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SECRET EB-196A

FILE DESTRUCTION,
AIR FED INCIN. MOD I

SECRET

SUMMARY REPORT

ON

TASK ORDER NO. Z

May 1, 1960

[redacted] 50X1

August 23, 1960

Dear Sir:

Enclosed is the "Summary Report on Task Order No. Z", which describes the research performed under this Task Order from May 1, 1958, through May 1, 1960. Other closely related research on Task Order No. KK, Work Order No. II, is also discussed in this report.

The report describes the experimental work done during the development of two prototype incinerators which achieved burning rates of up to 500 pounds of paper per hour. An experimental version of a manually operated, paper-feeding mechanism for incinerators of this type is also described.

We believe that the results of this development may also have commercial possibilities in selected areas of application. Therefore, we are hopeful that we shall have an opportunity to pursue this at a later date.

It has been a pleasure to work with you and your associates on this challenging development. We would appreciate any comments that you might care to make with regard to the research.

50X1

Sincerely,

[redacted]

[redacted]

In Triplicate

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SUMMARY REPORT

ON

TASK ORDER NO. Z

May 1, 1960

INTRODUCTION

A need existed for an improved method of destroying security-classified papers and documents under normal conditions of daily or periodic disposal, as well as under emergency conditions when the paper contents of many safes or filing cabinets would have to be destroyed quickly and conveniently. The quality of papers involved would represent a wide variety, generally ranging from onionskin types through relatively thick paper used as report covers, photographic types, and perhaps even more-difficult-to burn types. The degree of destruction of interest would be such that the original writing or typing could not be deciphered using any known technique. Further, a minimum of smoke, flames, heat, and the like would be tolerable during destruction; the destruction process should be relatively inconspicuous from the viewpoint of outsiders.

The amount of paper which might have to be destroyed on any one occasion probably would range from a few hundred pounds to 20 tons. The equipment involved should generally be as small as possible. It could be expected that water from the normal system would be available for use, but that

Note: Data upon which this report is based may be found in Laboratory Record Books No. 14186, pp 37 to 100; No. 15113, pp 1 to 100; No. 15615, pp 1 to 100; No. 15787, pp 1 to 100; and No. 16489, pp 1 to 5.

auxiliary fuel and electricity, if needed, would probably have to be provided. Also, the safes or filing cabinets could not be used as the containers for the destruction process.

In a previous summary feasibility study(1)* under Task Order No. I, Task Order No. III, several "mechanical" means were examined for potential application in the destruction of paper. In that effort, limited experimental work demonstrated that high burning rates could be obtained by directing relatively high velocity jets of air against the burning surface of a pile of paper. This jet action appeared to provide the most promising approach to the development of an experimental incinerator which would have relatively high sustained rates of burning.

Thus, the initial objective of Task Order No. I was to develop a full-scale experimental paper-burning incinerator employing the cyclone-jet principle of burning. Maximum burning rates of 900 lb per hr under emergency conditions, no auxiliary fuel, virtually complete destruction, low emission of smoke, odor, and fly ash, and simple, reliable, and safe operation were the specific requirements which the effort was directed toward satisfying. Subsequently, phases of the research were aimed toward the development of two lightweight prototype incinerators having emergency capacities up to 500 lb per hr (Model 1), and of an experimental feeding device for charging paper into the Model 1 incinerator. Additional effort was then performed on the preparation of working drawings for use in the commercial fabrication of the first group of Model 1 incinerators.

This report summarizes the above-outlined research which was conducted under Task Order No. I during the period from May 1, 1958, through May 1, 1960.

*Superscript numbers in parentheses refer to items listed in the "References".

For purposes of continuity, the closely related research performed under Task Order No. KK, Work Order No. II, is also described in this report.

SUMMARY

Initial research with a full-scale refractory-lined experimental incinerator showed that the cyclone-jet principle of burning was capable of achieving rapid destruction of paper at rates up to the goal of 500 lb per hr without the use of auxiliary fuel. Acceptably low emissions of smoke, odor, and flames were also achieved. The emission of fly ash was excessive for some locations of use, but probably could be tolerated in other areas. No legible paper or residue escaped with the stack gases in the later stages of development of this experimental unit. Manual feeding was used in loading the paper in the combustion chamber. The experimental unit, with all of its air ducts, was bulky and also heavy.

In view of the need for minimal size and weight consistent with rapid rates of burning, the concept of air-film cooling of a sheet-metal liner for the combustion chamber, as previously developed in the laboratory for high-rate combustion of pulverized coal, was then applied in the development of a prototype incinerator. With design criteria from the experimental refractory-lined unit at hand, the first prototype was constructed without the use of a refractory lining and of a size and configuration which were more practical.

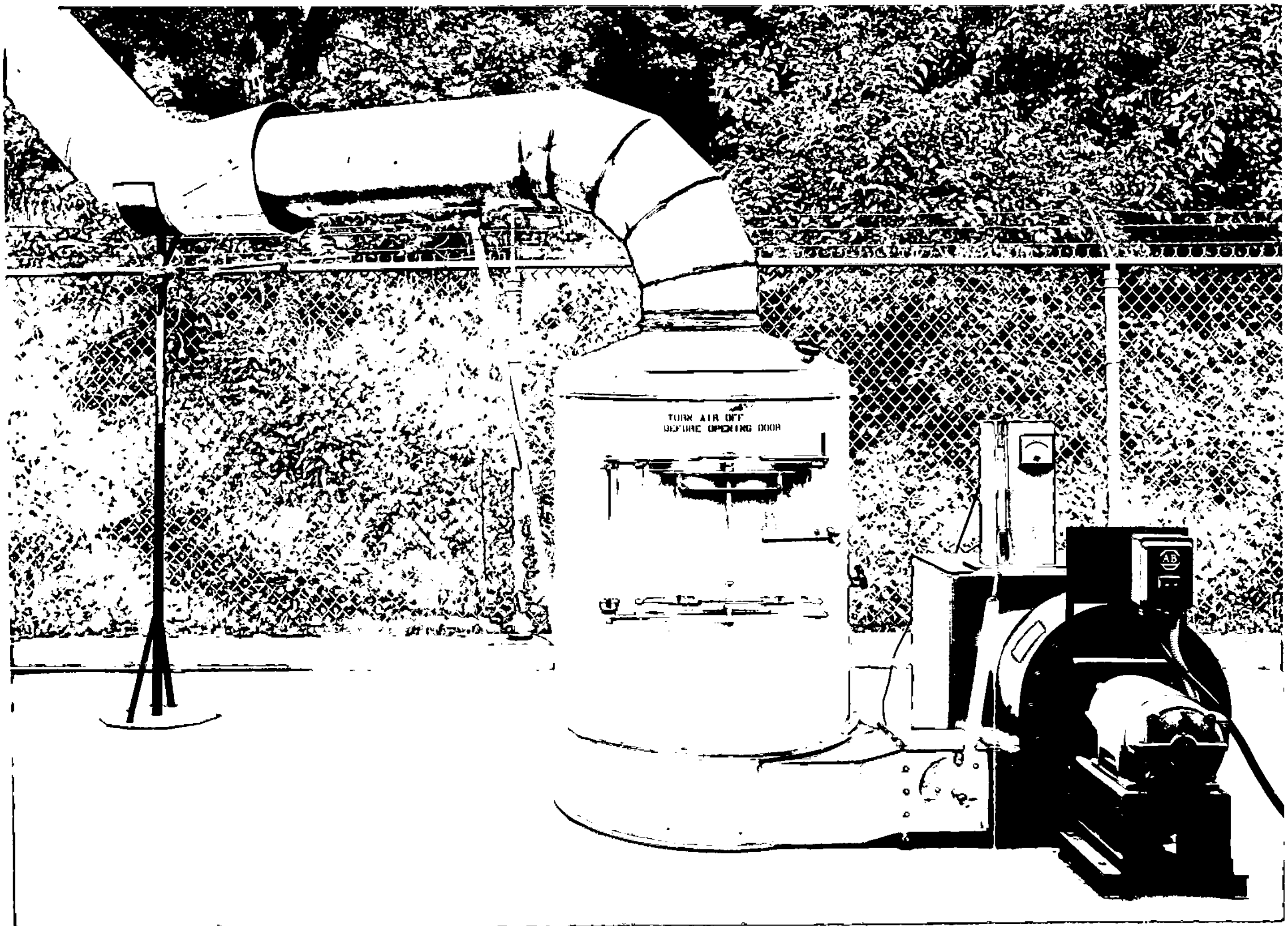
Evaluation of the prototype on burning a variety of papers demonstrated the feasibility of air-film cooling in this application and the ability of this design to achieve almost as high a burning rate as the

larger refractory-lined experimental unit. Other performance factors were also satisfactory, with the possible exception of fly-ash emission. A quick-opening loading door was provided on the prototype; this made loading more convenient, but required that the air flow be interrupted while the feeding was performed manually.

Figure 1 shows the first prototype incinerator and a tabulation of the pertinent features. The major requirements of the Sponsor have generally been satisfied in this unit, as indicated by reactions to demonstrations of the unit and by subsequent field trials by the Sponsor.

A second prototype unit, with a slightly modified design to permit all of the disassembled parts to fit through a standard 33-in.-wide doorway, was also built and evaluated. Its performance compared favorably with that of the first prototype unit. In addition, operation in a relatively small room typical of office space, with either the electric-motor-driven blower or an auxiliary gasoline-engine-driven blower, was shown to be feasible, but perhaps not ideal, because of noise and heat in the room.

A relatively simple fly-ash collector intended for partial removal of particles in the flue gas was designed, constructed, and evaluated on the second prototype. This fly-ash "skimmer" removed about 30 per cent of the fly ash and a larger percentage of the visible, but illegible, pieces of charred paper, to give a noticeable decrease in fly-ash fall in the area immediately adjacent to the incinerator. Further consideration of the use of such a simple unit or of more efficient conventional cyclone dust collectors is likely to be needed for some geographical locations of intended operation.



(1)	Burning rate	200 to 500 lb per hr
(2)	Height of unit (excluding flue pipe)	[illegible] in.
(3)	Maximum diameter of unit	[illegible] in.
(4)	Weight of unit and blower (excluding flue pipe)	1,100 lb
(5)	Diameter of flue pipe	16 in.
(6)	Inside diameter of combustion chamber	36 in.
(7)	Feed opening in combustion chamber	[illegible] by [illegible] in.
(8)	Supply of combustion air	2,400 std cfm
(9)	Blower power	7-1/2 hp, 220 v, 60 cycle, 3 phase
(10)	Has quick-opening feed door	
(11)	No auxiliary fuel required	
(12)	Has air-pressure gage and flue-gas temperature gauge.	

Figure 1. First Prototype Paper-Burning Incinerator (Model 1)

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An experimental feeding mechanism was developed that facilitates the feeding of paper into the incinerator. The unit represents a feasible design in that it is capable of permitting unskilled personnel to feed papers and documents into an incinerator such as the Model 1 conveniently and without personal discomfort. Operation of the experimental feeding mechanism did not disturb the combustion process significantly.

CYCLONE-JET PRINCIPLE OF RAPID INCINERATION

When stacks of paper in a condition of close packing are burned in a conventional incinerator with natural draft, combustion is slow since it is limited to the outside surface of the mass that eventually becomes coated with a protective layer of ash. Manual poking or mechanical devices can be employed to agitate the mass of paper, thereby dislodging the ash and exposing fresh surfaces. However, appropriate mechanical devices are relatively expensive to build and to maintain in the hot zone when they are applied to units smaller than municipal incinerators.

From the above considerations, it was apparent, during the feasibility study(1) under Task Order No. R, Work Order No. III, that an unconventional approach would probably be needed to develop an incinerator for the rapid destruction of security-classified papers and documents. A British development known as down-jet combustion(2,3) was considered in an effort to attain higher burning rates. This method had been developed for high-rate burning of coke. The physical force of high-velocity air jets impinging on a mass of uncrumpled paper was expected to sweep away the residue and expose fresh combustible material. As a result of some of the air jets being directed tangentially into a cylindrical combustion chamber, as in other combustion technology[4,5] the resulting vortex or cyclone motion of the hot gases was expected to force the dislodged pieces of char and unburned paper to the outer walls; in this location, additional residence time and turbulence in the hot swirling gases would promote rapid and effective combustion.

Limited trials of the cyclone-jet principle during the previous feasibility study[1] were found to be encouraging. Therefore, a program of research was started on May 1, 1958, to develop a full-scale, refractory-lined experimental incinerator based on the cyclone-jet principle. The goals for this research were as follows:

(1) To achieve high burning rates of up to a maximum of about 500 lb per hour of paper.

(2) To achieve a turndown ratio* ranging from 5 to 1 to 2 to 1 and thus provide for reduced burning rates.

(3) To effect collection of fly ash and elimination of fumes such that, at a burning rate of about 200 lb per hr, the emission of fly ash, smoke, or odor would be low. Under emergency conditions at the maximum burning rate, stack emissions in excess of these low levels would be permitted.

(4) To achieve, under all intended conditions of use, simplicity and reliability of operation, without presenting a safety hazard to personnel and the surroundings.

*Maximum feasible rate of operation divided by minimum feasible rate of operation.

(5) To operate without the need for auxiliary fuel such as gas or oil, other than for initial ignition of the charge with a match.

(6) To achieve destruction of the paper to a degree that the original writing or typing could not be deciphered.

Initial Refractory-Lined Experimental Incinerator

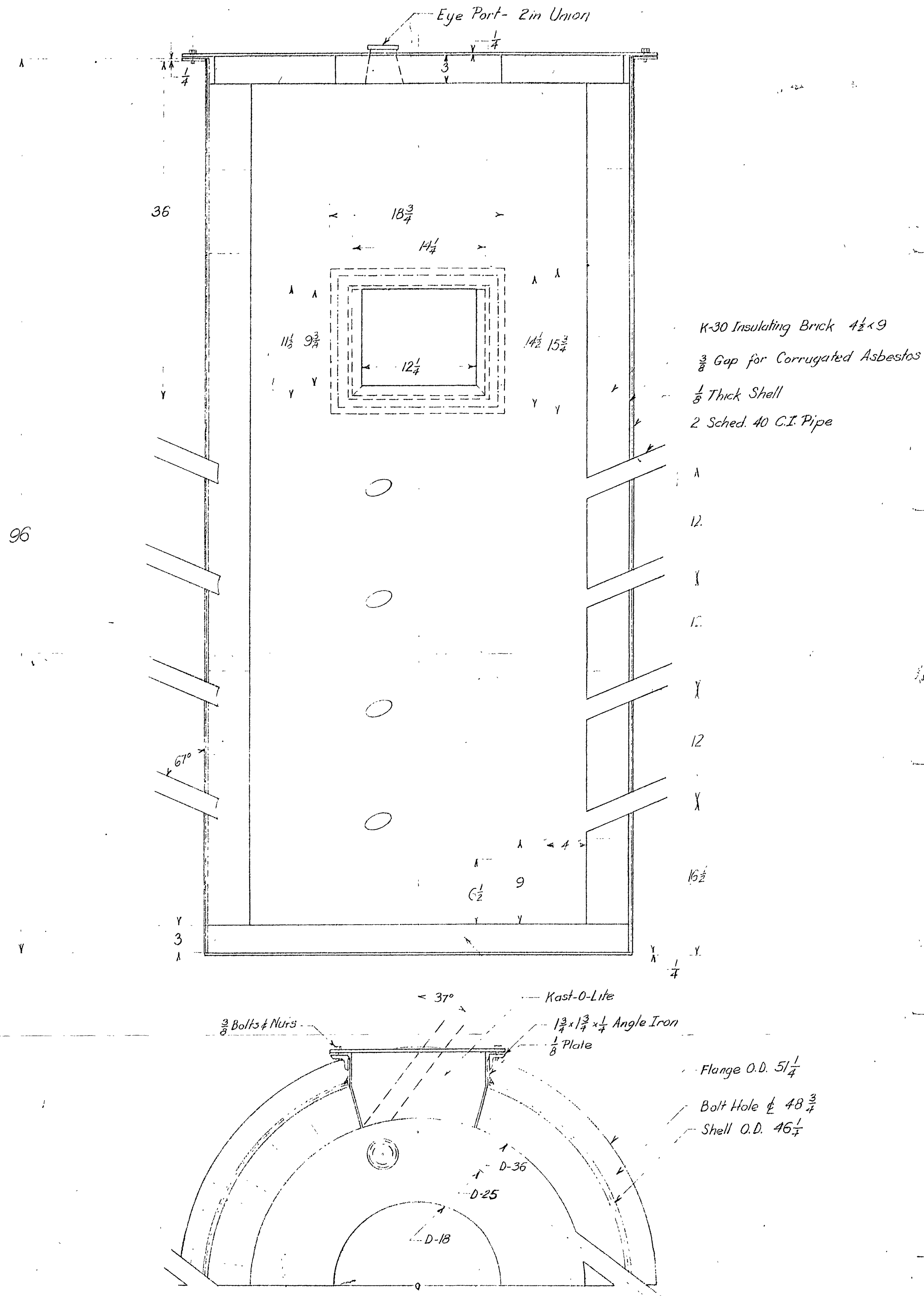
Description of Unit and Test Facilities

The initial refractory-lined incinerator was designed strictly for experimental purposes, so as to provide for flexibility of operation and ease of modification in the investigation of the pertinent variables. The general design configuration selected was a hollow vertical cylinder with internal dimensions sufficient to provide space for 500 lb of various kinds of paper when dumped into the unit in packed form, and with volume, above the pile, sufficient for gas-phase combustion.

Figure 2 shows a cross-sectional view of the refractory-lined experimental unit. The over-all height of the vessel was 96 in. and the outside diameter was about 46 in. Readily available high-temperature insulating bricks were used to line the cylinder and castable refractory was used as a lining for the upper and lower ends. A total of 16 nozzles were provided for the introduction of combustion air at four elevations approximately 1, 2, 3, and 4 ft above the bottom of the chamber. Each nozzle was a piece of standard 2-in. pipe 12 in. long that could be fitted later with smaller inserts in order to increase the air-jet velocity. The four nozzles at the

FIG. 2. CROSS-SECTIONAL VIEW OF INCINERATOR

SCALE 8" = 1'



upper level supplied secondary air for gas-phase combustion in the space above the burning paper. Primary air was supplied by the three lower levels of nozzles, first from the ports at the 3-ft level, then from those at the 2-ft level, and finally from those at the 1-ft level, as burning progressed downward through the charge of paper. All of the nozzles were pointed about 23 degrees downward from the horizontal so that the air jets would impinge on the burning surface. Also, they were pointed slightly inward from the refractory wall (tangent to a circle 25 in. in diameter) to increase the turbulence and yet preserve the cyclone action.

Figure 3 is a photograph of the initial experimental incinerator and the auxiliary test equipment. The blower and motor unit (not shown, but located in a position to the left of the panel board included in Figure 3) supplied air through two 6-in.-diameter manifolds which were equipped with orifice meters and dampers. The upper manifold supplied the four secondary-air nozzles and the other 12 nozzles were ducted to the lower or primary-air manifold. Valves at each nozzle entrance were used for on and off control of the air jets. The photograph used as Figure 3 was taken after two of the original nozzles at the lower level were experimentally replaced with two radially directed nozzles as described later in the report. Four sight ports installed in one vertical row of nozzles, and two sight ports in the top of the unit permitted visual observation within the combustion chamber.

The first 4 ft of the 16-in.-diameter stack was wrapped with a spiral of water-cooled copper tubing to minimize difficulties from overheating of the metal stack during experimental operations. The stack extended outside of the building, where observations were made for fly ash, smoke, and flame. Other test equipment shown on the panel board in Figure 3 included (1) a

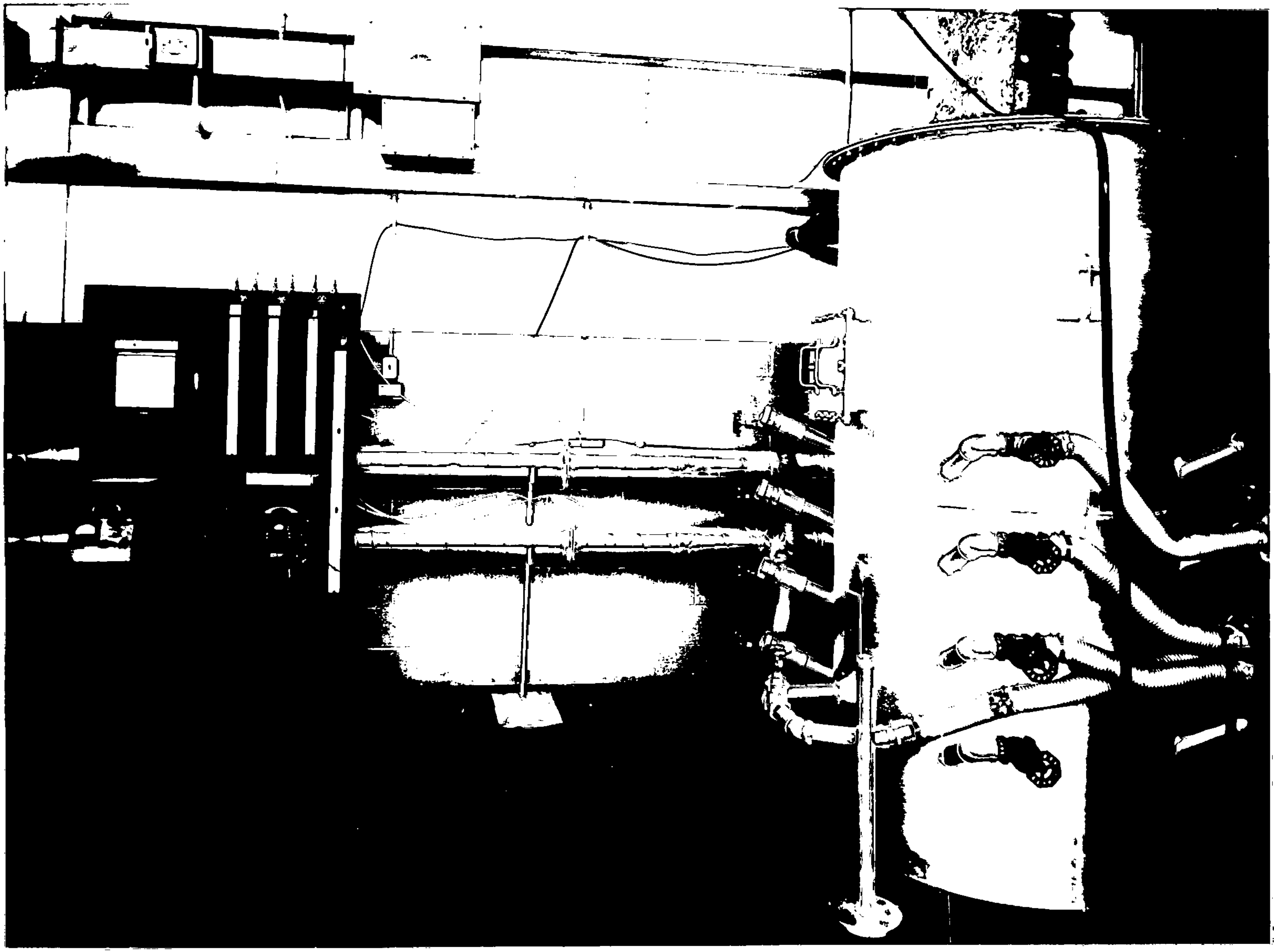


Figure 3. Experimental Refractory-Lined Incinerator

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recorder for stack-gas temperature, (2) manometers for static-pressure measurements in the combustion chamber and orifice meters, and (3) a recording thermal-conductivity instrument for the measurement of carbon dioxide in the stack gas. Instantaneous burning rates were calculated from measurements of the total air flow and of the carbon dioxide content of the stack gas. Average rates of burning were determined from the total weight of paper charged and the total time of the test period.

A large supply of obsolete telephone directories was obtained to serve as a uniform type of combustible material which was generally similar to file paper. In order to simulate the condition of the paper which would have to be destroyed in an actual situation, the phone books were torn into several (5 to 7) sections along the bound edge, and thus provided both loose-leaf and bound, close-packed paper.

Results of Single-Batch Tests

During each of the first six test runs, the experimental refractory-lined incinerator was loaded with a single charge of up to 500 lb of paper, and about 6,500 lb per hr or 1,400 cfm of air was supplied at jet velocities of from 100 to 130 fps. Average burning rates of up to 400 lb per hr were obtained, and the possibility of higher rates was in evidence. Because of the comparatively loose packing of paper in the unit, a 500-lb charge occupied more space in the combustion chamber than had been estimated originally; it filled the chamber to a level above the upper (secondary) air nozzles. This condition altered the intended pattern of jet impingement on the upper surface of the charge during the early part of each test run and contributed to a decrease in the average rate of burning. In addition, the paper around the periphery of the charge burned faster than that at the center; thus, a conical stack of paper was left unburned at the center of the chamber. This suggested that higher jet velocities might improve the burning rate through increased air penetration and turbulence above the charge.

In view of the large amount of space required for the initial 500-lb charge of paper and the anticipated requirements of several hours per day of operation, it was mutually agreed that the effort be directed toward a study of the feasibility of changing from single-batch operation to intermittent feeding of smaller batches of paper at suitable intervals of time.

Results of Intermittent-Feeding Tests

A horizontal chute was provided as a simple means for pushing the paper into the combustion chamber for intermittent feeding. The initial charge of paper was decreased to 200 lb, which ignited readily and thus provided a relatively large increase in the initial burning rate. In the course of subsequent feedings of 100-lb increments, the flow of combustion air was reduced to a minimum for about 3 min while the loading door was removed, the paper was charged, and the door was replaced. During this short period, the burning was intense, but neither flames nor fly ash were emitted through the open door; however, pieces of charred paper were observed in the stack effluent. Also, black smoke and flames were emitted for about 1 min after the flow of combustion air was returned to normal. In the preliminary tests with intermittent feeding, burning rates of about 300 lb per hr were obtained. Thus, this method of operation was shown to be feasible, especially if a simple, quick-opening door was provided.

Design Modifications and Test Results

In an attempt to minimize the occurrence of the previously described conical stack of unburned paper at the center of the combustion chamber, the use of radially directed air jets was investigated. The use of two jets located 15 to 20 in. above the bottom of the chamber (Figure 3) improved burning at the center of the charge. However, as a result, there were two stacks of slowly burning paper at the periphery of the charge because the radial jets disrupted the swirling or cyclone motion at the bottom of the chamber.

In the next phase of the experimental work, the diameter of the air nozzles was decreased progressively from 2.07 in. to 1.61 in. and then to 1.25 in., to permit a study of operating characteristics at increased air-jet velocities of about 110, 190, and 300 fps, respectively. The burning rates obtained at these jet velocities were 300 to 400 lb per hr, up to 580 lb per hr, and up to 600 lb per hr, respectively. At jet velocities of 190 and 300 fps, the burning was fairly uniform from the center to the periphery of the bed, and the central, conical stacks of unburned paper that had persisted in previous tests at 110 fps were less evident. Agitation of the upper part of the bed increased at the higher jet velocities, and, at the velocity of 300 fps, appeared to be excessive, with respect to possible carry over of burning paper and char.

From these test results and observations, it was concluded tentatively that the optimum air-jet velocity for this experimental incinerator with a 36-in.-diameter combustion chamber was about 190 fps. Higher velocities gave only slightly higher burning rates and would require increased blower power.

It was also found that, under the procedure of intermittent feeding, the upper two levels of primary-air nozzles (eight nozzles) could be left on simultaneously, and the lower level of four primary-air nozzles turned on only during the final burnout of the charge. With twice the number of primary-air nozzles in operation (i.e., eight nozzles rather than four) and with the nozzle diameter decreased to 1.25 in., the jet velocity was maintained at about 190 fps.

The escape of unburned paper and legible char from the stack was only slight at low average burning rates of about 125 lb per hr, but such carryover was excessive at the higher rates. During the intermittent-batch-feeding periods, excessive emission of large pieces of char occurred, and, during turn up of the air after intermittent-batch feeding was concluded, dark smoke, flames, and sheets of burning paper were emitted. Observation of the burning bed under these conditions revealed that loose sheets of burning paper and char escaped from the combustion chamber by following a path up the central core of the chamber where the tangential air velocities were the lowest. This indicated that special provision, such as a central baffle, a grid, or wire mesh, would be needed to minimize the loss of legible material in this manner.

In order to assess the carryover problem more closely before investigating such control measures, a sampling device was prepared in the form of a conical-shaped basket of 15-mesh screen which could be held over the end of the stack for short periods. Subsequent sampling with this device showed that an excessive amount (from 16 to 153 pieces per min) of unburned material larger than 1/4 in. (in any one dimension) escaped from the stack at average burning rates of from 250 to 500 lb per hr. It was also found that shutting off the air jets completely prior to loading reduced the carryover from a total of about 3,500 pieces to about 600 pieces during the period of loading and return to normal air-flow rates. The most objectionable period of carryover usually corresponded to the last few minutes of a burning operation when whole sheets of paper escaped unburned.

A grid for limiting the size of the material escaping from the combustion chamber was then constructed and suspended in front of the stack exit. The grid consisted of a vertical cylinder of No. 3-1/2 mesh wire screen (0.092-in.-diameter wire and 0.194-in.-square openings) that was 10 in. in diameter and 15 in. in length. The bottom of the cylindrical grid was closed with 16-gage sheet metal so as to cause any volatile or smoky constituents in the region of the chamber axis to flow outward into the turbulent region where better combustion occurs. Both the wire screen and the bottom plate were Type 304 stainless steel.

Figure 4 shows a cross-sectional view of the modified unit, including the grid and the other changes. In all 10 of the subsequent test runs, the grid prevented the escape of fly ash and unburned paper in the legible size range above 3/16 inch. The grid did not become plugged while burning was in progress and satisfactorily withstood the gas temperatures which reached peaks up to 1800 F.

In line with the objective of developing as compact a unit as possible, the height of the unit was reduced by closing off the lower 18 in. of the burning chamber as shown in Figure 4. The original lowest level of air nozzles was closed off, thus leaving the other three levels for primary air. A new set of four horizontal nozzles (standard 2-in. pipe) was installed

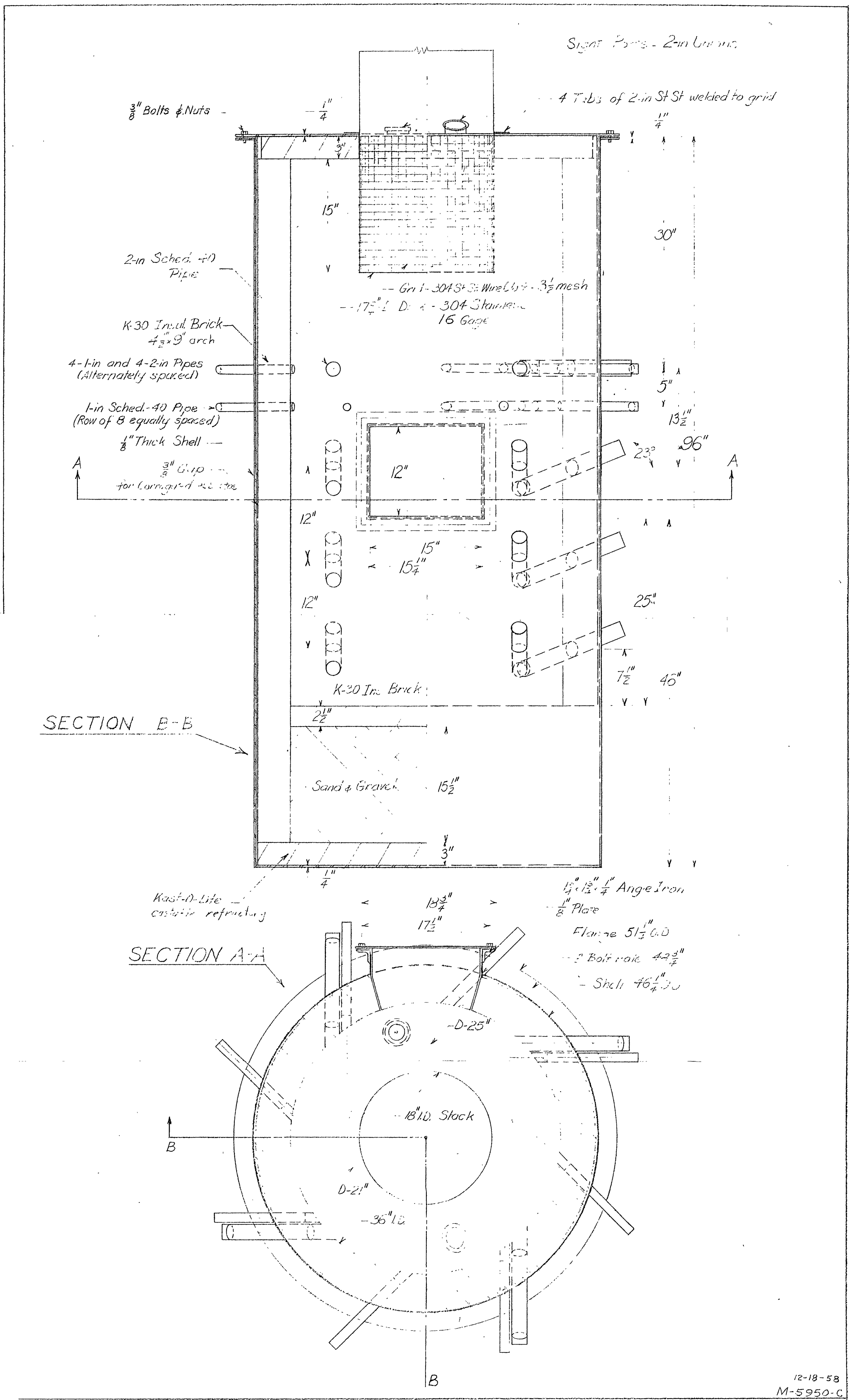

FIGURE 4. CROSS-SECTIONAL VIEW OF MODIFIED EXPERIMENTAL INCINERATOR

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to provide secondary air above the loading door, which was moved to a lower, more convenient position. Subsequent test runs yielded burning rates up to 500 lb per hr, which showed that the original volume provided for a large single batch was not needed for operation on an intermittent-batch-feeding basis.

In one test run, the four upper (secondary air) horizontal nozzles were pointed radially instead of tangent to a 25-in.-diameter circle as they had been previously. This new direction was selected in an attempt to obtain better penetration and mixing of air in the central region of the chamber that might result in an improvement in the gas-phase burning. The results showed a marked reduction in smoke emission which previously had occurred in bursts, up to 45 sec in duration, of dense black-brown smoke; also, the incidence of long flames shooting beyond the exit of the stack was less frequent. However, the radially directed secondary air destroyed the vortex or swirl over the bed and thereby reduced the burning rate by nearly 50 per cent. Further development was then aimed at obtaining better mixing of the combustible gases and secondary air through the use of increased flow of secondary air and additional secondary-air nozzles.

Figure 4 also shows the final arrangement of secondary-air nozzles used in the refractory-lined unit. Twelve additional horizontal nozzles (standard 1-in. pipe) at two levels were installed to direct secondary air tangent to a 21-in.-diameter circle. These nozzles, together with the four larger horizontal nozzles, provided for an increase in secondary-air flow up to about 75 per cent above that used in previous tests, and necessitated an increase in the total flow of air required by about 40 per cent, to a total of 2,000 cfm. Subsequent tests revealed that the emission of smoke was almost completely eliminated by this increase in secondary air. The frequency of occurrence and duration of flame emission were likewise reduced, but not to the degree desired at the maximum burning rates. However, at the lower burning rates of about 200 lb per hr, the smoke and flames were completely eliminated.

In an effort to reduce further the duration of the emission of flames to less than a total of 1 to 2 min per hour of operation, air was supplied to the central core of the burning chamber by means of an axial duct (3 in. in diameter) installed through the bottom of the incinerator. The purpose of this air was to eliminate any possible deficiency of oxygen at the center that might have caused delayed burning. Three tests were made with the unit so modified. (This modification is not shown on Figure 4.) The first test was run with one 1.5-in.-diameter jet of air directed upward from a level 28 in. above the bottom of the chamber. The second involved 36 jets, each 1/4 in. in diameter, directed radially outward and located along the axial duct up to a height of 15 in. above the bottom of the chamber. The third test was conducted with an increased air flow, obtained by enlarging some of the 36 jets to 3/8 and 1/2-in. in diameter. These three experimental modifications, however, did not produce a sufficient decrease in flame emission to warrant the inclusion of this type of central duct in any subsequent design, particularly since there would be attendant disadvantages such as interference during loading of the paper charge, and the like.

In all but two of the 34 test runs made in the refractory-lined experimental unit, obsolete telephone books were burned as a standard charge material. To check the effect of using other kinds of paper, two runs were made using a typical assortment of letters, folders, and small, bound reports which were obtained from outdated files. During these two test runs, as in some of the other later runs, the flow rate of primary air was regulated frequently in order to maintain high, but not excessive flue-gas temperatures of from 1000 to 1500 F; this was necessary in order to obtain maximum sustained burning rates during the periods between batch loadings. Average burning rates for typical file papers were 500 to 520 lb per hr, which compared favorably with the burning rates obtained using torn telephone books.

The total weight of the experimental refractory-lined unit was approximately 3,000 lb.

Conclusions

Development work with the full-scale experimental refractory-lined unit showed that the cyclone-jet principle of incineration was capable of providing rapid destruction of paper at rates up to the goal of 500 lb per hr without the use of auxiliary fuel. The emissions of smoke, fumes, odor, and flames were generally tolerable; however, in some geographical locations, the emission of fly ash would be unacceptable as all of the ash present in the paper was blown out the unit in the form of a light-gray haze. With a grid installed at the stack exit of the burning chamber, no legible material larger than 3/16 in. (in any one dimension) escaped from the unit.

The major disadvantages of the refractory-lined experimental unit were (1) that the thick, heavy refractory construction contributed appreciably to the space requirements and to the weight of the unit, and (2) that the method of feeding manually appeared to be inconvenient and perhaps inadequate. In view of the need for minimum size and weight, consistent with high rates of burning, a new design concept was evolved that would eliminate the need for refractory lining and minimize the space required for the distribution of the combustion air to the entry ports. Further work in this connection is described in the following.

DEVELOPMENT OF AN AIR-FILM-COOLED INCINERATOR

Air-film cooling for combustion-chamber liners has been used for several years in can-type combustion chambers for conventional jet engines(6) and in other gas-turbine combustors(7,8). This type of cooling is accomplished by blanketing the inside surface of the metal liner with incoming air, called film-cooling air, from many suitably placed louvers or small slots in the liner. The design usually embodies two concentric cylindrical vessels of sheet metal separated by an annular space which serves as a plenum chamber for the incoming combustion and film-cooling air.

Fully louvered, air-film-cooled combustion chambers had not been used previously for the combustion of solid fuel in a batch or fixed-bed process. However, this type of construction appeared to merit experimental investigation aimed at reducing the size and weight of the cyclone-jet paper incinerator. Work on the first prototype of the air-film-cooled incinerator was started in November, 1958, concurrent with the development of an experimental manually operated feeding mechanism for the intermittent charging of paper. This was followed by the construction of a second prototype unit starting in July, 1959, and the preparation of working drawings (for the first few production units) starting in December, 1959, as described in the following sections of this report.

The requirements to be satisfied by the prototype units were essentially the same as those outlined previously in this report for the first refractory-lined incinerator.

First Prototype Unit (Model 1, Type 1)

At the conclusion of the experimental work with the refractory-lined incinerator, most of the factors bearing on the design of a prototype unit had been determined, as follows:

(1) The burning chamber would be about 36 in. in diameter and 5-1/2 to 6 ft in height.

(2) Air-jet velocities of about 190 fps would be needed, and the number and placement of the primary- and secondary-air nozzles were known.

(3) The air-flow rate needed would be in excess of 2,000 cfm because of the need for additional air for film cooling of the liner in the prototype. Some of the cooling air would undoubtedly travel away from the liner and serve as combustion air; therefore, it was estimated that a total air flow of about 2,400 cfm would be needed for the prototype.

Design and Construction of Unit

After a period of detailed design of all the parts, the prototype unit was constructed. Figure 5 shows the prototype on the right and the

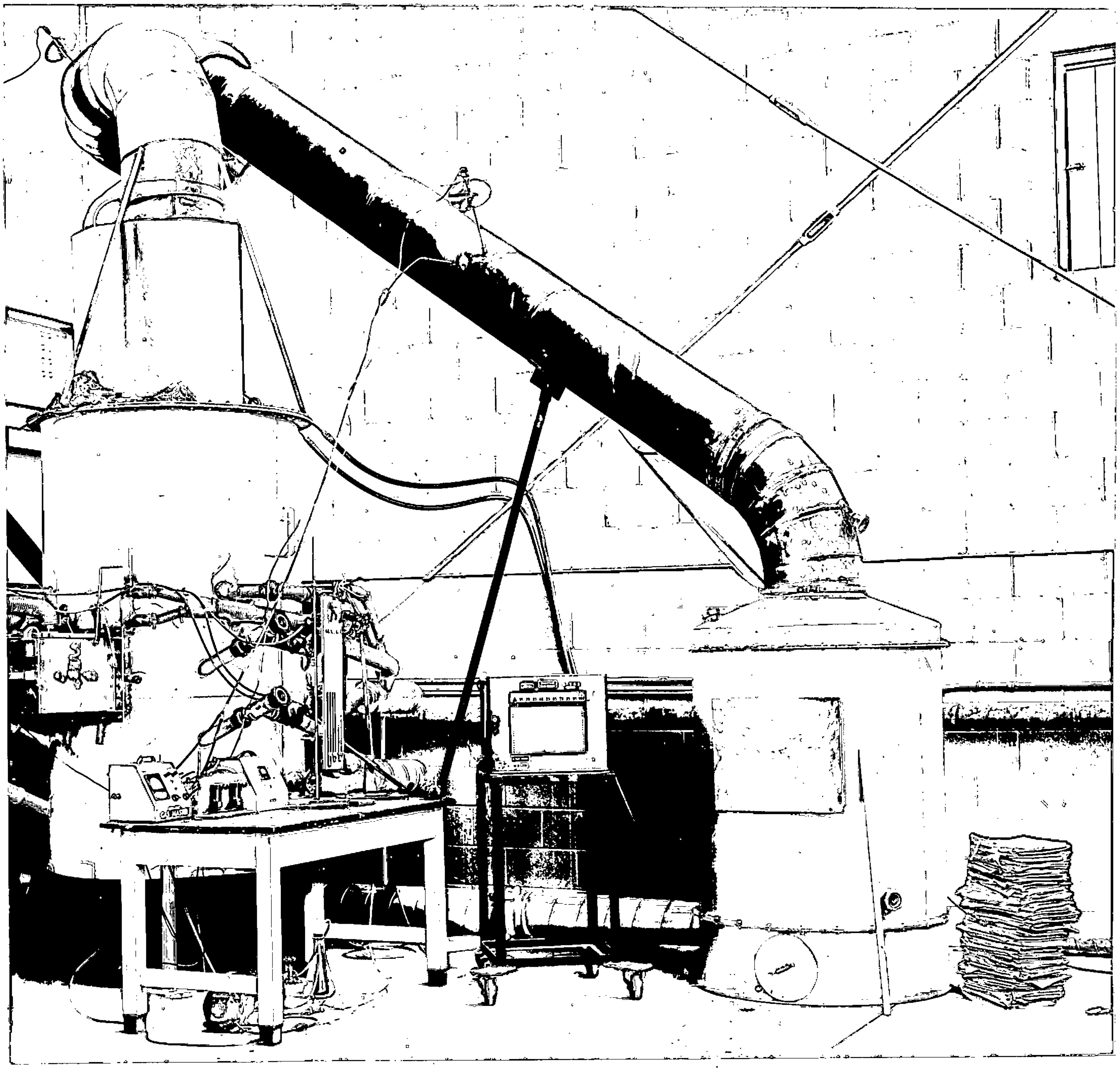

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Figure 5. Partially Completed Prototype Unit

larger experimental refractory-lined unit on the left; at this stage, the prototype had been completed to the extent that preliminary tests with an existing air supply had been in progress, to evaluate performance and to determine the changes, if any, which would be needed in the distribution of the combustion air.

The shell of the prototype had an outside diameter of 40 in. (42-in. outside diameter for the flanges) and a height of 64 in. to the base of the flue pipe; and was made of 16-gage mild steel. All of the components within the shell, including the combustion-chamber liner, the grid, and the thermal-radiation shield which was placed between the liner and the outside shell, were made from Type 304 stainless steel sheet metal.

Figures 6 through 15 show disassembled or partially assembled parts of the unit. In Figure 6, the upper part of the shell is removed so as to show the pleated radiation shield of 26-gage Type 304 stainless steel. In Figure 7, the radiation shield is removed so as to show the combustion chamber, i.e., the 16-gage Type 304 stainless steel, air-film-cooled liner, with the vertical rows of staggered louvers (1/32- x 1-in. gap) and nozzles for the entry of the combustion air. Figure 8 is another view of the liner with the bottom portion of the outer shell and the lower inspection door removed. The liner was a completely separate structure which was free to expand upward or outward without interference from or binding against other parts. The upper and lower conical sections of the liner, Figures 9 and 10, were made to be joined to the cylindrical section, Figure 11, by slip-fit flanges and cotter pins. Figure 9 also shows the grid (also Figure 12) attached to the upper conical section of the liner.

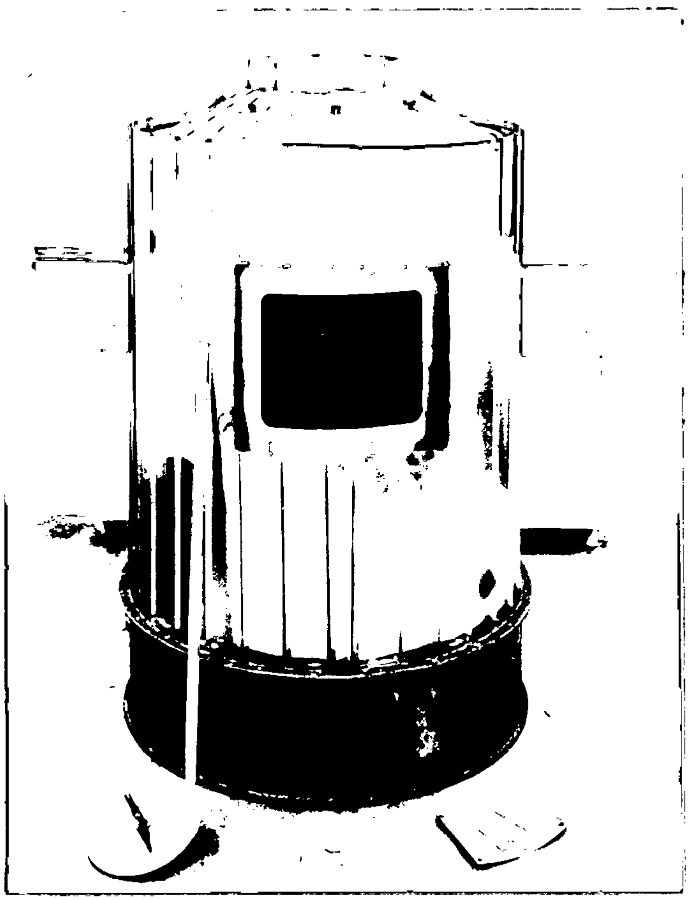

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Figure 6. Prototype Unit With Part of Shell Removed

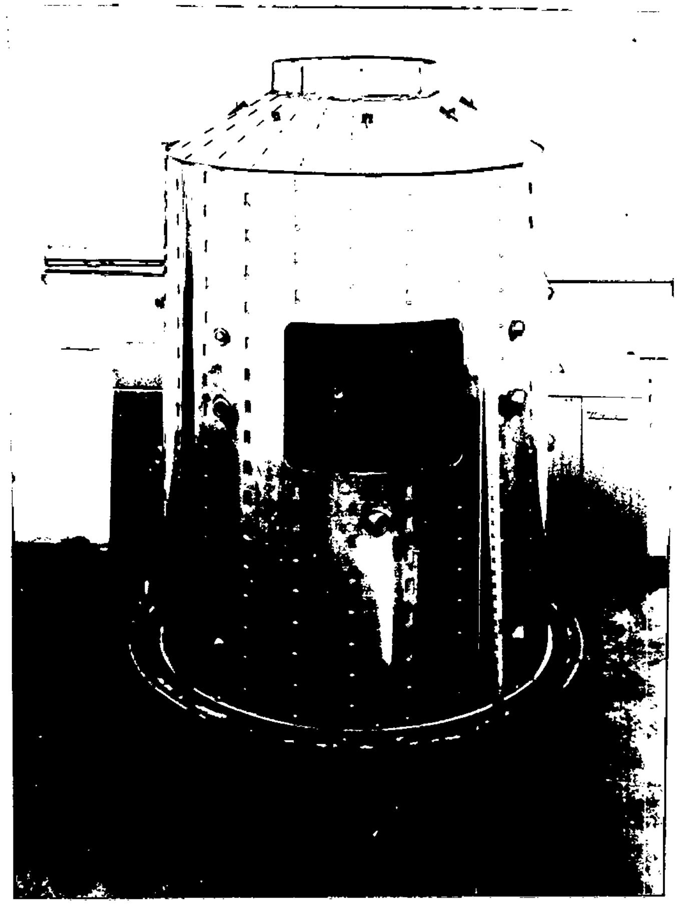

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Figure 7. Prototype Unit With Combustion-Chamber Liner Exposed

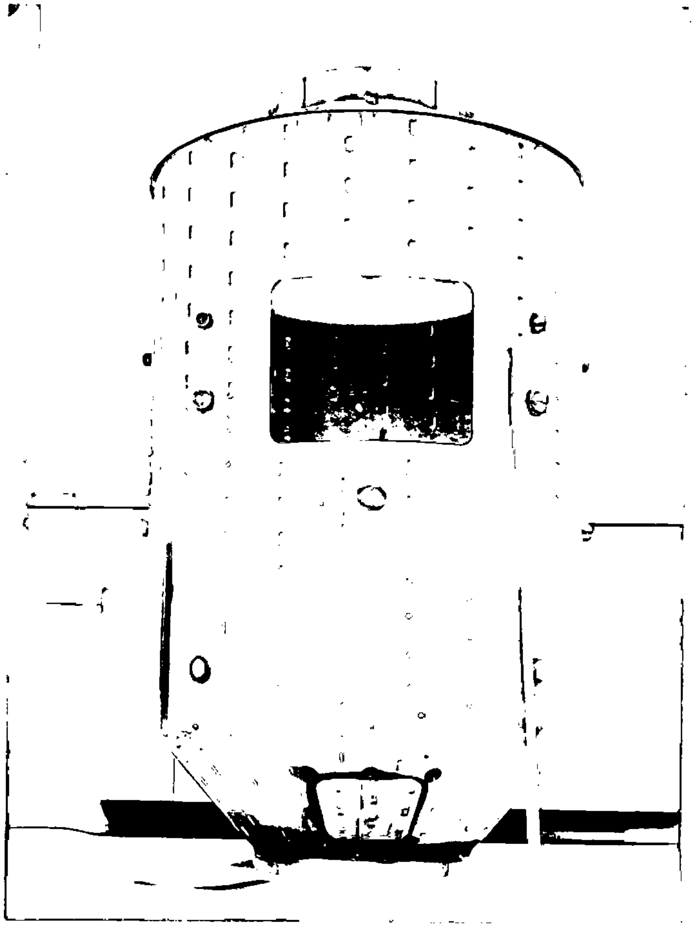

Figure 8. Combustion-Chamber Liner

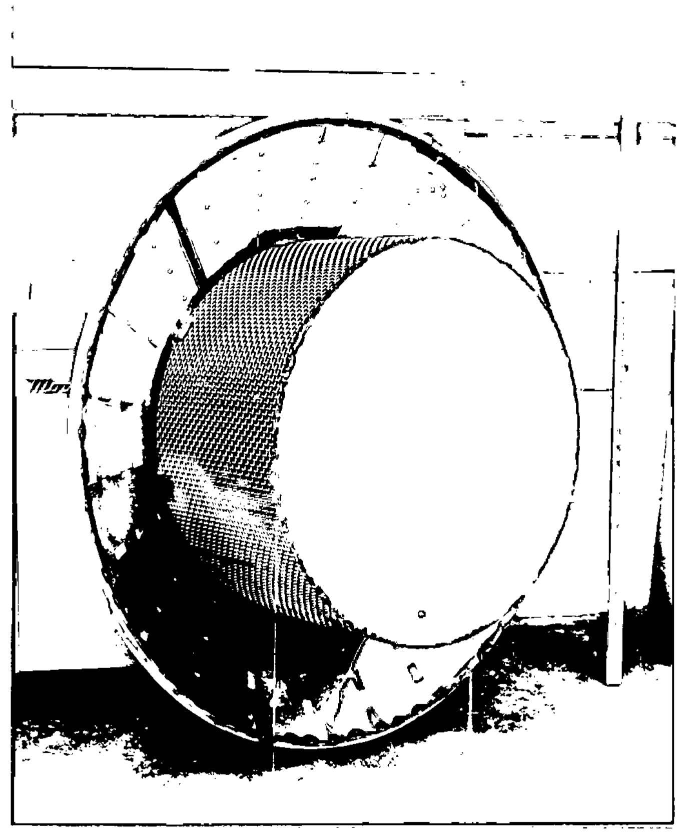

Figure 9. Upper Cone of Liner, With Grill Attached

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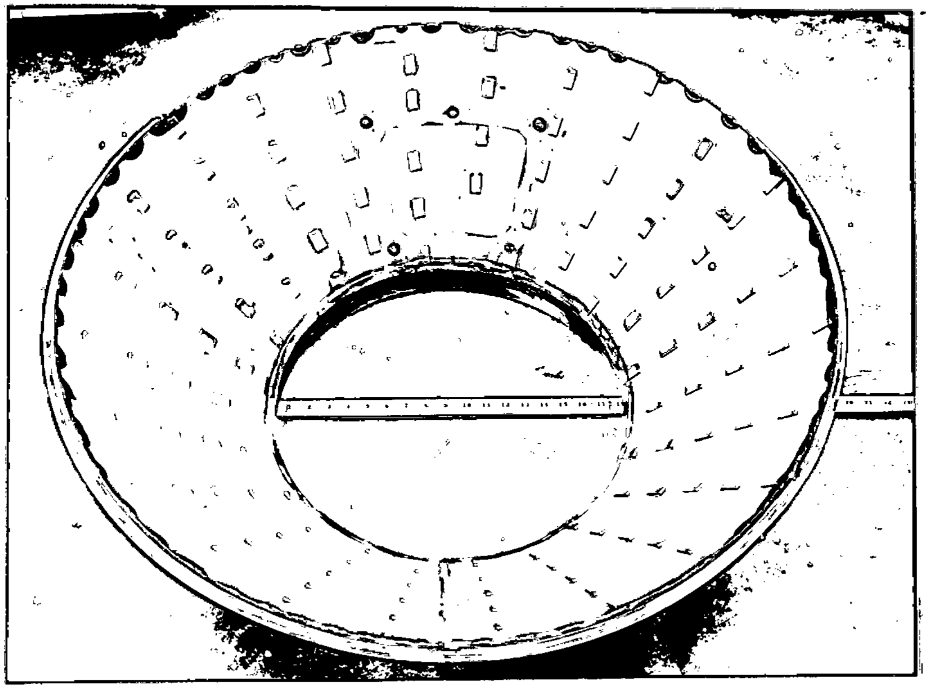

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Figure 10. Lower Cone of Liner

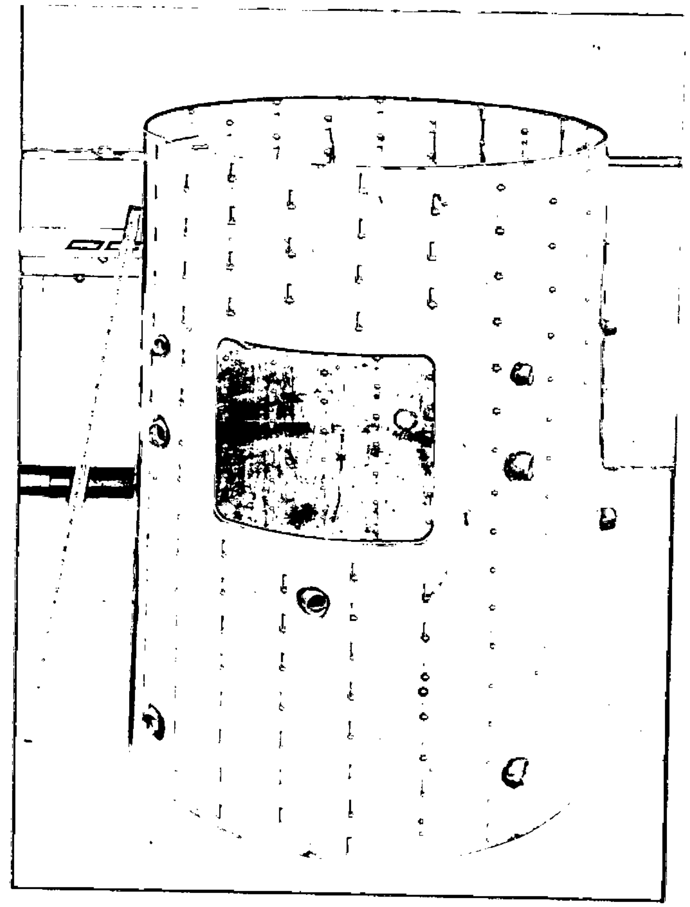

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Figure 11. Cylindrical Section of Liner

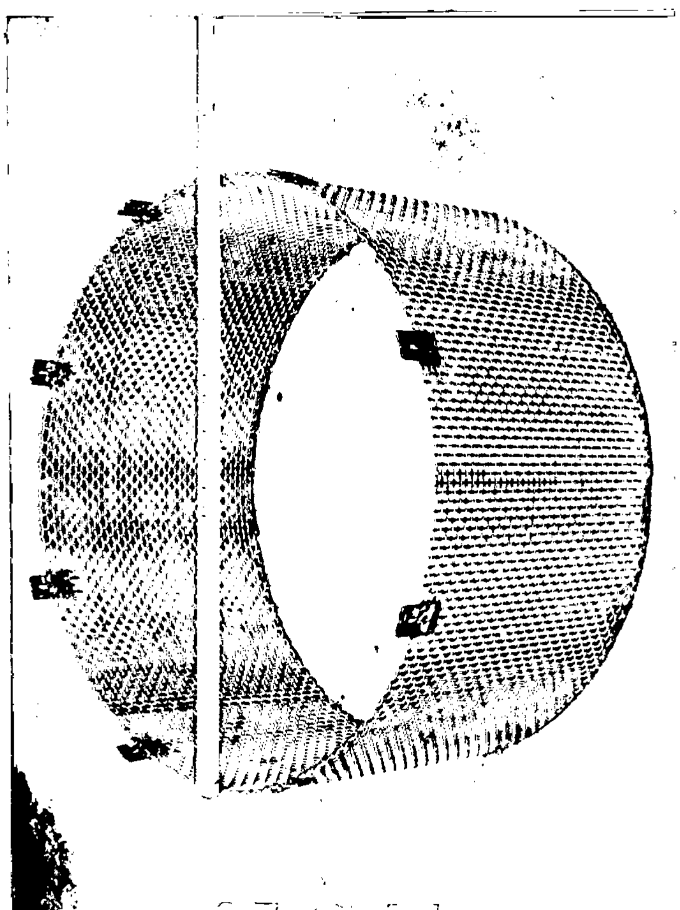

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Figure 12. Grid

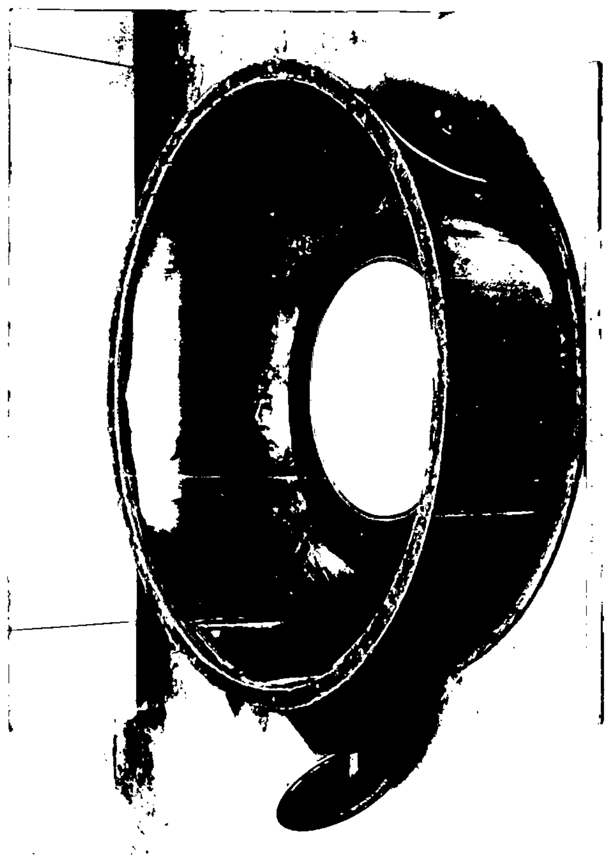

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Figure 13. Lower Section of Outer Shell and Bottom of Unit

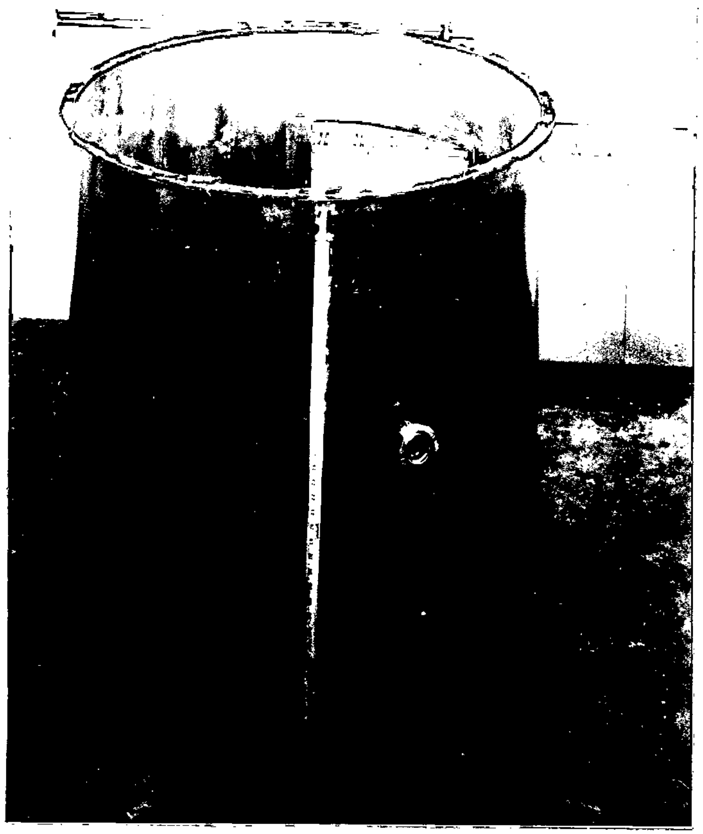

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Figure 14. Middle Section of Shell

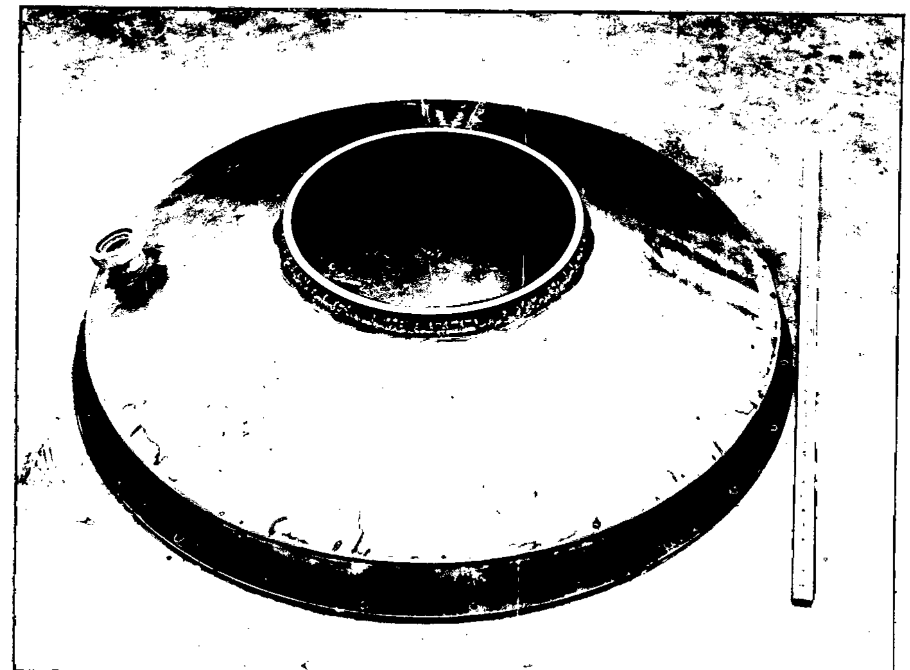

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Figure 15. Upper Cone of Shell

Figure 13 presents the bottom section of the outer shell with a disc of heat-resistant material which served as the initial bottom of the combustion chamber. The middle section and upper cone of the outer shell, each with one observation port, are illustrated in Figures 14 and 15.

Figure 16 is a photograph of the finished first prototype incinerator, including the air blower and motor, intake muffler, instrument panel, stack, and thermal shield for the stack, which was subsequently shipped to the Sponsor for demonstrations and field tests. The loading door was a quick-opening type which pivoted within a swinging frame, thus allowing the hot inner surface to be swung safely away from the operator when the door was in the open position. The inner construction of the door was such that, when the door was closed, the loading openings in the liner and in the radiation shield between the liner and the outer shell were closed. The liner portion of the door was louvered and was prepared from Type 304 stainless steel, in line with the construction of the liner proper; the curvature was such as to conform to the configuration of the liner. The same relationship existed, respectively, between the radiation-shield portion of the door and the radiation shield.

The total weight of the assembled unit, including the blower and motor and excluding the stack, was about 1,100 lb.

Operating Test Results and Modifications

During final assembly of the prototype unit prior to the first test run, temperature-sensitive paints (Tempilaq) representing various melting points up to 1500 F were applied to small selected areas of the stainless steel liner, to permit determination of the liner temperature in subsequent test runs. Also, one

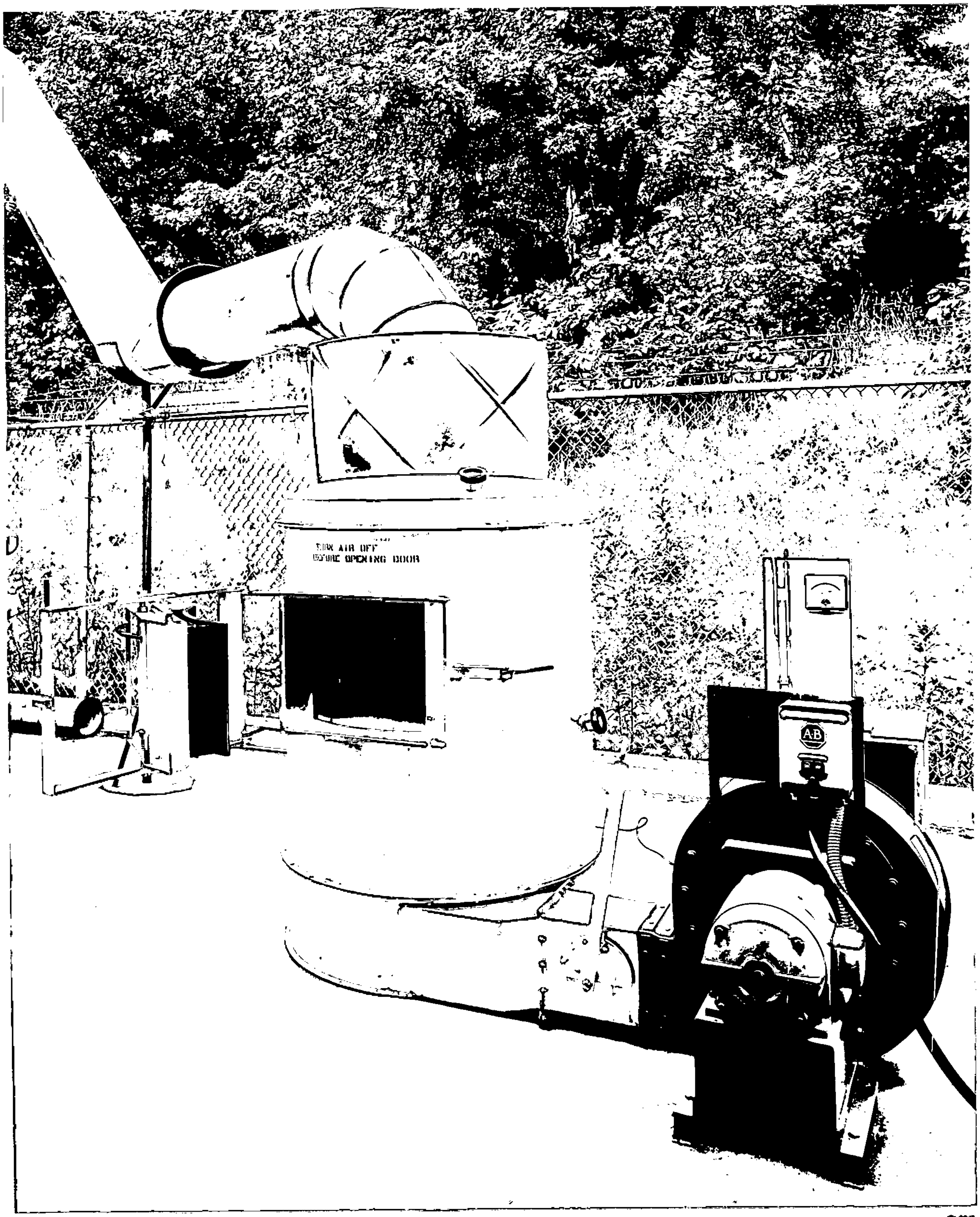

Figure 16. First Prototype Incinerator

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thermocouple was embedded in the lower part of the liner, where the maximum temperatures were expected to occur.

The initial test runs were made by burning single batches of from 200 to 250 lb of telephone books torn into sections as previously described. Minor changes in the amounts of louver air and main-jet air were made between runs. The results of these tests were generally encouraging, in that the metal-liner temperatures did not exceed 1400 F, and the outside shell remained relatively cool to the touch with a bare hand. Maximum instantaneous burning rates up to 370 lb of paper per hr were achieved for periods of up to 10 min. However, the average burning rates for the first hour of operation on a 250-lb batch of paper were about 225 lb per hr. The maximum instantaneous burning rates were reached within the first half-hour of operation at the designed air-flow rate of 2,400 cfm; the burning rate then declined for the remainder of each test run.

The difficulty in sustaining the higher burning rates appeared to stem from the lack of direct impingement of the main-jet air on the charge of burning paper. From observations of air flow alone in the empty unit, and of the action during the burning of paper, it was evident that the main-jet air was deflected toward the liner by the tangentially directed louver air swirling in at high velocities. Thus, it appeared that modifications were needed in the arrangement of the main-air jets in order to obtain deeper penetration of air into the center of the mass of paper.

To this end, in the main burning zone below the loading door and still in the cylindrical portion of the liner, four additional nozzles were installed at a horizontal level halfway between the two original levels of nozzles below the door as previously shown in Figure 8. Also, the size and angular position of these eight original nozzles were changed to those, respectively, of the four additional nozzles. Thus, each of these 12 nozzles was 1-1/8 in. in inside diameter and 3-1/2 in. long, and was directed toward the central axis of the unit and tilted 30 degrees downward. Almost the entire length of each nozzle was allowed to project inside the liner, to insure that the corresponding air jets would not be deflected tangentially by the high-velocity swirling air from the louvers. This arrangement of air nozzles improved the burning rates and promoted fairly uniform consumption of paper across the burning chamber. However, the burning rate still decreased appreciably as the mass of paper decreased during the closing period of each test run.

The configuration of the bottom of the burning chamber was then modified, to eliminate the central inactive zone, by installing an upright metal cone assembly 18 in. in diameter at the base and 7 in. in height. This provided a circular, V-shaped trough at the very bottom of the combustion chamber. Additional air was then directed into this trough via four additional nozzles, each 1-1/8 in. in inside diameter; these were installed through the lower cone of the liner, were tilted 20 degrees downward, and were tangent to a 12-in.-diameter circle. The central metal cone was formed by stacking three conic sections, each of decreasing size, so as to be separated by 1/16-in. gaps; thus, provision was made for film-cooling air to flow downward and outward along the conical surface.

The above changes in the lower part of the burning chamber improved the burning rate during the final burnout period, but not to the degree desired for high-rate, single-batch operation. However, the use of an operating procedure based on intermittent-batch feeding gave such high average burning rates that the significance of the low burning rate during the final burnout period was minimized.

By the time the first 15 test runs had been conducted, sustained burning rates of 900 lb of telephone books per hr were obtained during intermittent-batch feeding of 12-lb increments. The intermittent loading was done manually, without a feeding mechanism. The air supply was shut off during the 10 to 15 sec required to feed each batch. At this high sustained rate of burning, the stack-gas temperature exceeded 1600 F for periods of less than 30 sec immediately following some of the loading periods.

The kind of paper burned and the degree of packing of the charge influenced the burning rate. Newspapers, which do not pack so densely as do the pages of telephone books, were burned at average sustained rates of 700 lb per hr. In the few tests with newspapers, instantaneous burning rates of over 1,000 lb per hr occurred several times and led to excessively high gas temperatures of about 2200 F.

The agitation and turbulence which contributed to this high burning rate for newspapers also occasionally caused some loose papers to be blown up from the charge to positions against the grid, where they subsequently burned. This kind of burning, together with the high gas temperature, resulted in severe carburization of the stainless steel grid and subsequently in the burning away of an appreciable area of the interlaced grid wire. During these same tests, the stainless steel air-film-cooled liner reached temperatures slightly over 1500 F at times; but, except for showing moderate warpage, it successfully withstood the conditions associated with the highest burning rate obtained with newspapers. As a result of these tests, no changes in the original design of the air-film-cooling louvers were made; however, the grid was replaced with one made from Nichrome 5 wire mesh, so as to provide better resistance to high temperature and carburization.

It was noted that some unburned and partially burned paper was present on the combustion-chamber bottom at the end of each test run. Consequently, an extended effort was made in an attempt to obtain complete burnout of the residue and also to improve the burning rate during the normally slow period at the end of each burning operation. Several changes in the configuration of the lower cones (the central cone and the lower conical section of the liner) were investigated, along with changes in the operating procedure, as listed below:

(1) An annulus of perforated sheet metal was placed horizontally about 4 in. above the bottom junction of the two lower cones, to support the residue and hence to allow air to circulate upward through it.

(2) With the annulus removed, four fire bricks were set on edge in equally spaced positions, in the bottom circular "V" trough, to introduce local turbulence (instead of the circular swirling action).

(3) With the fire bricks removed, the four air nozzles in the lower cone of the liner were closed to reduce the swirl which was believed to cause some of the unburned paper residue to be swept up and carried unignited to the grid. Air without swirl was then supplied via 24 holes, each 1/2 in. in diameter, drilled near the bottom of the lower liner cone.

(4) A change in operating procedure was explored. This involved stopping and starting the air flow at about 5-min intervals near the end of the burning operation, in order to allow unburned paper on the grid to drop

and become ignited by the paper which was still burning at the bottom of the unit. This modification of procedure was used during most of the runs made to evaluate the other changes indicated in the following.

(5) The original four nozzles in the lower liner cone were modified to blow four 5/8-in.-diameter jets of air in a direction reverse to the general swirl pattern. This was done in an attempt to reduce the tendency for the paper at the bottom to swirl and to be lifted up to the grid near the end of the burning operation.

(6) An obstruction in the form of an annulus of perforated sheet metal, of 36-in. OD and 24-in. ID, was installed horizontally about 12 in. below the feeding opening of the liner, in an attempt to hold the swirling paper down close to the burning zone.

After about 95 test runs were conducted to evaluate the above-indicated changes, it was found that the most effective change relative to reducing the residue of unburned paper was the procedural modification which involved stopping and starting the flow of air near the end of the burning period. However, even when this procedural change was employed, loose unburned paper still persisted in small amounts of 10 to 20 pieces at the end of each burning period. Because the above-mentioned changes which involved reduction of the air flow or swirl were accompanied by a detrimental decrease in the rate of burning, the four original nozzles in the lower liner zone were restored and the 24 small holes were closed, to preserve the swirl.

Additional efforts to eliminate the unburned residue involved the use of auxiliary heat or fuel. An electric heating coil operating at a dull-red heat at the bottom of the trough was fairly effective in reducing the residue to a few small pieces. The use of about 10 lb of coke briquettes loaded at the bottom prior to the addition of paper also provided a source of ignition for the last remains of telephone-book paper near the end of each single-batch burning operation. The effect of the accumulation of ash over an extended period of burning, during which the paper was fed by intermittent-batch loading, was not determined on the performance of either the electric coil or the coke briquettes.

The unburned paper residue which usually amounted to only a fraction of a pound in weight was most successfully eliminated by sprinkling about 1/2 pt of kerosene over the residual paper lodged in and around the electric heating element. Ignition of the kerosene filled the combustion chamber with flames, which burned all of the paper resting at the bottom and on the grid.

After a discussion of these results with the Sponsor, it was decided that the use of an electric coil, coke briquettes, or kerosene would not be feasible under service conditions; and that in this unit the unburned residue could be eliminated satisfactorily by turning the air off at the end of the burning period and igniting the residue manually with a match.

During the final burnout period after the last increment of paper was fed, an appreciable increase in the normally slow burning rate was obtained by manually poking the last remains at 5-min intervals to loosen and expose fresh unburned paper at the bottom of the combustion chamber. This procedure was safe and inoffensive in the air-film-cooled unit, as the metal temperatures were low during the final burnout period and consequently it was practical to turn off the air completely during poking, without any harmful aftereffects.

The above-described experimental evaluation involved a total of about 65 test runs, many of which were relatively short single-batch operations. In these runs, the air was supplied from a laboratory blower and motor, and laboratory-type instrumentation was used to facilitate the evaluation. In preparation for the final performance demonstrations and subsequent shipment of the incinerator assembly to the Sponsor for further demonstrations and field tests, several alterations and additions (shown in Figure 16) were made, as follows:

(1) The bottom section of the shell was rotated 180 degrees, and a new rectangular inlet duct and air damper were installed so as to fit the new blower and motor, described below.

(2) A new blower and motor assembly was obtained from the Buffalo Forge Company, to fulfill the air-flow requirements of 2,400 cfm at a static discharge pressure of 12 in. of water. The blower was identified as their No. 25, MW, Industrial Exhauster, Arrangement 4, modified wheel diameter of 14-1/2 in., with a 3,600-rpm, 7-1/2-hp, 220-volt, 3-phase dripproof motor and a magnetic starter.

(3) To reduce the noise level during operation, a muffler was provided at the inlet of the blower. This was a simple device consisting essentially of a cylinder of expanded metal, wrapped with 1-in.-thick Fiberglas, that was enclosed with an open-ended wooden box which was also lined with 1-in.-thick Fiberglas.

(4) A water manometer was provided for the measurement of the static pressure in the lower plenum of the incinerator. Also, the handle of the air damper was fitted with a limiting stop, which was adjusted so as to provide for the desired air flow for the rated operation. With the air-damper handle at this stop, the static pressure in the plenum was 4.3 in. of water when the unit was empty (and the air flow was being checked).

(5) Two heavy-wire Chromel-Alumel thermocouples (one as a spare) were provided for the measurement of the flue-gas temperature. A Sim-Ply-Trol instrument (obtained from Assembly Products, Inc., Chesterland, Ohio) for indicating the temperature of the thermocouple bead from 0 to 2000 F was mounted on a stand with the manometer.

(6) An actual correlation of burning rate versus stack-gas temperature, as read on the Sim-Ply-Trol, was plotted

(Figure 17), for use in estimating instantaneous burning rates during operation of the unit. When the air-damper throttle is set at the operating position, the burning rate can be estimated to within approximately ± 10 per cent by reading the stack-gas temperature and then referring to Figure 17.

(7) As previously described, a hinged device for opening and closing the loading door was built and installed on the unit.

(8) A stack was built to fit the location where the unit was to be field tested. The first section of the stack including the elbow was fabricated from 16-gage Type 304 stainless steel. This was arranged so as to discharge into a bell mouth for aspiration of cooling air into an 18-in.-diameter, 16-gage mild-steel section of stack, which inclined upward at an angle of about 45 degrees. Also, a radiation shield was provided for use at the base of the stack, to shield the operator from the stack heat.

(9) A spare grid and also a spare "V" band coupling for the flange at the base of the stack were provided at a later date.

The last tests with this incinerator assembly were made by burning larger quantities of paper consisting of discarded file papers, small file cards in cardboard cartons, paper from waste baskets, and a small proportion of

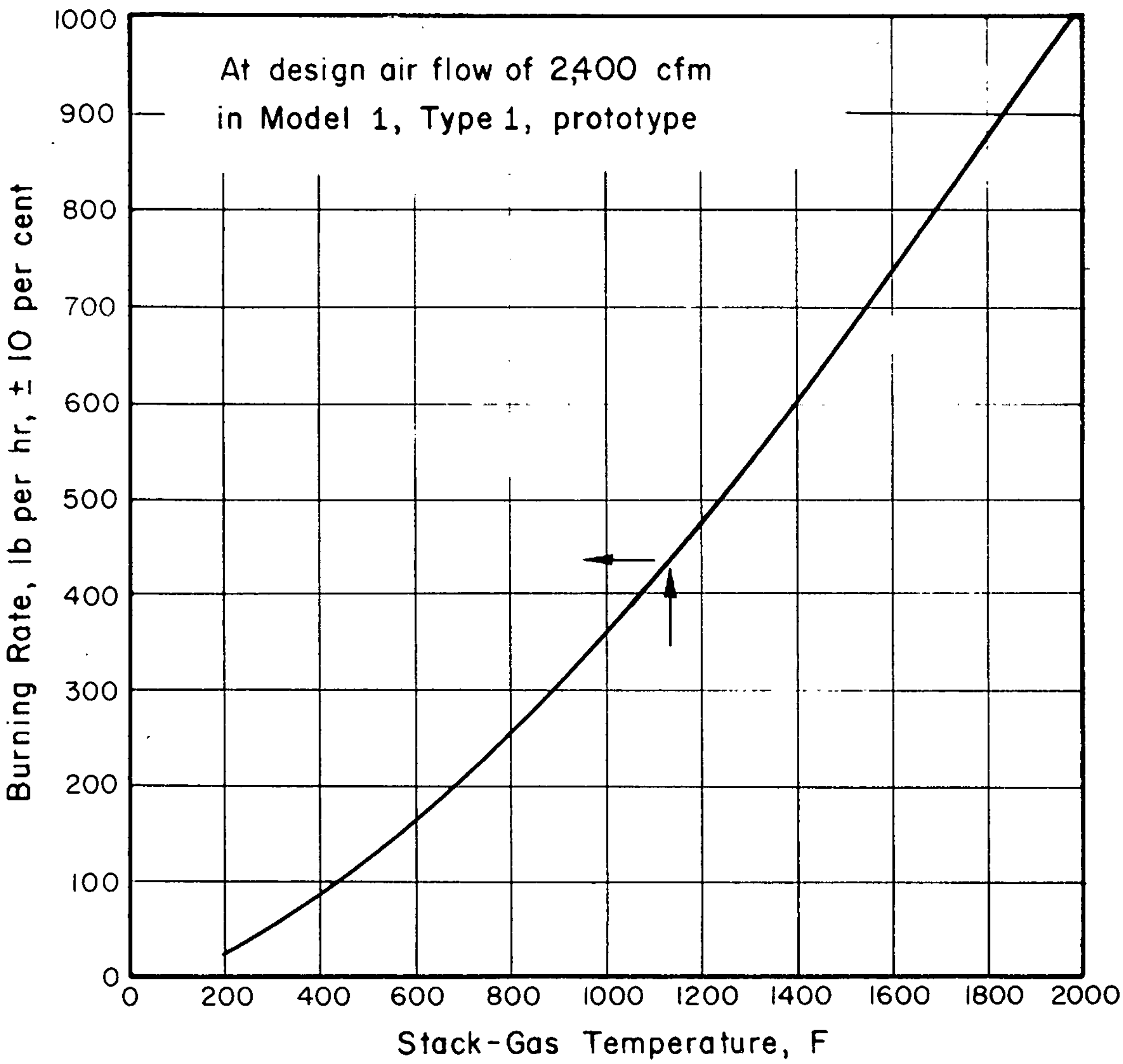

FIGURE 17. CORRELATION OF BURNING RATE VERSUS STACK-GAS TEMPERATURE

telephone-book paper. In two test runs, 1,040 and 1,130 lb of paper were charged by manual, intermittent-batch feeding. The average burning rates obtained were 275 to 300 lb per hr. The residue remaining in the unit at the end of these two tests amounted to 16 and 9 lb, or 1.5 and 0.8 per cent, respectively, of the paper charged. This residue consisted mainly of loose ash, but also contained small pieces or clumps of lightly fused ash, and a small amount of charred and unburned paper which apparently mixed with the ash during poking in the later part of the runs.

During all of the experimental burning tests with the prototype incinerator, the stack gases were free from smoke. A light-gray haze, composed of finely divided fly ash, was visible most of the time; virtually all of the noncombustible mineral matter (ash) in the paper (5.8 per cent by weight) was blown out of the burning chamber. This was also accompanied, at times, by small pieces of black char which escaped through the mesh openings of the grid. Except for one or two occasions when the grid was not seated snugly against the upper cone of the liner, the grid prevented the escape of legible-sized pieces of char and paper.

Suggested Operating Procedure

During demonstrations of the incinerator assembly on June 11 and 12, 1959, the Sponsor was familiarized with the procedure for operating the unit. The suggested procedure is outlined in the following.

For the incineration of a single batch of paper, a charge of 200 lb is loaded. After ignition of the paper with a match, and while the fire is being observed through the sight ports, the air rate is increased in steps of 1/4, 1/2, 3/4, to full throttle over a period of about 5 min, or until the fire is well established. Normally at the end of about 1 hr, this charge is burned out, except for a few loose pieces which accumulate on the grid and which fall down when the blower is turned off. Burning is then completed by re-igniting and operating for 1 or 2 min at an air flow corresponding to the "1/2" position for the air-damper throttle. If an operator is present throughout the burning period, burnout can be hastened by poking after 1/2 hr and by increasing and decreasing the air-flow rate when the last pile of residue begins to break apart.

Higher rates of burning (300 to 500 lb per hr, depending on the kind of paper) can be achieved by manual intermittent-batch feeding. In this case, the initial charge should be about 50 lb of paper; the air-flow rate should again be increased gradually during the first 5 min of operation. As soon as the fire is well established, the air can be turned off momentarily while the door is opened and a small batch of 10 to 25 lb of paper is fed. In the course of restoring the air flow to the full-throttle position after feeding, a gradual increase in air flow over a period of about 1/2 min is recommended, to avoid momentary excessive burning rates due to the burning of the loose, freshly charged paper. Stack-gas temperature should be kept below 1800 F by throttling back when necessary, in order to avoid overheating of the grid. Intermittent feedings are made so as to keep the level of the charge at a position about 12 in. below the bottom of the feed entrance. Higher beds do not derive full benefit from all three of the downwardly pointed air jets in the lower part of the cylindrical liner. This is also true for lower than normal bed levels. The achievement of maximum burning rates is also favored by successively charging small increments (10 to 15 lb) of paper, as this size of increment charge necessitates frequent loading, which promotes looser packing and better penetration by the air jets.

Poking the bed during final burnout also promotes higher average burning rates. This technique is particularly useful near the end of a long burning period of several hours. If this is not done, the accumulation of ash can shield and insulate any residual unburned paper, and thus prevents it from igniting and burning.

Conclusions

The first prototype of the air-film-cooled, cyclone-jet incinerator demonstrated the feasibility of this type of construction. Burning rates almost as high as those obtained in the somewhat larger, experimental, refractory-lined unit were obtained. The operation was convenient and safe, and the exterior-surface temperatures were acceptably low.

As a result of several demonstrations in our laboratories and subsequent demonstrations at the field test site, the Sponsors and their associates were favorably impressed with the performance of the first prototype. To permit further exploitation of its portability, stemming from its low weight and simple construction, they recommended that the design be modified so that all of the components of the disassembled unit would fit through a standard, 33-in.-wide doorway.

Based on operating experience with the first prototype unit, it was recognized that the fly-ash emission was generally acceptable, but might be considered excessive for some of the intended locations of use.

Second Prototype Unit (Model 1, Type 2)

In July, 1959, work was begun on the re-design of the incinerator, to incorporate selected modifications, and on the laboratory construction of a second prototype unit. Later, under Task Order No. KK, Work Order No. II, further related effort was performed. This consisted of (1) the design, construction, and evaluation of a simple fly-ash collector, and (2) the investigation of the feasibility of substituting an auxiliary stand-by source of air (gasoline-engine-driven blower) for use with the unit operated in a small room typical of small-office space.

Changes in Design
of Prototype

Changes in the design of the second unit were made to permit all of the parts, in the dismantled condition, to fit through a standard, 33-in.-wide door opening. These changes included moving the lower 42-in.-diameter flange joint to a position about 1 ft higher than previously on the outer shell (Figure 16); and separating the cylindrical portion of the liner horizontally into two pieces, and providing a slip joint which was located a few inches below the feed opening of the liner. Also, the junction between the cylindrical section and the lower conical section of the liner, which previously was a slip flange, was replaced by a welded junction, to minimize warpage and air-leakage problems encountered in the first prototype.

In addition, the cleanout opening in the lower cone of the liner was eliminated, because operating experience had shown that the opening was not needed. However, the circular access port near the bottom of the outer shell was retained, to permit entry to the air plenum. At a position corresponding to the junction between the grid and the upper cone of the liner, a band was welded to the upper cone, to eliminate any possible gap through which paper or char might escape into the stack gases. An extra sight port was also provided at the top of the unit to the left of the loading door.

Further, in order to reduce the possibility of accidental opening of the loading door while the air was on, an interlock was provided by extending the damper handle. The metal damper-handle extension was long enough so that it rested in front of the hand grip on the door latch when the air damper was open (i.e., the throttle was in the full open position); thus, the door could not be unlatched when the damper was open.

Type 304 16-gage stainless steel was again used for construction of the liner of the second prototype. The arrangement of louvers (1 in. long, with 1/32-in. gap) and main-air nozzles was the same as in the final version of the first prototype. Nichrome 5 wire mesh was utilized for the grid, as it had given good service in field trials of the first prototype. Except for the stack, the second-prototype assembly (including the incinerator, blower, intake muffler, and instruments) was very similar in appearance to that shown in Figure 16. A short, vertical length of stack was used during the experimental evaluation of the second prototype that was conducted out of doors.

Results of Test Operation

Twenty test runs were made with the second prototype before it was shipped to the Sponsor. The longest burning period was obtained in the course of a test run in which 1,900 lb of telephone-book pages were incinerated. In this run, an average rate of 350 lb per hr was attained under restrained operation, in which the air was manually throttled to avoid flue-gas temperatures in excess of 1800 F. Assorted file papers, including obsolete records from an insurance company, 3 by 8-in. file cards, outdated form pads, and other miscellaneous papers were burned in several relatively short test runs and demonstrations for the Sponsor at average burning rates of from 190 to 320 lb per hr.

In general, the performance of the second prototype compared favorably with that of the first unit. At a rated air flow of 2,400 cfm, the static pressure in the lower plenum chamber was 6.5 to 7.5 in. of water; this value was obtained in a routine air-flow check on the empty unit. Thus, the static pressure of the second prototype was higher than the 4.3-in. value for the first prototype; the reason for the difference was that air leakage at the lower liner junction was eliminated in the second prototype by using a welded joint.

The resistance of the Nichrome 5 wire mesh of the grid to gas temperatures up to 1800 F and to carburization, which had damaged a previous Type 304 stainless steel grid, appeared to be fairly good. However, the use of a supplementary grating below the grid was given consideration as a means of protecting the grid from direct contact with burning paper. Brief trials were made with a temporary metal grating which consisted of a 36-in.-diameter disc of perforated sheet metal (diamond-shaped openings, 0.53 by 1.63 in.) suspended 4 in. below the bottom of the grid. Observations during three test runs showed that loose sheets of burning paper were caught effectively by the grating without any disruption of the other performance factors.

The choice of a suitable material for such a grating narrowed down to the use of a refractory material such as silicon carbide, which would be rather fragile and relatively costly. Therefore, the use of such a protective grating was ruled out on the basis that the Nichrome 5 would have adequate service life, particularly under routine daily incinerating conditions in which control of the burning rate could and would be exercised with reasonable prudence by throttling of the air flow. However, in view of the lack of definite data on the service life of the grid, and of the relative criticality of this component, it was recommended to the Sponsor that a spare grid be provided with each unit.

Slight, but progressive, warpage of the lower outer cone of the liner occurred in the second prototype, as had been the case with the first prototype. It is believed that this condition can be tolerated, with no impairment of the performance of the incinerator. However, it was recommended to the Sponsor that a substitution of Type 310 (25 Cr - 20 Ni) stainless steel sheet for the Type 304 (18 Cr - 8 Ni) should be made in future units, in order to take advantage of the increased heat resistance with only a slight additional cost.

<u>Exploration of a Simple Fly-Ash Collector</u>

An effort under Task Order No. XX, Work Order No. II, was performed in conjunction with the activity on the second prototype unit. This was directed toward the exploration of a simple, low-pressure-loss collecting device (fly-ash skimmer) for use in reducing the fly ash and unburned bits of illegible char emitted in the flue gases.

It was estimated that a conventional cyclone collector capable of cleaning the entire flow of flue gases from the Model 1 incinerator would be almost as large as the incinerator and would probably cost as much as or more than the incinerator. The pressure loss across such a collector would have to be about 4 in. of water in order to create a high-velocity spin or cyclone action and to overcome the friction losses in a collecting unit designed to remove about 80 to 90 per cent of the fly ash. It appeared that in a unit for use with the Model 1 incinerator, a collection efficiency of about 80 per cent might be needed in order to satisfy the more rigorous fly-ash codes in some of the urban areas of the United States; however, it was believed that, in many areas of the world, lower collection efficiencies might be acceptable for this type of incinerator.

In view of this situation, it was felt mutually that a simplified type of fly-ash collector merited consideration.

Fortunately, an axial spin exists in the flue gases exiting from the top of the Model 1 unit. This spin creates centrifugal forces on the particles of fly ash in much the same manner as in a cyclone collector. Thus, the larger, heavier particles are thrown to the periphery of the flue pipe where they, along with a small portion of the flue gas, can be "skimmed" off through an annulus section located adjacent to the periphery of the duct. This smaller flow of flue gas, containing a relatively high concentration of fly ash, can then be passed through a much smaller cyclone collector than would be involved in the above-mentioned conventional cyclone collector for handling the entire needs of the Model 1 unit. As only the larger sizes of particles would be expected to be present in the "skimmed" gas, the small cyclone collector would function adequately with a relatively small pressure loss; this would not necessitate a large increase in blower power, as would be required for a conventional large high-efficiency collector.

Figure 18 shows a sketch of the fly-ash-skimmer arrangement which was set up and tested on the second prototype incinerator. The experimental skimmer was actually a part of the flue pipe, which was extended vertically about 24 in. above the incinerator. The skimmer annulus was formed by inserting a 7-in. length of 14-in.-diameter duct concentric with the 16-in.-diameter flue pipe. An offtake scroll and ducting led the skimmed-off gas into two parallel-connected, 9-in.-diameter cyclone collectors (which were available at our laboratories). A single cyclone about 12 in. in diameter would also be suitable for this purpose.

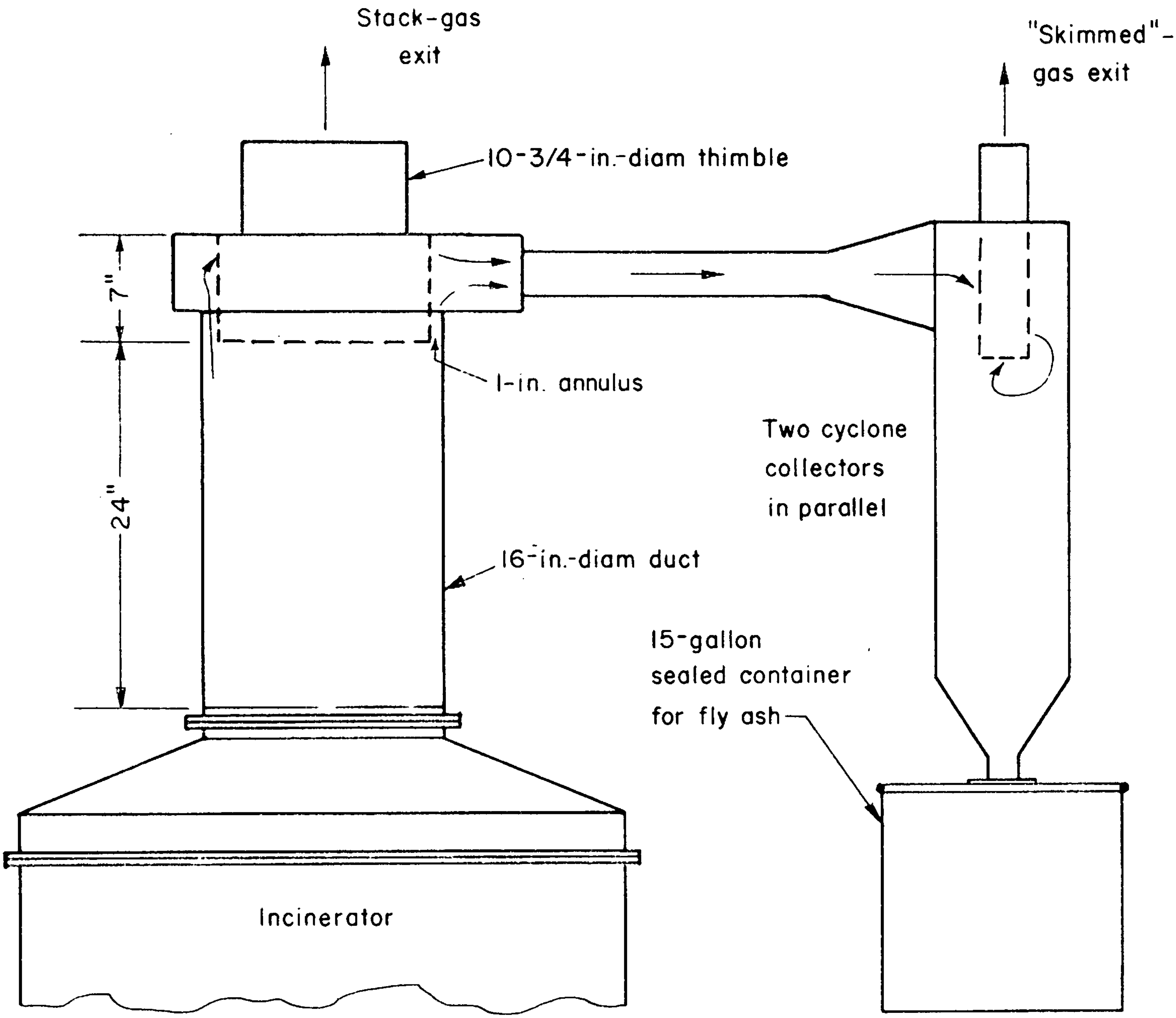

FIGURE 18. SKETCH OF THE FLY-ASH "SKIMMER"

Back pressure was applied to the incinerator by constricting the flue exit to 10-3/4 in. in diameter, to provide a static pressure of about 3 in. of water in the scroll. This pressure was sufficient to divert about 10 per cent of the total flow of flue gases into and through the cyclones. The net effect was that the operating static pressure in the plenum chamber of the unit was increased from 8 in. to about 9.5 in., which was still within the maximum pressure of 12 in. of water available from the blower.

The performance of the skimmer-type collector was evaluated in three test runs in each of which 500 lb of telephone-book paper were burned, and in one test run of 500 lb of assorted file paper. On the basis of the known ash content of the telephone-book paper (5.8 per cent, by weight), and the measured ash content and weight of the material collected in the container below the cyclones, the collection efficiency for the mineral ash present in the paper was found to be 30.2, 30.9, and 29.0 per cent for the three telephone-book-paper test runs. The average ash content for the assorted file paper was not determined. But, on the assumption that it was the same as that of the telephone-book paper, the fourth test run was found to indicate that 22.0 per cent of the mineral ash was collected. In addition to the above percentages of mineral matter, nearly all of the visible pieces of char were caught by the skimmer; the appearance of the plume was improved more by the collection of this material than by the above-indicated reduction in finely divided mineral matter. The normal gray haze persisted, but deposition of black flakes of char in and around the incinerator was decreased considerably. The exit gases from the small cyclones also displayed the normal gray haze stemming from the presence of finely divided, mineral fly ash.

Demonstrations for the Sponsor were conducted with and without the fly-ash skimmer on November 23, 1959.

Performance of Incinerator in Small Room With Auxiliary, Gasoline-Engine-Driven Blower

Also included in the effort under Task Order No. KK, Work Order No. II, was an investigation of incinerator operation in a small, typical office room with both the electric-motor-driven blower and an auxiliary, gasoline-engine-driven blower.

The room selected for this installation was about 11 by 22 ft with a 9-ft ceiling. It was on the top floor of a four-story building. The only window in the room was removed, and the opening was closed with concrete block, except for a 16 by 26-in. rectangular opening left for a horizontal flue pipe which was 20 in. wide and 10 in. in height. A short length of vertical flue (16-in. in diameter and 7 in. long) was used between the incinerator and the horizontal duct, which extended about 3 ft outside of the building. In the 3-in.-wide space between the horizontal duct and the concrete block, two sheets of polished stainless steel bent to a corresponding rectangular form were mounted with 1-in. spacing to serve as a thermal radiation shield for the concrete block. Aluminum-foil-backed Fiberglas insulation was placed against the ceiling over the stack, and in the 1/2-in.-high space between the incinerator and the concrete floor.

The auxiliary gasoline-engine-driven blower assembly for this study was made up as a completely separate unit, since the electric-motor-driven blower could not be modified readily for gasoline-engine drive. The auxiliary blower was an unmodified No. 25 MW Buffalo Forge blower with a 17-1/2-in.-diameter wheel.

An Arrangement No. 4 blower was used since this has two outboard bearings and a shaft for mounting a V-belt sheave, which facilitated arranging for a gasoline-engine drive. When driven at 2,800 rpm, this blower had the same capacity as the modified No. 25 MW blower which had a 14-1/2-in.-diameter wheel and was directly driven from the 3,450-rpm electric motor. The bed of the blower was extended to permit mounting of the gasoline engine.

A single-cylinder, Wisconsin air-cooled gasoline engine, Model AENL, 9.2 hp at 3,300 rpm, was obtained and coupled to the blower through properly sized V-belt sheaves. It was found that this engine started easily with the manual starting rope and without disconnecting the blower. After the engine governor was adjusted and the engine was "run in" for a few hours, a trial test was made with the blower connected to the unit, to verify the air-flow rate by measurement.

In preparation for the demonstration in the room, the Sponsors helped in disassembling the incinerator and in re-assembling the unit and setting up the installation within the room; this entire operation involved about 6 hr. All of the components passed easily through a standard 33-in. doorway. As a precaution against fire hazard, the fuel tank was removed from the gasoline engine and mounted on the wall outside the room in the hall. Several feet of copper tubing were used to connect the tank to the engine. In order to reduce the operating noise and to discharge the toxic engine-exhaust gases outside, the muffler on the engine was replaced with a small tractor muffler and a length of flexible metal tubing was used to conduct the exhaust to the outdoors.

Three short demonstration runs were made for the Sponsors and their associates on December 16, 1959. The first involved a demonstration of the experimental model of the feeding mechanism, which is described later in this report. The second was conducted with the electric-motor-driven blower, and the third with the gasoline-engine-driven blower. A total of about 900 lb of assorted file papers were burned at average rates of about 300 lb per hr while the operations were being observed.

Measurements of the sound intensity in various parts of the room yielded values of from 96 to 106 decibels when the unit was operated with the electric-motor-driven blower, and from 105 to 112 decibels when the gasoline-engine-driven blower was used. The background sound level in this room measured 70 to 76 decibels when the unit was not operating. During operation, the noise levels indicated above were annoying but not distressful; noise levels up to 110 decibels are tolerated in many industrial areas.

A check for the presence of carbon monoxide within the room showed 0.005 per cent near the gasoline engine during operation. This was well below the maximum allowable concentration of 0.010 per cent for continuous 8-hr-per-day exposure. By the end of the demonstration period, which involved about 1/2 hr, the room temperature had increased by about 30 F.

As a result of these demonstrations, it appeared that the operation of the Model 1 incinerator in typical office space would be quite feasible under emergency conditions wherein a gasoline engine might be required as an auxiliary power source to drive the air blower. Because of the relatively high noise level with either electric-motor or gasoline-engine drive and the heat given off to the room, routine daily operation within such space would be annoying to office personnel working in the room, unless special installations were provided to minimize the noise and the increase in temperature.

At the end of the experimental work described above, the second prototype was disassembled and crated for air-cargo shipment. This shipment included the incinerator, both blower assemblies, selected spare parts, the rectangular stack, and several tools and supplies needed to assemble and install the unit. Shipment was made to an indicated address on January 8, 1960.

Conclusions

Experimental work with the second prototype Model 1 incinerator confirmed the ability of this type of unit to destroy papers and documents rapidly, safely, and conveniently. It also demonstrated the portability, and the ease of assembly and disassembly of the unit. Operation in a relatively small room, which was typical of office space, using either the electric-motor-driven blower or an auxiliary gasoline-engine-driven blower was shown to be feasible, but perhaps not ideal because of the associated increased noise and heat.

As at least a partial remedy for the emission of fly ash and small illegible pieces of char, a relatively simple collector, such as the experimental fly-ash skimmer, should be given further consideration as an accessory for use with the Model 1 unit when reduced emissions are required.

The Nichrome 5 wire mesh material used in the grid is expected to provide a reasonable service life of at least 6 months if the average burning rates are held below 350 lb per hr by manually throttling the air flow so as to limit the flue-gas temperatures to a maximum of 1800 F. Higher emergency rates of burning would undoubtedly shorten the life of the grid, but it is expected that this type of operation would be infrequent.

In order to achieve added heat resistance, it is believed that the liner material should be changed from Type 304 to Type 310 stainless steel sheet metal. Other minor improvements in the design and arrangements of the parts appeared desirable and were subsequently made during preparation of the working drawings, as described in the next section.

PREPARATION OF WORKING DRAWINGS FOR MODEL 1 UNIT

It appeared to the Sponsors that at least four additional Model 1 incinerators would be required for various installations. This need offered an excellent opportunity for the Sponsors to get a good feel for the cost and the problems which would be involved in the production of a quantity of these units. It was subsequently decided by the Sponsors that four Model 1 incinerators would be made by a commercial fabricating company.

While many drawings of various kinds had been prepared in connection with the experimental units, some of these were simple sketches. It was thus apparent that a complete set of drawings had to be provided before the four incinerators could be fabricated by a commercial firm. However, the cost of a set of drawings can vary greatly depending upon the amount of effort expended in an attempt to anticipate and provide for the many possible fabrication and operation problems. In view of the fact that the incinerator design was still relatively new, it seemed very likely that some modifications would be required in future units as a result of the experience gained from the operation of the four units to be produced, and possibly also of the two prototype units. For this reason, we recommended that a set of working drawings be provided. Working drawings are prepared with sufficient care to prevent gross errors, the rectification of which would require a large expenditure of funds. On the other hand, they do not receive the care and thought which are usually necessary in order to eliminate practically all errors, to reduce fabrication costs to the minimum, and to insure proper assembly without personal liaison with the fabricator. Thus, with working drawings, it would be necessary for either the Sponsors or our personnel to be in contact with the fabricator to discuss possible problems which might arise in the course of manufacture. It would also be necessary to allow some time and funds for some changes to be made after final assembly, in order to insure proper operation. After a discussion of the requirements, the Sponsors requested that a set of working drawings for the Model 1 unit be provided.

These drawings were prepared and delivered to the Sponsors on January 20, 1960. The set consisted of 181 drawings. The tracings and one set of prints were transmitted to the Sponsors, and one set of prints and a set of reproducibles were retained at our organization for future reference. The working-drawing numbers and descriptions are included in Appendix 1. Also, on the basis of mutual agreement, we provided a brief resume of the problems anticipated in the manufacture of the Model 1 unit and our recommended solutions to these problems. For the record, this resume is presented in Appendix 2.

Subsequently, a description of selected changes and additions to the working drawings, and also a list of recommended spare parts to be packaged with each incinerator were prepared and submitted to the Sponsors. These are included in Appendixes 3 and 4, respectively.

EXPERIMENTAL PAPER-FEEDING MECHANISM

During the early experimental work on the refractory-lined incinerator, it appeared desirable to provide for the intermittent feeding of paper while burning was in progress. The burning rates obtained in the refractory-lined incinerator were satisfactory; however, the intermittent-batch-feeding method which was used required that the air supply be shut off during the loading of the paper. The objective of this portion of the Task Order No. X research program was to investigate the design, development, and evaluation of an experimental mechanism which would permit the easy introduction of papers intermittently into the experimental incinerator during the burning operation.

The initial effort under this phase of the program involved a series of idea meetings with selected engineering personnel to discuss various methods of feeding paper intermittently into the incinerator. The ideas evolved were then evaluated and the most promising one selected for further evaluation. Layouts and shop drawings were then prepared, and the necessary parts fabricated. Two additional designs, which were modifications of the first design, were also fabricated and tested. These are discussed in subsequent paragraphs.

Idea Meetings

A number of idea meetings were held with various staff engineers to secure ideas on methods of feeding paper intermittently. In addition, several individual conferences were held.

A total of 23 ideas were evolved. The ideas generally represented some type of gravity feed through a hopper, or a mechanical feed involving either a rotating mechanism or a ram which forced the paper into the incinerator. The selection of the most promising idea was made on the basis of simplicity, ease of operation, and a minimum of moving parts.

Design No. 1

The selection of the basic idea for a mechanism to feed paper into the incinerator was followed by the preparation of a detail layout of the design.

Detail drawings were then prepared; the necessary parts were fabricated and the unit assembled. The mechanism was subsequently attached to the refractory-lined incinerator and its performance evaluated. The mechanism and the results obtained during the tests conducted are described below.

Description

The initial design (Design No. 1) selected for fabrication and evaluation consisted of three basic pieces: (1) the loading box, (2) the housing, and (3) the fire door.

Figure 19 shows the loading box; this was comprised of a Transite box which was open at the top and bottom and of two stainless steel guide rods which were fastened to the sides of the box. Transite was selected for this application because of its light weight and low coefficient of thermal expansion, which permitted the use of very close clearances around the sides of the box. The loading box was large enough to take 8-1/2 by 11-in. paper in any position and legal-sized paper in one position; and had a capacity for approximately 25 lb of paper.

Figure 20 shows the housing for the feeding mechanism. It was approximately 24 in. long, 12 in. high, and 15 in. wide, and was fabricated from 1/4-inch-thick steel plate. The plate parts were held together by bolts, to permit easy assembly and disassembly for any modifications which would be required. A steel-angle frame was fastened around the housing to assist in final assembly to the incinerator. Transite sheets were fastened to both internal sides of the housing to serve as insulation and to provide guide slots for the loading box and fire-door guide rods. Two holes were provided in each side of the housing

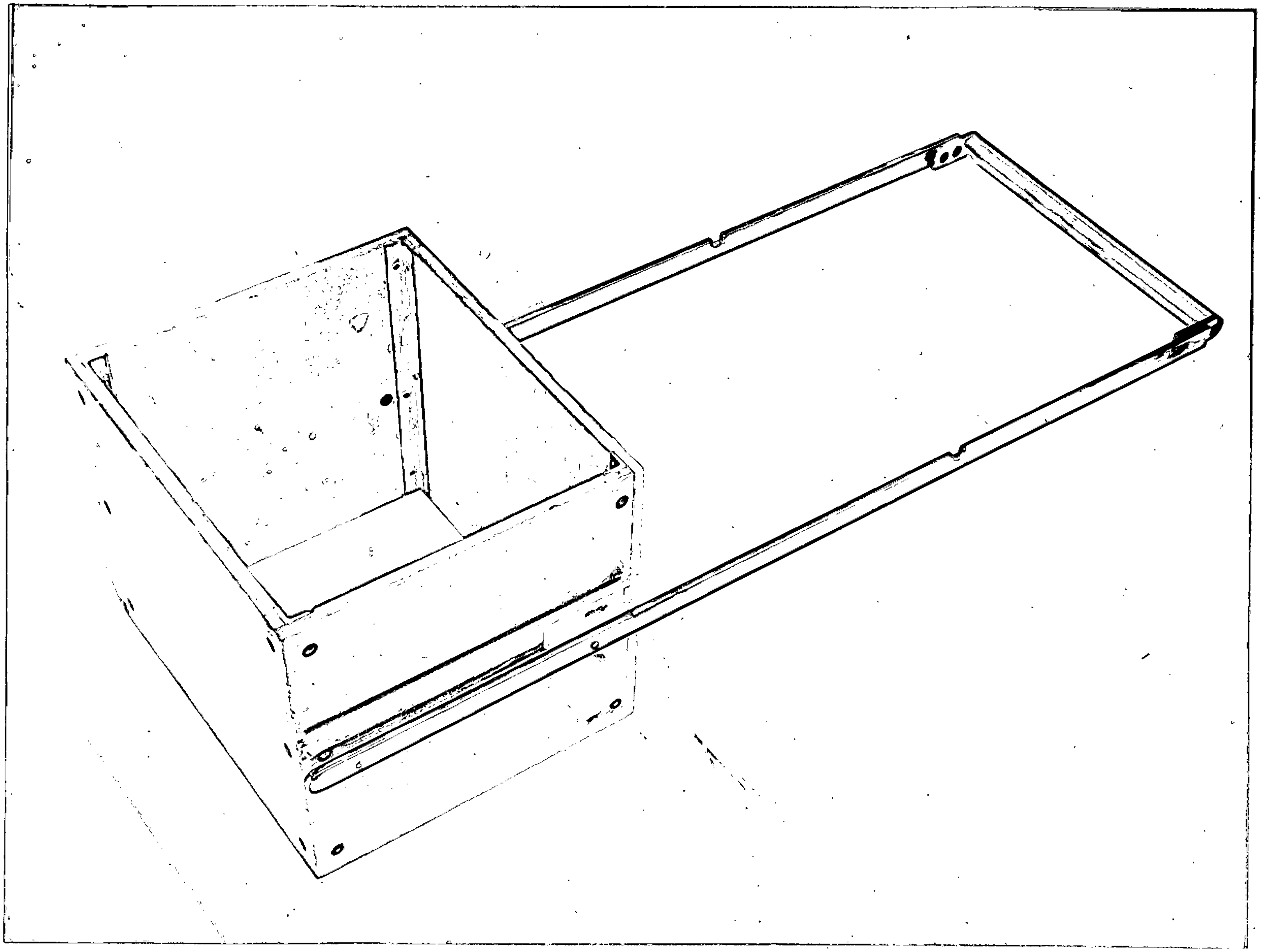

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Figure 19. Feeding Box for Experimental Feeding Mechanism
(Design No. 1)

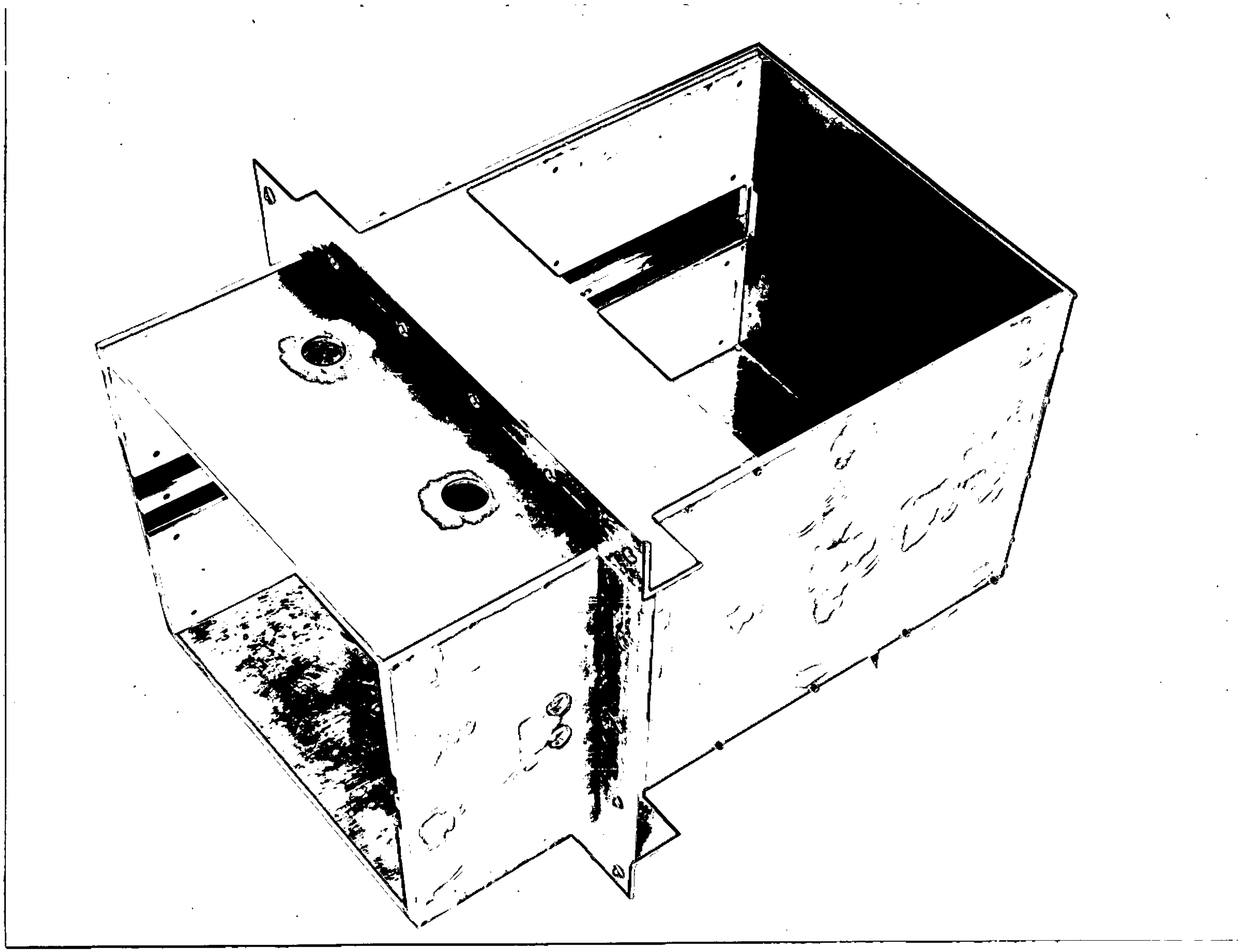

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Figure 20. Housing for Experimental Feeding Mechanism (Design No. 1)

to allow air from the blower to enter the housing; this air was used to cool the walls and to purge the chamber between the loading box and fire door when the mechanism was in the feeding position.

Figures 21 and 22 show the fire door which was fabricated from stainless steel sheet and rod. The door was of hollow (double wall) construction. The side facing the loading chamber was a flat plate with a series of holes of size and location such as to permit the cooling air to flow to and through the louvers in the curved plate which faced the inside of the incinerator. Thus, the air, at high velocity, passed through the hollow fire door when it was in the closed position, and cooled the surfaces and kept smoke and debris from entering the loading chamber.

Figures 23 and 24 illustrate the assembled unit in the loading position. This unit operated as follows: In order to feed, the operator pushes the loading box forward into the incinerator. The fire door remains closed until the front of the box contacts the back of the door; by that time, the latch at the end of each of the two fire-door guide rods has pivoted and the two pins in each latch have moved into slots in the loading-box and in the fire-door guide rods. Figure 25 presents the mechanism in the delivery or feeding position. As the operator pulls back on the handle attached to the loading box, the loading box moves back and the fire door also travels back to the closed position, at which time the latches are released. The operator can then pull the loading box back to the original loading position.

Test Results

A preliminary test run was made with the experimental feeding mechanism to observe the loading- and delivery-of-paper characteristics before it was

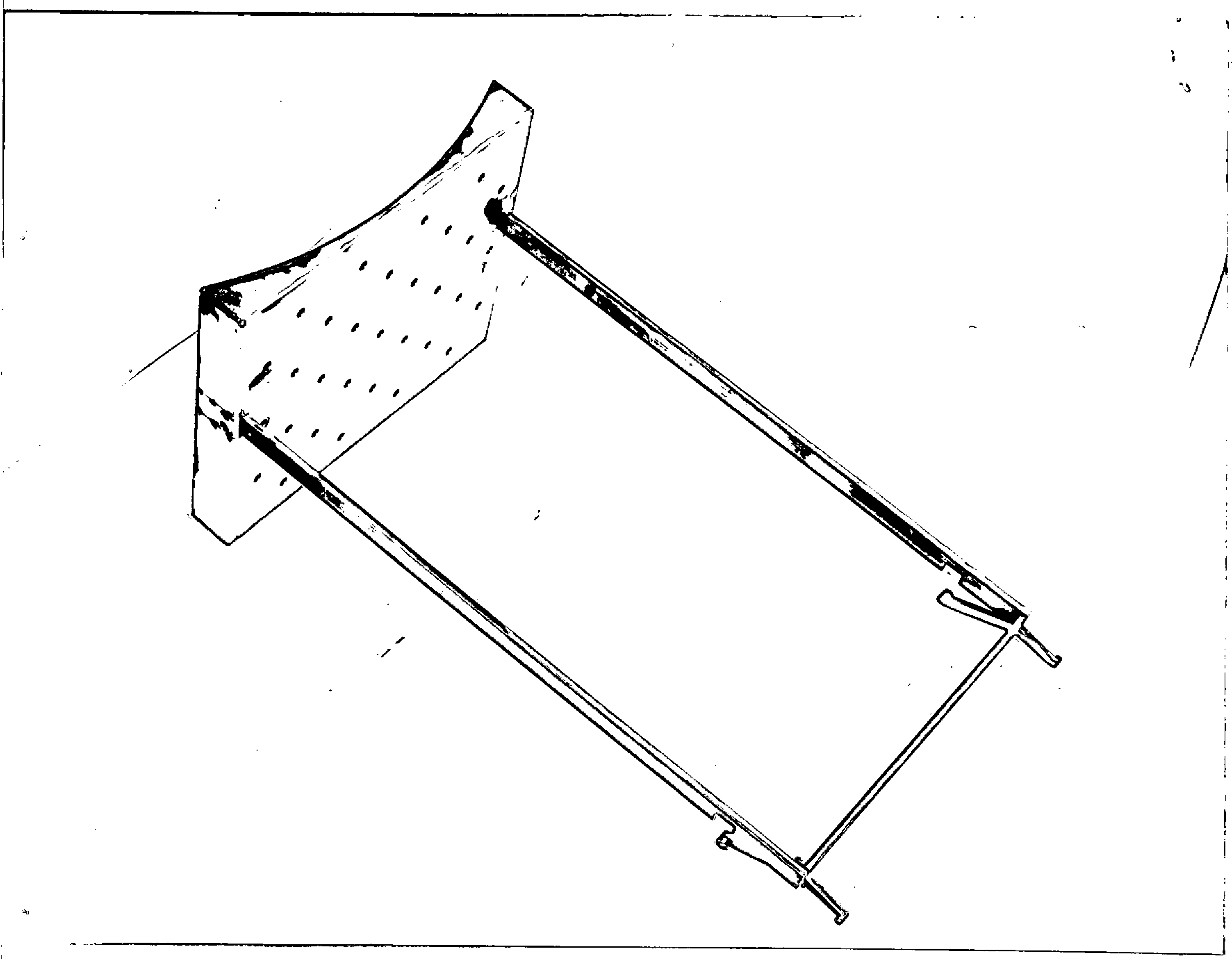

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Figure 21. Fire Door for Experimental Feeding Mechanism (Design No. 1)

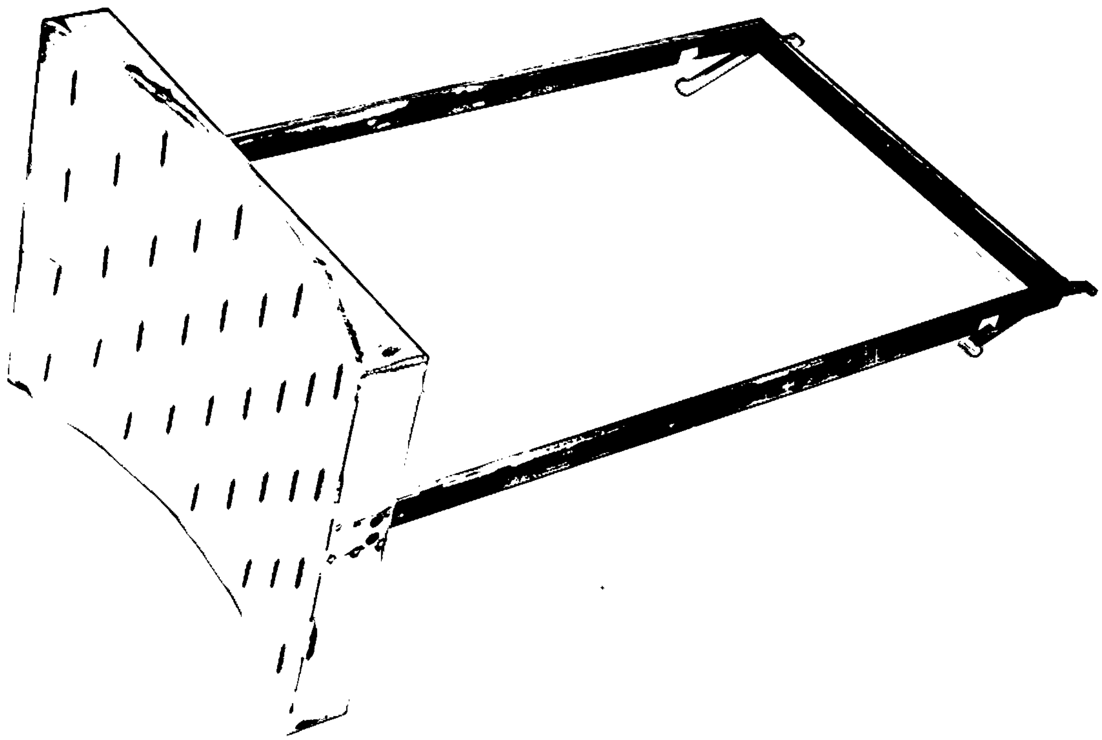

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Figure 22. Fire Door for Experimental Feeding Mechanism (Design No. 1)

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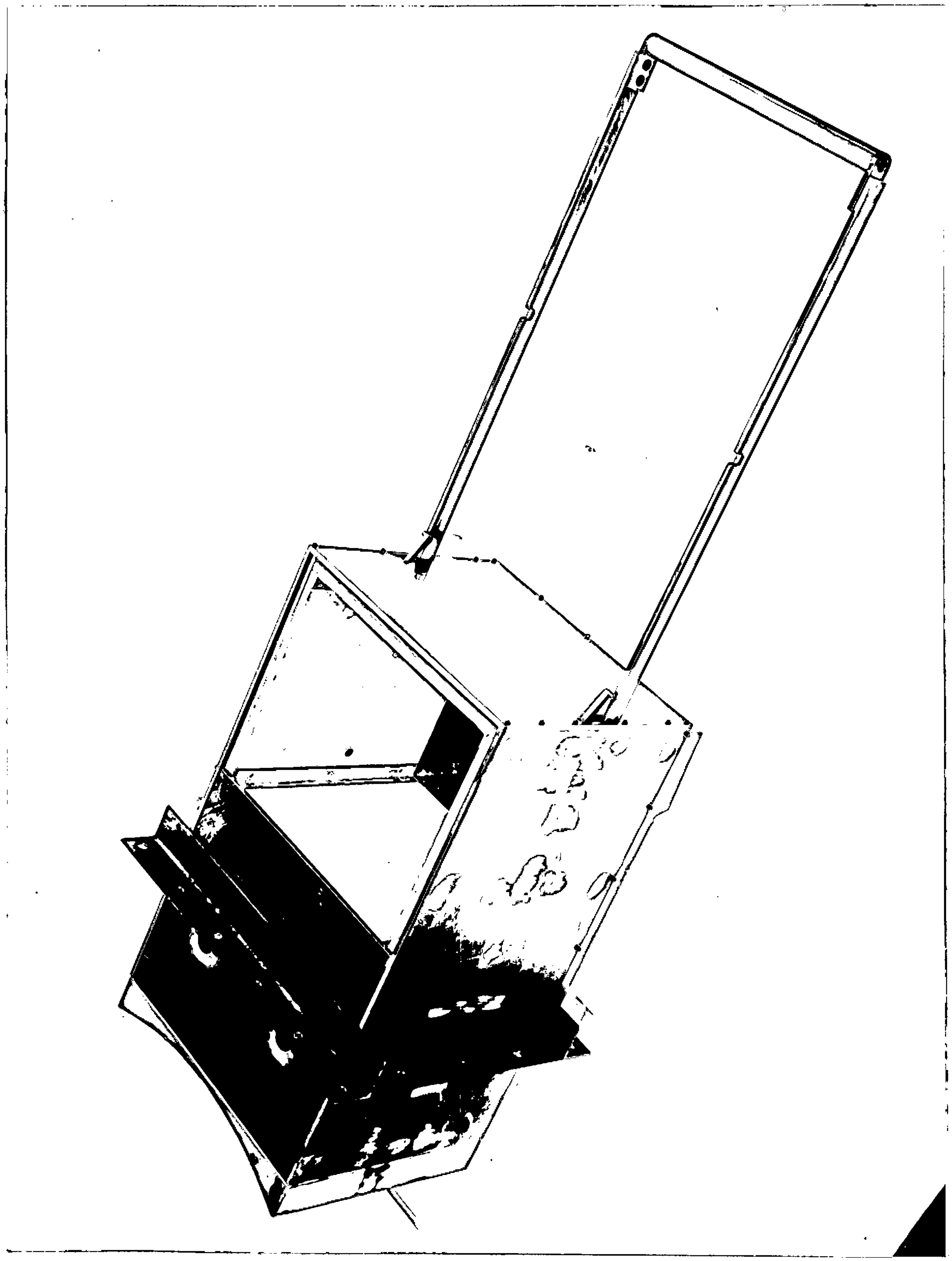

Figure 23. Assembled Experimental Feeding Mechanism (Design No. 1)

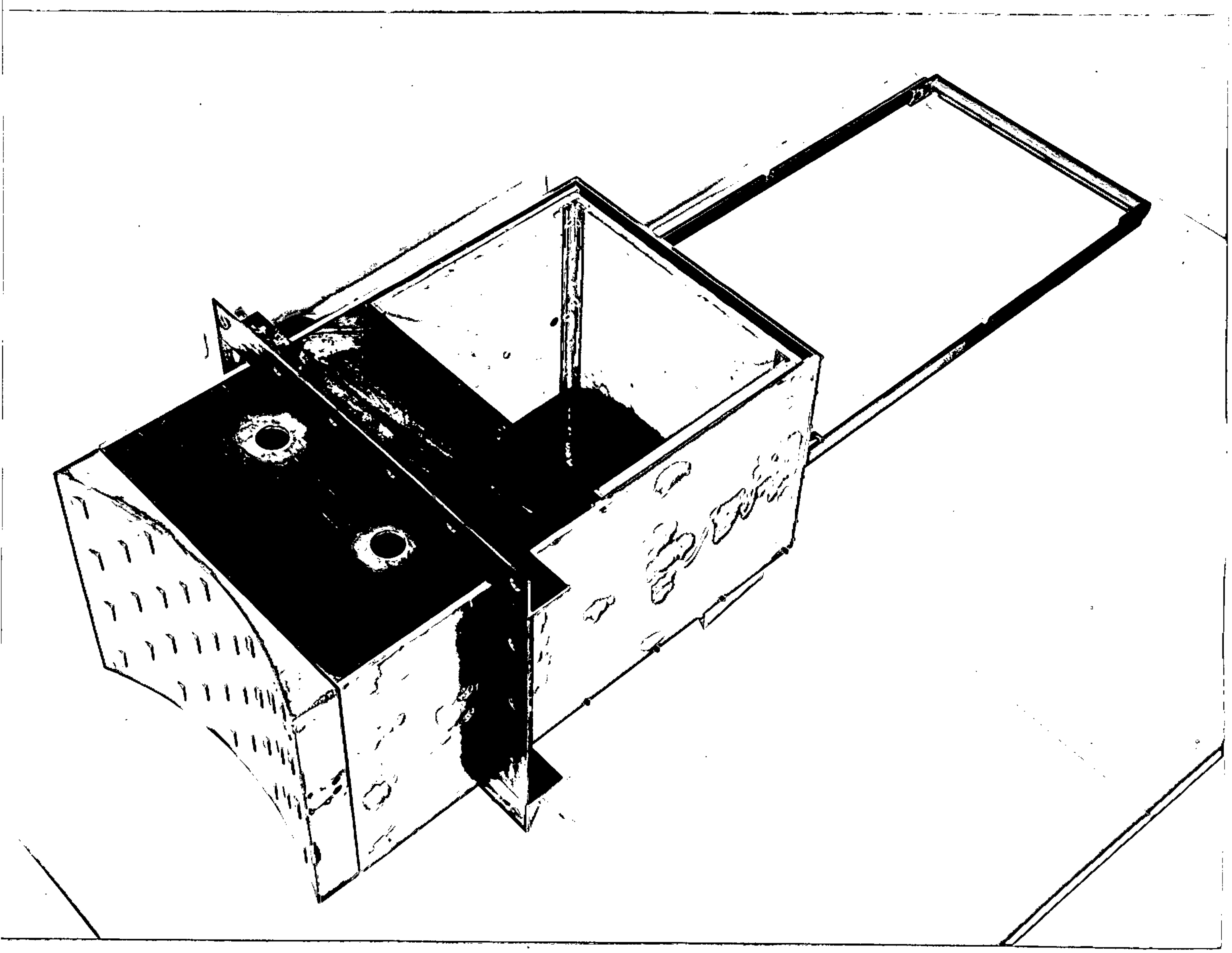

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Figure 24. Assembled Experimental Feeding Mechanism (Design No. 1)

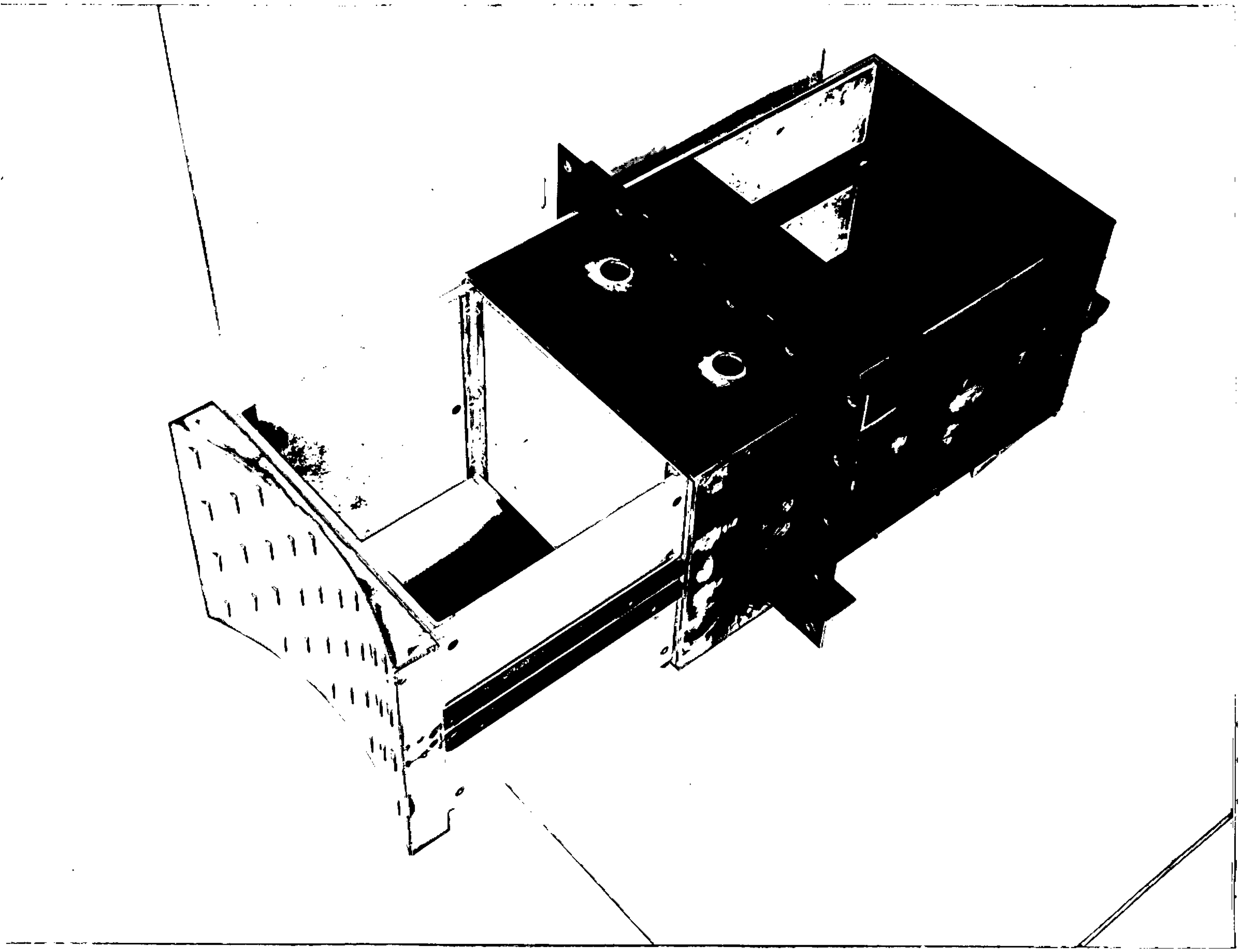

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Figure 25. Experimental Feeding Mechanism (Design No. 1) in the Feeding or Delivery Position

installed on the incinerator. The mechanism performed satisfactorily, and paper was delivered at a rate of over 500 lb per hr.

The mechanism was then installed on the experimental refractory-lined incinerator, and a number of tests were conducted to check out the feeding mechanism while the incinerator was operating. The following undesirable features were noted during these tests:

(1) The paper piled up in the combustion chamber close to the door area and was not evenly distributed across the bed.

(2) The piled-up paper slowed down and interfered with the feeding operation; on occasion, the fire door and loading box jammed on the return stroke.

(3) Smoke and fly ash were trapped in the loading box on the return stroke and were released into the room when the loading box was returned to the loading position.

In a subsequent meeting with the Sponsor, the tests were discussed and the following changes in the experimental feeding mechanism were agreed upon:

(1) Remove the sliding fire door and replace it with a hinged door to be located approximately 12 inches from the inner liner of the incinerator.

(2) Replace the loading box with a ram-type mechanism.

(3) Add a hinged cover to the loading zone of the feeding mechanism, to aid in preventing leakage of smoke and debris to the room when the ram delivered the paper into the incinerator.

It was expected that the above changes would permit the paper to be hurled across the combustion chamber and thus to be distributed more evenly over the bed. They would also obviate the need for any part of the mechanism to project into the hot combustion chamber during the feeding operation.

Design No. 2

The redesign of the experimental feeding mechanism involved the preparation of a layout incorporating the modifications discussed above and of the necessary detail drawings; the fabrication of the new parts; and the assembly and testing of the redesigned unit on the incinerator.

Description

The redesign of the feeding mechanism did not involve any significant changes in the housing, which was described previously. Modifications in the mechanism included the addition of a hinged cover at the loading zone, of a hinged fire door, and of a ram and guide rods. These are discussed in detail in subsequent paragraphs.

Various views of the modified feeding mechanism are shown in Figures 26 through 32. The hinged cover, which sealed off the loading chamber (from the room), was constructed from 1/2-in.-thick aluminum plate and 1-in.-thick Transite, and had an aluminum handle fastened at the front and top. The cover was fastened to a continuous aluminum hinge on top of the loading chamber. The loading-chamber cover is shown in the closed position in Figure 26 and in the open position in Figures 27 and 28. The 1-in.-thick Transite lining for the cover, as shown in Figure 27, was used to add weight to the cover, and also to make it impossible to load paper to a height in the loading chamber such that the paper might be

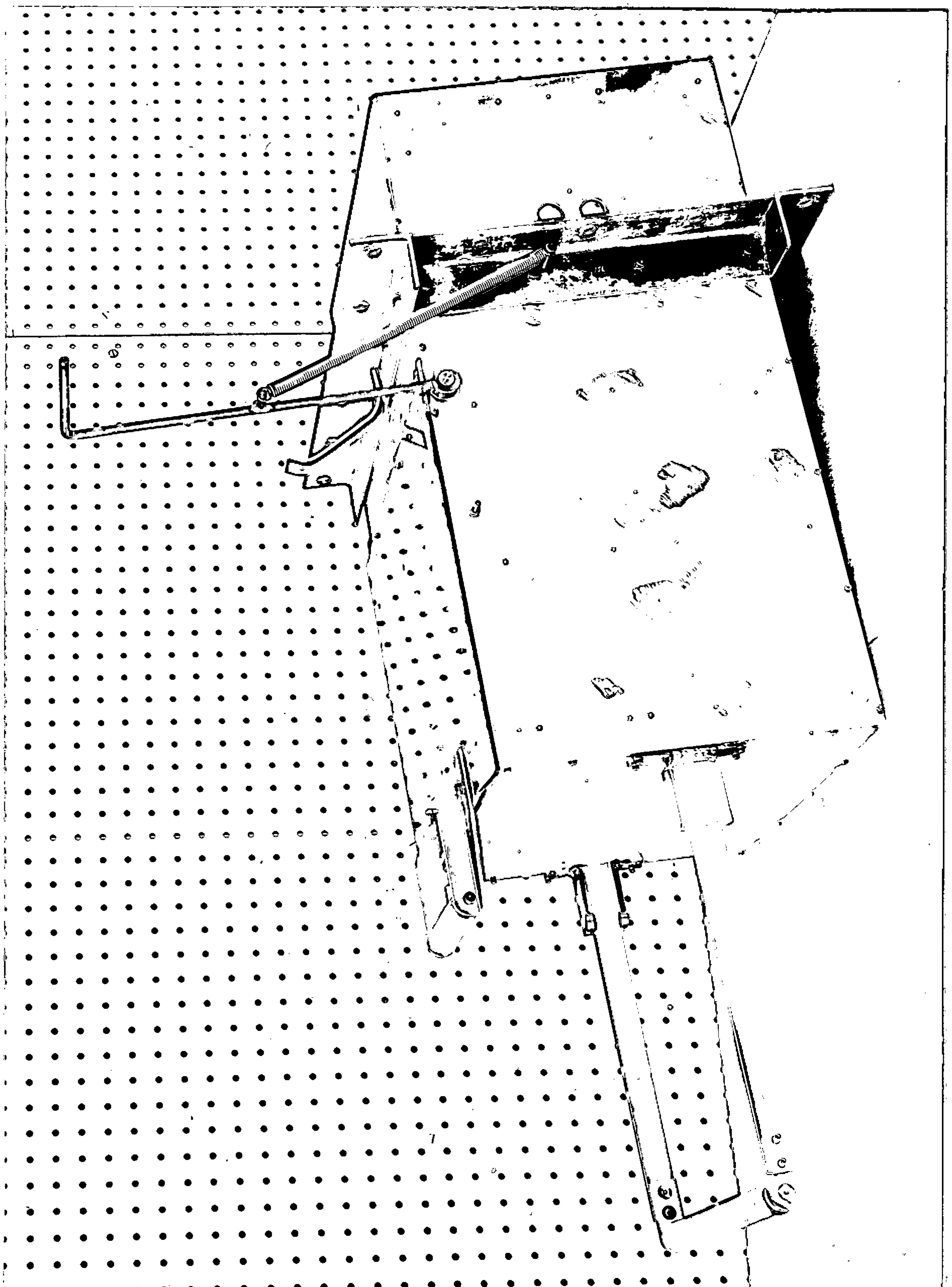

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Figure 26. Individual Feeding Mechanism With Loading-Chamber Cover Closed (Design No. 2)

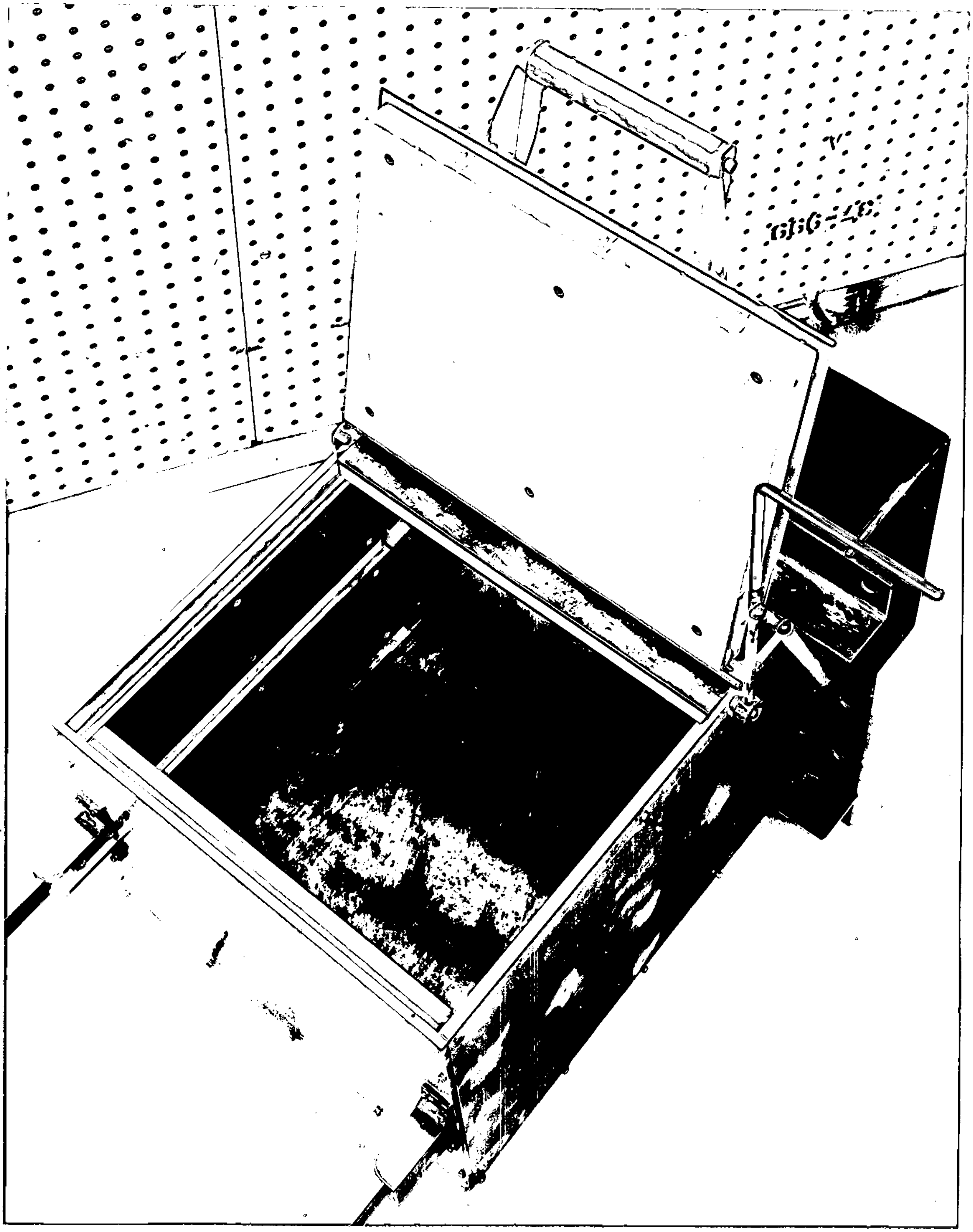

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Figure 27. Modified Feeding Mechanism With Loading-Chamber Cover Opened (Design No. 2)

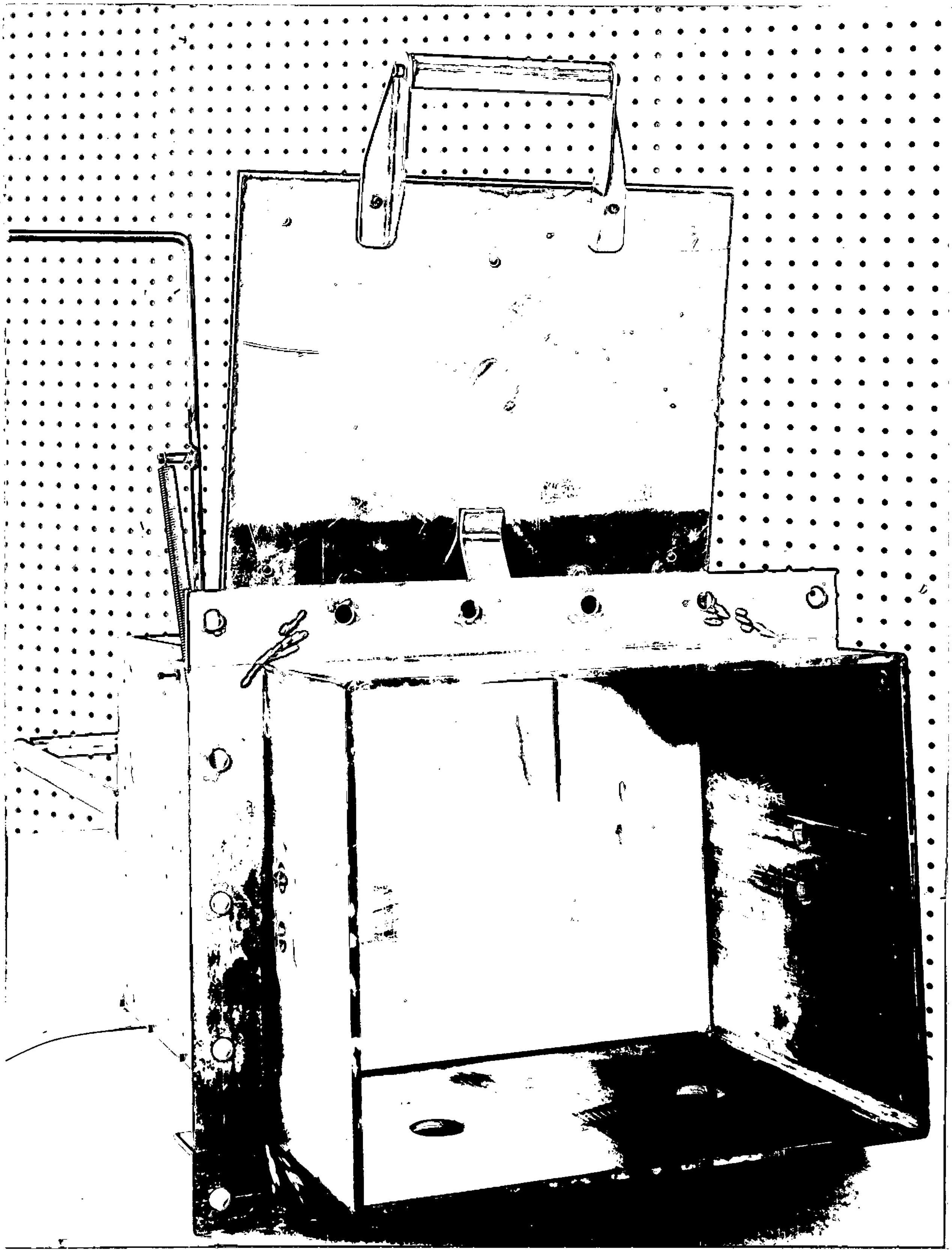

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Figure 23. Modified Feeding Mechanism With Loading-Chamber Cover Opened and Fire Door Closed (Design No. 2)

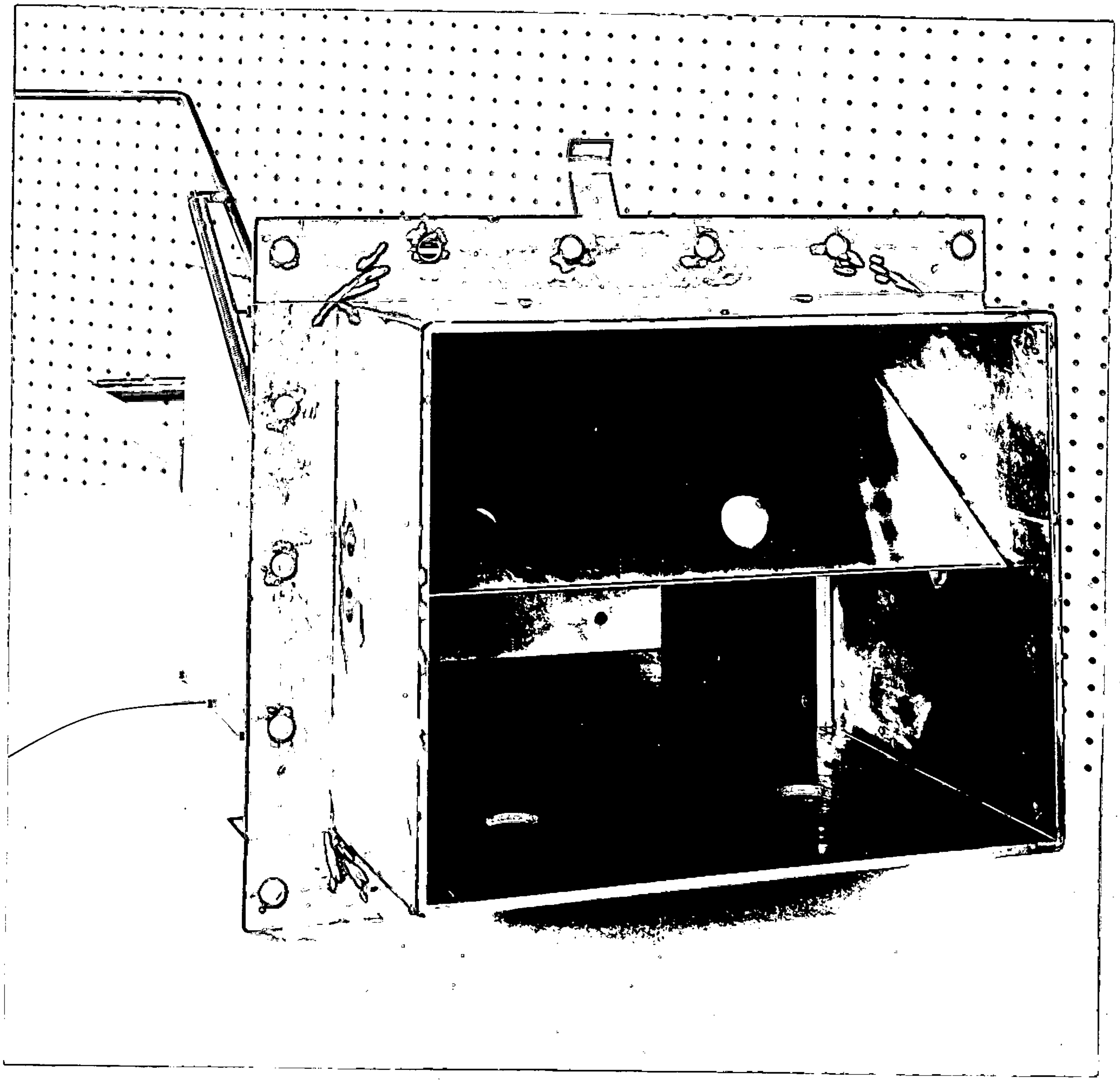

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Figure 29. Modified Feeding Mechanism With Fire Door Half Open (Design No. 2)

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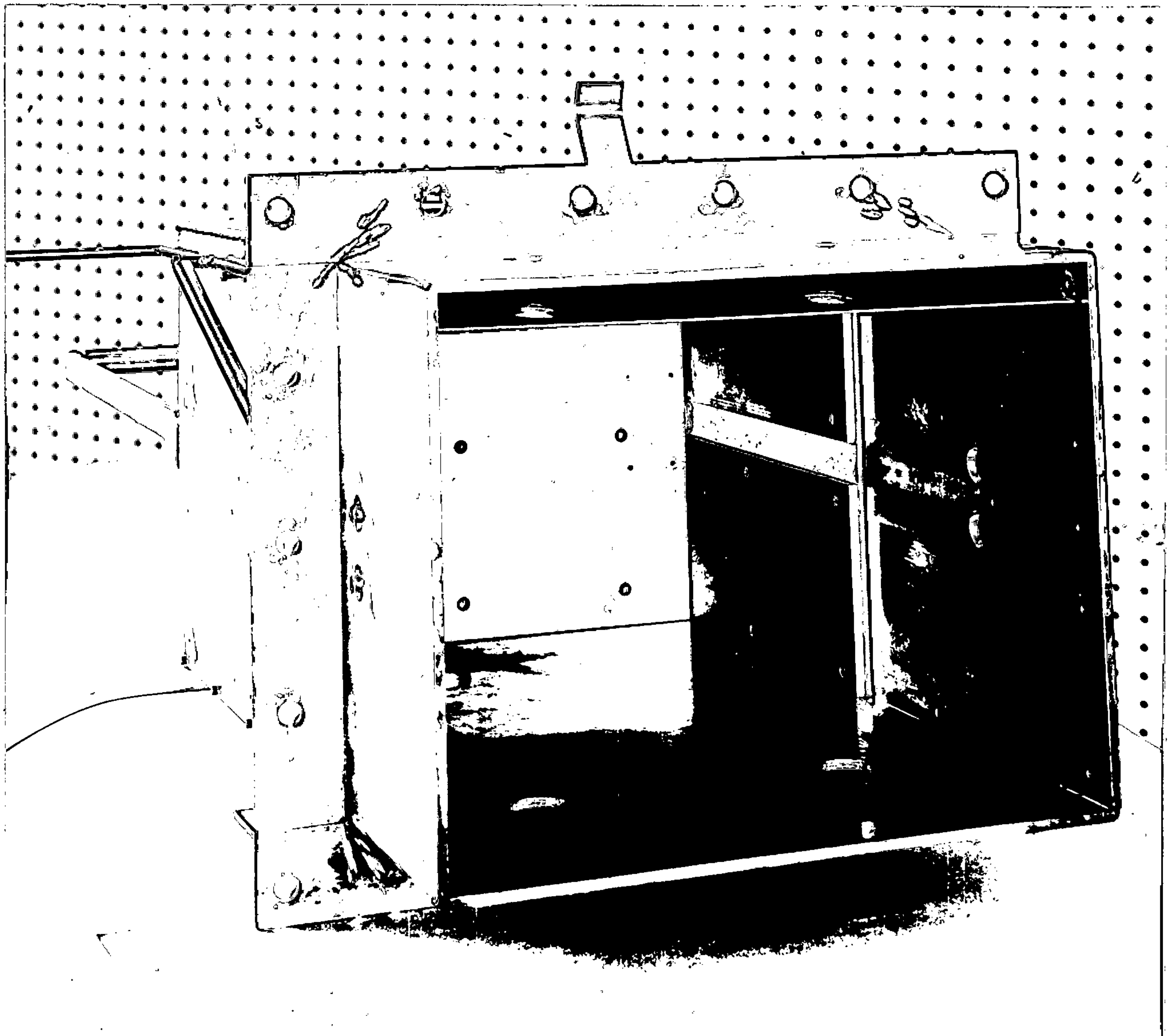

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Figure 30. Modified Feeding Mechanism With Fire Door Open (Design No. 2)

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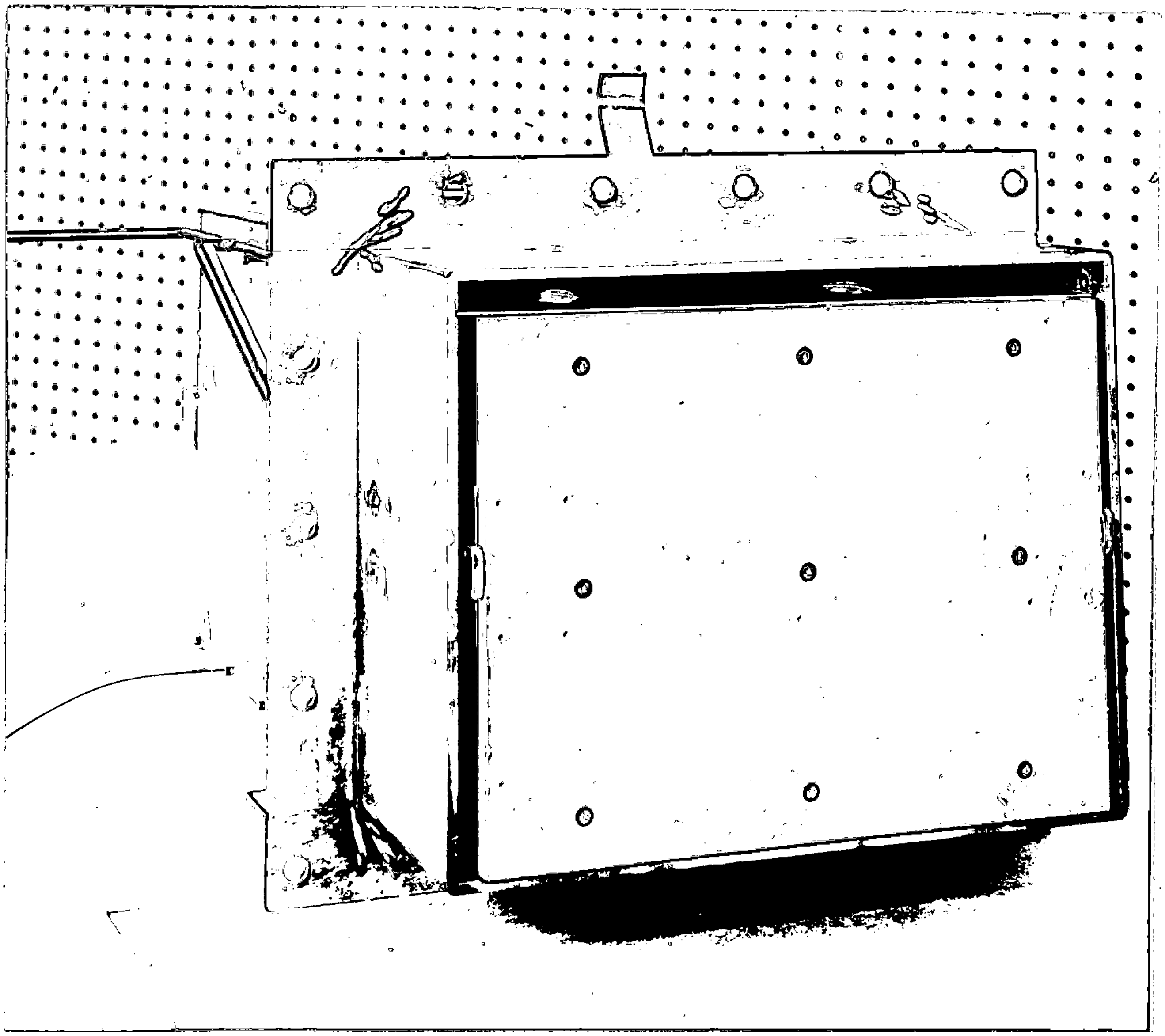

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Figure 31. Photograph of Feeder With Ram Pushed Forward

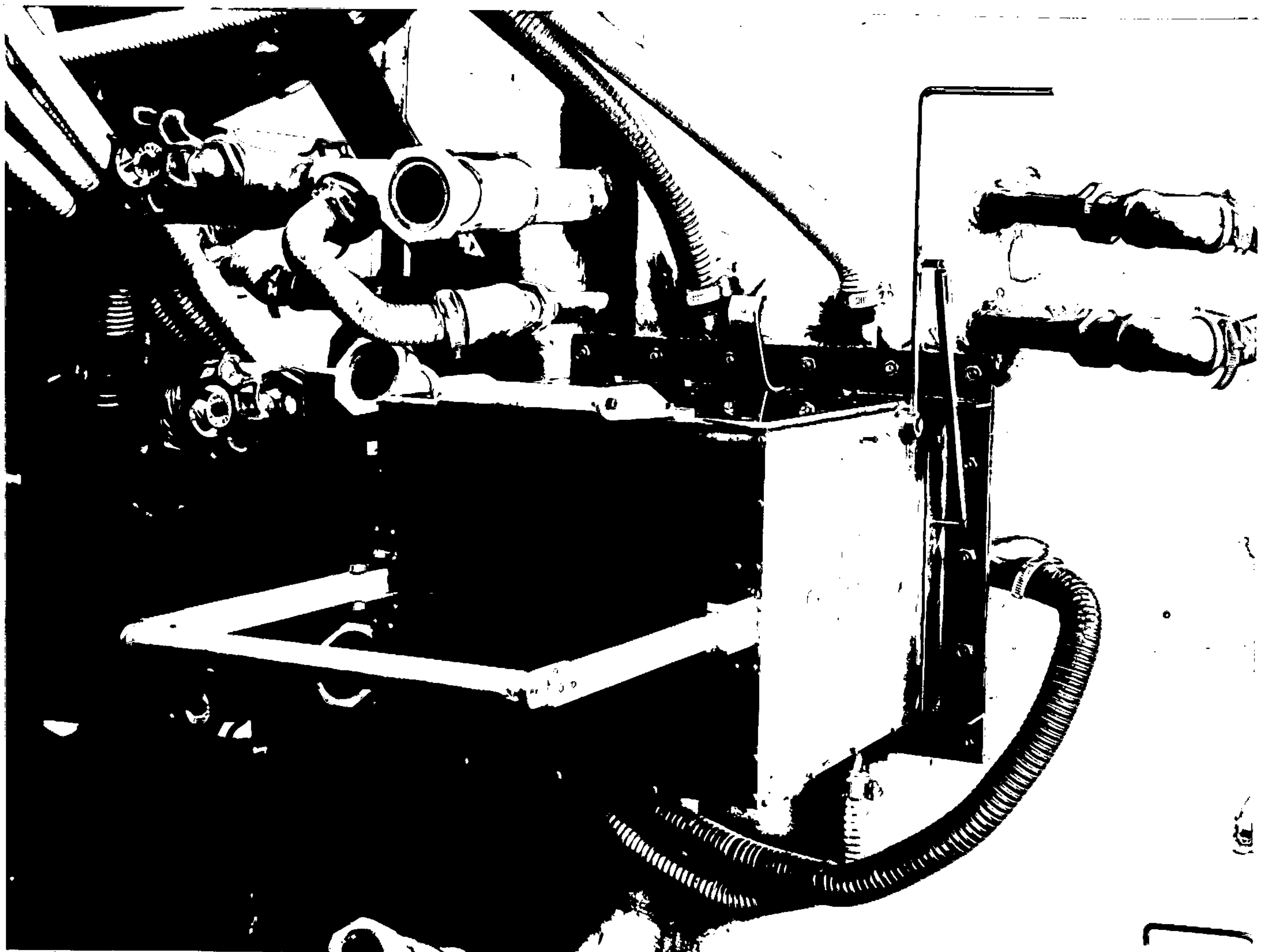

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Figure 32. Photograph of Feeder Attached to Incinerator

jammed between the top of the ram and the top of the fire door during the delivery stroke. A 1/8-in.-thick neoprene gasket was cemented to the underside of the aluminum cover, at the outer edges, to provide a seal for the loading chamber.

The fire door was fabricated from 16-gage stainless steel sheet and then fastened to a stainless steel rod at the top. The ends of the rod were positioned in brass bushings which were pressed into the sides of the housing. A handle, with an over-center spring, was then fastened to one end of the rod, to permit actuating the fire door. In the closed position, the door sealed against Transite at the top and sides, and was provided with sufficient clearance at the bottom to allow for thermal expansion. The fire door is shown in the closed, half open, and open positions in Figures 28, 29, and 30.

The ram face was fabricated from 1/2-in.-thick Transite sheet fastened to 1/4-in.-thick aluminum plate. The use of Transite, with its low coefficient of expansion, permitted fabrication with a maximum clearance of 0.015 in. between the ram face and the inside of the loading chamber. Steel guide rods were fastened to the aluminum plate with angle-iron brackets. The Transite face of the ram can be seen in the loading position in Figure 30 and in the extreme delivery position in Figure 31.

Figure 32 shows the feeding mechanism attached to the experimental refractory-lined incinerator. The following procedure was evolved for delivering paper into the incinerator:

(1) Open the loading-chamber cover

(2) Load paper

(3) Close the loading-chamber cover

(4) Open the fire door

(5) Ram the paper into the incinerator combustion chamber

(6) Return the ram to the loading position

(7) Close the fire door

(8) Open the loading-chamber cover and repeat the cycle.

Preliminary tests conducted prior to installation of the modified mechanism on the incinerator showed that the mechanism performed satisfactorily and could distribute the paper more evenly across the bed than could the previous design.

Test Results

A number of test runs were made after the modified mechanism was installed on the incinerator. The results of these tests and additional modifications which were made are discussed in detail in the following.

The first test run conducted revealed two major problems in the design. The first of these was occasional jamming of paper between the bottom of the ram and the loading-chamber housing. The second was the leakage of smoke and debris under the fire door and into the loading chamber. Modifications were then made to the ram and fire door in an attempt to eliminate these difficulties.

A spring-loaded steel plate was placed in a slot at the bottom of the Transite ram face, to prevent paper from slipping under the ram. Subsequent tests showed that the jamming was eliminated. A spring-loaded plate was also fastened to the bottom of the fire door, to obtain a floating seal and thus prevent smoke and debris from entering the loading chamber. During additional tests, the intense heat caused the springs of both plates to fail, and, as a result of the large quantity of debris in the combustion-chamber atmosphere, the fire-door plate jammed open. It was readily apparent from these tests that the major problem in the development and operation of any mechanism for feeding paper into the incinerator would be to prevent smoke and debris from entering the loading chamber. A decision was then made to investigate an air seal at the bottom of the fire door, and an air-purging system to blow the smoke and debris back into the incinerator before the loading-chamber cover was opened.

Temporary modifications were then made to the fire door, to obtain double-wall construction on the lower half of the door. Flexible tubing was fastened to the loading side of the door, to introduce sealing air to the space formed by the two walls of the lower part of the door. The idea was to cause clean air to flow out at high velocity under the bottom edges of the door and thus keep smoke and debris from passing under the door when it was in the closed position. A temporary air-purging system was also arranged to control the flow of clean air from the blower to the loading chamber so as to permit purging of the chamber prior to closing of the fire door.

Two test runs were then conducted to evaluate the air-sealing and -purging systems. Approximately 200 lb of paper were loaded into the incinerator initially because the temporary flexible hoses would have interfered with the normal feeding procedure. Suitable valves were installed in the air-seal and -purging lines to control the air flow from none to the maximum available through a 3-in.-diameter duct. An effective seal was maintained at the bottom of the fire door during the tests. The air-purging system was somewhat limited relative to the quantity of air flow available and did not remove all of the debris from the loading chamber. However, the system showed sufficient promise to warrant further investigation with a more permanent system, which could be designed for higher air flow and better distribution of the air to the loading chamber. Based on the results of these tests, it was decided that the feeding mechanism would be redesigned and modified to incorporate an air seal at the fire door and an air-purging system for the loading chamber as permanent parts of the experimental unit.

Design No. 3

A detailed layout was made of the experimental feeding mechanism incorporating a new completely double-walled fire door, an air-sealing system, an air-purging system, and suitable valves and ducting. The unit was redesigned to be attached to the refractory-lined incinerator and to be adaptable, with minor modifications, to the air-film-cooled incinerator. Detailed drawings were made, parts were fabricated, and the unit was assembled and attached to the incinerator. A number of test runs were conducted and the unit was demonstrated to the Sponsor on May 14, 1959.

Description

Figures 33 through 37 show the redesigned mechanism (Design No. 3) prior to installation on the refractory-lined incinerator. The modifications which were made included (1) a new completely double-walled fire door, (2) an air manifold on each side of the housing for the delivery of sealing air to the fire door, (3) a purging chamber, with a quick-operating blast gate, located at the rear of the loading chamber, (4) a series of holes in the ram face, and (5) suitable valves and ducting to permit control of the flow of air from the blower outlet to the feeding mechanism.

The new fire door was made up of two panels (sheets) of stainless steel held 1/2 in. apart by suitable spacers. A stainless steel tube was welded between the plates at the top of the door, and a separate steel shaft was inserted

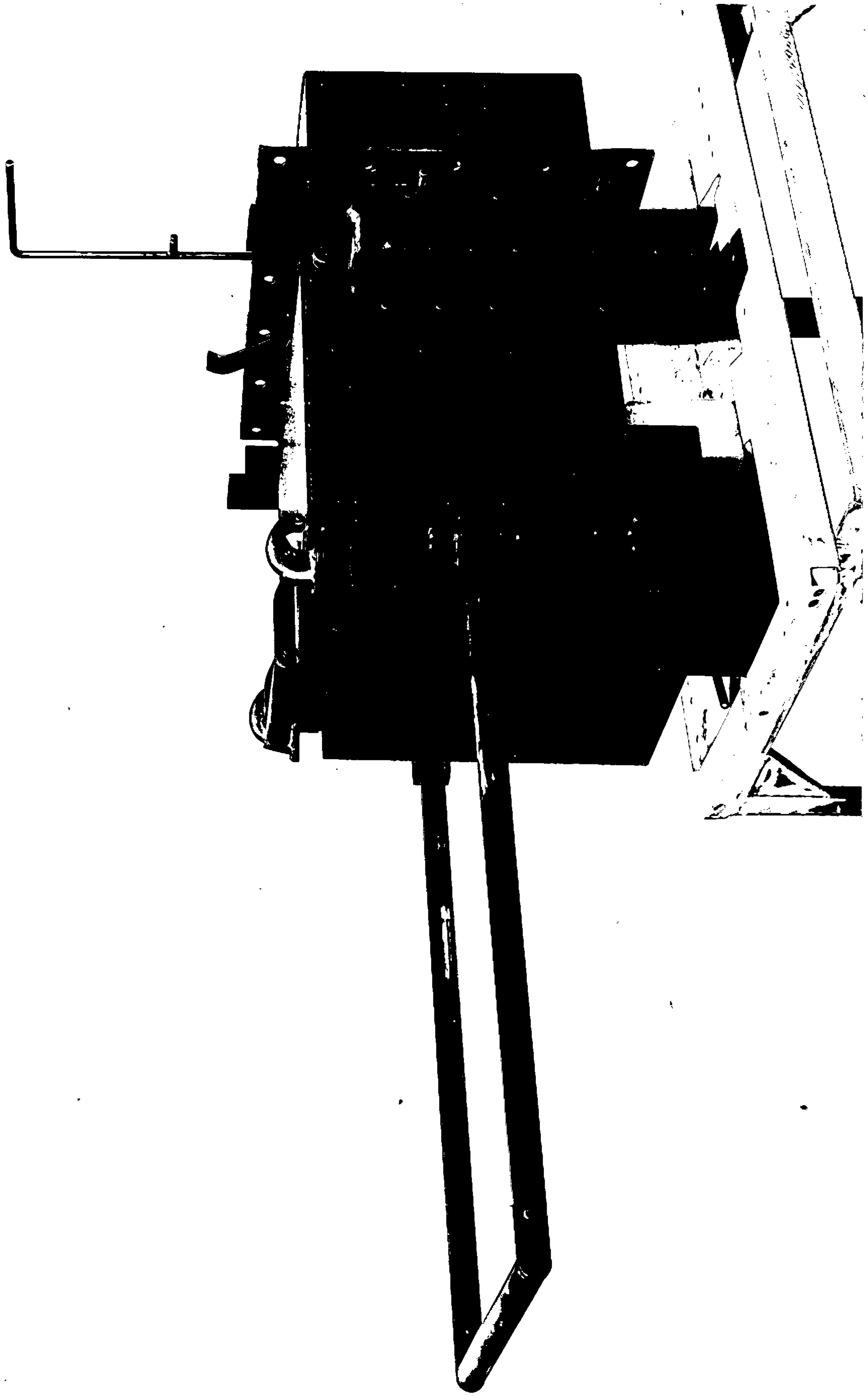

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Figure 33. Redesigned Feeding Mechanism (Design No. 3)

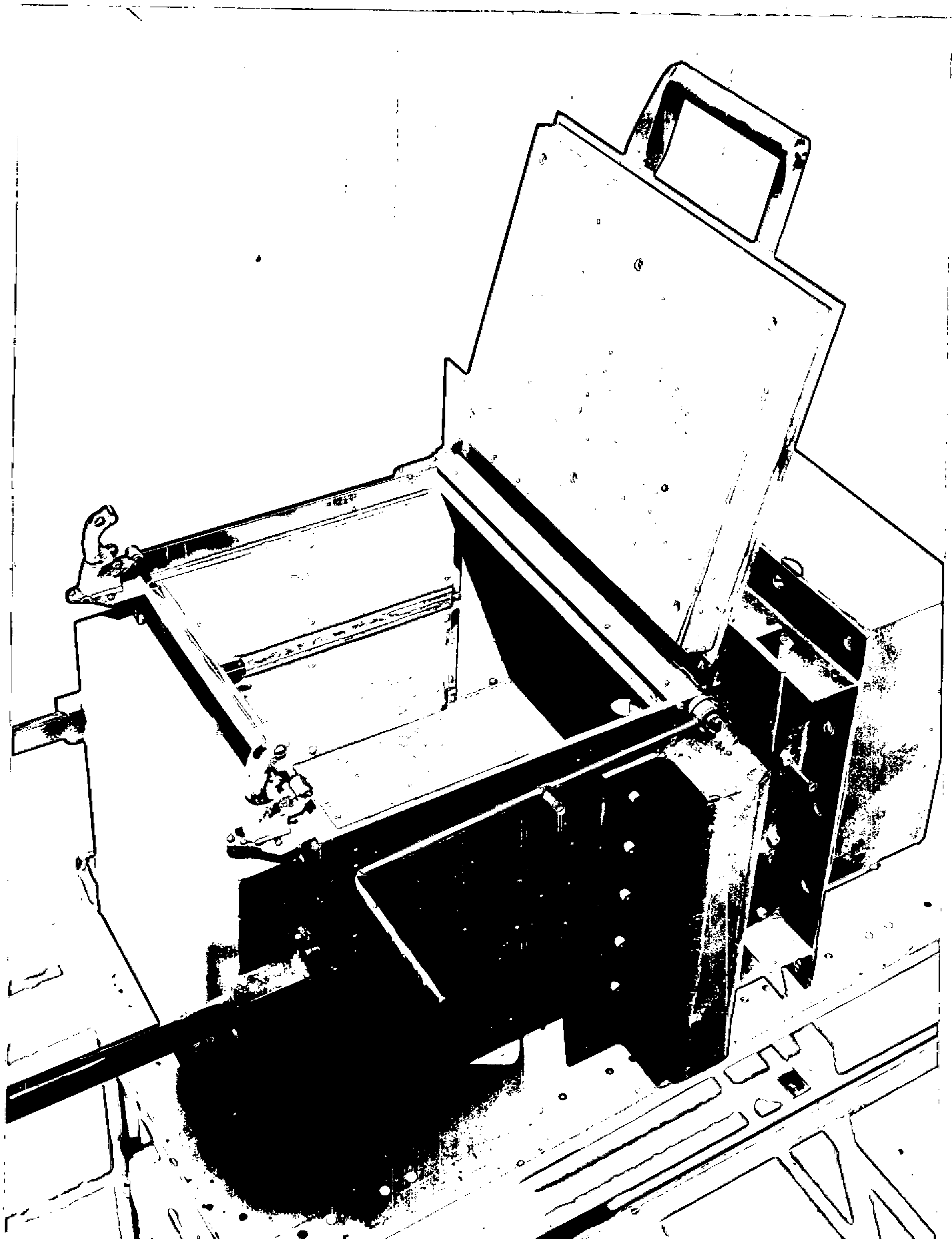

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Figure 34. Redesigned Feeding Mechanism With Loading-Chamber Cover Opened and Ram in Loading Position (Design No. 3)

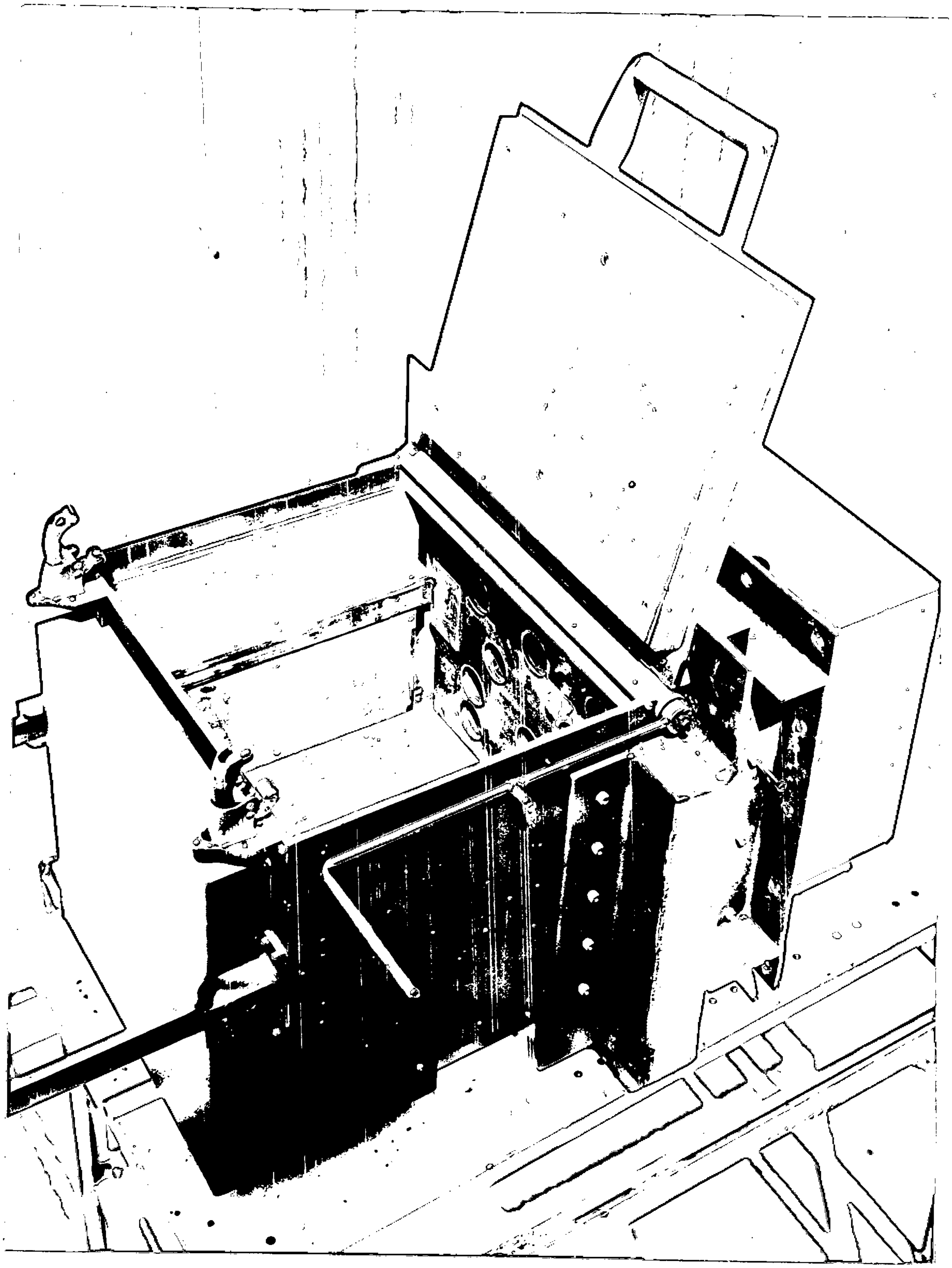

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Figure 33. Redesigned Feeding Mechanism With Loading-Chamber Cover Opened and Ram in Partial-Forward Position (Design No. 3)

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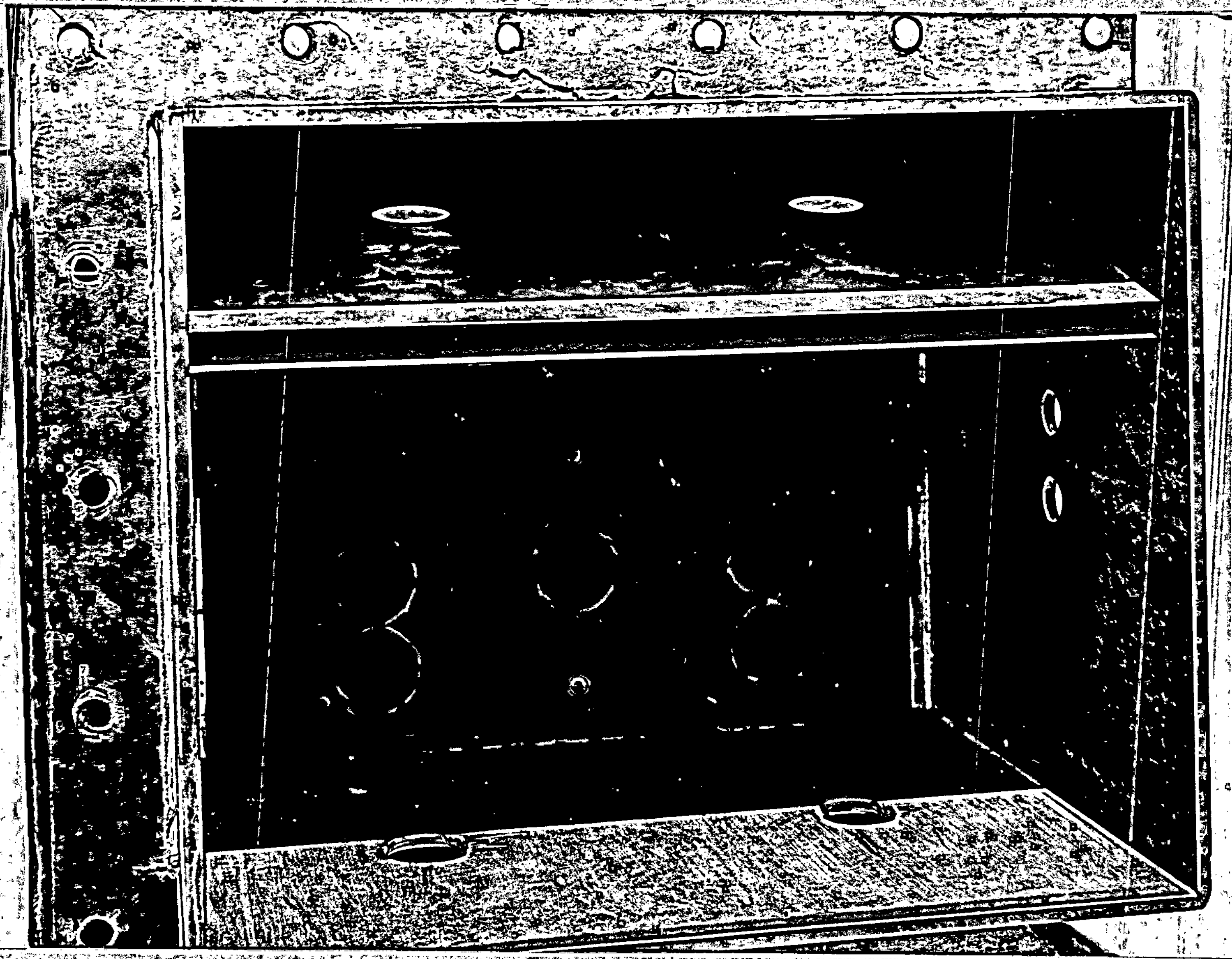

D58743

Figure 36. Redesigned Feeding Mechanism With
Fire Door Partially Opened

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N58744

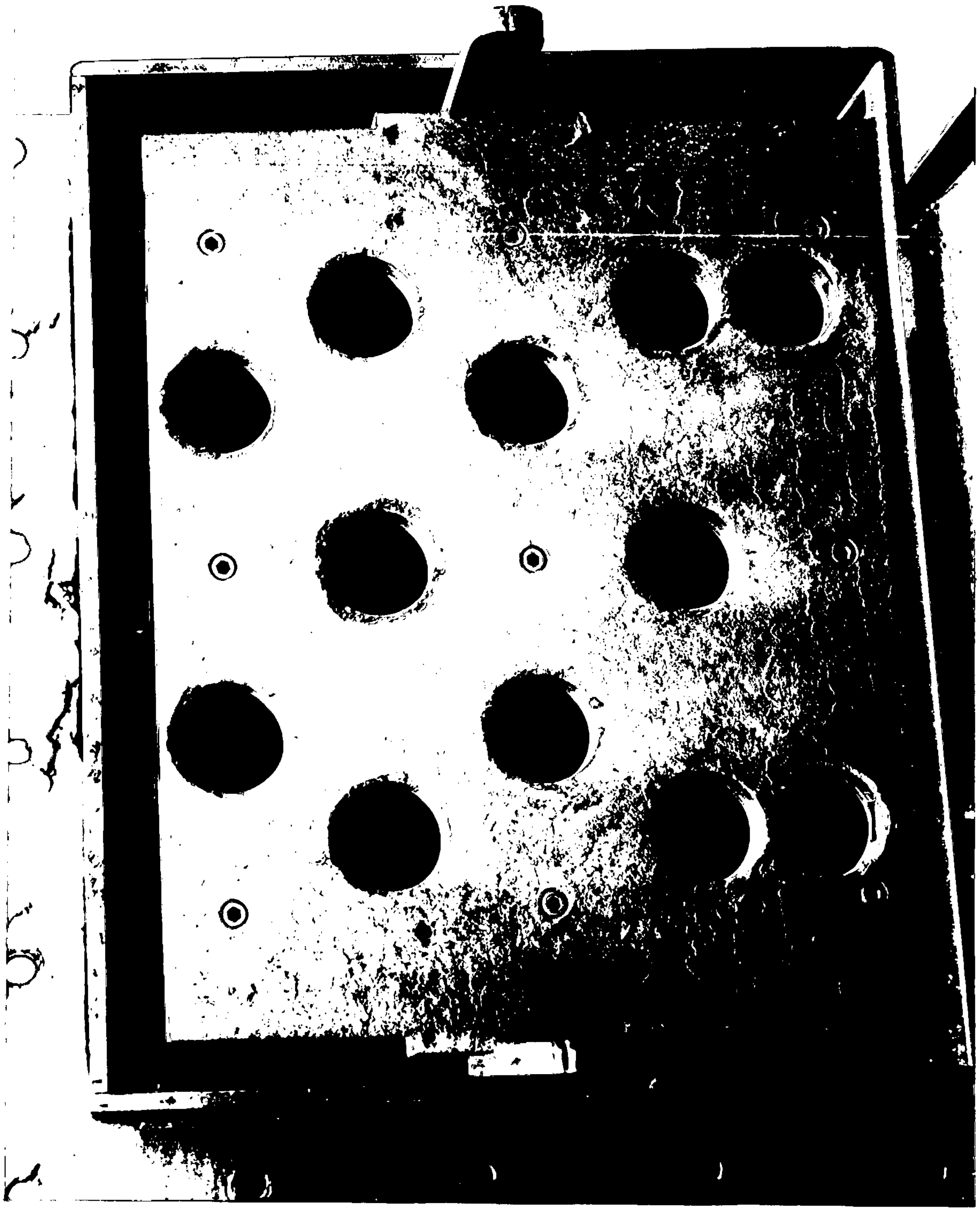


Figure 37. Redesigned Feeding Mechanism With Ram in Completely Forward or Feeding Position (Design No. 3)

through the support bushings and fastened to the stainless steel tube. This two-piece method of assembly permitted easy removal and replacement of the fire door. A clearance of 1/32 in. was maintained at the sides and bottom of the inner panel of the fire door when it was closed. Thus, when air was introduced to the space between the door panels, the air escaped at high velocity toward the combustion chamber and prevented smoke and debris from entering the loading chamber.

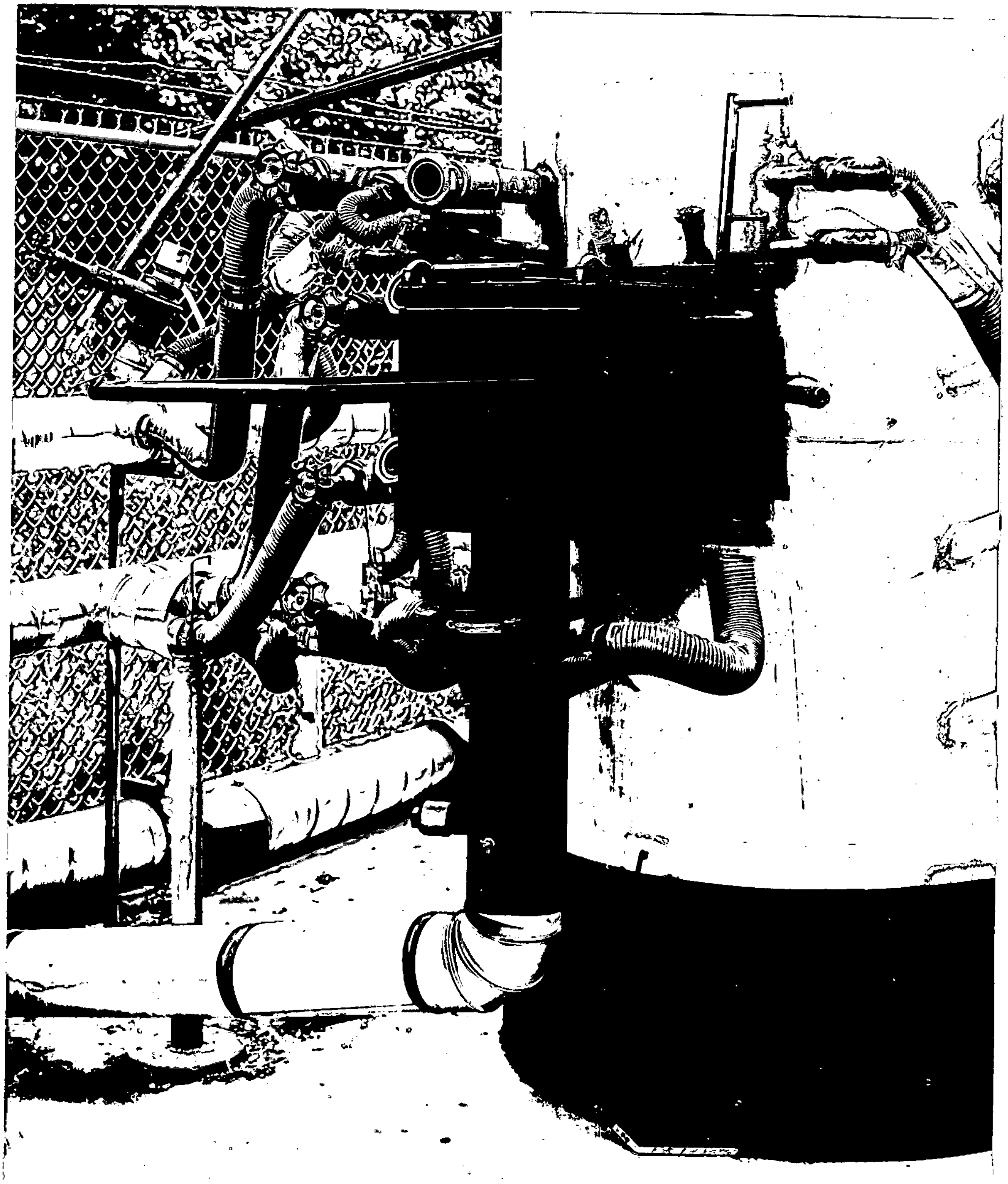
Two rectangular air manifolds, fabricated from aluminum angle, were installed at both sides of the loading chamber in line with the fire door. Slots 3/8 in. wide by 10 in. high were milled in each side plate of the loading chamber to permit air to enter the air space in the fire door. Air was introduced to the side manifolds through 3-in.-diameter sheet-metal ducts from the main 6-in.-diameter supply line. A butterfly valve was located in each 3-in.-diameter duct to permit control of the flow of air to each side manifold.

A purging chamber, fabricated from sheet metal, was installed at the loading end of the unit. Air from the main blower entered this chamber through a quick-operating sliding-gate valve in a 6-in.-diameter duct. The ram face was perforated with 1-in.-diameter holes, and the clearance at the sides was increased to permit purging air to flow through and around the ram on the return stroke.

Figures 38 and 39 show the redesigned feeding mechanism installed on the refractory-lined incinerator.

Test Results

Three test runs were made after the mechanism was installed on the refractory-lined incinerator. Minor mechanical difficulties were encountered with



D60057

Figure 38. Redesigned Feeding Mechanism Attached to Experimental Refractory-Lined Incinerator

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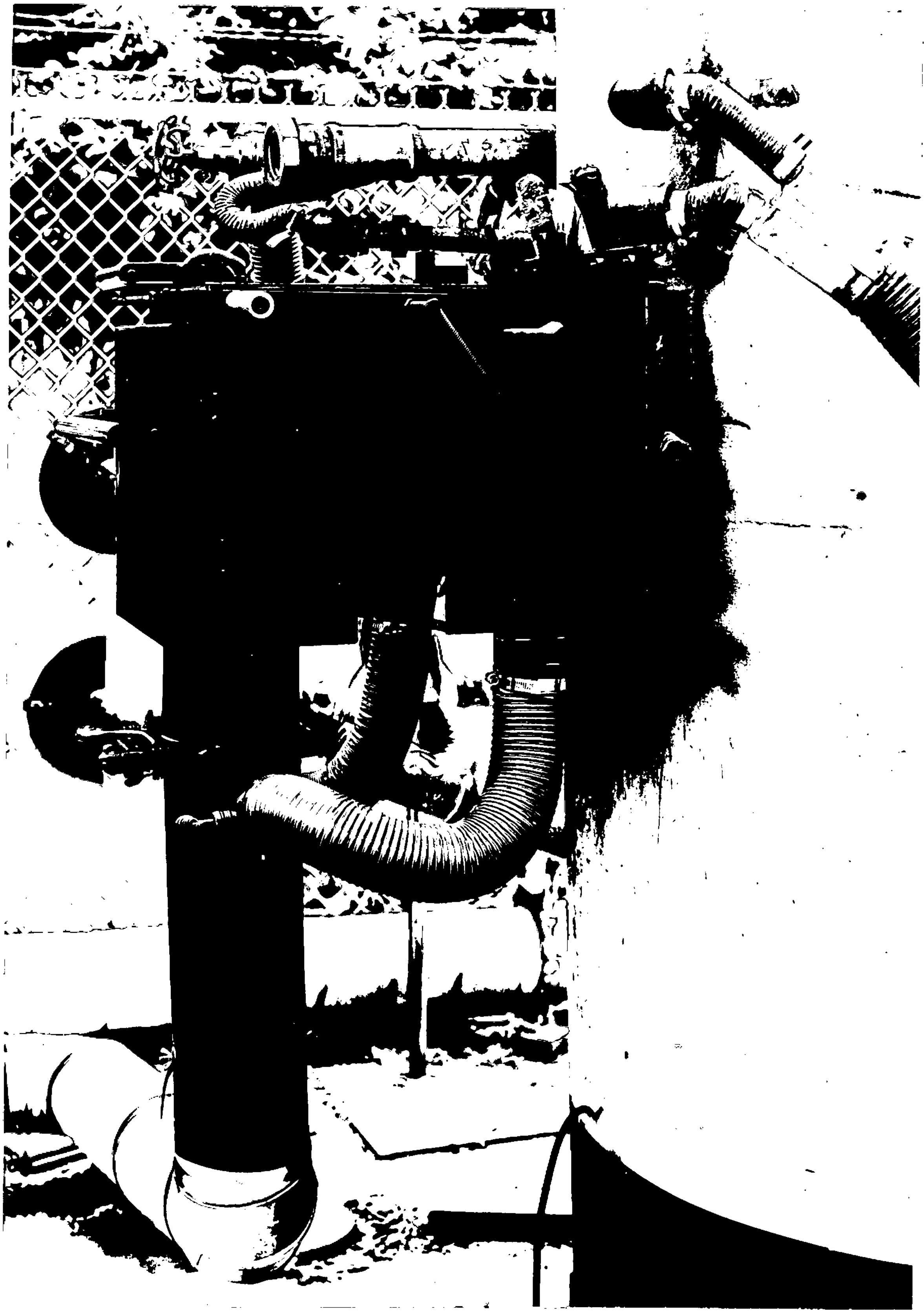

Figure [illegible]. Telescoped Feeding Mechanism Attached to Experimental Refractory-Lined Incinerator the fire door in the first two tests. These difficulties, which prevented the door from closing completely and sealing the loading chamber, were corrected and all moving parts worked satisfactorily in the final test.

The final test of the feeding mechanism on the refractory-lined incinerator was made on May 14, 1959. During this test, loose sheets of paper, crumbled paper, and packages of paper were fed into the incinerator. When normal air flow was maintained to the incinerator, the amount of air required to seal the fire door was such that the air flow into the loading chamber during the loading of small amounts of paper caused loose sheets of paper to be blown out of the chamber. This difficulty was not encountered in the loading and delivery of paper in batches of approximately 5 lb or more. When the air flow to the incinerator was reduced to the minimum, the amount of air required to seal the fire door was small enough to allow small amounts of loose paper to be placed in the loading chamber. Although a choice of loading conditions would eventually have to be made, it is believed that the air-sealing function was demonstrated satisfactorily. In addition, the purging function, as described in the previous section, was satisfactory.

Demonstration of Experimental Feeding Mechanism on Prototype Incinerator

After the second prototype incinerator (air-film cooled) was completed, the experimental feeding mechanism was modified slightly to fit the opening in the unit. Air for purging and sealing was taken from the blower shroud of the incinerator air-damper throttle, so as to maintain a continuous source of air. During trials of the feeding mechanism, it was found that the air flow to the incinerator had to be reduced to the "1/4" position of the air-damper throttle while feeding, in order to avoid excessive temperatures from flash burning of the loose, dropping paper. The sealing and purging operations were satisfactory and distribution of paper in the combustion chamber was acceptable.

During demonstrations for the Sponsor on December 16, 1959, the experimental feeding mechanism was installed again on the prototype air-film-cooled incinerator and one short trial run was made. Again, the operation of the feeding mechanism was quite satisfactory.

Conclusions

The experimental paper-feeding mechanism represents a good device for feeding paper intermittently to the Model 1 incinerator. It appears that this unit is capable of permitting unskilled personnel to feed papers and documents into the Model 1 or a similar incinerator conveniently and without personal discomfort, and also without disturbing the combustion process significantly.

FUTURE WORK

Because of the demonstrated performance of the air-film-cooled prototype incinerator for the destruction of paper at rates between 200 and 500 lb per hr, the Sponsor envisioned smaller size units of the same type to fulfill the needs where lower rates of burning would serve the purpose. After discussions with the Sponsor and his associates, it appeared that two smaller sizes would be highly desirable.

For example, a Model 2 unit, capable of about one quarter to one third of the burning rate of the Model 1, would fulfill a definite need. It was estimated that the Model 2 could have about the same height as the Model 1, but should be about 24 in. in maximum diameter rather than 42 in. In addition, as a result of making the combustion chamber shorter, it may also be possible to locate the air blower below the combustion chamber, but still within the common outer shell of the assembly, to give a compact unit with an attractive appearance.

(At the Sponsor's request, a proposal which provided for a research program directed toward the development of the above-described, reduced-size unit was submitted. This effort was subsequently initiated under Task Order No. [illegible].)

A still smaller, miniature-size, incinerator was also visualized by the Sponsor, for routine daily destruction of papers in a small office. A desirable size for this type of unit would be about [illegible] in. in height and [illegible] in. in diameter. The separation and collection of a substantial part of the fly ash would also be a goal for such a unit, to permit the flue gases to be discharged unobtrusively from a stack or vent pipe.

(At the Sponsor's request, a proposal which described a research program directed toward the development of such a miniature-size incinerator was submitted. This effort was subsequently initiated under Task Order No. [illegible].)

The auxiliary stand-by blower driven by a gasoline engine, which was assembled for demonstration purposes, is not the optimum arrangement for use with the Model 1 incinerator. The use of an integral assembly or a remotely located gasoline-engine-driven electric generator is being considered by the Sponsor. (Subsequently, a proposal was submitted and an effort was set up under Task Order No. [illegible], Work Order No. [illegible], that was directed toward the development of an integrated electric-motor- and gasoline-engine-driven blower assembly for use with the Model 1 incinerator.)

Each installation of the Model 1 unit may require custom-made stack ducting. However, there may be merit in the Sponsor selecting a few typical designs, in an attempt to fulfill the needs of the majority of installations, as anticipated.

Further attention to the collection of fly ash from the Model 1 or subsequent models will undoubtedly be needed in order to achieve acceptance of these units in geographical areas which are particularly conscious of air pollution, and in order to satisfy security requirements. (To this end, a proposal dated August 10, 1960, was submitted to the Sponsor that described a feasibility study of the various methods of cleaning the stack gases of incinerators such as the Models 1 and 2 units.)

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7. B. O. Buckland and D. C. Berkey, "Combustion System for Burning Bunker C Oil in a Gas Turbine", Mechanical Engineering, 1949, Vol. 71, p. 167.

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APPENDIX 1

MODEL 1 INCINERATOR WORKING-DRAWING NUMBERS AND DESCRIPTIONS

Drawing No.	Description	Drawing No.	Description
354-100	Incinerator assembly	354-208	Bottom plate assembly
-101	Outer shell top assembly	-209	Damper housing assembly
-102	Outer shell middle assembly	-210	Door liner
-103	Bottom assembly outer shell	-211	Duct assembly
-104	Top liner assembly	-212	Door frame assembly
-105	Liner middle section assembly	-213	Firing door front panel assembly
-106	Liner lower section assembly	-214	Inspection door screw assembly
-107	Liner bottom cone assembly		
-108	Inner liner base cone assembly	-215	Latch assembly
-109	Reflector assembly	-216	Handle weldment
-110	"V" band assembly	-217	Clamp band assembly
-111	Basket assembly	354-300	Base plate
-112	Handle assembly	-301	Stiffener
-113	Liner bottom section assembly	-302	Stiffener
-114	Door assembly	-303	Side plate
-115	Stack ring assembly	-304	Damper housing panel
354-202	Butterfly assembly	-305	Bracket
-203	Inspection door assembly	-306	Control plate
-204	Door channel assembly	-307	Duct side
-205	Door stiffener	-308	Duct side
-206	Frame	-309	Duct panel
-207	Frame assembly	-310	Duct panel

Drawing No.	Description	Drawing No.	Description
354-311	Duct flange	354-336	Bracket
-312	Damper blade	-337	Bracket
-313	Damper center tube	-338	Washer
-314	Damper shaft	-339	Spring retainer
-315	Spacer	-340	Pivot bar
-316	Collar	-341	Door stiffener
-317	Stop	-342	Door stiffener
-318	Screw	-343	Door inner liner
-319	Handle	-344	Door inner flange
-320	Washer	-345	Door shield
-321	Inspection door	-346	Door front
-322	Gasket	-347	Door gasket
-323	Channel	-348	Door gasket
-324	Nut	-349	Washer
-325	Shield	-350	Cotter pin
-326	Basket bottom	-351	Screw
-327	Basket top band	-352	Nut
-328	Hanger	-353	Latch cam
-329	Wedge	-354	Latch handle
-330	Corner fill	-355	Pivot block
-331	Door frame side	-356	Link
-332	Door frame top and bottom	-357	Screw
-333	Nozzle	-358	Washer
-334	Nozzle	-359	Cap screw
-335	Nozzle	-360	Nut

Drawing No.	Description	Drawing No.	Description
354-361	Cap screw	354-386	Cover
-362	Nut	-387	Cover
-363	Hinge pin	-388	Screw
-364	Nozzle	-389	Trigger rod
-365	Pivot bar	-390	Set screw
-366	Bracket	-391	Radiation shield
-367	Hinge	-392	Handle
-368	Latch block	-393	Screw
-369	Door frame	-394	Spring
-370	Door frame	-395	Spring
-371	Stiffener	-396	Flange gasket
-372	Frame	-397	Cap screw
-373	Frame	-398	Sight glass
-374	Frame	-399	Gasket
-375	Handle	-400	Sight glass holder
-376	Stiffener	-401	Sight glass nut
-377	Grab rail	-402	Latch
-378	Pivot angle	-403	Nut
-379	Handle	-404	Lock washer
-380	Handle hub	-405	Spacer
-381	Ball	-406	Central cone top section
-382	Slide	-407	Seal strip
-383	Slide	-408	Basket
-384	Spring	-409	Liner upper cone lower flange
-385	Jam nut	-410	Liner upper cone upper flange

Drawing No.	Description	Drawing No.	Description
354-411	Central cone middle section	354-435	Clamp
-412	Central cone bottom section	-436	Clamp band
-413	Central cone base ring	-437	Blower
-414	Liner middle section	-438	Duct flange gasket
-415	Liner lower section	-439	Cap screw
-416	Liner bottom cone	-440	Nut
-417	Liner upper cone	-441	Lock washer
-418	Sight glass nipple	-442	Clamp block
-419	Sight glass nipple	-443	Clamp block
-420	Vent pipe ring	-444	Set screw
-421	Coupling flange	-445	Lock washer
-422	Outer shell top ring	-446	Lock washer
-423	Coupling flange	-447	Nut
-424	Top ring outer shell	-448	Lock washer
-425	Outer shell flange		
-426	Outer shell top cone		
-427	Middle section outer shell		
-428	Bottom section outer shell		
-429	Inspection port ring		
-430	Reflector shield		
-431	Reflector shield		
-432	Reflector shield		
-433	Reflector shield		
-434	Flexible duct		

APPENDIX 2

ANTICIPATED FABRICATION PROBLEMS AND RECOMMENDED SOLUTIONS

During the development of the second prototype unit and the preparation of the working drawings, it was noted that 11 points should be watched particularly by the fabricator during the production of the Model 1 incinerator. These are listed below:

(1) The "V" Band Assembly shown on Drawing No. 354-110 was not detailed because it is a purchased part. Three weeks or more should be allowed for the delivery of this assembly.

(2) When the louvers are formed, particular care must be taken to have the louvers open in the proper direction and to deburr all of the louver edges. The parts involved are: Door Inner Liner (Drawing No. 354-343); Liner Upper Cone (Drawing No. 354-417); Liner Bottom Cone (Drawing No. 354-416); Liner Lower Section (Drawing No. 354-415); and Liner Middle Section (Drawing No. 354-414).

(3) When the Basket Top Band (Drawing No. 354-327) is tack welded to the Liner Upper Cone (Drawing No. 354-417) in the Top Liner Assembly (Drawing No. 354-104), care should be taken not to warp the Liner Upper Cone or to allow gaps to occur between the Basket Top Band and the Liner Upper Cone.

(4) When the Stiffener (Drawing No. 354-301) and Stiffener (Drawing No. 354-302) are tack welded to the Base Plate (Drawing No. 354-300) in the Bottom Plate Assembly (Drawing No. 354-208), care should be taken not to warp the Base Plate.

(5) When the Radiation Shield (Drawing No. 354-391) is tack welded to the Stiffener (Drawing No. 354-301) and Stiffener (Drawing No. 354-302) in the Botton Plate Assembly (Drawing No. 354-208), care should be taken not to burn

holes in the Radiation Shield. Likewise, care should be taken not to burn holes in the Shield (Drawing No. 354-305) when it is tack welded to the Channel (Drawing No. 354-309) in the Door Channel Assembly (Drawing No. 354-404).

(6) When the Nozzle (Drawing No. 354-364) and the Nozzle (Drawing No. 354-333) are welded into the Liner Middle Section (Drawing No. 354-414) in the Liner Middle Section Assembly (Drawing No. 354-105), it is essential that the Nozzles be aligned as shown in the assembly drawing. The proper angularity of the Nozzles is critical and important to the proper air flow.

(7) When the Reflector Assembly (Drawing No. 354-109) is inserted into the Outer Shell Middle Assembly (Drawing No. 354-102) and the Bottom Assembly Outer Shell (Drawing No. 354-103) in the Incinerator Assembly (Drawing No. 354-100), the Reflector Assembly should be collapsed enough to pass by the Firing-Door tunnel projection.

(8) When the two parts of the Flexible Duct (Drawing No. 354-434) are connected together, the end of the Damper Housing Assembly (Drawing No. 354-409) should be used as a form.

(9) When the complete Inner Liner Assembly is inserted into the Outer Shell Assembly (see Item 10 below) with the Reflector Assembly installed as shown in Incinerator Assembly (Drawing No. 354-100), the notch in the Central Cone Base Ring (Drawing No. 354-413) on the Liner Bottom Section Assembly (Drawing No. 354-113) should be aligned with the proper end of the Stiffener (Drawing No. 354-302) on the Bottom Assembly Outer Shell (Drawing No. 354-103).

(10) It should be noted that the Inner Liner Assembly drawings (Nos. 354-104, 354-105, and 354-113) and the Outer Shell Assembly drawings (Nos. 354-101, 354-102, and 354-103) are marked with assembly reference lines to facilitate proper orientation during assembly.

(11) During final assembly when the Outer Shell Top Assembly (Drawing No. 354-101) is placed on the Outer Shell Middle Assembly (Drawing No. 354-102), care should be taken to avoid damaging the Seal Strip (Drawing No. 354-407) attached to the Top Liner Assembly (Drawing No. 354-104). To minimize difficulty, tape may be used to hold the Seal Strips in place during assembly.

APPENDIX 3

CHANGES AND ADDITIONS TO THE WORKING DRAWINGS FOR THE MODEL 1 INCINERATOR

Our letter dated March 1, 1960, transmitted to the Sponsor a list of changes and additions which were to be made to the working drawings of the Model 1 incinerator.

These were as follows:

(1) On Drawing 354-100, Incinerator Assembly, lower right-hand corner:

"-302 Hinge Pin" should read "-363 Hinge Pin".

(2) On Drawing 354-311, Duct Flange:

Change "9/32 diam" to "3/8 diam" for all 12 holes.

(3) On Drawing 354-438, Duct Flange Gasket:

Change "9/32 diam" to "3/8 diam" for all 12 holes.

(4) On Drawing 354-397, Cap Screw (3/8"); Drawing 354-403, Nut; and Drawing 354-404, Lock Washer:

Add 12 to the number required, i.e., increase the number required from 64 to 76.

(5) Drawing 354-439, Cap Screw (5/16"); Drawing 354-440, Nut; and Drawing 354-441, Lock Washer:

These drawings are obsolete.

(6) On Drawing 354-103, Bottom Assembly Outer Shell:

Install fittings which serve as pressure tap for rubber hose leading to manometer.

(7) On Drawings 354-430, -431, -432, and -433, Reflector Shield; Drawing 354-391, Radiation Shield; and Drawing 354-345, Door Shield:

The polished side of the 26-gage Type 304 stainless steel should have a No. 4 finish.

(8) On Drawing 354-325, Shield:

The polished side of the 20-gage Type 304 stainless steel should have a No. 4 finish.

(9) On Drawing 354-407, Seal Strip:

Change the 26-gauge stainless steel sheet from Type 310 to Type 304. Although a polish is not needed on the Seal Strip, nevertheless the 26-gauge Type 304 polished stainless steel sheet specified for Radiation Shields can also be used in constructing these Seal Strips.

(10) On Drawing 354-400, Vent Pipe Ring:

Change from 3/4" long to 15-3/4" long, to provide initial 15" length of straight stack.

(11) On Drawing 354-225, Stack Ring Assembly:

Install fitting to hold thermocouple.

(12) On Drawing 354-372, Stiffener; Drawing 354-374, Frame; and Drawing 354-376, Pivot Angle:

Change all 11/32"-diam drilled holes to 21/64"-diam drilled holes, for tighter fit on pivots.

(13) On Drawing 354-387, Basket Top Band:

Reduce OD from 21-5/8" to 21-1/2" to provide assurance of fit between Basket Assembly and top band during assembly.

The following items are needed and can either be purchased or prepared:

(1) Instruments and mounting panel.

(2) Obtain two thermocouple assemblies (one as a spare). Suitable thermocouples can be ordered from:

Conax Corporation
2300 Walden Avenue
Buffalo 25, New York

Specify No. Q83-CA-(24)[illegible], which is a 24"-long, 3/16"-diameter well of Type 304 stainless steel with a

1/8" standard pipe thread (male) fitting, and has 20-gage Chromel-Alumel wires. Locate the end of the thermocouple at the center of the 16" stack by slipping it in the fitting supplied with the thermocouple.

(3) Obtain 12 feet of extension lead wire for Chromel-Alumel thermocouples to run between the thermocouple and the temperature indicator. This is sometimes called duplex lead wire. This duplex lead wire should not be larger than 1/4" diameter. It can be purchased from:

Arklay S. Richards Co., Inc.
Newton Highlands 61, Massachusetts

or from:

L. H. Marshall Company
Columbus 2, Ohio

Specify 14-gage stranded wire with a durable covering such as cotton wrap, waterproof braid, and rubber covering. Observe polarity when connecting the thermocouple circuit; determine the wire type with a small magnet, as follows:

(a) Chromel wire is non-magnetic, and is the positive terminal

(b) Alumel wire is magnetic, and is the negative terminal.

(4) Obtain 12 feet of laboratory-type rubber tubing, 3/32" ID and 1/8" wall thickness, for use in connecting one side (either side) of the manometer to the pressure tap at the bottom of the outer shell of the incinerator.

(5) Paint the outside surface of the unit with aluminum paint after taking the usual precaution of removing oil, dirt, and rust from the metal. Ordinary aluminum paint such as the "Peerless" brand, available from the Hanna Paint Manufacturing Company, Columbus, Ohio, or its equivalent, can be used for this purpose.

APPENDIX 4

RECOMMENDED SPARE-PARTS LIST FOR MODEL 1 INCINERATOR

It is recommended that the following spare parts be packaged with each incinerator:

Drawing No.	Description	Number
354-110	"Y" band assembly	1
354-111	Basket assembly	1
354-217	Clamp band assembly	2
354-329	Wedge	4
354-347	Door gasket	2
354-348	Door gasket	2
354-350	Cotter pin	8
354-357	Screw	24
354-396	Flange gasket	45 feet
354-397	Cap screw	24
354-398	Sight glass	2
354-399	Gasket	4
354-403	Nut	24
354-404	Lock washer	24
354-434	Flexible duct	1
354-438	Duct flange gasket	1
354-447	Nut	24
354-448	Lock washer	24

In addition, one 3-ounce tube of No. 1 Permatex Form-A-Gasket, or its equivalent, should be provided for use in cementing the Door Gaskets (Drawing Nos. 354-347 and 354-348) to the Door Assembly as indicated on Drawing No. 354-114.

Also, one spare thermocouple assembly shall be provided (as described in the list of changes and additions indicated in Appendix 3.

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