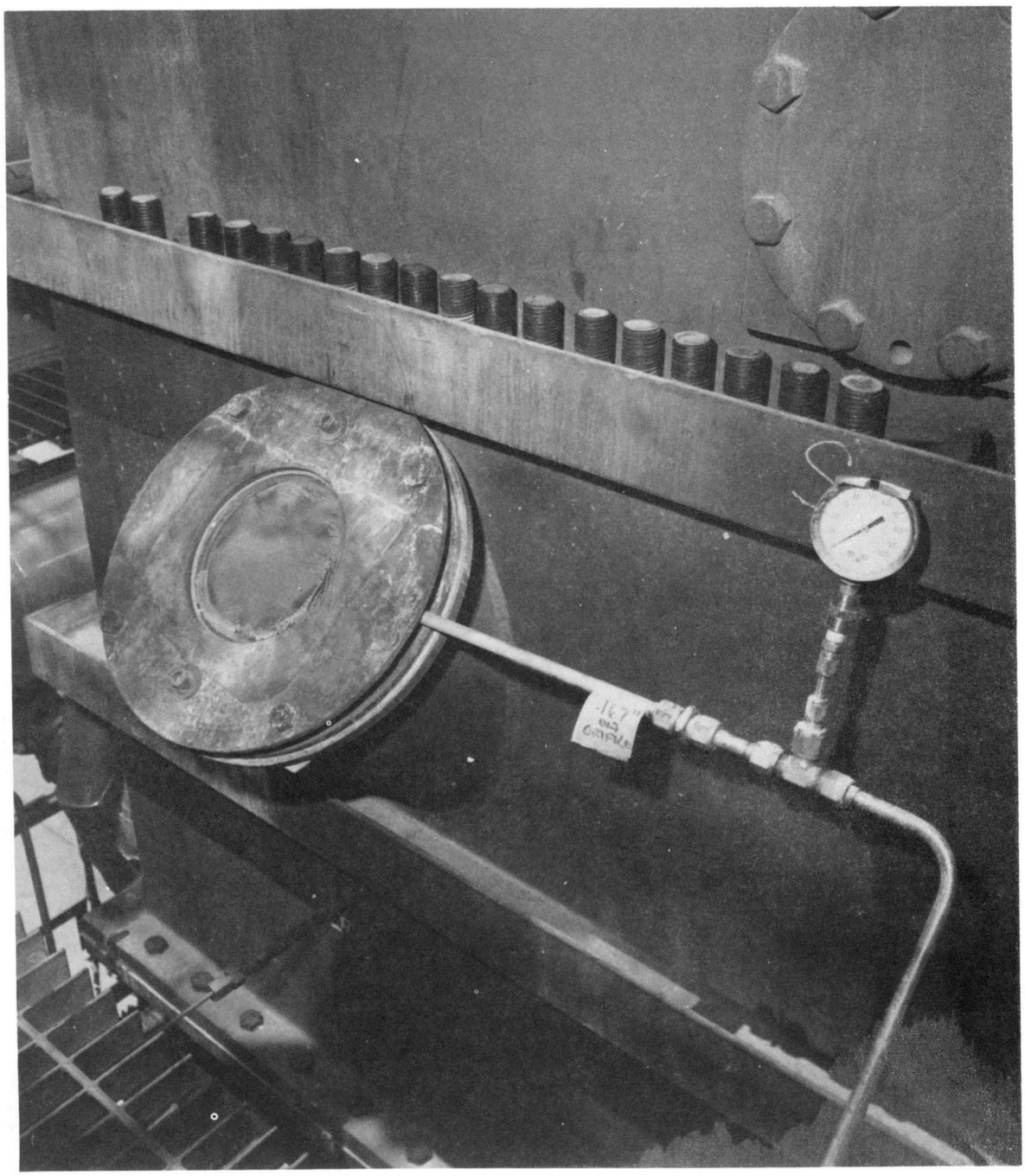

Figure C-58. Observation Window (allows viewing the top of the fluidized bed

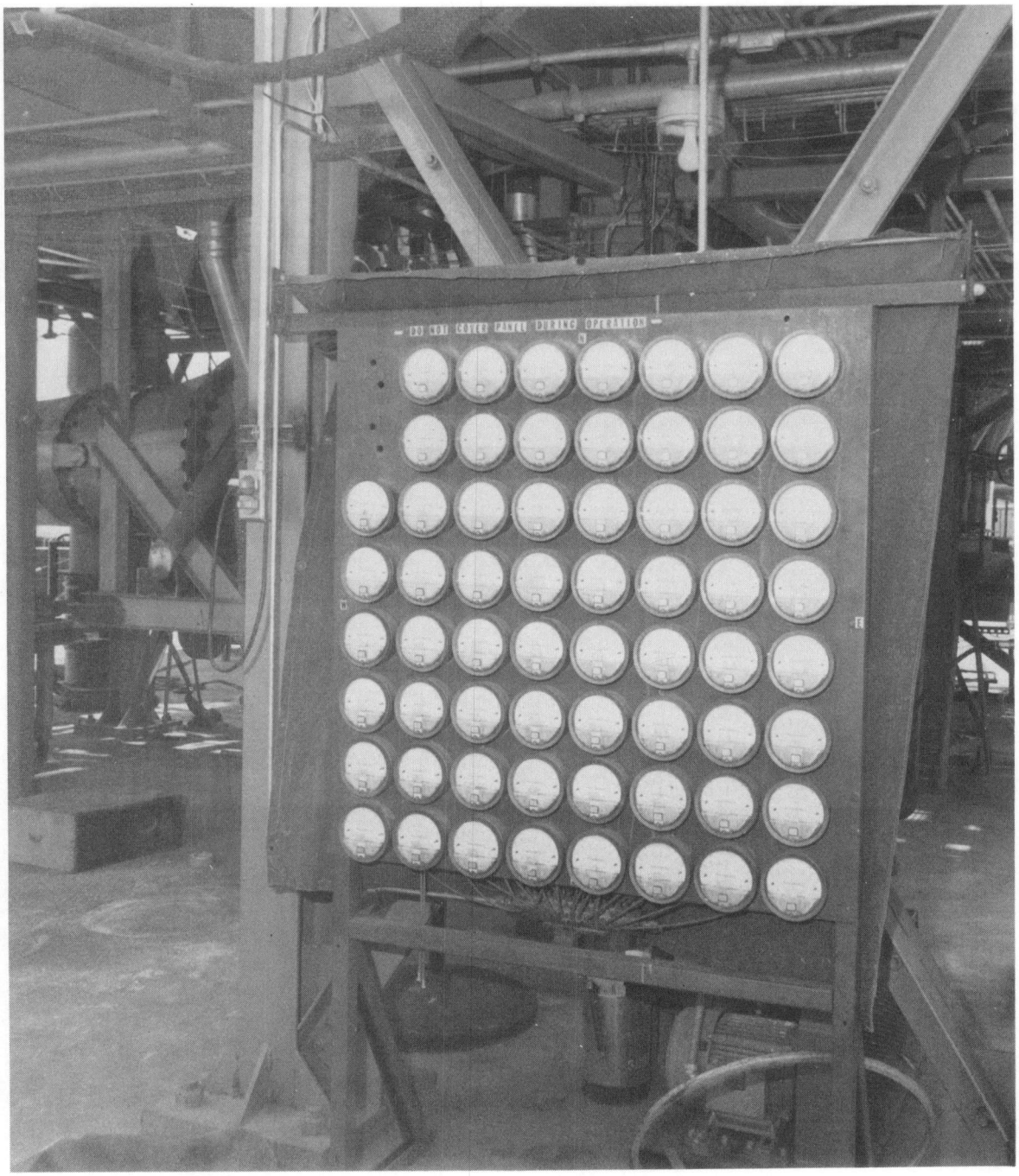

Figure C-59. Tuyere Air Monitoring Panel (monitors the combustion air flow in the 64 tuyere feedlines)

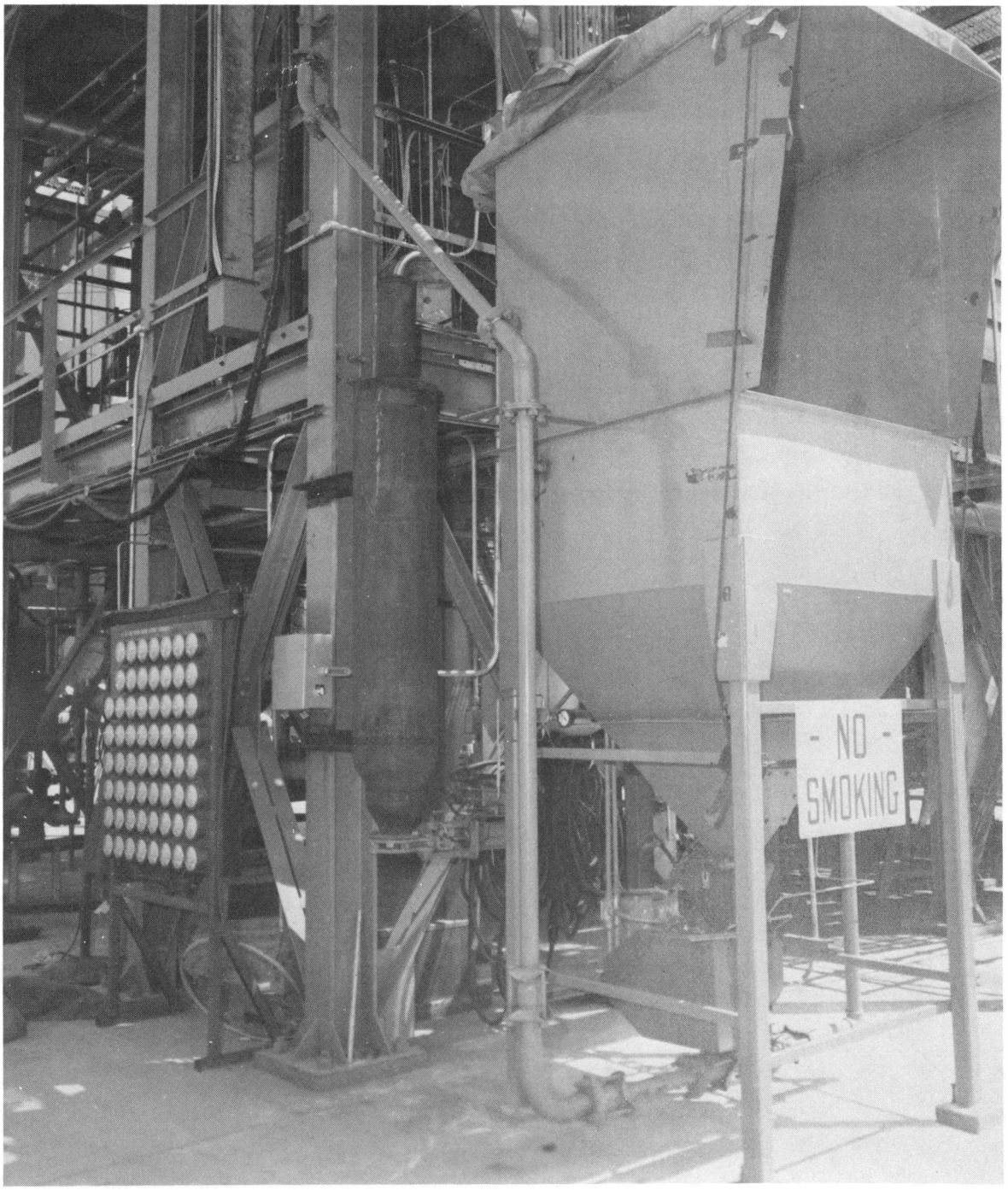

Figure C-60. Limestone Fill Station (drums of limestone are dumped into hopper with rotary valve at the bottom; the limestone is pneumatically conveyed to the hopper located at the top of the main platform)

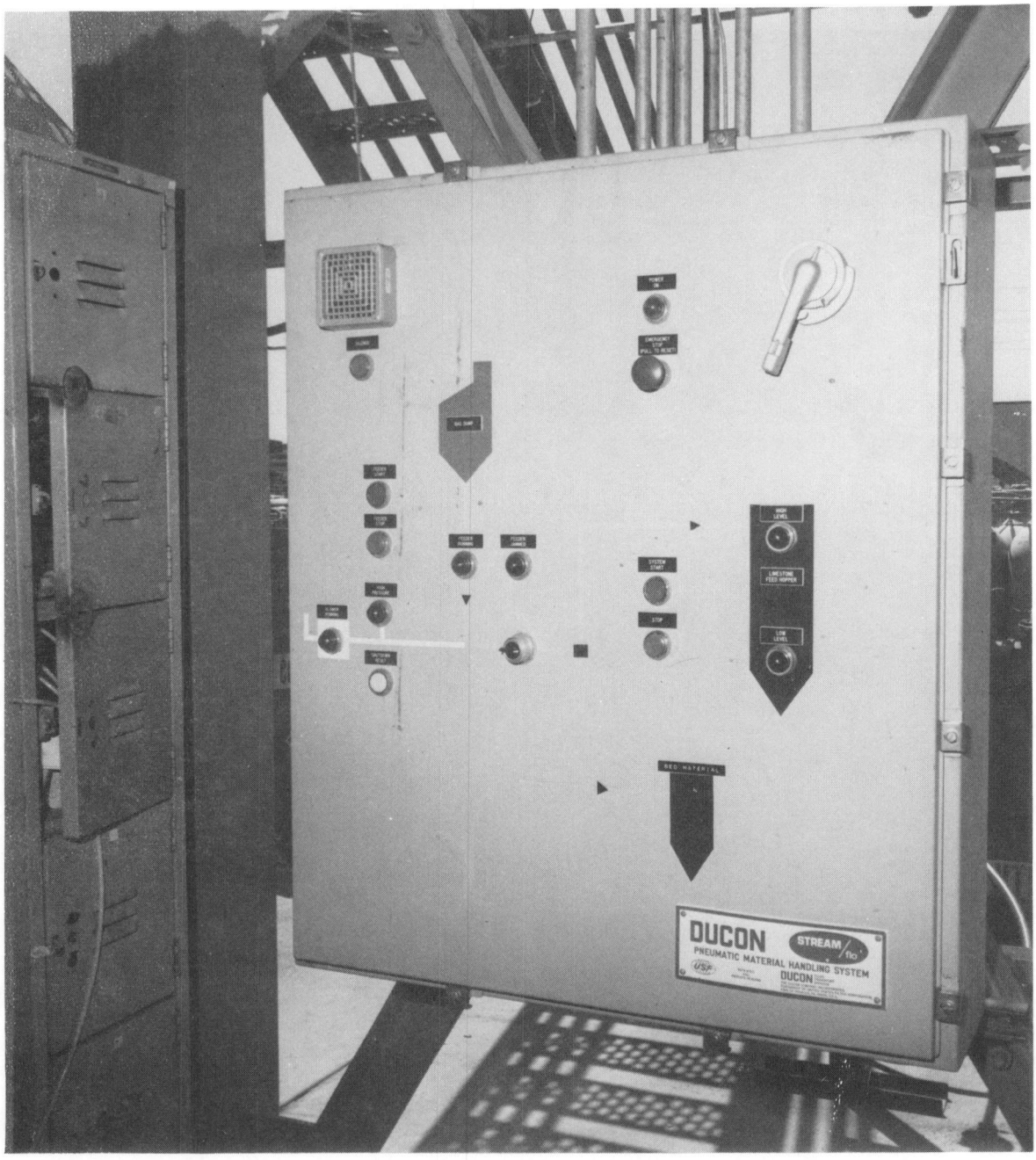

Figure C-61. Limestone Fill Station Control Panel

Figure C-62. Baghouse Drain (periodically, the baghouse was drained into drums used for disposal)

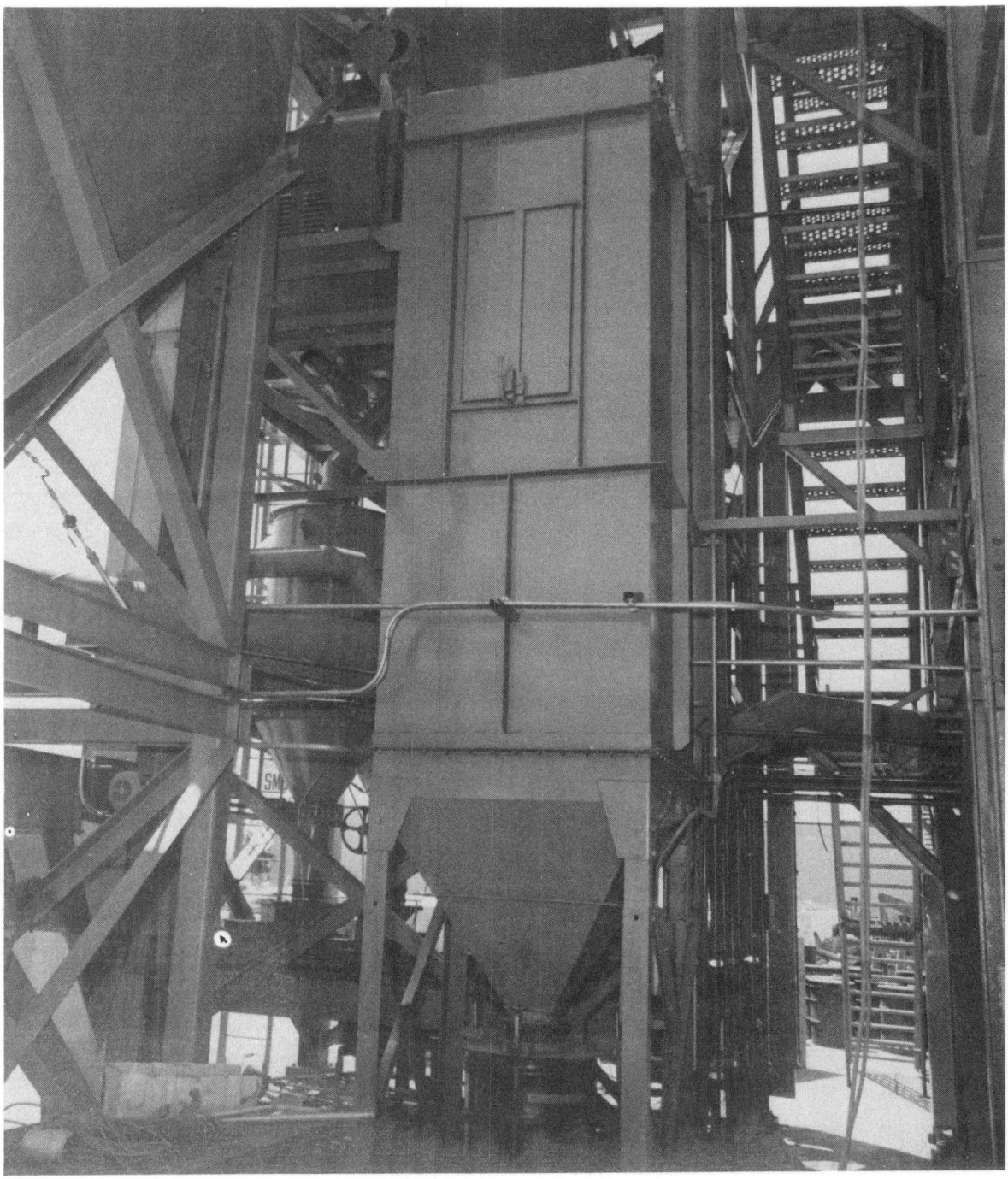

Figure C-63. Dust Control Baghouse

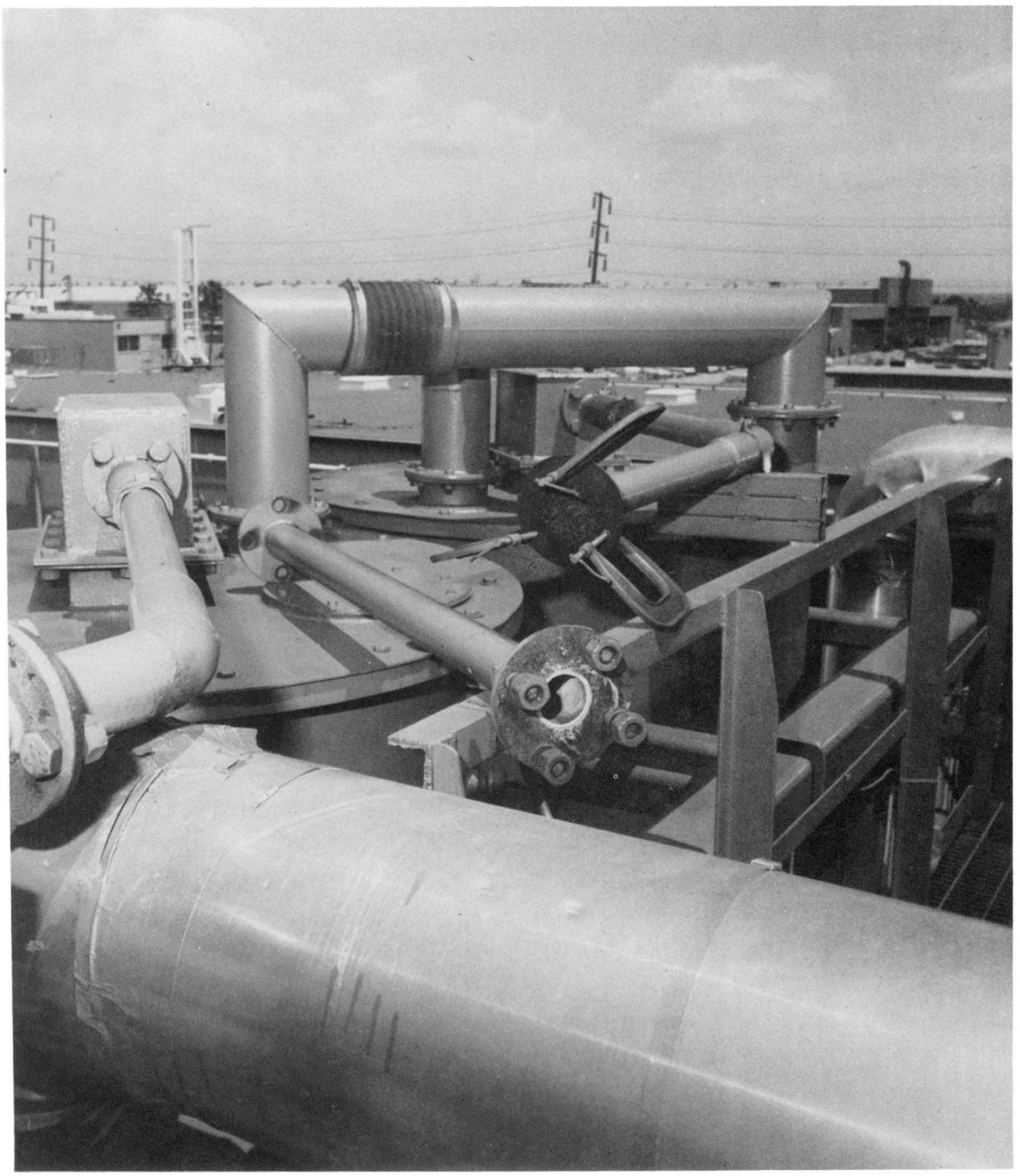

Figure C-64. Top of Limestone and Spent Bed Material Bins (lines were changed to allow the limestone fill station to be used to fill either bin)

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