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Nuclear Waste Management

DESCRIPTION OF A PILOT PLANT TO PRODUCE A PELLETED FORM FROM SIMULATED ICPP HIGH-LEVEL CALCINED WASTES

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ABSTRACT

A description of a pilot plant for pelletizing high-level calcined nuclear wastes is given. Details of equipment are given and operating and safety procedures are outlined.

SUMMARY

A pilot plant was completed to produce a pelleted form from simulated ICPP high-level calcined wastes. The pilot plant uses techniques learned in the laboratory to combine calcine with solid and liquid binders to form hard, leach-resistant pellets. The pilot plant is designed to process up to 25 kg/h of calcine and will provide information necessary to verify the operational feasibility of pelletizing calcined waste. Also, information for the design of a possible full-scale pelletizing plant will be obtained.

All components of the pelletizing operations are described. The solids feed system consists of two loss-in-weight feeders: one for calcine and one for solid binders. Intimate mixing of the solids is accomplished in a screw mixer-feeder. A metering pump is used to pump liquid binders to the pelletizer through a spray nozzle. A 12.7 mm mesh, vibro screen separator removes oversize pellets, leaving the pelletizer. A 0-6 kW microwave-heated dryer operating at 150-200°C removes moisture from the pellets in about 15 minutes. To impart leach resistance, the pellets are heat treated at 800-900°C for 1-2 hours in a kiln. Pellets move down through a set of 6-8 stacked, rotating trays inside the kiln. Pellets are collected from the heat treater and tested for strength and leach resistance. An off-gas system cools and removes dust present in the off-gas from the pilot plant.

Basic startup and shutdown procedures are given. A list of the facility drawings is included in Appendix A.

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FIGURES

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I. INTRODUCTION

At the Idaho Chemical Processing Plant (ICPP) a wide variety of spent uranium fuels are reprocessed to recover the uranium. A by-product of the process is a liquid high-level radioactive waste that is currently being solidified using a fluidized-bed calcination process.[1] The product is currently being stored in underground, stainless steel bins. However, because the granular product from the fluidized-bed calciner may be unsuitable for long-term disposal, an alternative to calcine, a pelleted form wherein certain solid and liquid additives are combined with calcine to form pellets is being developed.[2] These pellets are dried and heat treated giving a hard, leach-resistant waste form.

Laboratory and bench-scale studies have been on-going for some time to develop pellet formulations and pelletizing conditions best suited for the various types of calcined waste currently stored at ICPP. A pilot plant was recently completed to extend the study further. The primary purpose of the pilot plant is to study the entire pelleted waste form process on an integrated long-term basis, including complete off-gas treatment. In addition, the pilot plant will provide scale-up information necessary in a design for a full-scale facility to process actual radioactive wastes.

Briefly, the pilot plant consists of two loss-in-weight feeders, a screw mixer to intimately mix calcine and solid additives, a liquid binder feed system, a rotating-disc pelletizer, a screen separator, a microwave-heated dryer, a rotating-tray heat treater, and an off-gas system. The system is designed to process up to 25 kg/h of simulated calcine. The pellet formulations tested will be those developed in the laboratory that give the best pellet properties.

II. GENERAL PROCESS DESCRIPTION

Pellets are formed in the pellet pilot plant using a 41-cm-diameter rotating-disc pelletizer. The pelletizer features solids and liquid feed, and forms spherical pellets ranging from 1-20 mm diameter. A convenient pellet size selected for the pilot plant was 4-6 mm diameter.

The composition of the solids and liquid fed to the pelletizer depends upon the type of calcined waste being processed. However, certain materials have proven useful over a wide range of waste compositions.[2,3] These include: bentonite, metakaolin, boric acid, silica, and a phosphoric nitric acid solution used as the liquid spray. The pellets formed will have sufficient "green" strength to withstand a drop of 30-60 cm onto a hard surface. The pellets must also not stick together when piled to about 10 cm high.

Since a certain amount of oversize product will be inevitable, especially during start-up, the pilot plant has a screen to separate material over 12 mm diameter. The oversize material can be crushed and recycled, but this is not provided for at the present stage of development.

The pellets are then dried at 150-200°C to remove water and a small amount of NO_x present in binders and calcine. Microwave-heated drying was selected because it gave a satisfactory product in the shortest time.[4] Another important point is that the entire microwave power source can be located remotely from the processing cell. This would be very desirable in any radioactive waste processing system.

Heat treating the pellets at 800-900°C for 1-2 hours promotes reaction between the additives and various highly leachable components in the calcine, such as cesium and strontium, thereby greatly increasing the stability of the waste. Heat treating also removes the remaining NO_x from the pellets. To maintain a two hour residence time in a continuous system and yet keep the heat treater as compact as possible, a rotating tray assembly was designed. It consists of 6-8 stacked, slotted trays that rotate, forcing pellets to move from tray to tray. The trays are located inside a kiln.

The final product is collected in air-cooled canisters and then tested for leach resistance and compression and impact strength. Some pellets are also pneumatically transported to determine their attrition under transport conditions.

III. DETAILS OF PILOT PLANT EQUIPMENT

1. Pilot Plant Location

The pelletizing pilot plant is located in the northwest corner of the old Gamma Facility (see Figure 1). A schematic of the pilot plant is shown in Figure 2. The pilot plant occupies an area about 5.5 m x 3.7 m and is 6.4 m high. The plant has two floors above the ground floor (see Figure 3) at 2.3 m and at 3.9 m. A stairway leads to the 2.3 m level and a ladder leads from there to the 3.9 m level. The off-gas blower is located on the roof of the building.

2. Solid Feed System

The heart of the solid feed system is two Model LWF-20 loss-in-weight feeders manufactured by K-TRON Corporation (see Figure 4). One feeder will deliver up to 25 kg/h calcine and the other will deliver up to 10 kg/h solid binder. To avoid overranging the feed hopper weight, the calcine feeder has a smaller hopper. Both feeders use a positive displacement twin screw arrangement.

The feeders, located on the top level, are operated from a control panel (designated LCP-2) containing a power supply, relays, and two controllers (see Figure 5). The feeders may be operated in either mass or volumetric flow. In mass flow, the change in weight is measured over a very short time period. Should this time derivative of weight differ from the set point, the speed of the twin screws is changed accordingly. Volumetric flow is accomplished by maintaining a constant screw speed; for constant material density the two types of feeding are the same.

Under conditions of large, sudden weight changes -- such as bumping the feeder, or refilling the hopper -- the controller will automatically change from mass flow to volumetric flow. Following the disturbance, the controller will change back to mass flow. There are also lights to indicate when refill is necessary and when refill is complete.

The two controllers are currently set up in a master-slave arrangement with the calcine feeder being the master. In this arrangement, the set point on the binder controller becomes a percentage of the set point of the calcine feeder controller. For example, if the calcine controller set point is 20 kg/h and the binder controller set point is 8, the feed rate of the second feeder would be 8% of 20 or 1.6 kg/h. There are other options available; these are outlined in the K-TRON manual.

To get the raw materials up to the feeders, a Lodestar Model A electric chain hoist with a loading bucket is used (see Figure 4). The 114 kg capacity hoist is mounted on a jib crane with a 200^{o} rotation. This rotation permits the loading bucket to be swung over both feeders and over an opening in the third level grating.

The pilot plant has a screw mixer-feeder to intimately mix the calcine and various solid additives. The variable speed screw, designed and built by Austin-Mac, Inc., will both mix the solids and convey them to the pelletizer.

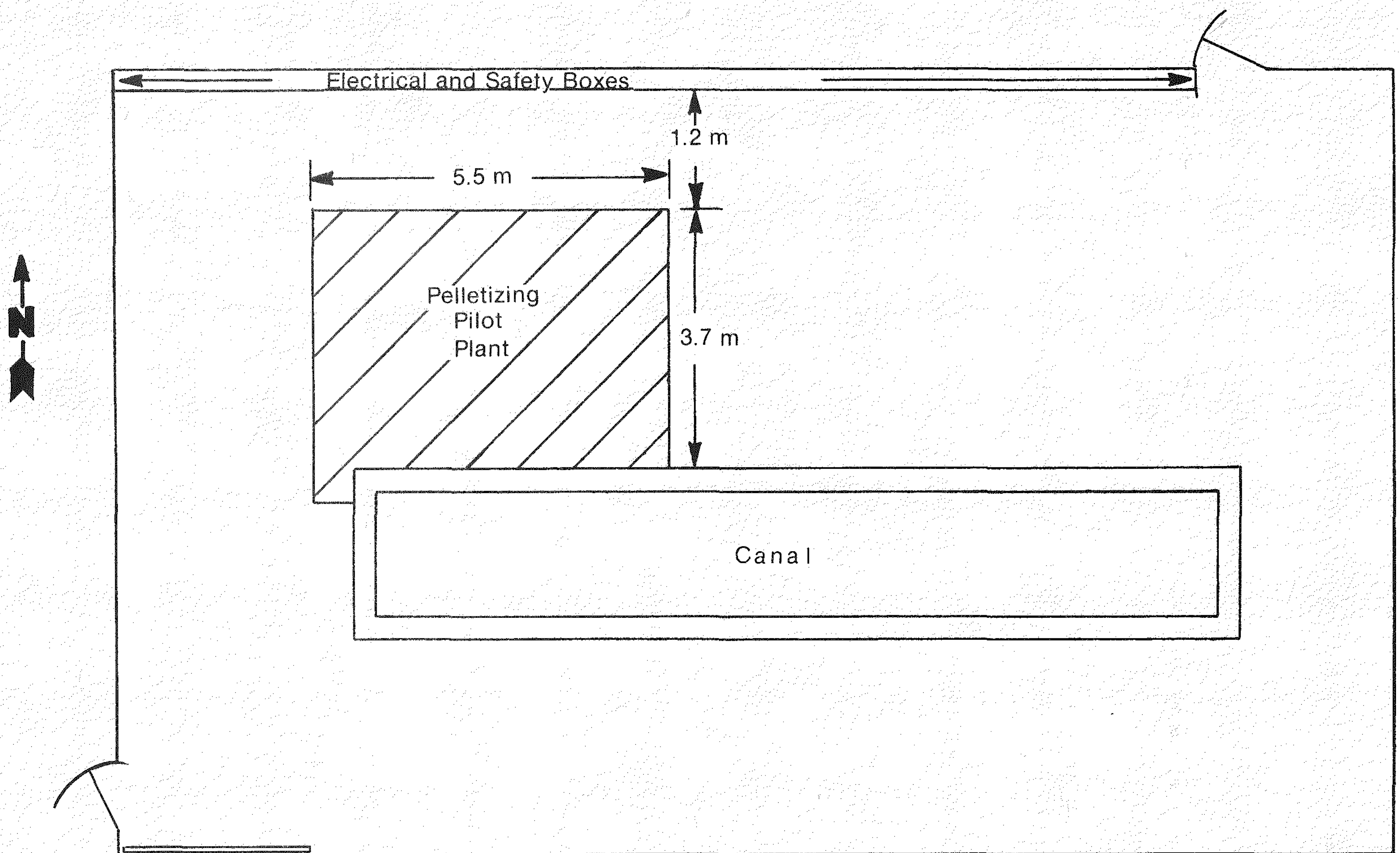

Figure 1. Location of Pelletizing Pilot Plant in Gamma Facility

ICPP-A-4639

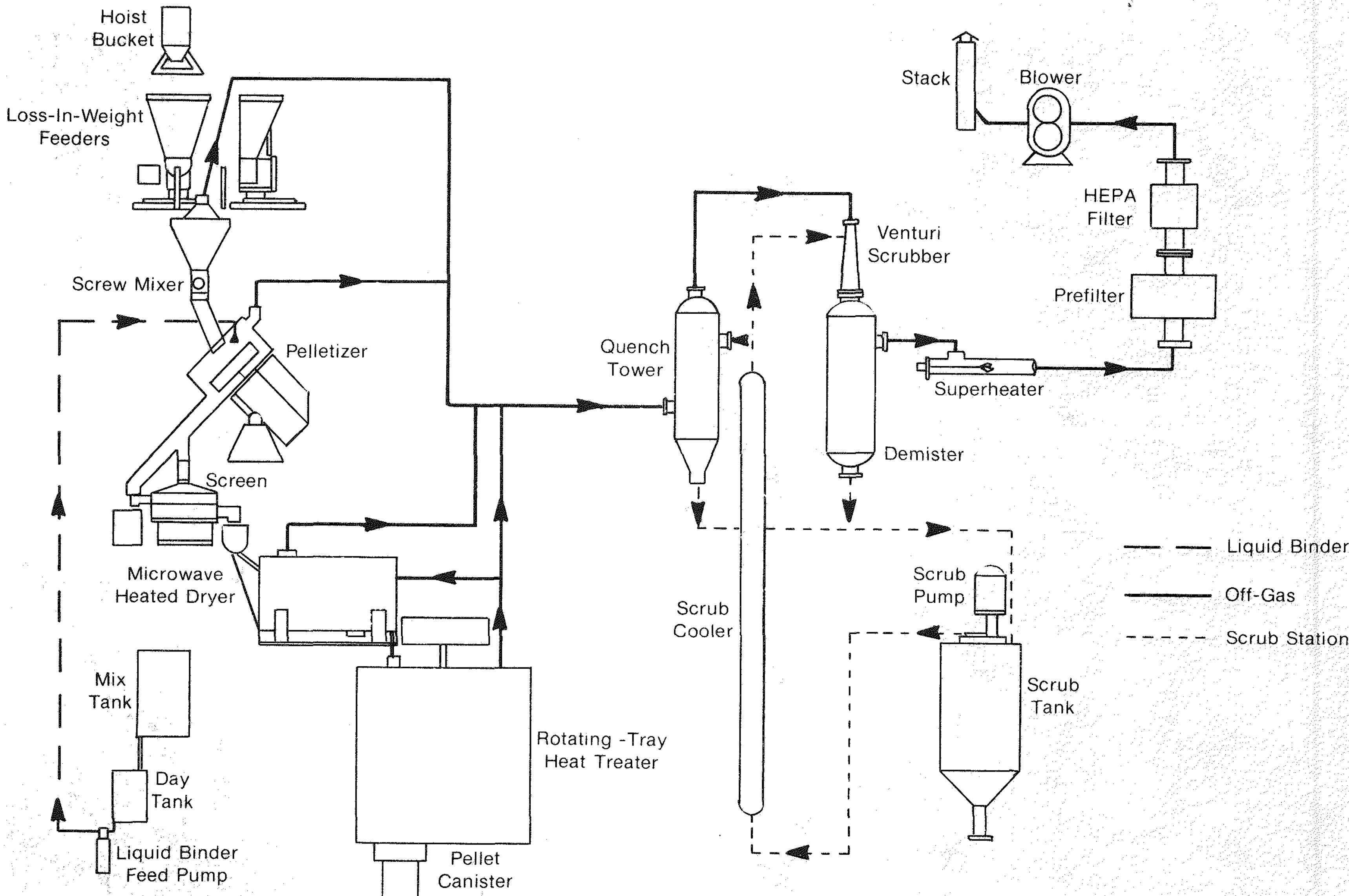

Figure 2. Schematic Flowsheet of Pellet Pilot Plant ICPP-A-4642

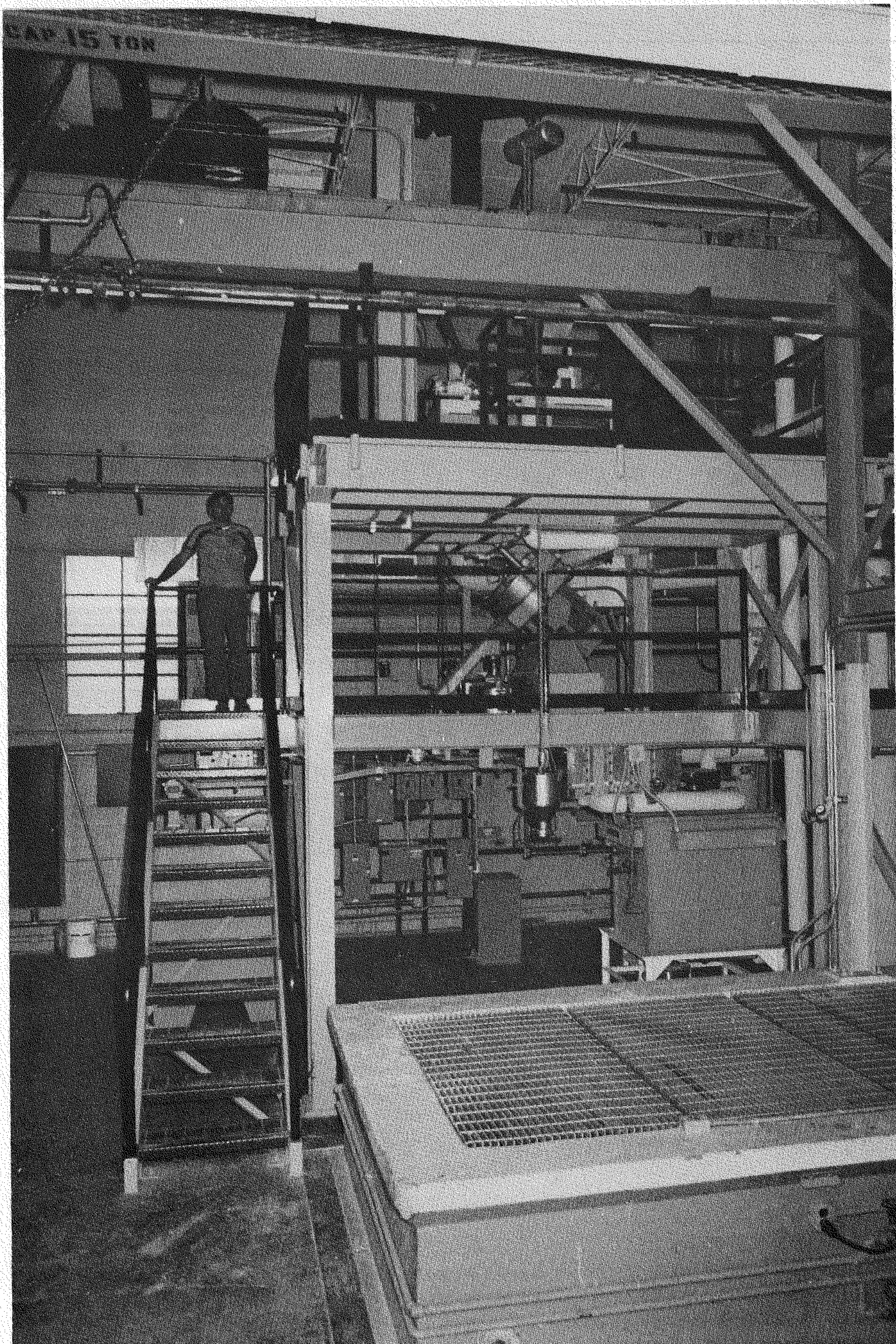

Figure 3. Photograph of Pellet Pilot Plant

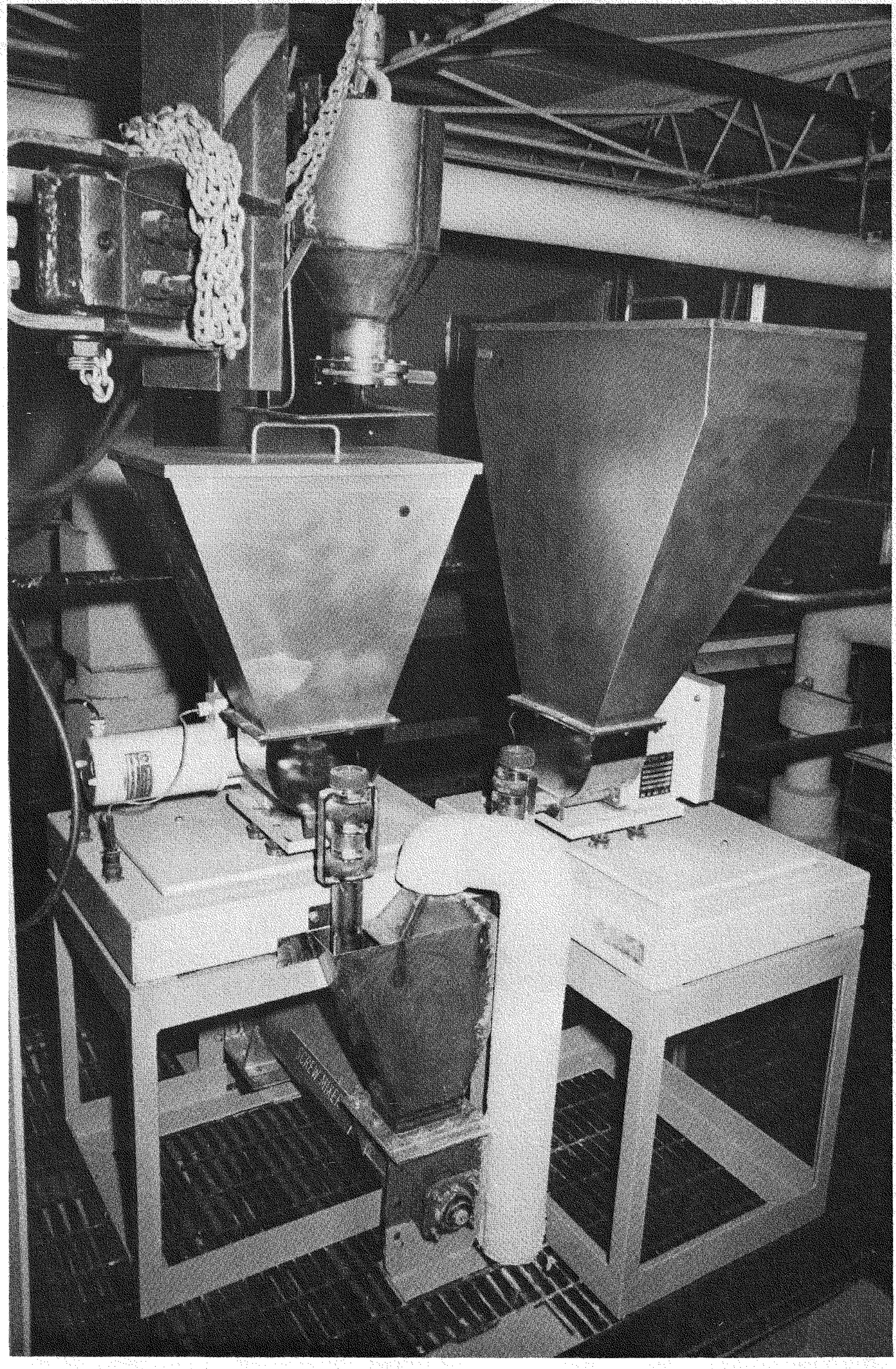

Figure 4. Photograph of Loss-in-Weight Solids Feeders

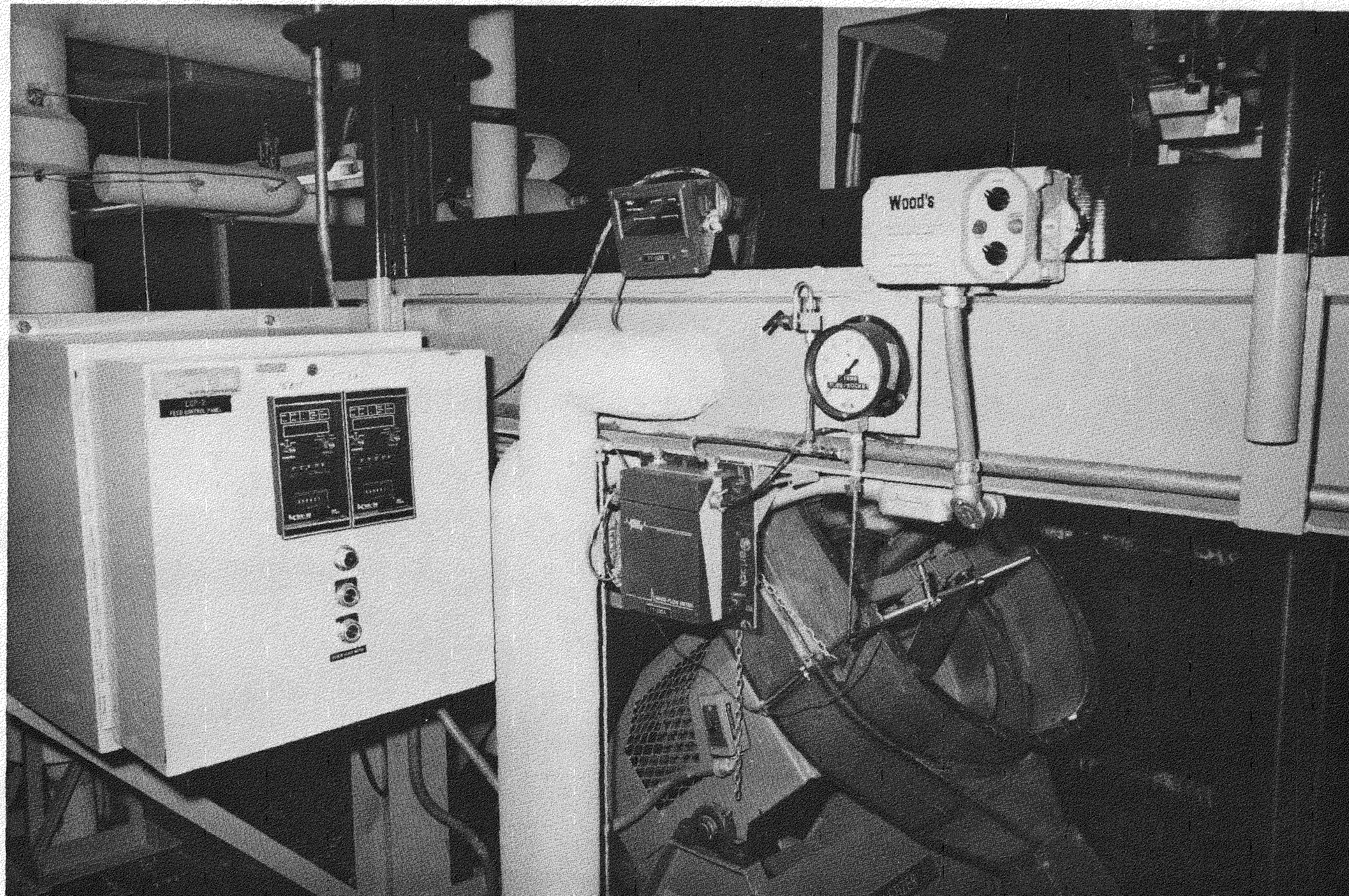

Figure 5. Photograph of Feed Control Center

3. Liquid Feed System

There are two liquid additive tanks (see Figure 6). The first is a mix tank and the second (directly below the first) is the feed tank. Both tanks are equipped with portable lab stirrers. Liquid is pumped to the pelletizer with a variable speed gear pump made by Micropump. The pump capacity is about 0.5 L/min at 280 kPa (40 psi), and has an internal bypass for the protection of the pump.

Between the pump and the pelletizer are a check valve and a 350 kPa (50 psi) pressure relief valve. The relief valve vents back to the feed tank and the check valve prevents backflow through the pump.

Liquid flow is measured with a Micro-Motion mass flowmeter. Liquid flows through a U-shaped tube that causes the tube to deflect. The amount of deflection determines the flow rate. Liquid is sprayed onto the pelletizer through a Spraying Systems Co. cone-jet nozzle. This nozzle produces a hollow cone spray pattern.

4. Pelletizer

The pellet pilot plant has a 41-cm diameter rotating-disc pelletizer manufactured by Ferro-Tech, Inc. (see Figures 7 and 8). The pelletizer has a 9-cm deep stainless steel pan that can rotate at variable speeds. Depending upon rotational speed, and locations and rates of liquid and solid feeds, pellets of a given size are formed and spill over the side of the pan.

Solid feed location in the pelletizer (slightly below center) can be varied over about 15 centimeters vertically by changing the position of a deflector plate located directly below the feed inlet tube. The liquid spray location can also be changed, within the lower right-hand quadrant, to suit the operating conditions.

The angle of the pelletizer, which is normally variable, is fixed at 48 degrees in the pilot plant due to space limitations. Three stainless steel plows prevent material buildup on the bottom and sides of the pan.

A stainless steel and Plexiglas hood enclosing the pelletizer serves a dual purpose: 1) to contain off-gas and dust, and 2) as a pellet chute between the pelletizer and the screen separator. A hinged door on the hood permits access to the pelletizer pan for routine cleaning and maintenance. Occasionally, during startup and major operational upsets, the pelletizer performs roughly, creating ragged and sometimes large agglomerates. Therefore, there is a flop-gate in the pellet chute to bypass the screen and send unacceptable product to a recycle canister. In the future, an automatic grinding and recycle loop will be built-in to handle the off-spec material.

5. Screen Separator

During normal operation of the pelletizer a small amount of oversize product (>6 mm) is inevitable. Since the dryer and heat treater will not operate with larger than 12 mm pellets, a screen separator was provided for in the pilot plant. The screen chosen is a Kason Corporation 45-cm diameter Vibroscreen (see Figure 7) with a screen opening of 12 mm.

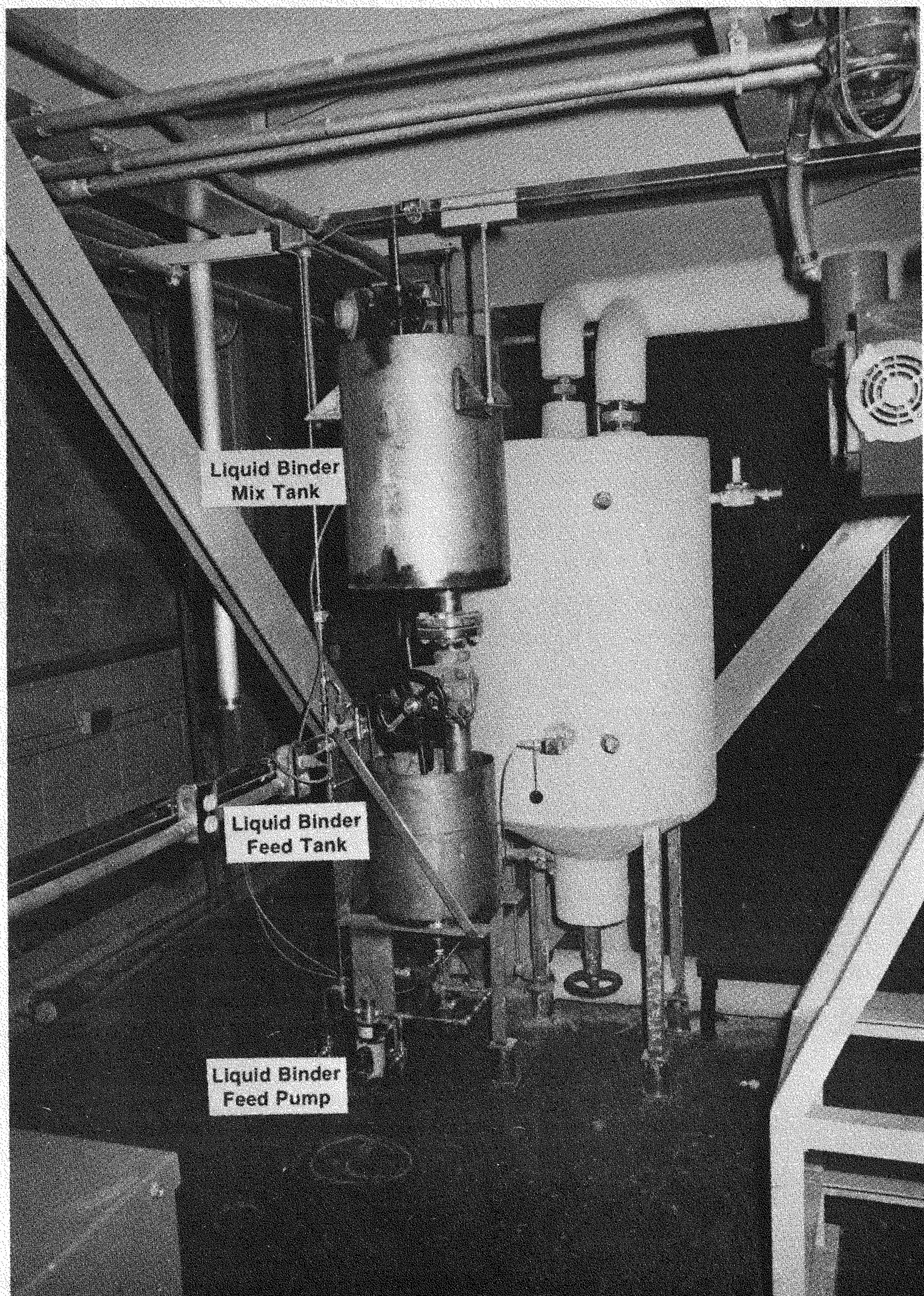

Figure 6. Photograph of Liquid Binder Tanks

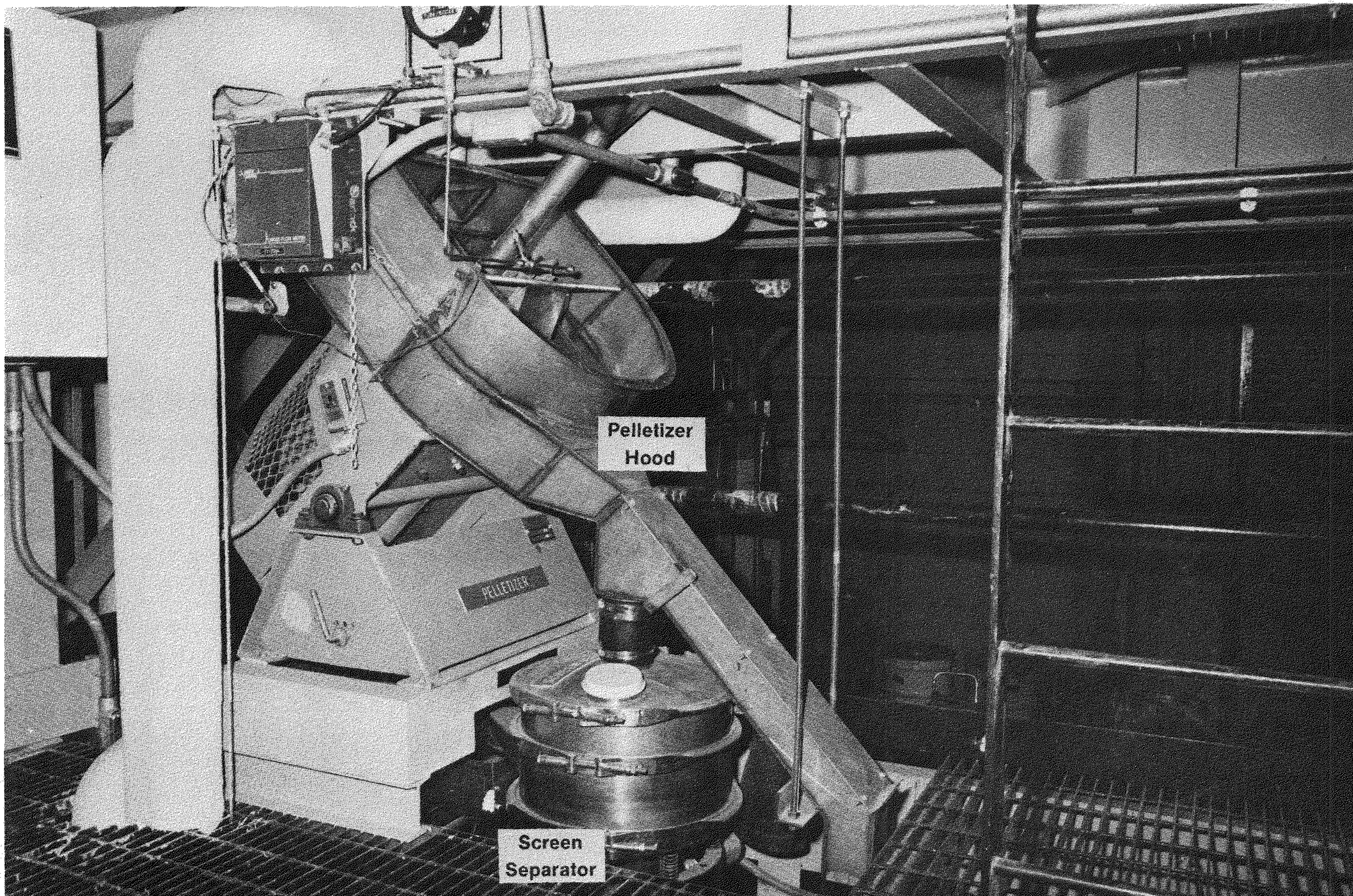

Figure 7. Photograph of Pelletizer

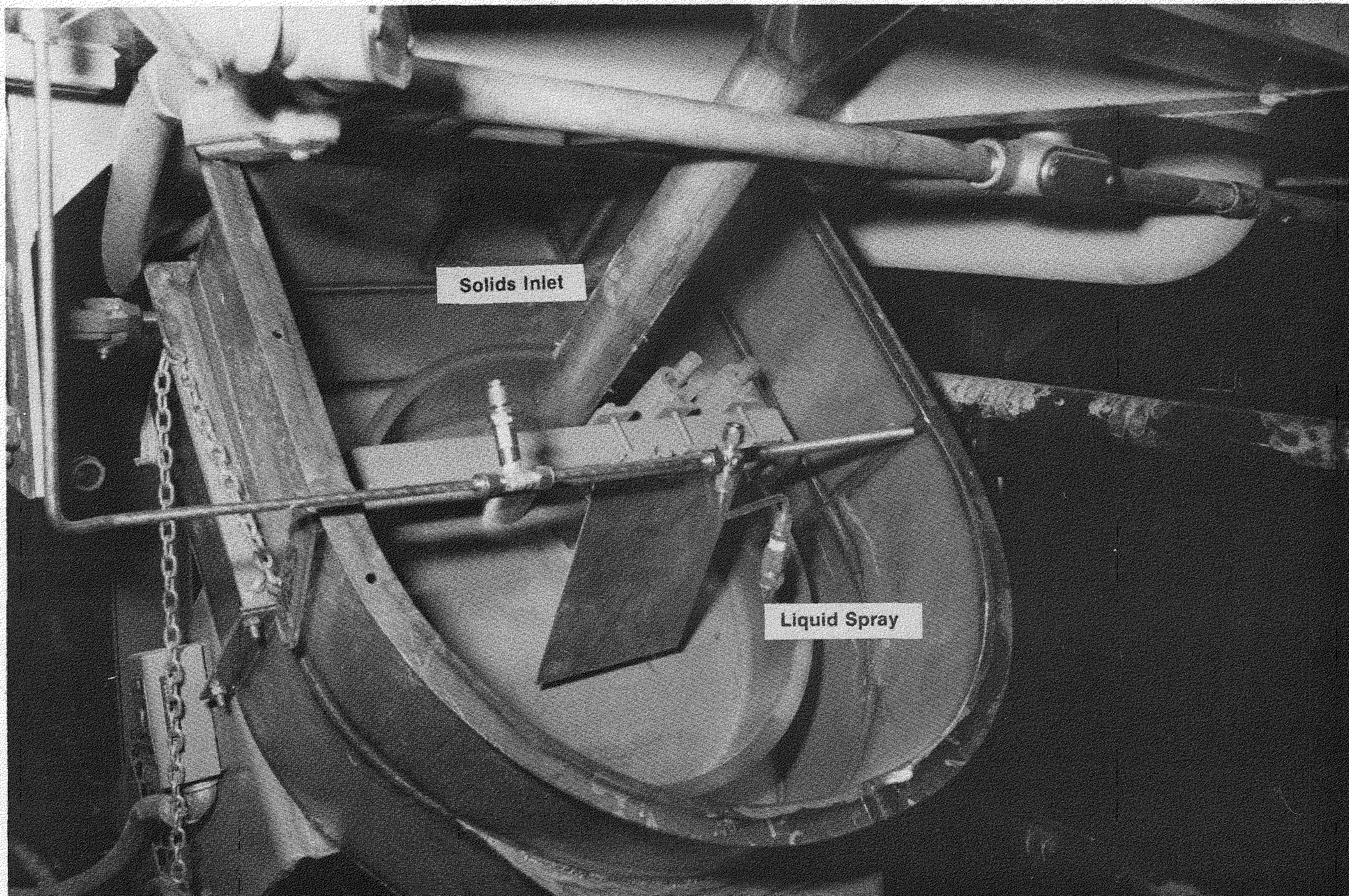

Figure 8. Photograph of Pelletizer Pan

The screen operates with a pair of rotating, eccentric weights that act to throw the pellets to the outside of the screen. Oversize pellets are sent to the same recycle container as off-spec startup material. Operating conditions for the screen will be determined during initial testing for the pilot plant.

6. Microwave-Heated Dryer

Microwave energy has proven very useful in drying pelleted waste. A hard, dried pellet can be formed faster by this method than by other heating methods. Pellets are dried for about 15 minutes at 150-200°C. A microwave-heated dryer consists of two parts: a microwave generator and a microwave applicator, the two being connected by hollow waveguide.

The microwave generator being used in the pilot plant is a Cober Electronics Model S-6F (see Figure 9). Output power is continuously variable from zero to six kilowatts at a frequency of 2450 MHz. The unit has builtin forward and reflected power meters and an arc detection circuit. There is also a waveguide fan to keep off-gas out of the waveguide.

The microwave energy is generated in a magnetron tube from Amperex (Model YJ1191A). A minimum of 4 L/min of cooling water is required to cool the magnetron tube and to supply the dummy load. Power is supplied to the generator through a fused safety switch mounted near the generator.

The actual pellet drying occurs at the microwave applicator. The applicator (dryer) is a hollow, stainless steel box with three pyrex trays inside (see Figure 10). The size of the dryer (51 cm x 56 cm x 91 cm) was designed to maximize the number of modes inside the dryer.[4] A mode stirrer creates a uniform microwave field in the dryer.

In the dryer, pellets travel along glass trays sloped at 2-3 degrees (Figure 11). By having three flights of trays rather than one, the size of the dryer was reduced. Shallow grooves in the trays prevent pellets from rolling too fast down the trays.

Pellet inlet and outlet are through one-inch diameter tubes that are large enough to freely pass pellets, but small enough to contain the microwaves inside. An air-operated vibrator on the bottom of the dryer helps move pellets through the dryer.

One end of the dryer is removable to provide access to the trays and to permit cleaning. A WR-284 waveguide transmits the microwave energy from the generator to the dryer.

7. Pellet Heat Treater

To promote the reaction between calcine and additives, it is necessary to heat treat the pellets. This is generally done at about 800°C for about two hours. These are fairly severe operating conditions for a compact, continuous piece of equipment. Several options were available including conveyor, rotary kiln, or rotating drum, but the design finally chosen was a rotating-tray kiln.

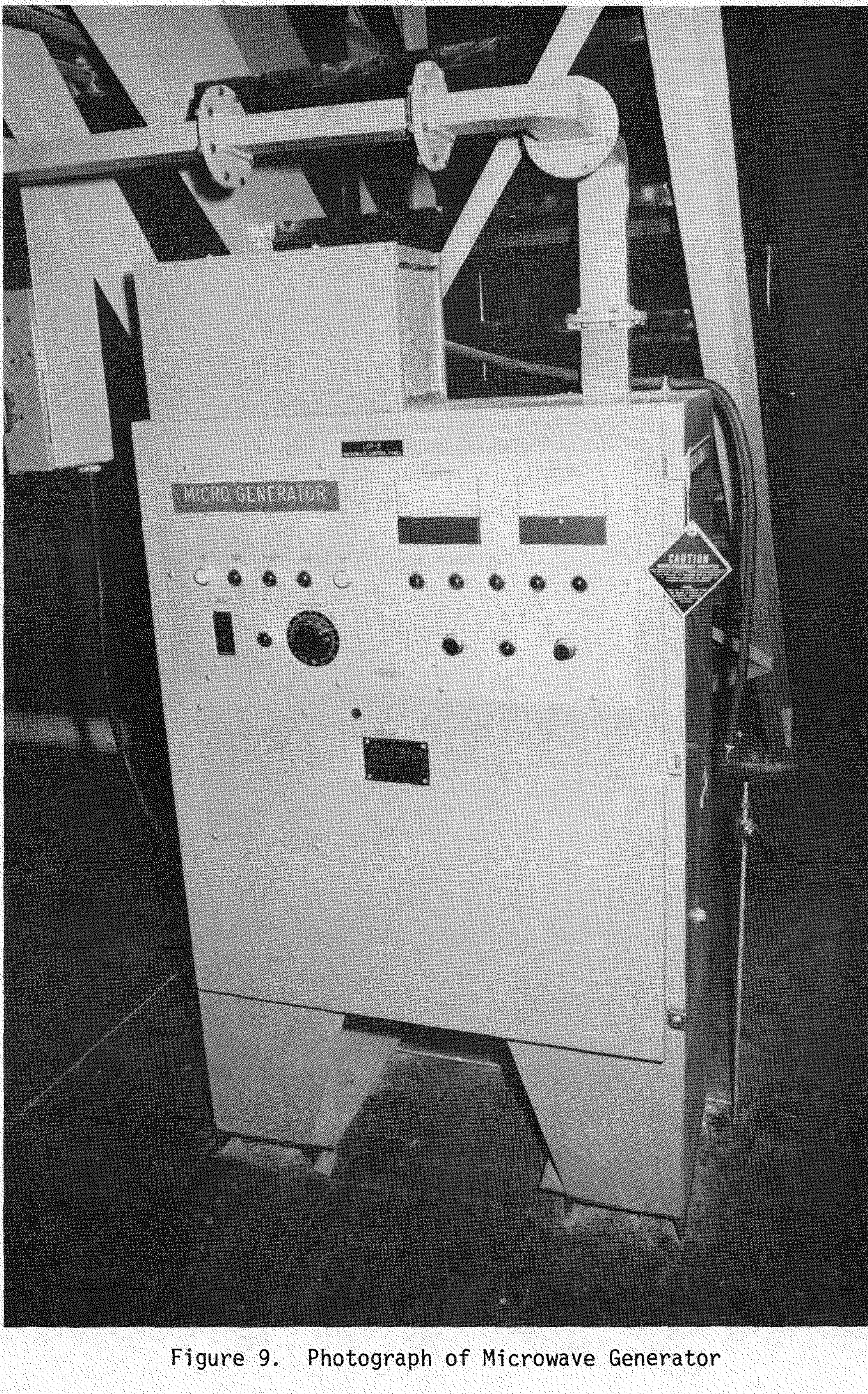

Figure 9. Photograph of Microwave Generator

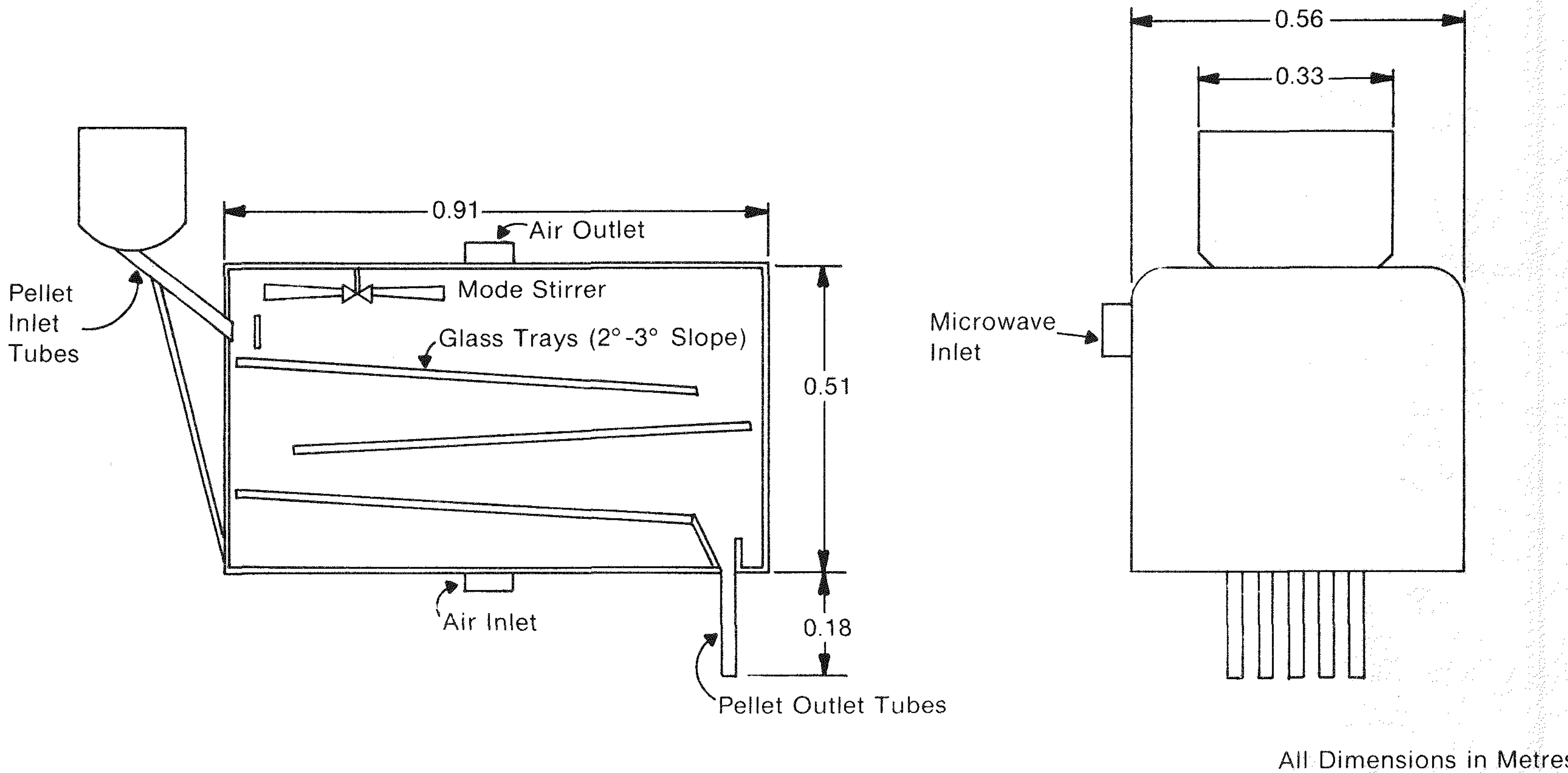

Figure 10. Schematic of Microwave Applicator

ACC-A-3726

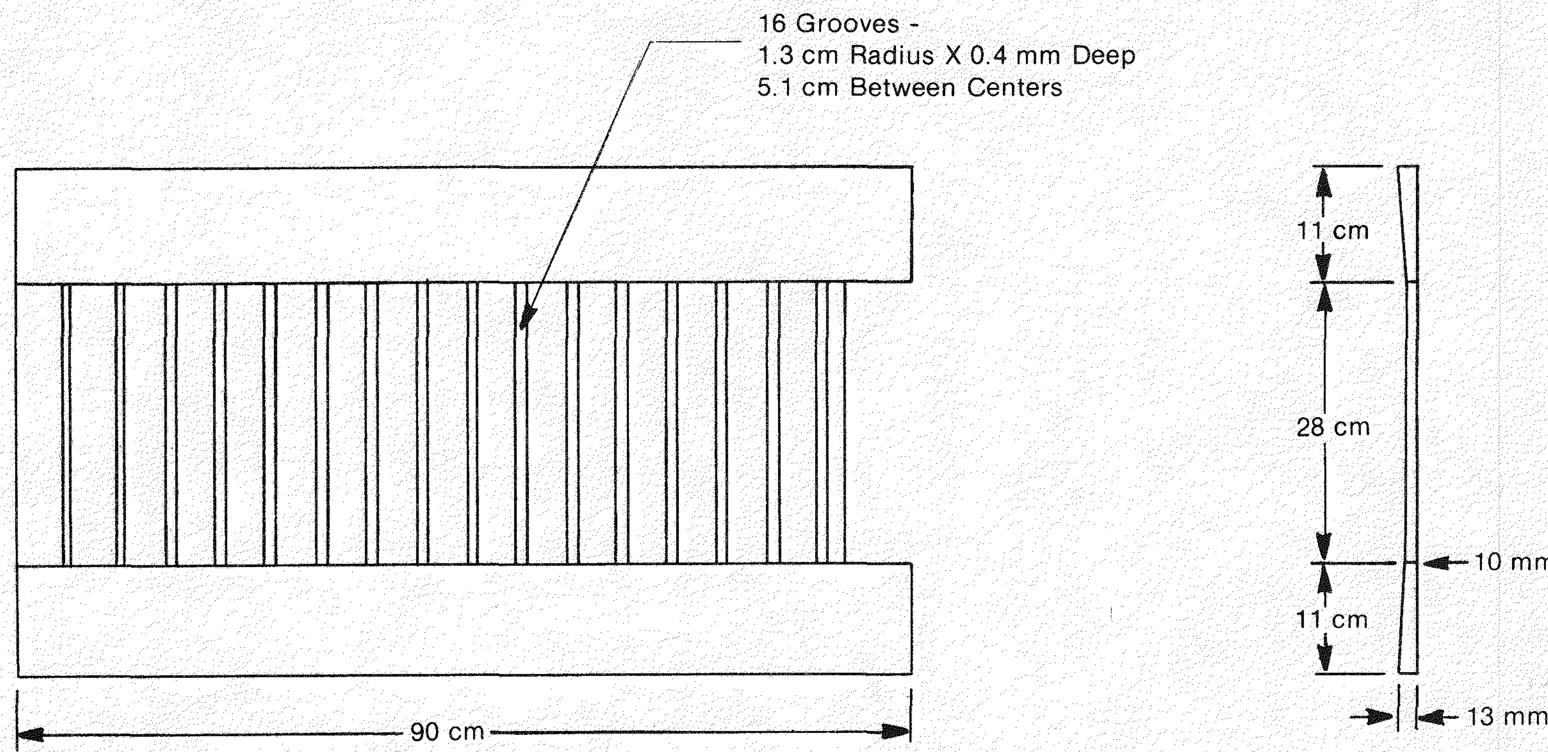

Figure 11. Detail of Glass Tray from Dryer

ICPP-A-4640

The unit consists of a stack of six to eight slotted, rotating trays (see Figure 12 and 13) inside a kiln. After each tray rotation, fixed scrapers force the pellets through the slots to the next tray. To withstand the harsh environment, the trays are fabricated from Inconel 601 and are spaced to allow for thermal expansion.

The kiln, manufactured by J. T. Thorpe, Inc., has outside dimensions of about 1.2 m wide x 1.2 m deep x 1 m high; and interior dimensions of 0.7 m on a side (Figure 14). Twelve heating elements in three parallel circuits give an operating temperature of 850°C for 25 kg/h of pellets. Heat input to the kiln is controlled using a thermocouple in the center of the kiln.

A number of safety features are built into the heat treater, including a high-temperature limit, loss-of-power shut off, over-current protection, and an automatic safety switch on the door.

The heat treater trays are driven by a 1/4-Hp Emmerson Electric DC motor (Figure 14). The motor has a gear reduction of about 20,000:1. The motor is equipped with a variable speed controller to give a final rotational speed of two to eight revolutions per hour.

8. Pellet Canisters

Pellets fall from the bottom of the heat treater into air-cooled stainless steel canisters (see Figure 15). There is a dual system for the canisters so that while one is receiving pellets and being cooled, another can get additional cooling while set aside. The additional cooling allows safe handling of the final pellets when changing canisters. The canisters are on dollies to facilitate handling and an off-gas hood mounted to the bottom of the heat treater allows easy positioning.

9. Off-Gas System

The primary constituents of the off-gas from the pellet pilot plant are water, NO_x, and dust. The off-gas must be cooled. The pilot plant off-gas system (Figure 16) is similar to that for the 30-cm-diameter pilot plant fluidized-bed calciner at the ICPP.

Off-gas is collected from the inlet funnel on the mixer-feeder, the pelletizer hood, the pellet dryer, and the heat treater. Flow rates from each source can be adjusted to suit the operating conditions. For energy efficiency, a portion of the off-gas from the heat treater is diverted into the dryer. Off-gas from these four sources is combined in a header to give a mixed temperature of 300-400°C.

The off-gas first enters a quench tower where it is cooled to about 80°C by a scrub solution spray. Scrub solution is generally 2 M nitric acid. After being cooled the off-gas passes through a wet venturi scrubber, equipped with four spray nozzles to remove the dust, then through a demister to remove entrained liquid. If the screen mesh inside the demister becomes plugged, it can be cleaned by spraying nitric acid through nozzles located above and below the mesh.

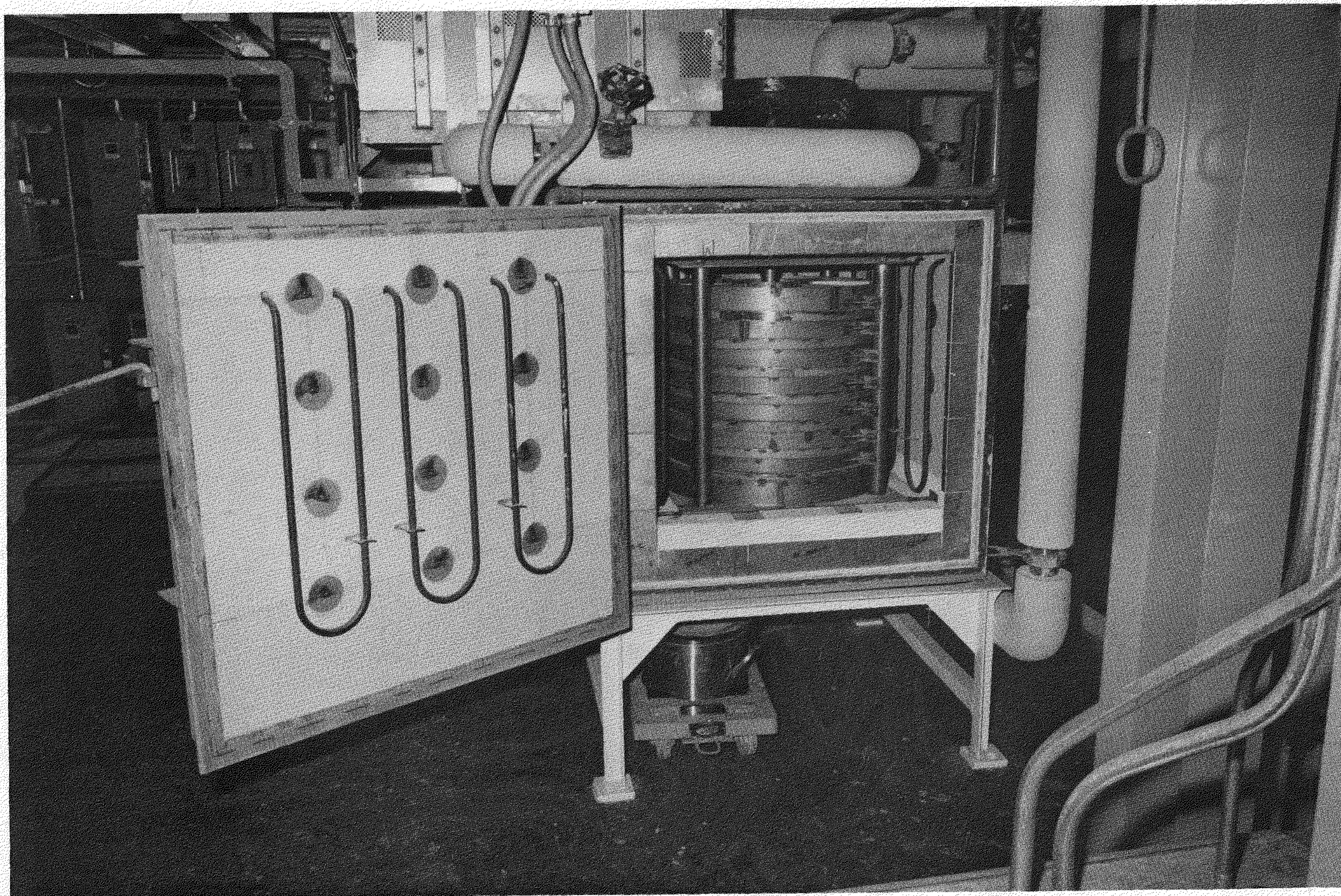

Figure 12. Photograph of Pellet Heat Treater - Inside

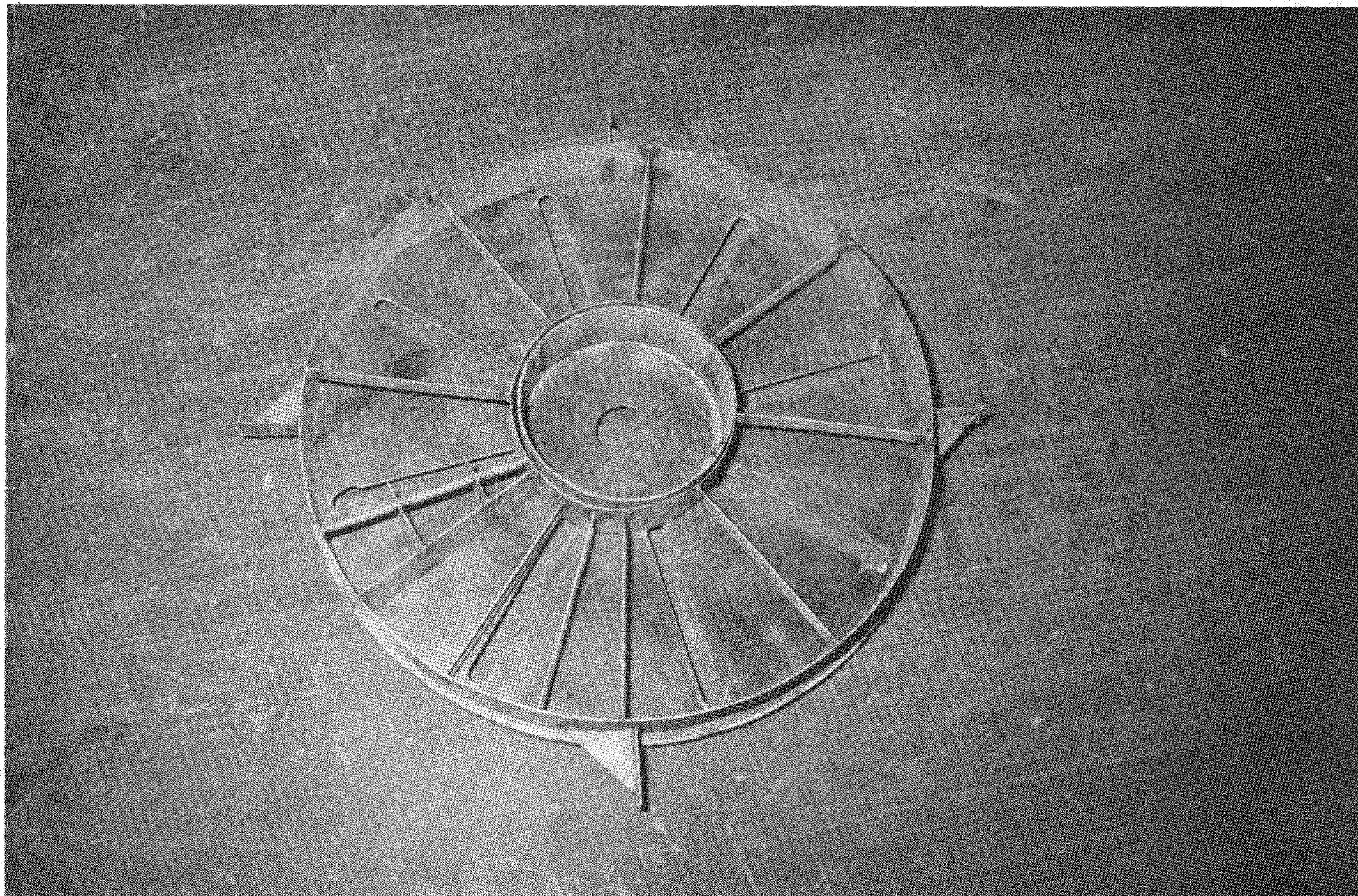

Figure 13. Photograph of Heat Treater Tray

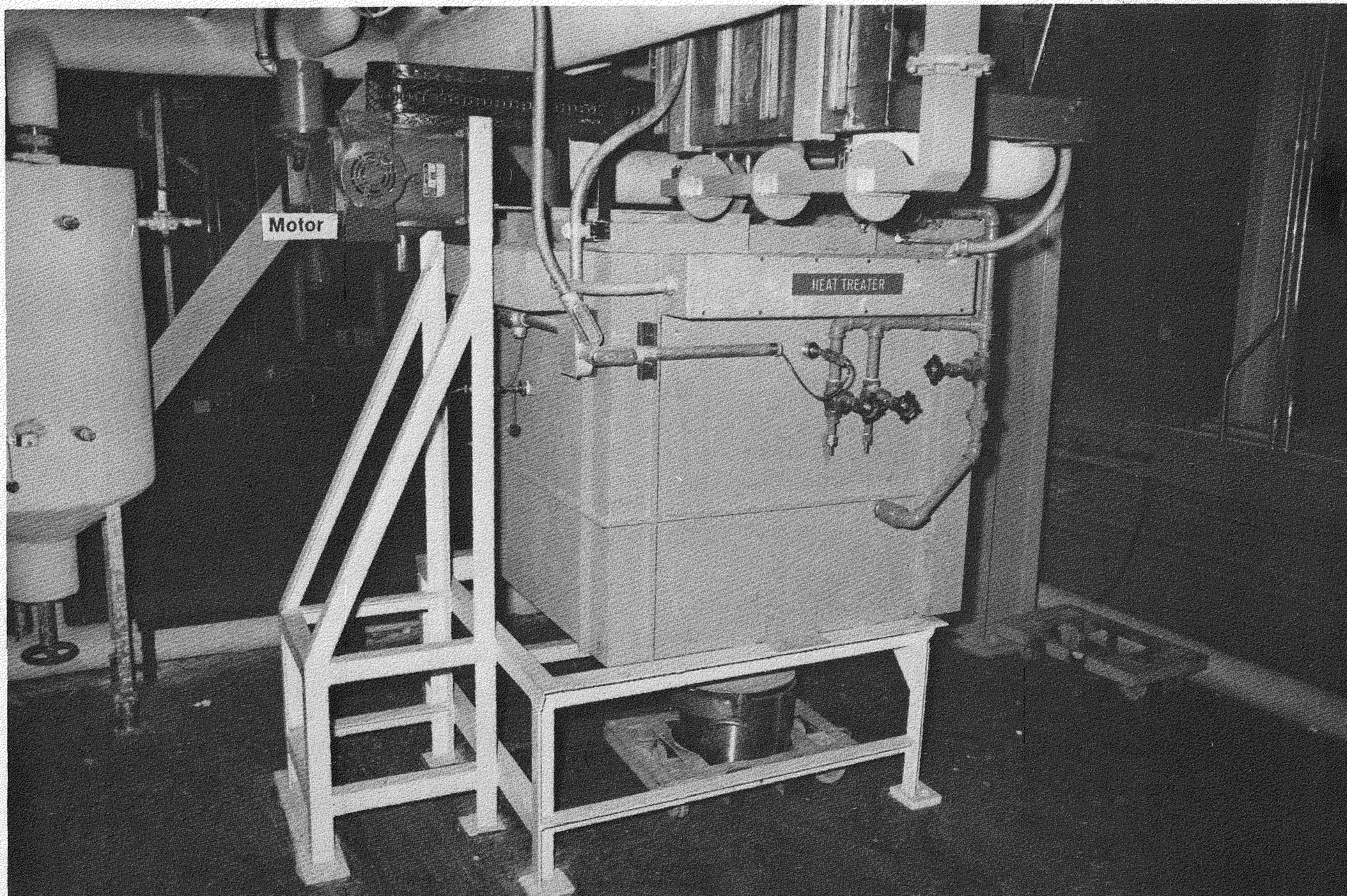

Figure 14. Photograph of Heat Treater and Motor

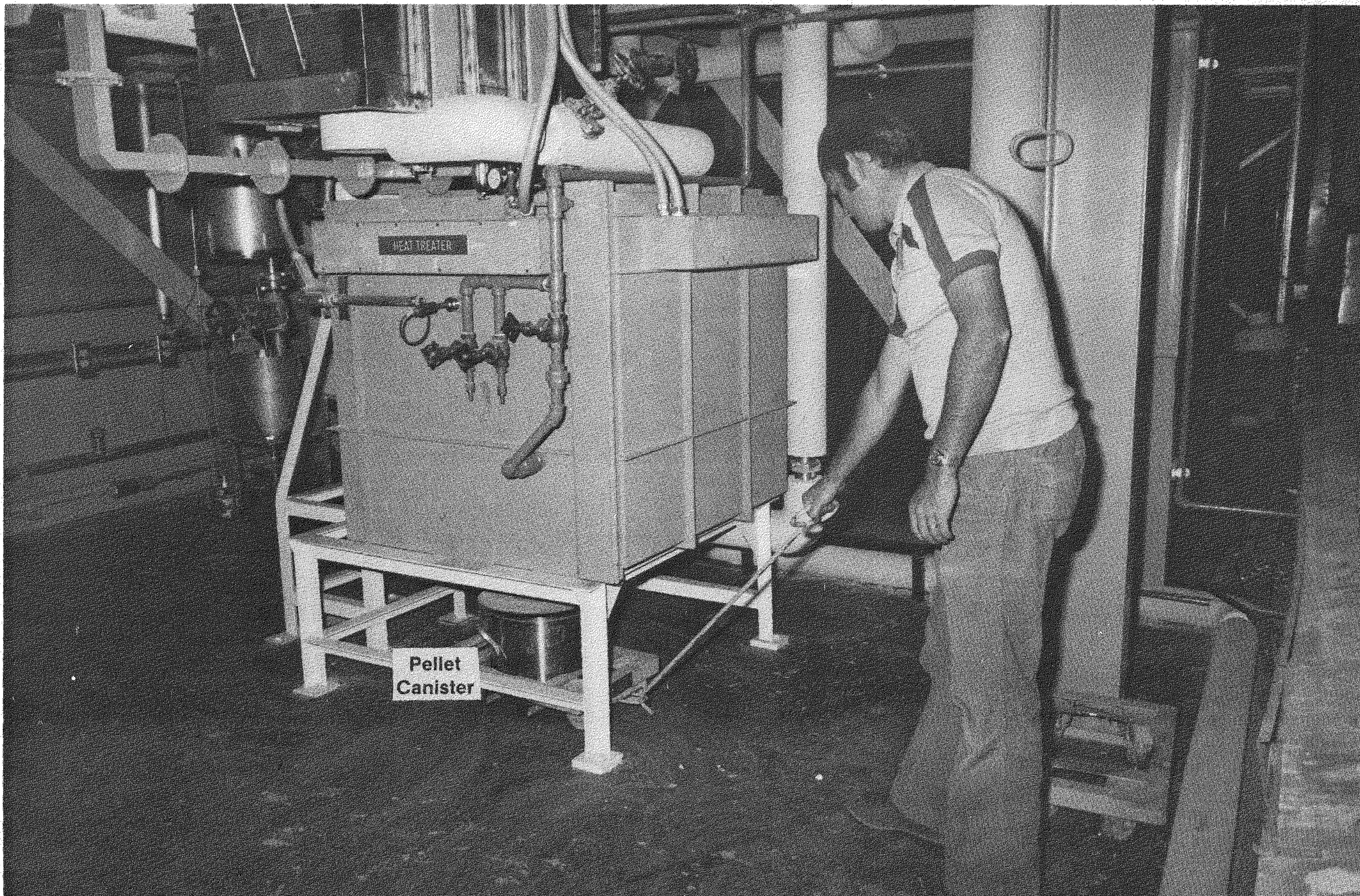

Figure 15. Photograph of Heat Treater With Pellet Canister

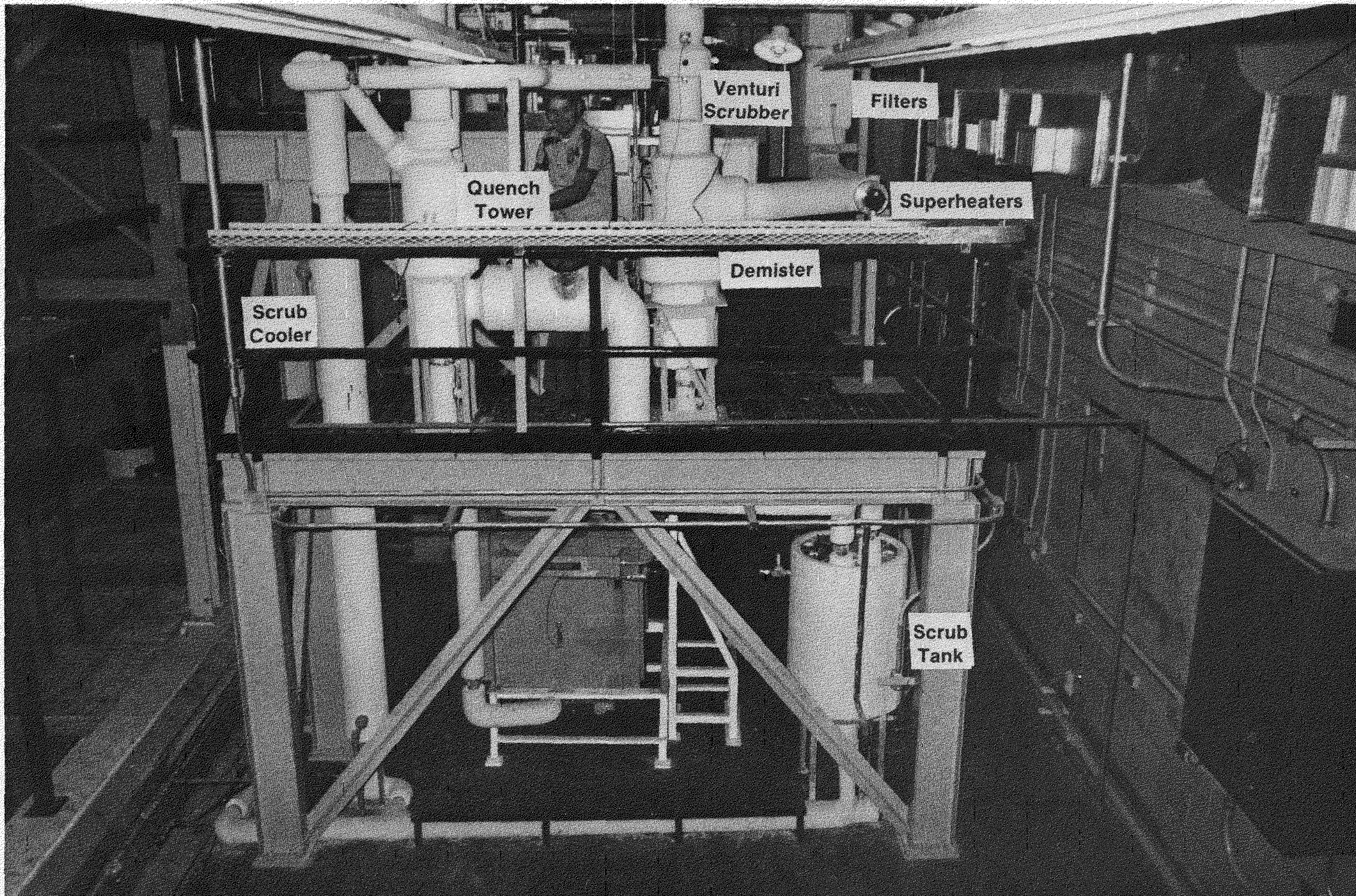

Figure 16. Photograph of Off-Gas System

Because some dust may still be present after the demister, a prefilter and a HEPA filter are included in the off-gas system. To prevent condensation within the filters, a Chromalax flanged immersion heater will heat the off-gas above the dew point (about 40°C).

The off-gas blower (Figure 17), made by M. D. Pneumatics, Inc., is a rotary positive displacement type capable of 1.5 m^3/min (50 scfm) at 7.5 kPa (30" water) static pressure. To reduce the noise level, the blower is located on the roof of the Gamma Facility. With the blower is an external oil cooling loop that must be checked periodically to be certain the proper oil level is maintained. The blower also has two vibration sensing devices to shut down the blower in the event of too much or too little vibration.

Nitric acid scrub solution is collected from the quench tower and the demister and sent to a scrub tank. Here, solids can settle out somewhat. Solids and cold scrub solution can be drawn from the bottom of the tank while fresh makeup scrub can be added at the top.

A Hazelton Type VNL vertical sump pump in the scrub tank pumps the scrub solution through a scrub cooler (a shell and tube heat exchanger) and back to the main off-gas vessels. The scrub cooler lowers the scrub solution temperature to 60°C with water on the shell-side of the exchanger.

Scrub solution, when drained from the bottom of the scrub tank goes to a hold-up tank located at the bottom of the canal. When the tank is full a switch is activated that will automaticaly drain the tank to the TRA disposal system. The acid dumped into this tank has to be neutralized before transfer to the disposal system.

10. Instrumentation

Full instrumentation is essential in any pilot plant operation to control the process and to obtain information for possible scaleup. Instrumentaton also facilitates trouble shooting. Among the measurements taken in the pellet pilot plant are temperatures, differential and absolute pressures, liquid levels, and liquid and solid flowrates Locations of these instruments are shown in Figure 18. Instrument signals are monitored either on a multipoint recorder or on a digital temperature indicator. Table I gives the legend for the instrumentation symbols shown in Figure 18.

The recorder is an Esterline-Angus 24-point thermal printing model. It has a variable chart speed, variable print rate, and selective alarms. Any number and combination of the 24 points can be printed. The temperature indicator is a Doric Model DS-300 unit for up to 12-Type K thermocouples.

Discussion of the instrumentation in the pilot plant will be divided into two general areas: process instrumentation, and off-gas instrumentation.

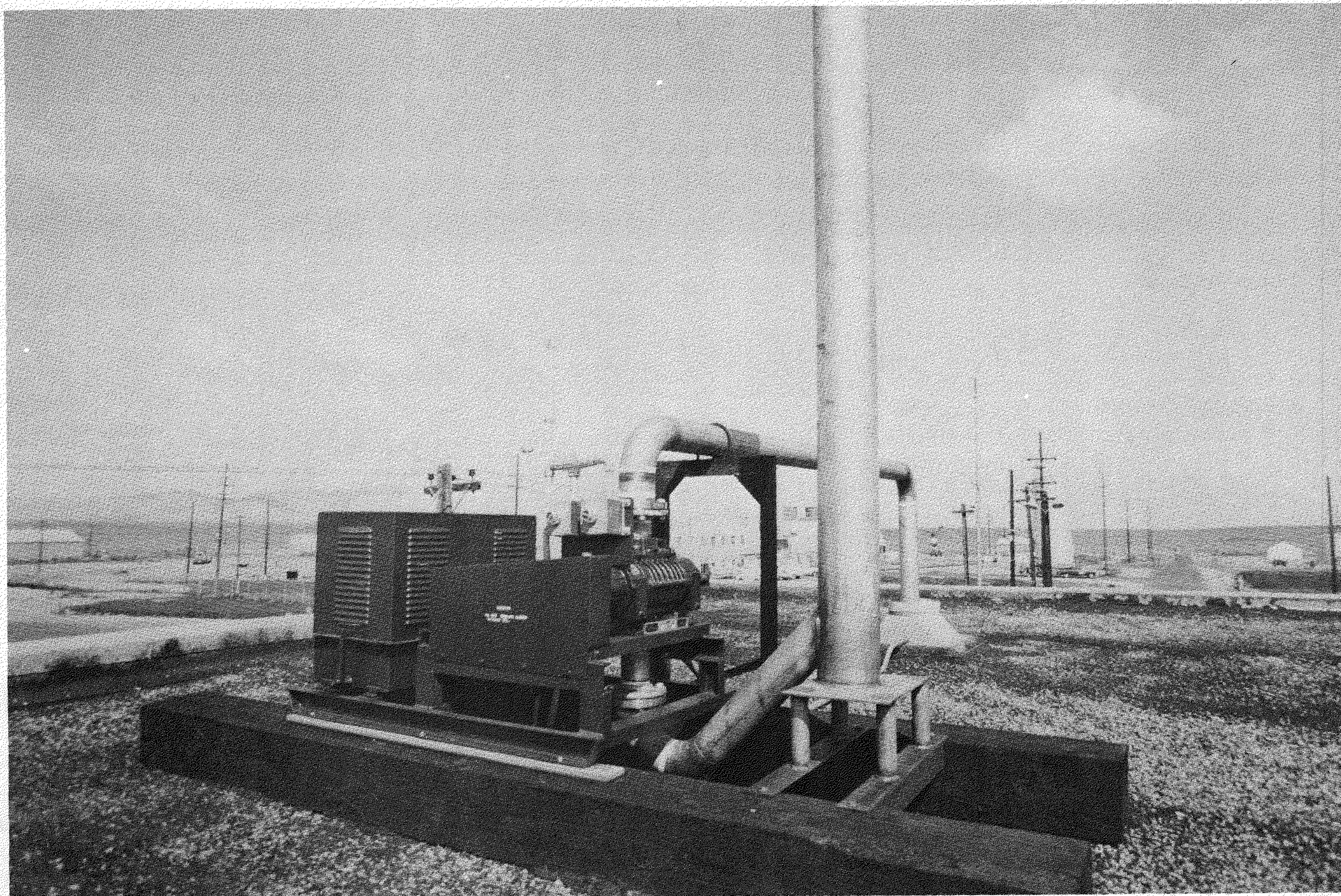

Figure 17. Photograph of Off-Gas Blower

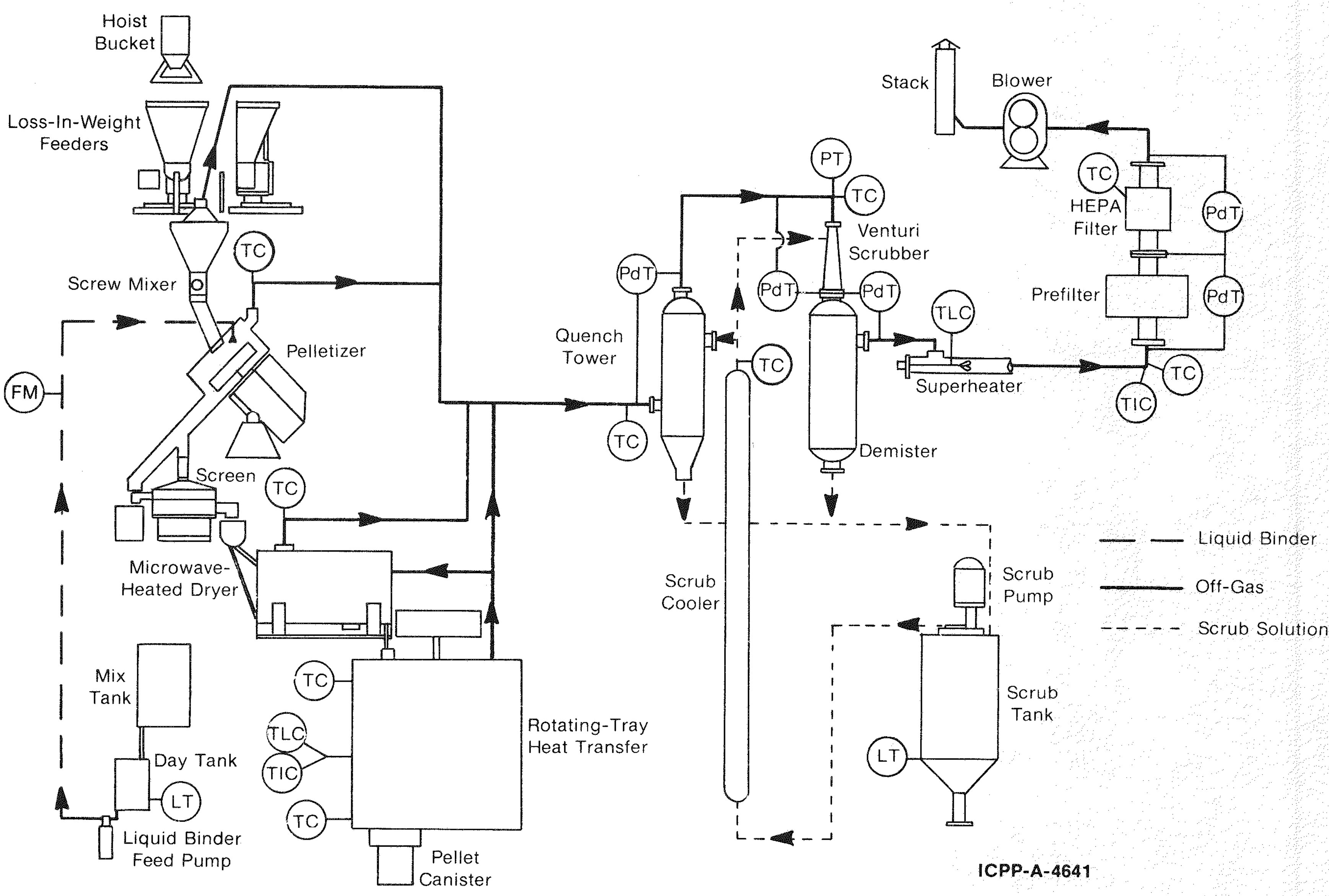

Figure 18. Pellet Pilot Plant Instrumentation

Table I

Legend for Instrumentation Symbols

(FM)	Liquid Flowmeter
(LT)	Liquid Level Transducer
(PdT)	Differential Pressure Transducer
(PT)	Absolute Pressure Transducer
(TC)	Thermocouple
(TIC)	Temperature Indicator Controller
(TLC)	Temperature Limit Controller

10.1 Process Instrumentation

Solid and liquid feed rate instrumentation has been discussed earlier in this report.

Certain pelletizing formulations can generate heat, which, in turn, can affect the "green" properties of the pellets. A thermocouple inside the pelletizer hood monitors deviations from ambient temperature due to pellet reactions.

Because the function of the microwave-heated dryer is to dry the pellets, it is not of major concern how hot the dryer operates. However, to avoid excessive energy use, the lowest temperature that can dry the pellets is used (generally 150-200°C). In addition, by monitoring the temperature in the dryer, changes in microwave absorbance can be detected and appropriate changes in power levels can be made. To avoid problems of grounding the thermocouple inside the dryer, the thermocouple is located immediately outside the dryer in the off-gas line.

Three thermocouples are located inside the heat treater: at top, middle, and bottom. Any local cooling that might occur due to cold pellets entering can thus be seen. The center thermocouple is also used for the signal to the kiln temperature controller and to the high temperature limit controller. An audible alarm sounds under several conditions: initial power on, loss of power to the heating elements, kiln door not being completely closed, and high temperature limit is exceeded.

The level in the liquid binder feed tank is measured with a Validyne DP-15 differential pressure transducer. The high side of the transducer is connected to the bottom of the tank and the low side is open to atmosphere.

10.2 Off-Gas System Instrumentation

Most of the instrumentation in the off-gas system is for diagnostic purposes. Differential pressure transducers are used to measure pressure drop across the quench tower, venturi scrubber, demister and both filters. Using these pressure drops, the operator can determine where plugging might be occurring. In addition, the absolute pressure at the inlet to the venturi is measured. This ensures that the inlet pressure is sufficient to properly atomize the incoming scrub solution.

Temperature drop across the quench tower is measured with thermocouples at the inlet and outlet of the vessel. Scrub solution flowrate to the quench tower is adjusted to maintain a desired outlet temperature. The scrub solution temperature is also measured at the outlet of the scrub cooler. Liquid level in the scrub tank is measured with a differential pressure transducer similarly to the liquid binder level measurement.

To prevent condensation in the filters, a flanged immersion superheater is located just upstream from the filters. Temperatures measured in the inlet to the filters and on the outside surface of the filters enables proper power to be applied to the superheater. The superheater also has two thermocouples associated with it: one for the temperature controller, and one for the high temperature limit.

11. Control Centers

An attempt was made in the design of the pilot plant to centralize the control as much as possible into a single area on the main floor to simulate remote operation. However, because the pilot plant is an experimental facility, it was decided to place those controls directly related to the pelletizer in a location on the second level close to the pelletizer. This enables the operator to make critical corrections in feed rates while watching the pellets form.

The feed control center (shown in Figure 5) includes controls for the loss-in-weight solid feeders, control valve and flowmeter for the liquid feed, screw mixer-feeder controls and controls for the pelletizer. Indicators for the liquid and solid feed rates are also in this center.

The remainder of the control system is located in the northwest corner on the main level. It is divided into three sections: an electrical distribution rack (Figure 19), the self-contained microwave generator (Figure 9), and the main control console (Figure 20).

The electrical distribution rack contains circuit breakers, transformers, and magnetic motor starters for various items of the process equipment. The microwave generator has already been described.

Most of the process monitoring occurs at the main control console. Pushbutton switches for the off-gas blower, scrub pump, vibroscreen separator and pellet heat treater are located here. The temperature and high limit controllers for the heat treater and the off-gas superheater are also in the main panel. The temperature indicator, multipoint recorder, and signal conditioning units for the Validyne transducers are in the panel. A Hewlett-Packard system for recording the liquid binder flowrate is used; it includes a pulse counter and mainframe assembly, and a printer. Control power is also routed from the main control panel to the feed control system above.

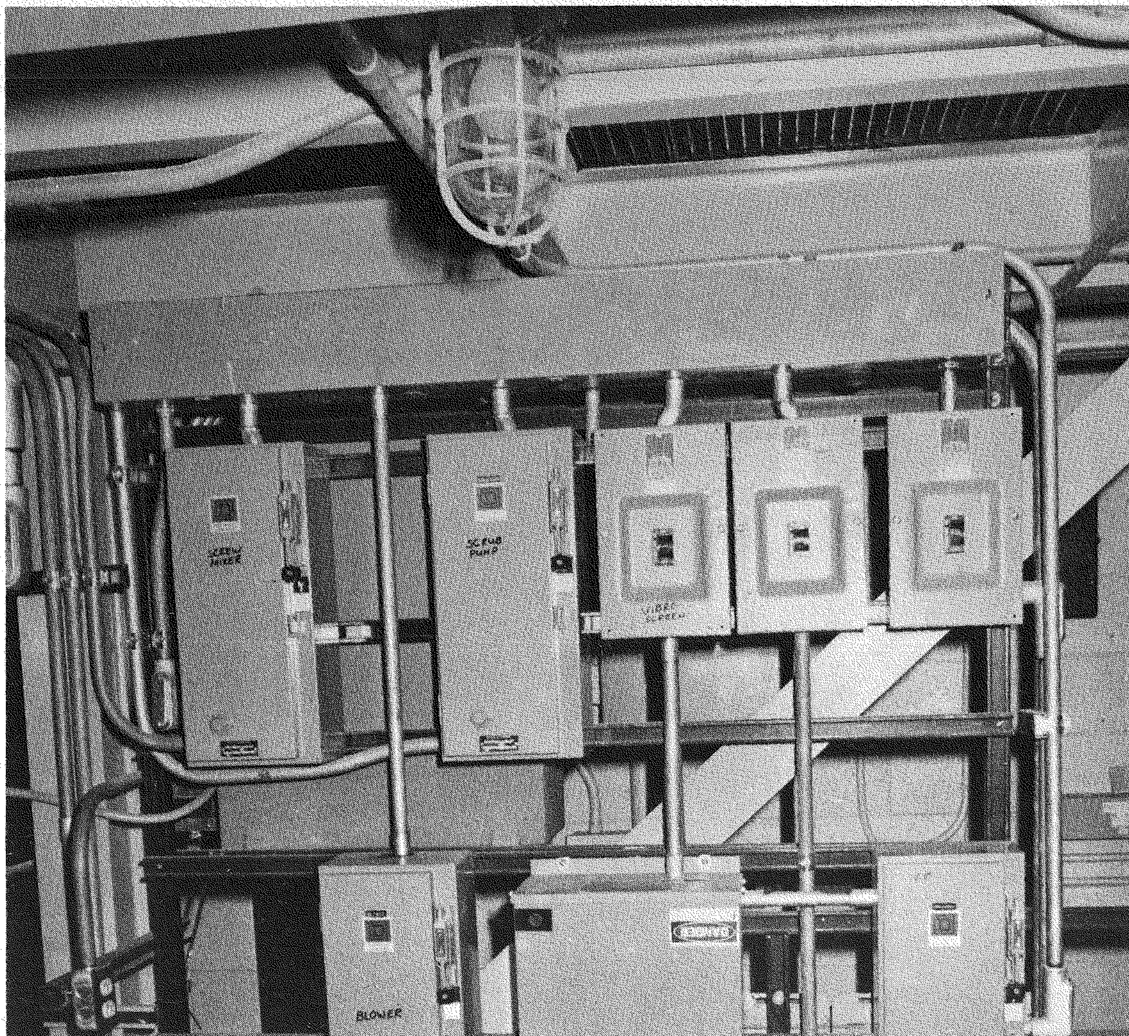

Figure 19. Photograph of Electrical Distribution Rack

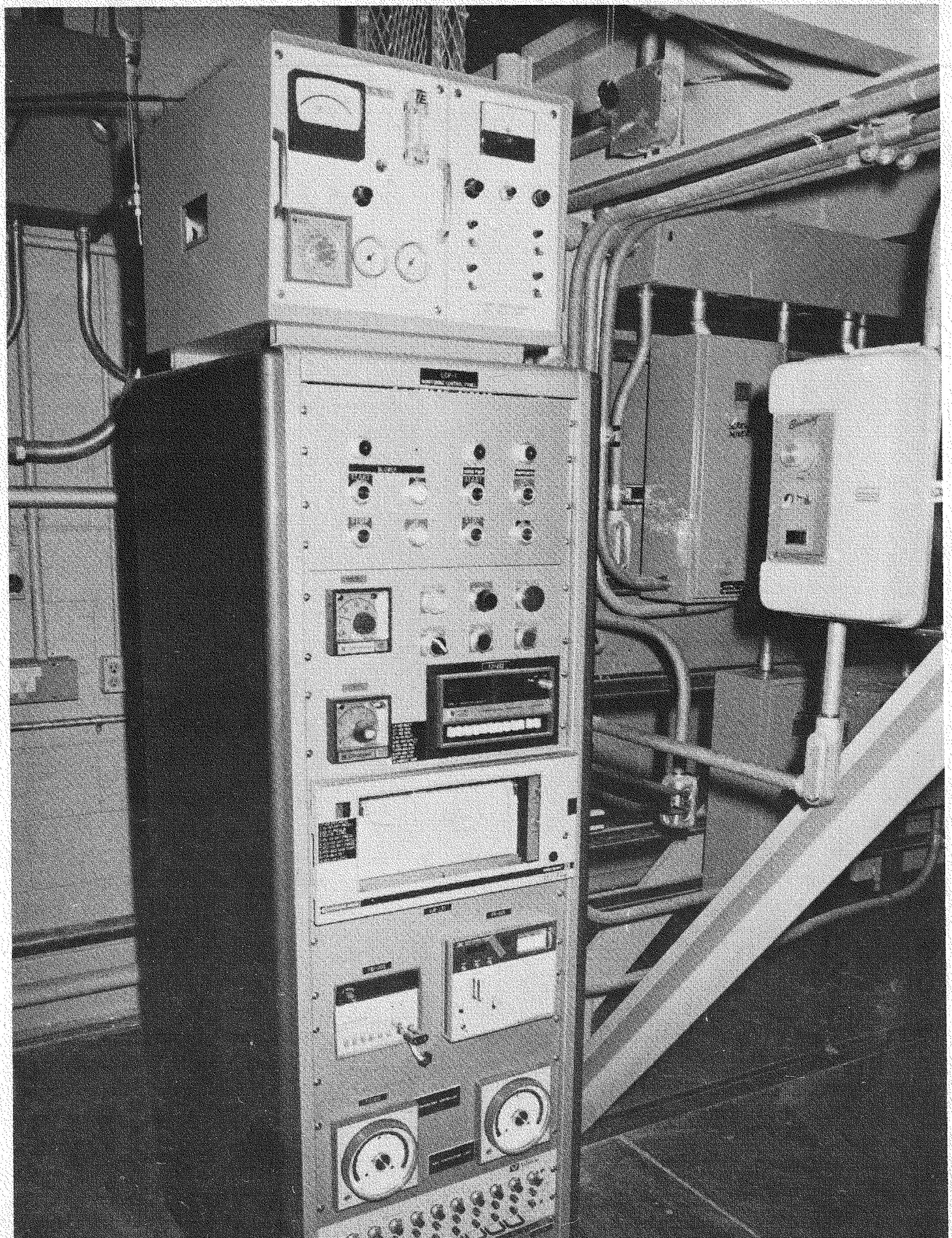

Figure 20. Photograph of Main Control Console

IV. PELLET PILOT PLANT OPERATION

Since the pellet pilot plant is experimental, operating procedures will vary slightly and may change if alterations are made to the system. Therefore, only a very brief operating procedure will be given here for the system as described.

1. Pilot Plant Startup

Following is a list of startup procedures for the pilot plant. In addition, all pertinent equipment operating manuals must be consulted.

1) Start off-gas superheater and blower.
2) Start off-gas scrub pump.
3) Turn on heat treater.
4) Fill solid feed hoppers and liquid binder tank.
5) Turn the flop gate in the pelletizer chute to bypass.
6) Turn on microwave generator and bring to "Ready". (Do not turn on magnetron at this point).
7) Start pelletizer.
8) Start screw mixer-feeder and liquid binder pump.
9) When acceptable pellets are formed, turn flop gate to screen and start screen.
10) Turn on magnetron and increase power slowly as pellets begin to enter dryer.

Although deviations from this startup procedure are possible, depending upon the particular experiment in progress, there are several items that are mandatory.

1) Off-gas blower must always be on when operating the pilot plant.
2) Never operate the microwave unit if the dryer is empty.
3) Open the heat treater kiln door only when the kiln is cooled.

2. Pilot Plant Shutdown

Listed below is the shutdown procedure.

1) Turn solid feeders off.
2) When screw mixer-feeder empties, turn it and liquid binder feed pump off.
3) Turn flop gate to bypass.
4) Turn off pelletizer.
5) Turn off microwave power.
6) Turn off vibro-screen.
7) Turn off heat treater.
8) Turn off scrub pump.
9) Turn off blower and superheater.

Major deviations from these procedures should be outlined in the report accompanying that experimental run.

V. SAFETY CONSIDERATIONS

Most of the safety considerations for the pellet pilot plant have been discussed previously, but they will be summarized here. In addition to those items listed, all safety procedures in equipment manuals are to be followed.

The entire pilot plant module is a safety glass area during all operation, testing or maintenance. All areas below open grating are hard hat areas and are marked as such. Appropriate clothing is to be worn when mixing acids for liquid binders.

The microwave generator, waveguide, and applicator are to be checked for leakage on a daily basis by operating personnel, and by safety personnel at specified intervals. Appropriate warnings are posted at all entrances to the building.

NO_x levels are monitored continuously to be certain that the maximum of 3 ppm is not exceeded. The NO_x annalyzer must be calibrated periodically to maintain proper operation.

An experimental facility safety and hazards checklist is to be posted and updated to reflect any specific conditions of operation.

VI. REFERENCES

1. Energy Reseach and Development Administration, Alternatives for Long-Term Management of Defense High-Level Radioactive Waste, Idaho Chemical Processing Plant, Idaho Falls, Idaho, ERDA 77-43 (September 1977).

2. K. M. Lamb and H. S. Cole, Development of a Pelleted Waste Form for High-level ICPP Zirconia Wastes, ICP-1185 (April 1979).

3. D. L. Plung, ed., Technical Quarterly Progress Report, July - September 1979, ENICO-1033 (March 1980).

4. S. J. Priebe, T. C. Piper, and J. R. Berreth, Application of Microwave Energy to Post-Calcination Treatment of High-Level Nuclear Wastes, ICP-1183 (February, 1979).

APPENDIX A - LIST OF PELLET PILOT PLANT DRAWINGS

Kaiser Engineers Drawings - on File at ICPP

137534	Index Sheet
137535-1S	Platform Framing Plans and Details
137536-2S	Equipment Supports
137537-3S	Structural Steel Notes and Misc. Details
137538-4S	Grating Details
137539-5S	Handrail Details
137540-6S	Stair Details
137541-7S	Ladder Details
137542-1M	General Arrangement Plans and Section
137543-2M	General Arrangement Sections and Details
137544-3M	Details
137545-1P	P & ID
137546-2P	Piping Plans
137547-3P	Piping Sections
137548-4P	Piping Details
137549-5P	Piping and Instrument Legend
137551-7P	Air and Water Tie-in Connections
137552-8P	Scrub Solution Drain & Water Return Tie-in Connections
137553-9P	Off-Gas System - Quench Tower, VES-100
137554-10P	Off-Gas System-Venturi Scrubber, VES-101
137555-11P	Off-Gas System - Demister, VES-102
137556-12P	Off-Gas System - Scrub Tank, VES-103
137557-13P	Off-Gas System - Scrub Cooler, HE-300
137558-1E	One-Line and Elementary Drawings
137559-2E	Lighting and Power Layout
137560-1T	Control Panel Layout
13761-2T	Control Panel Engraving

ENICO Company Drawings

056211	Calcine Pellet Rotating Tray Heat Treater Assembly & Details
056212	Calcine Pellet Rotating Tray Heat Treater Details
056219-R2	Calcine Pellet Rotating Tray Heat Treater Kiln Assembly
056311	Calcine Pellet Rotating Tray Heat Treater Kiln Support Assembly

EG&G Idaho, Inc. Drawings

210145	Calcine Pelletizing Pilot Plant Off-Gas System Scrub Tank, VES-103
210146	Calcine Pelletizing Pilot Plant Off-Gas System Demister, VES-102
210147	Calcine Pelletizing Pilot Plant Off-Gas System Venturi Scrubber, VES-101
210183	Calcine Pelletizing Pilot Plant Off-Gas System Scrub Cooler, HE-300
210185	Calcine Pelletizing Pilot Plant Off-Gas System Quench Tower, VES-100
410060	CPP Pellet Drying Microwave Applicator Fan
410061	CPP Pellet Drying Microwave Applicator Base
410062	CPP Pellet Drying Microwave Applicator Single Spring Clip Assembly
410063	CPP Pellet Drying Microwave Applicator Spring Clip Assembly
410064	CPP Pellet Drying Microwave Applicator Oven Assembly
410065	CPP Pellet Drying Microwave Applicator Assembly
410077	CPP Pellet Drying Microwave Applicator Pellet Funnel

J. T. Thorpe, Inc. Drawings

10605-A-1	Pellet Heat Treater Kiln
10605-R-1	Refractory Details - Pellet Heat Treater Kiln
10605-R-2	Refractory Details - Pellet Heat Treator Kiln
10605-C-1	Element Details - Pellet Heat Treater Kiln
10605-C-2	Electrical Diagram
10605-C-3	Control Cabinet Layout

J. T. Thorpe, Inc. Drawings (Cont'd.)

10605-C-4 Control Panel Layout
10605-S-1 Shell Steel Details - Pellet Heat Treater Kiln
10605-S-2 Door Steel Details - Pellet Heat Treater Kiln
10605-S-3 Steel Details - Pellet Heat Treater Kiln
10605-S-4 Shell Steel Details - Pellet Heat Treater Kiln