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Test Container Design/Fabrication/Function for the Waste Isolation Pilot Plant Gas Generation Experiment Glovebox

by

C.J. Knight, N.E. Russell, W.W. Benjamin, K.E. Rosenberg, and J.A. Michelbacher

Argonne National Laboratory-West
P.O. Box 2528
Idaho Falls, ID 83403-2528

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C. J. Knight, N. E. Russell (LMITCO), W. W. Benjamin, K. E. Rosenberg, J. A. Michelbacher

Argonne National Laboratory-West
P.O. Box 2528
Idaho Falls, Idaho 83403-2528
(208) 533-7707

Abstract

The Gas Generation Experiments (GGE) are being conducted at Argonne National Laboratory-West (ANL-W) with contact handled transuranic (CH-TRU) waste in support of the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico.

The purpose of the GGE is to determine the different quantities and types of gases that would be produced and the gas-generation rates that would develop if brine were introduced to CH-TRU waste under post-closure WIPP disposal room conditions. The experiment requires that a prescribed matrix of CH-TRU waste be placed in a 7.5 liter test container. After loaded with the CH-TRU waste, brine and inoculum mixtures (consisting of salt and microbes indigenous to the Carlsbad, New Mexico region) are added to the waste. The test will run for an anticipated time period of three to five years.

The test container itself is an ASME rated pressure vessel constructed from Hastelloy C276 to eliminate corrosion that might contaminate the experimental results. The test container is required to maintain a maximum 10 percent head space with a maximum working pressure of 17.25 MPa (2500 psia). Construction of the test container provided a large opening to allow easy loading. The test container gasket is uniquely designed for the GGE experiment. It contains a diamond shaped Hastelloy C22 ring that is radially compressed to provide a leak rate less than 1×10^{-7} cc/second of helium at 17.25 MPa (2500 psia). The test container is designed to provide a gas sample of the head space without the removal of brine. Additional functions of the test container include sparging, brine removal, brine temperature monitoring, and test container pressure monitoring.

A series of valves on the lid of the test container meet the functional requirements of the experiment. A double valve assembly is used for head space gas sampling. A check valve is used for sparging the test container of oxygen, a series of valves are used for pressure transducer calibration and isolation, and a valve is used for brine removal. All breakable connections on the test container are made with metal face sealed connectors which allow repetitive connections without sacrificing the leak integrity of the test container. Each valve was tested to ensure that it could maintain the leak rate requirements of the test container.

Assembly of the test container lid and process valves is performed inside an inert atmosphere glovebox. Glovebox mockup activities were utilized from the beginning of the design phase to ensure the test container and associated process valves were designed for remote handling. In addition, test container processes (including brine addition, sparging, leak detection, and test container pressurization) are conducted inside the glovebox.

Background

The GGE is a test program designed to determine the different quantities and types of gases that would be produced and the gas-generation rates that would develop if CH-TRU wastes were inundated with simulated brine relevant to the WIPP environment. The WIPP facility (located near Carlsbad, New Mexico) is the proposed repository site for CH-TRU waste disposal. Gas generation may effect the performance of the WIPP with respect to regulation for radioactive constituents in the TRU waste. ANL-W was selected by the Department of Energy Carlsbad Area Office to conduct gas generation experiments using CH-TRU waste.

The principal role of the GGE at ANL-W is to determine the quantities and species of gases generated under likely repository conditions. This will involve placing prescribed amounts of actual CH-TRU wastes in test containers. The wastes will be completely inundated with a mixture of brines and microbial inoculate (indigenous to the Carlsbad, New Mexico region) that will be added to the test containers. The test containers are pressurized with nitrogen to 14.8 MPa (2146.6 psia) and heated to 30±5°C (86±9°F) to simulate the post-closure WIPP disposal room conditions. The test containers are tested periodically for gas generation. Instrumentation on the test containers provide pressure and temperature measurements. The test containers are housed inside an environmentally controlled inert atmosphere glovebox. The data obtained from the GGE will be used to develop a predictive model of the gases generated within the WIPP disposal rooms. The CH-TRU waste materials and brine will be removed from the test containers at the tests' conclusion and examined for corrosion and microbial degradation.

The design of the test containers, as well as the program requirements, were developed using the technical requirements established by the Department of Energy Carlsbad Area Office (DOE-CAO), and Sandia National Laboratory (SNL), as well as other national laboratory personnel working on associated projects. Preliminary drawings of the test containers were developed and reviewed by members of the GGE design team at ANL-W. Visits to companies specializing in the fabrication of pressure vessels (test containers) were completed early in the design process to gain insight on the availability of similar containers and to further the design. Meetings were held with other national laboratory personnel working on similar related projects and a final design of the test container was completed. Following the design process, design drawings and a technical specification were prepared and 24 test containers were fabricated by an outside contractor.

Upon receipt of the test containers and completion of the glovebox and test container support systems, twelve test containers were loaded with a prescribed matrix of CH-TRU waste and brine per the test matrix requirements defined by the Technical Requirement Document for Gas-Generation Experiment (i.e. Reference 1, Technical Requirements for the Gas-Generation Experiments with Contact-Handled Transuranic Waste Materials, SAND93-3977). Two more test containers were loaded with brine and inoculum only, no CH-TRU waste. The remaining 10 test containers function as spares.

Test Container Functional and Design Requirements

Twenty-four (24) test containers were fabricated for the GGE. Each test container was manufactured to ASME Section VIII, Division 1 standards and is a "U" stamped pressure vessel. The test containers were designed for a maximum operating pressure of 17.25 MPa (2,500 psia) and a design pressure of 20.7 MPa (3,000 psia).

The technical requirements mandated that the test containers not allow helium gas leakage of more than 1 X 10^{-7}cc per sec at a test pressure of 17.25 MPa (2,500 psia). To satisfy this requirement, two twelve hour leak tests were performed at an independent-certified leak test company. In addition, a third leak test was performed after final loading of the test containers.

The interior dimensions of the test container are 15.3 cm (6 in.) I.D. by 40.6 cm (16.0 in.) in length. The O.D. of the test container head is 27.9 cm (11.0 in.). The overall height of the test container (excluding attachments beyond the top of the head) is 50.8 cm (20.0 in.). Each test containers has an interior volume of 7.5 liters with 10% of this volume reserved for head space gas collection. A waste inundation screen attached to the test container head holds the waste down in the brine and ensures the required 10% head space. (Ref. Figure 1, GGE Test Container and Figure 2, GGE Simulated Waste in Mockup Container.)

The test containers are constructed from Hastelloy C276. A corrosion resistant material was necessary to eliminate any corrosion or corrosion products that might add to the gases generated in the test container and thereby contaminate the experimental results. The test container body and head were machined from single billet pieces, thus eliminating any welds that would be exposed to the test container contents.

The test container is comprised of a container body and head. The head is attached to the body with 30 bolts. With the test container head removed, the full 15.3 cm (6 in.) I.D. of the test container is exposed, allowing easy loading of the test container. (Ref. Figure 3, Opened GGE Container — Top View.) Due to the requirement of an all metal container, a unique metal seal was designed especially for the GGE test containers. Through the combined efforts of ANL-W and the test container manufacturer, a seal was developed that uses a diamond shaped Hastelloy ring that is radially compressed.

The test container head has a total of six ports. The sparge port penetration is connected to a sparging defuser. (See center of Figure 3.) This port is used for sparging the waste and brine contents of the test container to remove entrapped oxygen prior to beginning the test period. During the sparging process, nitrogen is bubbled through a diffusion ring (with .16 cm holes) for 24 hours. (Ref. Figure 4, GGE Mockup Container Sparging Test.) The test container head has 5 additional ports. These ports include a sealed RTD thermal well for test container temperature monitoring, a rupture disk for overpressurization protection, and ports for brine addition temperature monitoring, brine removal, and test container gas sampling/pressure monitoring. (Ref. Figure 5, GGE Container Head Assembly.) A resistance temperature device (RTD) interfaces with the thermal well in the head for on-line monitoring of internal temperature. An absolute pressure transducer attaches to the gas sampling/pressure port in the head and provide test container internal pressure information throughout the test period. The gas sampling/pressure port also enables gas samples of the test container headspace to be taken during the test period. This port interfaces with the glovebox gas sampling system. The pressure/vent system can be connected to the gas sampling/pressure port to increase or decrease pressure as necessary. The operating pressure of the test containers may range from 14.6 to 17.25 MPa (2,115 to 2,500 psia) for up to 5 years. The brine removal system consists of a dip tube, attached to the head, that extends to near the bottom of the test container. At the completion of the testing period a brine sample will be taken under pressure through this dip tube. The rupture disk is a built-in safety device for the prevention of test container overpressurization.

Interface System Requirements

A series of valves on the lid of the test container provide the functional and interface requirements of the experiment. The most important function of the test container is to provide a test container head space gas sample. To satisfy this requirement, the gas sampling/pressure monitoring port was equipped with a double valve sampling system. When a sample is taken, the test container primary isolation valve is opened and the head space gas is allowed to expand into the volume located between the primary and secondary isolation valves. At this point the primary valve is shut and a gas sampler is attached to the test container. The sampler is used to draw the test container head space sample from this trapped gas. (Ref. Figure 6, GGE Gas Sampler.)

The double valve gas sampling system accomplishes three goals. First, it provided a known volume of gas to be collected and analyzed. Technical requirements for the experiment require that the head space volume be known to 1%. Prior to assembly, each double valve sampling assembly's volume was measured and recorded. Using this known volume and the test container pressure, the test container headspace can be determined. Second, brine is prevented from being introduced into the gas container sampling system. Sealing of secondary valve and protection of the gas sampling system (brine in the samplers and gas analyzing equipment would contaminate the experiment) depended upon eliminating brine from the gas stream. To accomplish this task, a 0.4 micron filter was placed between the primary and secondary valve. Third, by procedurally requiring that only one of the primary/secondary valves be opened at a time, accidental depressurization of a test container is mitigated. Depressurization of the test container would invalidate the test and require a restart of the test.

Another technical requirement that the test container valve assembly accomplishes is the task of pressure monitoring. A direct source pressure transducer was selected to provide pressure monitoring for each test container. To meet the operational requirements of the pressure transducer, two valves were installed on the gas sampling/pressure monitoring port (independent of the gas sampling system). These valves are used to isolate the test container from the pressure transducer and to provide a calibration port for pressure transducer calibration.

Two other valves provide the necessary functional requirement interfaces with the test container. First, a check valve is place on the sparging port to prevent oxygen from being reintroduced (through the suspect exhaust) into the test container during the sparging process. Second, at the conclusion of the testing period, a brine sample is to be removed from each loaded test container. To control brine removal, a valve was placed on the brine removal port.

During design of the test container valve assembly, it was identified that operation of the test container support systems would require that connections be coupled and uncoupled on a regular basis. These connections would need to provide leak tight integrity at test container pressures of 14.6 to 17.25 MPa (2115 to 2500 psia) and gas sample collection pressures (1×10^{-3} torr is needed to ensure sample purity). Metal face sealed connectors were chosen because they provide leak tight integrity at high pressures and vacuums, because they can be coupled and uncoupled multiple times without sacrificing leak tight integrity, and because the connections can be made under gloved handling conditions experienced in a glovebox environment. (Ref. Figure 7, GGE Container Remote Handling Testing.)

The test container valve assembly was leak tested and strength tested at the same pressures and under the same criteria established for the test containers themselves.

Test Container System Assembly and Mockup

Assembly of the container lid and process valves is performed inside an inert atmosphere glovebox. Glovebox mockup activities were utilized from the beginning of the design phase to ensure the test container and associated process valves were designed for remote handling. (Ref. Figures 6 and 7.) Loading and assembly of the test container lid and valve assembly was practiced during glovebox design and during operational testing. Feedback from these mockup activities was used to design the glovebox, the glovebox support systems, and the test container valve assembly; including special tools and handling fixtures necessary to support the remote-gloved activities inside the glovebox. These activities were also used to define proper process procedures including minimizing contamination spread inside the glovebox, eliminating contamination of the test container atmosphere (from nitrogen, oxygen, etc.), and proper brine/inoculum handling techniques. Test container processes (including brine addition, sparging, leak detection, and test container pressurization) are conducted inside the glovebox. This required that all system interfaces be adapted to remote-gloved handling and that system equipment located in the glovebox be repairable. It was from the mockup and testing activities that user friendly equipment and processes were developed. (Ref. Figure 8, GGE Test Containers in Glovebox — Final Configuration.)

Conclusion

The Gas Generation Experiments is a test program designed to determine the different quantities and types of gases that would be produced and the gas-generation rates that would develop if contact-handled transuranic (CH-TRU) wastes were inundated with simulated brine relevant to the Waste Isolation Pilot Plant (WIPP) environment. Results from the gas generation experiments will be used by the WIPP performance assessment team to evaluate compliance with Environmental Protection Agency's regulations.

Argonne National Laboratory-West's function is to determine the quantities and species of gases generated under likely repository conditions. The test containers will be loaded with CH-TRU waste, filled with brine/inoculum mixture, pressurized with nitrogen to 14.7 MPa and then heated to $30\pm5\,^{\circ}C$. The test containers will be tested periodically for gas generation.

From these requirements a test container design was identified. A series of valves were arranged on the lid of the test container to support the functional and interface requirements of the experiment.

Assembly of the test container lid and process valves is performed inside an inert atmosphere glovebox. Glovebox mockup activities were utilized to ensure the test container and associated process valves were designed for remote handling.

The overall design and construction of the test container and test container support systems resulted in user friendly equipment and processes.

References

1.) Technical Requirements for the Gas-Generation Experiments with Contact-Handled Transuranic Waste Materials, SAND93-3977.

Supporting Documents

1.) Support and Control Systems of the Waste Isolation Pilot Plant Gas Generation Experiment Glovebox, by W. W. Benjamin, C. J. Knight, J. A. Michelbacher, K. E. Rosenberg.

2.) Design/Build/Mockup of the Waste Isolation Pilot Plant Gas Generation Experiement Glovebox, by K. E. Rosenberg, W. W. Benjamin, C. J. Knight, J. A. Michelbacher.

3.) Technical Specification for ANL-W WIPP Gas Generation Experiments Test Container, Document No. A0005-0012-ES-00, December 1994, by N. E. Russell.

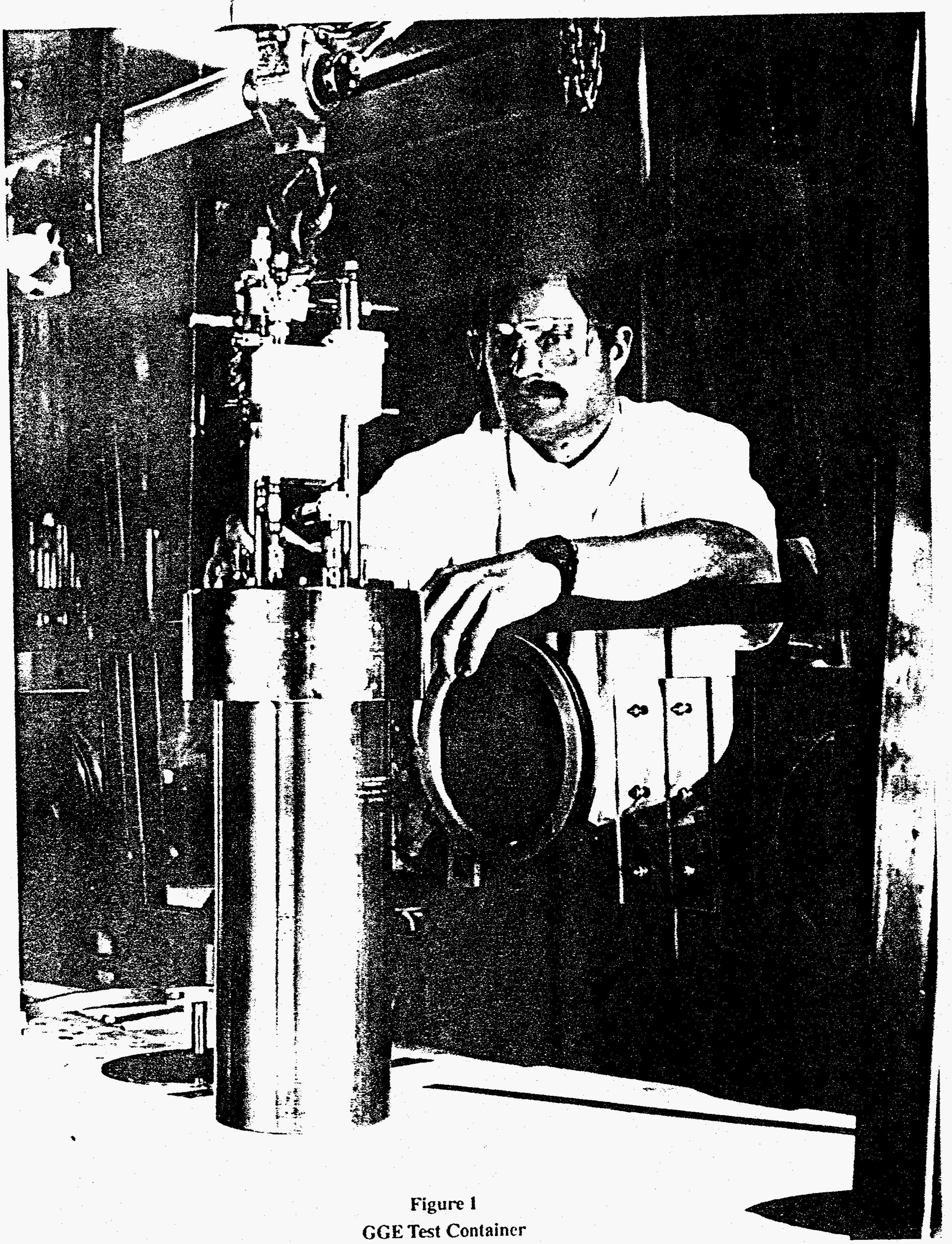


Figure 1
GGE Test Container

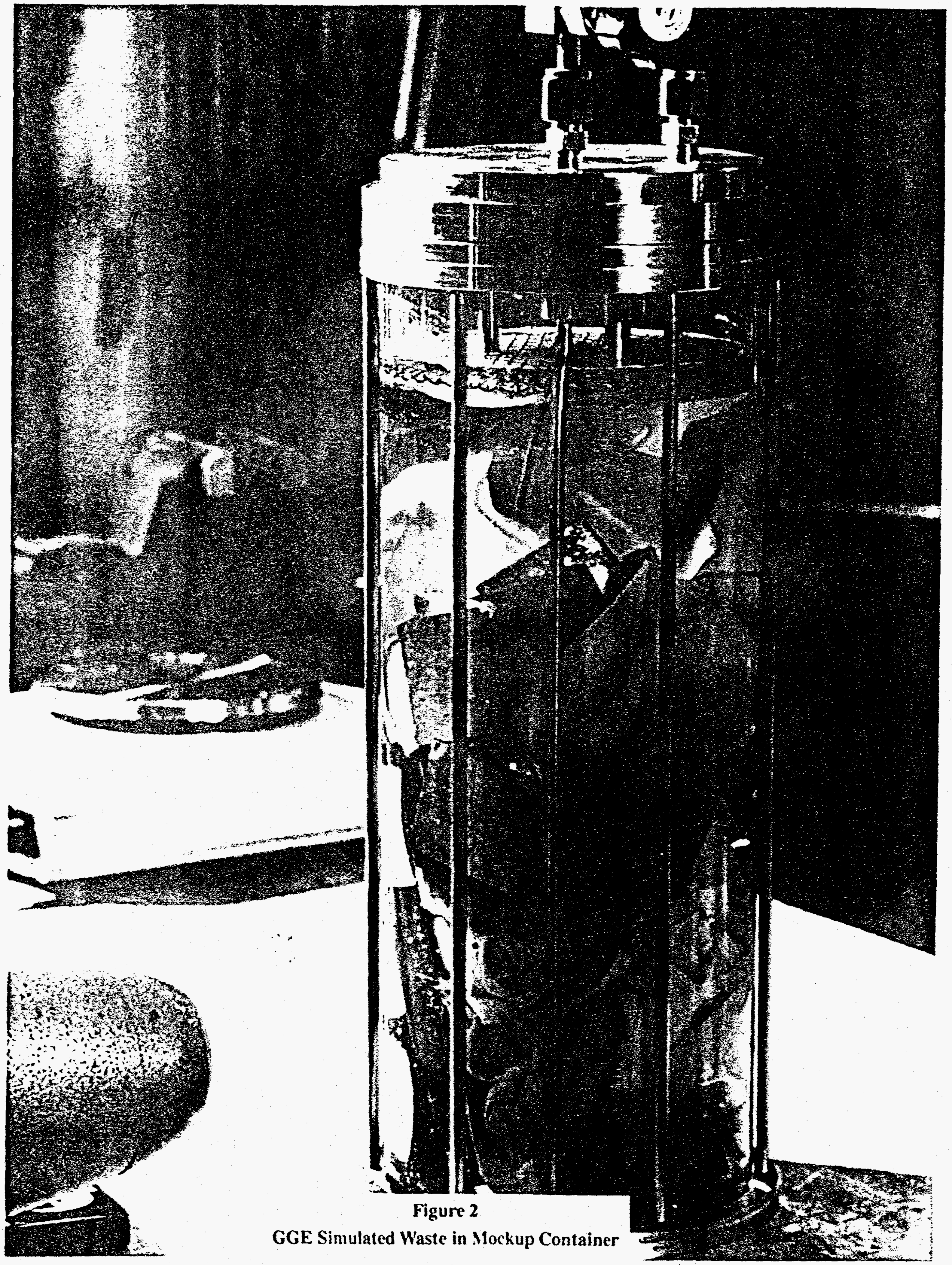


Figure 2
GGE Simulated Waste in Mockup Container

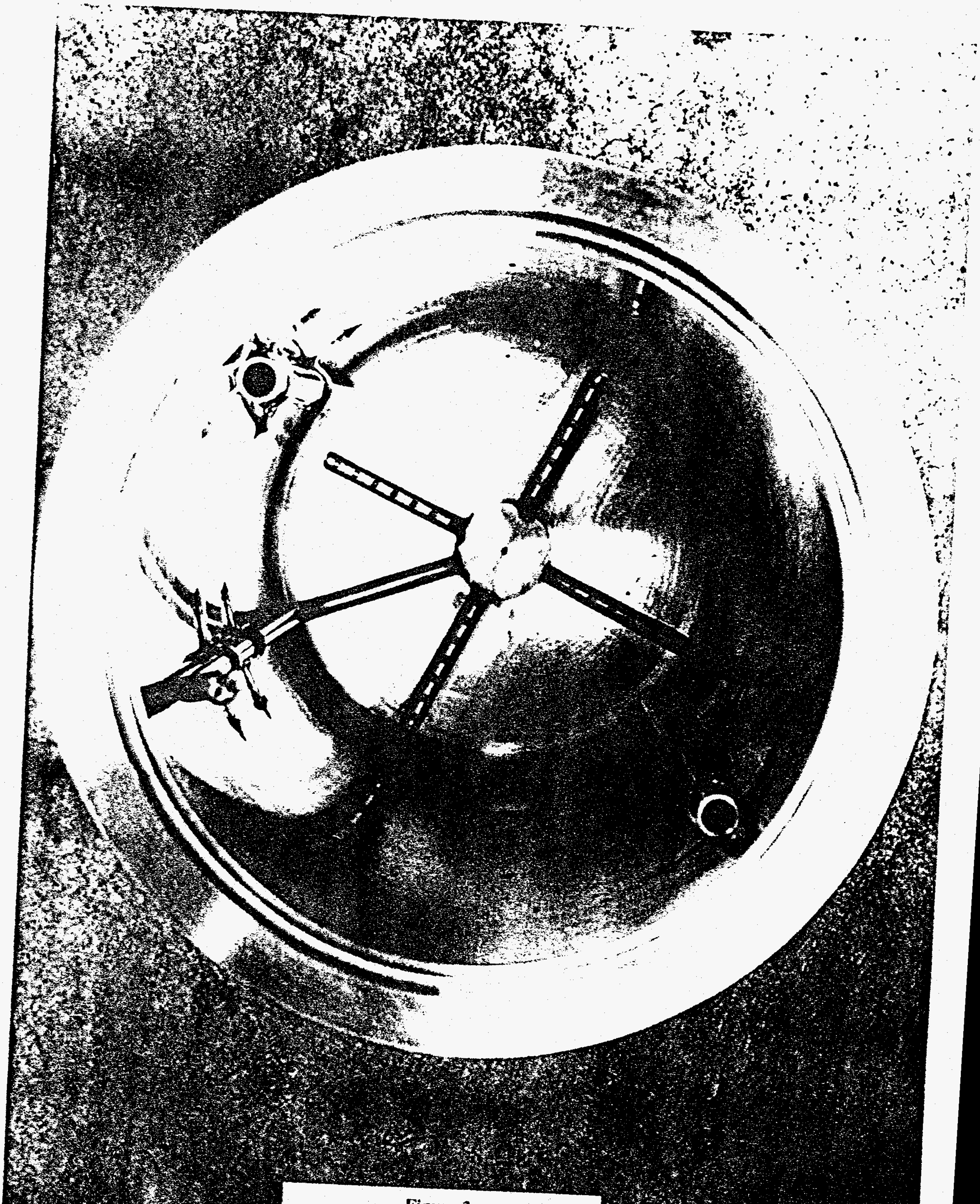


Figure 3
Opened GGE Container – Top View

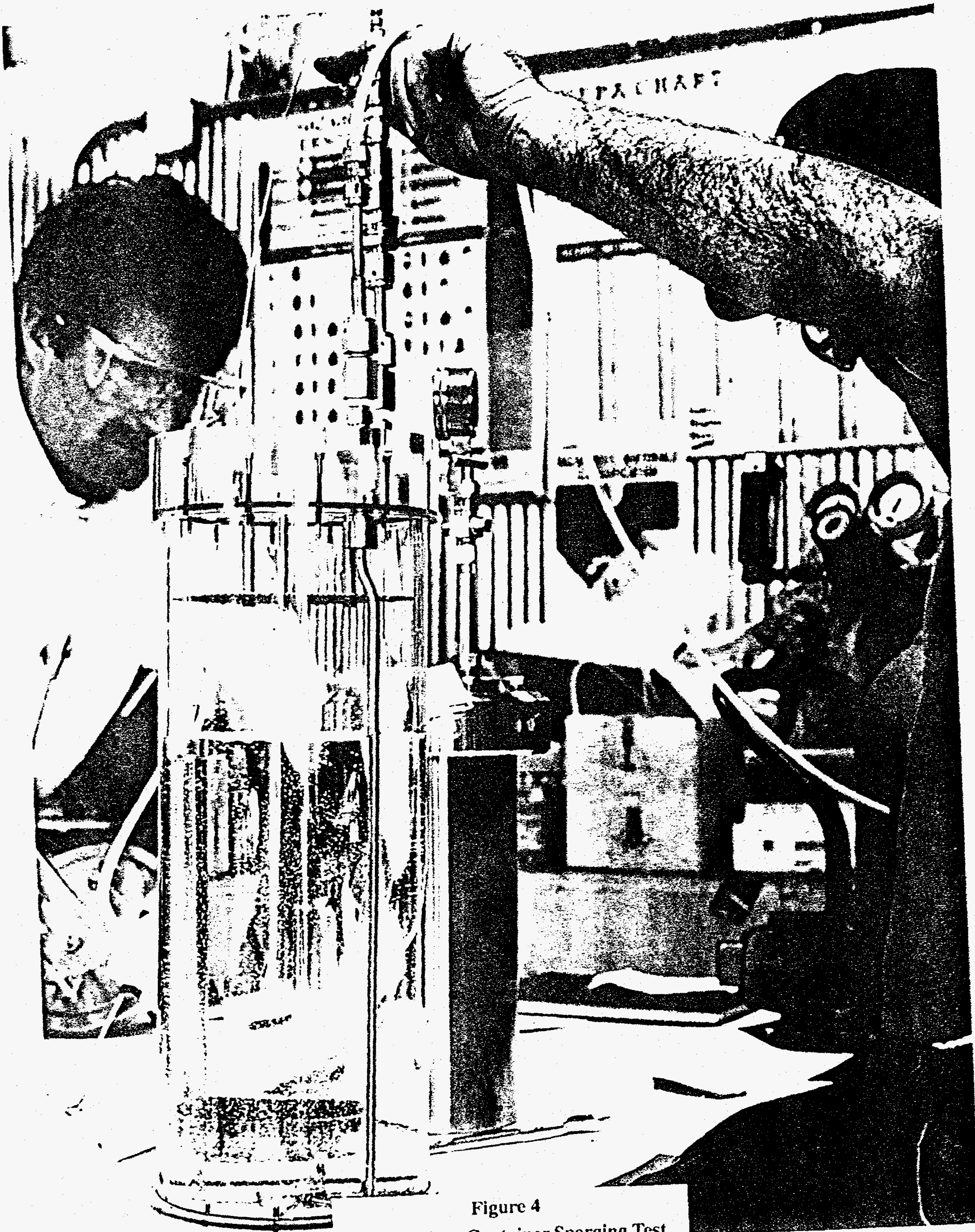
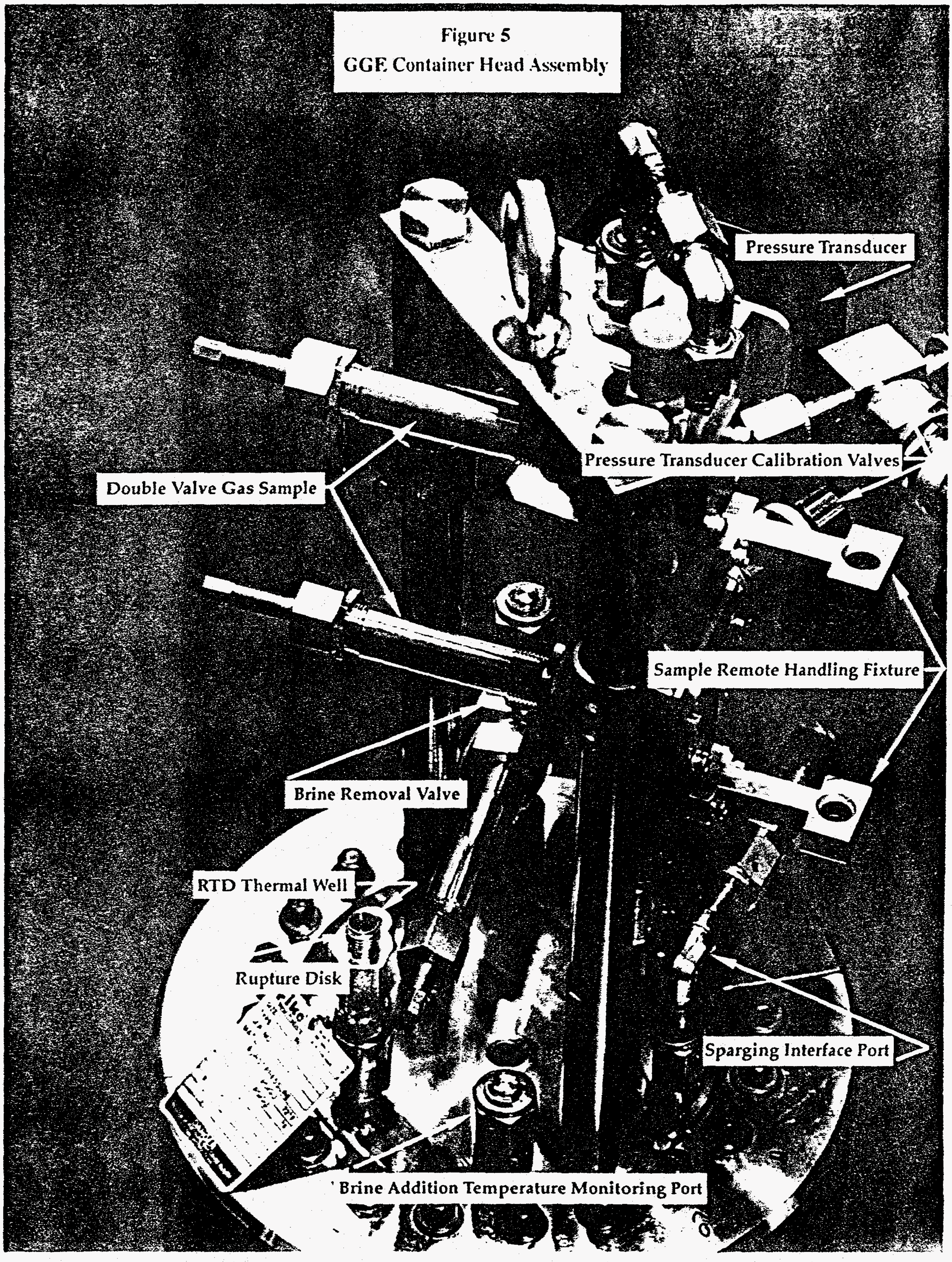


Figure 4
GGE Mockup Container Sparging Test

Figure 5
GGE Container Head Assembly



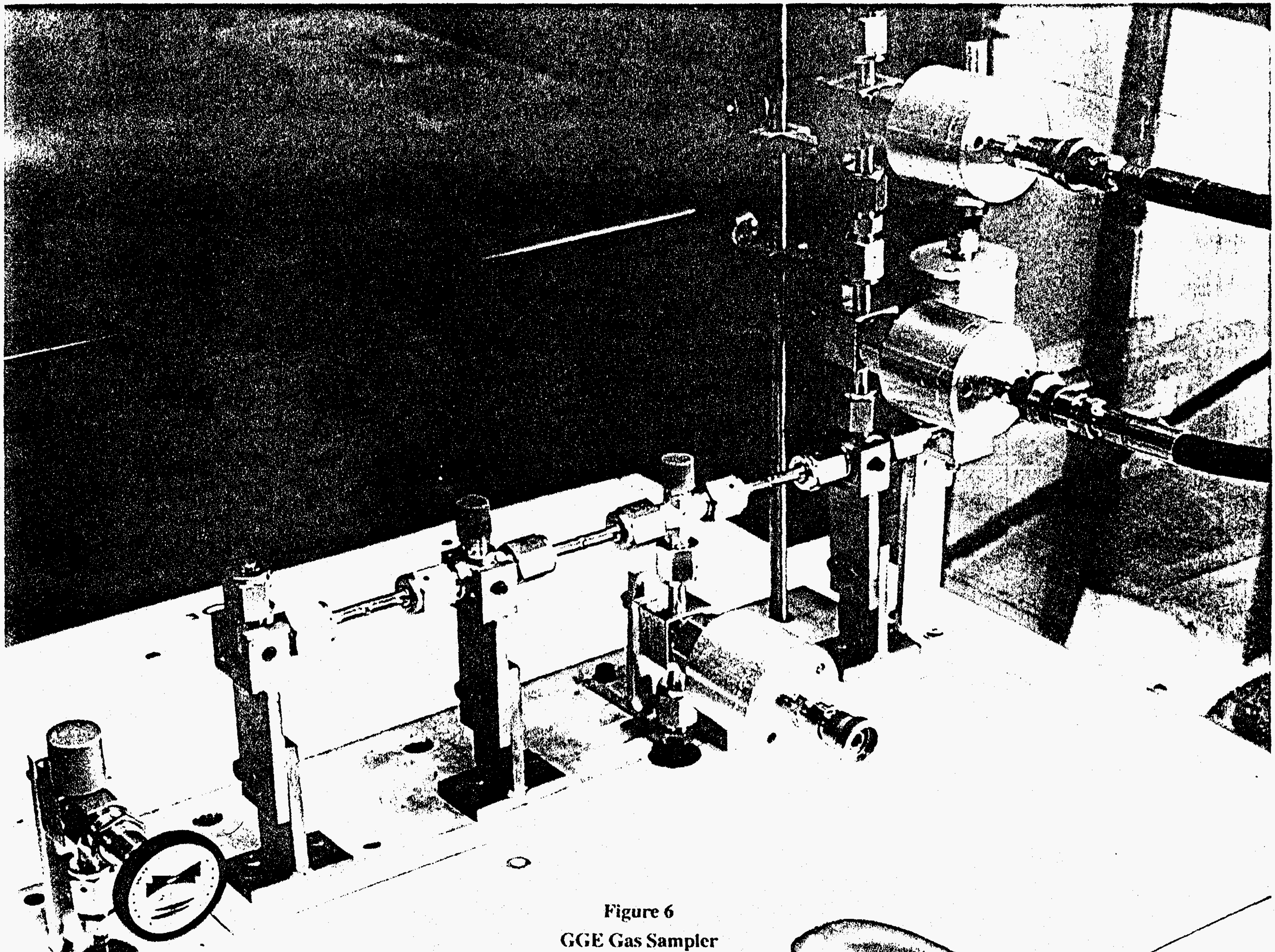


Figure 6
GGE Gas Sampler

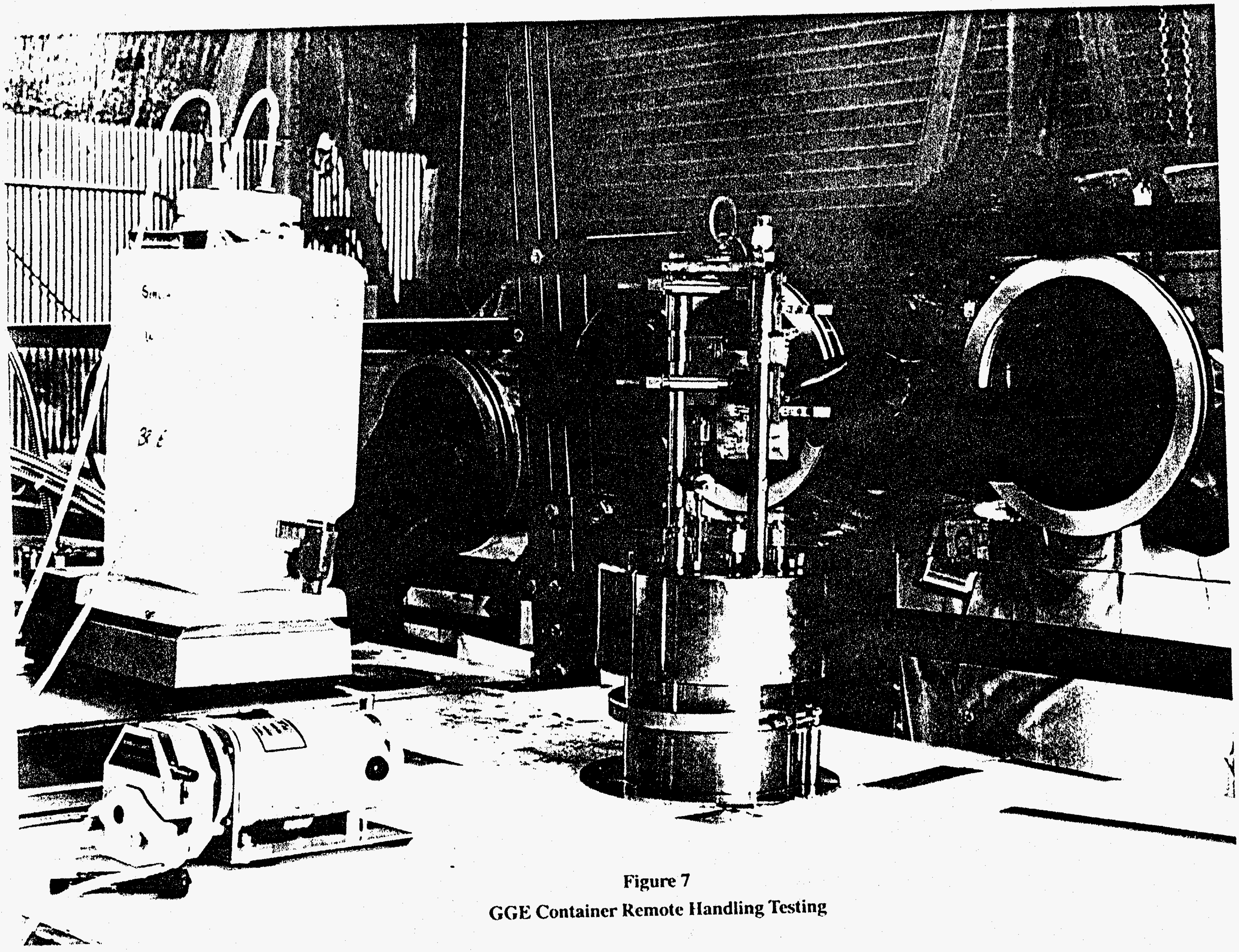


Figure 7
GGE Container Remote Handling Testing

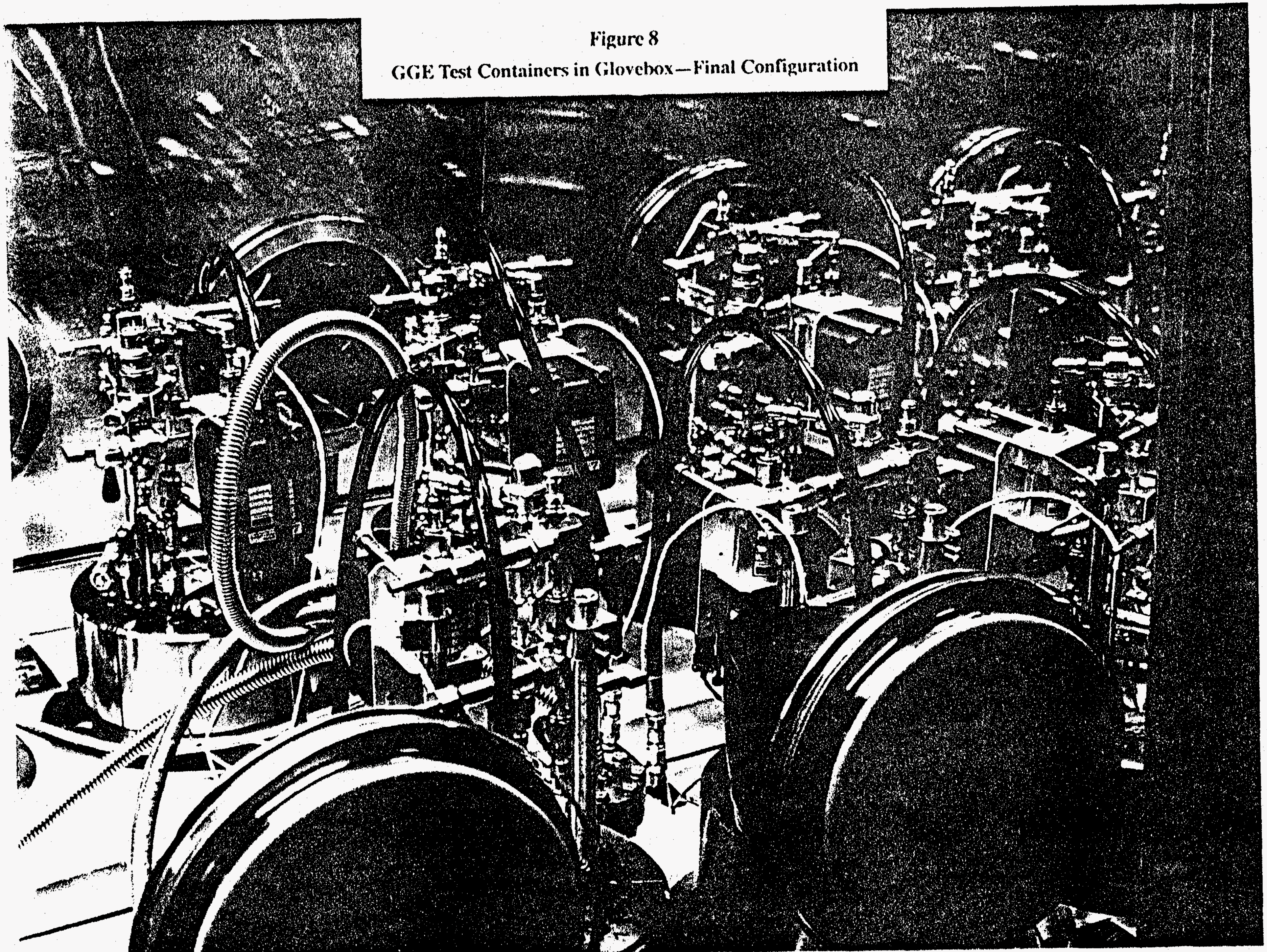


Figure 8

GGE Test Containers in Glovebox—Final Configuration