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AG AUTOMOBILE BODY INCINERATION
AP-42 Section 2.2
Reference Number 2

Smokeless Burning of Automobile Bodies

By

E.R. Kaiser and J. Tolciss

New York University

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ABSTRACT

This report describes furnaces for the smokeless burning of combustibles off automobile bodies preparatory to the baling and shipment of the steel scrap.

Particular attention is given to designs and tests of a burner for the small and medium-sized auto-wrecking yards. The furnace burns two car bodies at a time, and up to 28 bodies a day.

Design, cost and performance data are given. The furnace can be built by local contractors, utilizing new or used structural steel.

Based on the cost of the prototype burner, the projected cost of the recommended design is from $16,825 to $22,050 depending on local conditions. Based on a throughput of 6048 bodies a year, the total cost for burning will be close to $3.76 per body or $6.83 per ton of steel above the cost of open burning.

The information should be useful to auto wreckers, consulting engineers, incinerator manufacturers, and air pollution control officials in abating an important source of air pollution.

Plans are available at $5 a set, by written request to the authors, with checks made payable to "New York University".

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SMOKELESS BURNING OF AUTOMOBILE BODIES*

By E. R. Kaiser** and J. Tolciss***

INTRODUCTION

Open burning of automobile bodies to prepare the steel for baling has been practiced for years by auto-wrecking yards. The black smoke resulting from the partial combustion of the paint, sound deadening materials, rubber, upholstery, wire and plastics has frequently been the cause of complaint in urban communities(1). In recent years local and state legislation has outlawed the practice of open burning in many areas, and similar restrictions can be expected elsewhere.

Burning is a practical way to clean auto steel, and is necessary to produce the grade desired for remelting. An economical furnace for doing the job without air pollution has therefore been sought by both auto wreckers and air pollution control officials.

It was recognized at the outset that the cost of smokeless closed burning would be higher than that of open burning. The cost of closed burning could be offset by a slightly lower price paid for scrapped cars. As closed burning of auto bodies cannot reasonably be competitive with open burning in the same area, legislation to outlaw open burning is necessary to encourage the use of closed burners.

The lack of proven auto-burners within the financial reach of auto-wreckers has delayed the abatement of air pollution from wrecking yards. It is the purpose of this report to present the information for the construction and operation of tested designs.

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** Senior Research Scientist, College of Engineering, New York University New York 53, New York.

*** Associate Research Scientist, same.

State of Art

Several large conveyorized furnaces to burn auto bodies continuously without smoke emission have been built and operated within the last few years. The largest of these units, shown in Figure 1, is the Pyrocleaner, built and operated by Lipsett Steel Products, Inc., in Brooklyn, N. Y.[2]. Its capacity exceeds 300 bodies in 8 hours. The combustion of the smoke and hydrocarbons is completed by passing the products of combustion from the primary chamber through oil-fired afterburners.

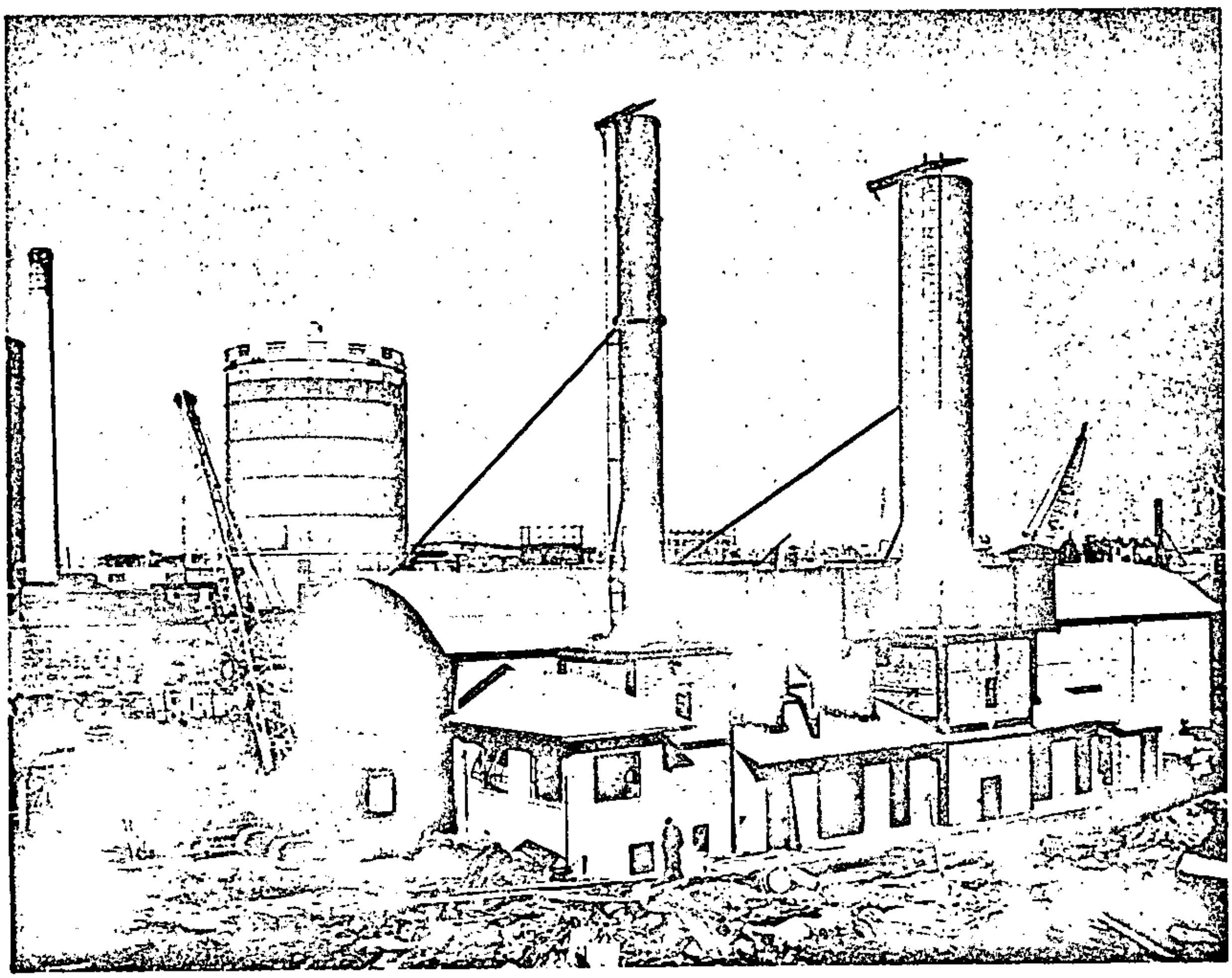

Figure 1. Pyrocleaner of Lipsett Steel Products, Inc. Brooklyn, N. Y. Capacity 300 auto bodies a day.

The electrostatic-precipitator principle has been employed to trap the smoke and dust particles in the Smokatron, manufactured by Summer & Co., Columbus, Ohio. Burners of this type are in use in New York City and Atlanta, Ga. Figure 2 illustrates the general features.

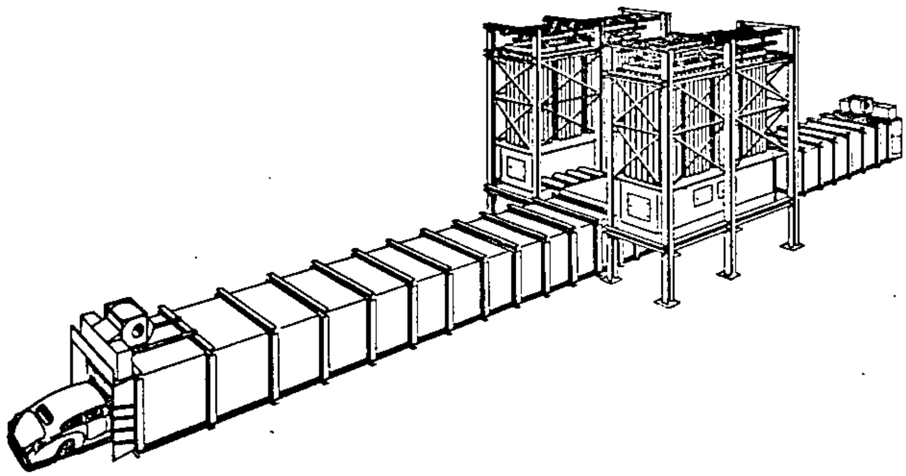

Figure 2. Smokatron Continuous Auto-Body Burner with Electrostatic Precipitator.

Bodies are moved aboard carts on rails at a few installations. The Harris Foundry & Machine Co., Cordele, Ga., has built furnaces with oil-fired afterburners in Clifton and Jersey City, New Jersey. Figure 3 illustrates the unit in Jersey City.

Numerous attempts, some successful, have been made by inventors and auto wreckers to produce body burners for the smaller yards(3)(4). In Cleveland, Ohio, for example, several steel-lined pits have been used to burn three or four partially collapsed bodies at one time. The pits were covered by steel lids. A stack supplied the draft to remove the smoke and gases from one end of a pit and induce air into the other end. The smoke emission was considerably less than from open burning, and could have been eliminated entirely by an afterburner.

Two refractory-lined sheds with afterburners in the Cleveland area have also been reported as burning bodies successfully on carts. In other localities similar efforts have been underway.

Specific information and test data have not been available for a detailed evaluation of any of these units.

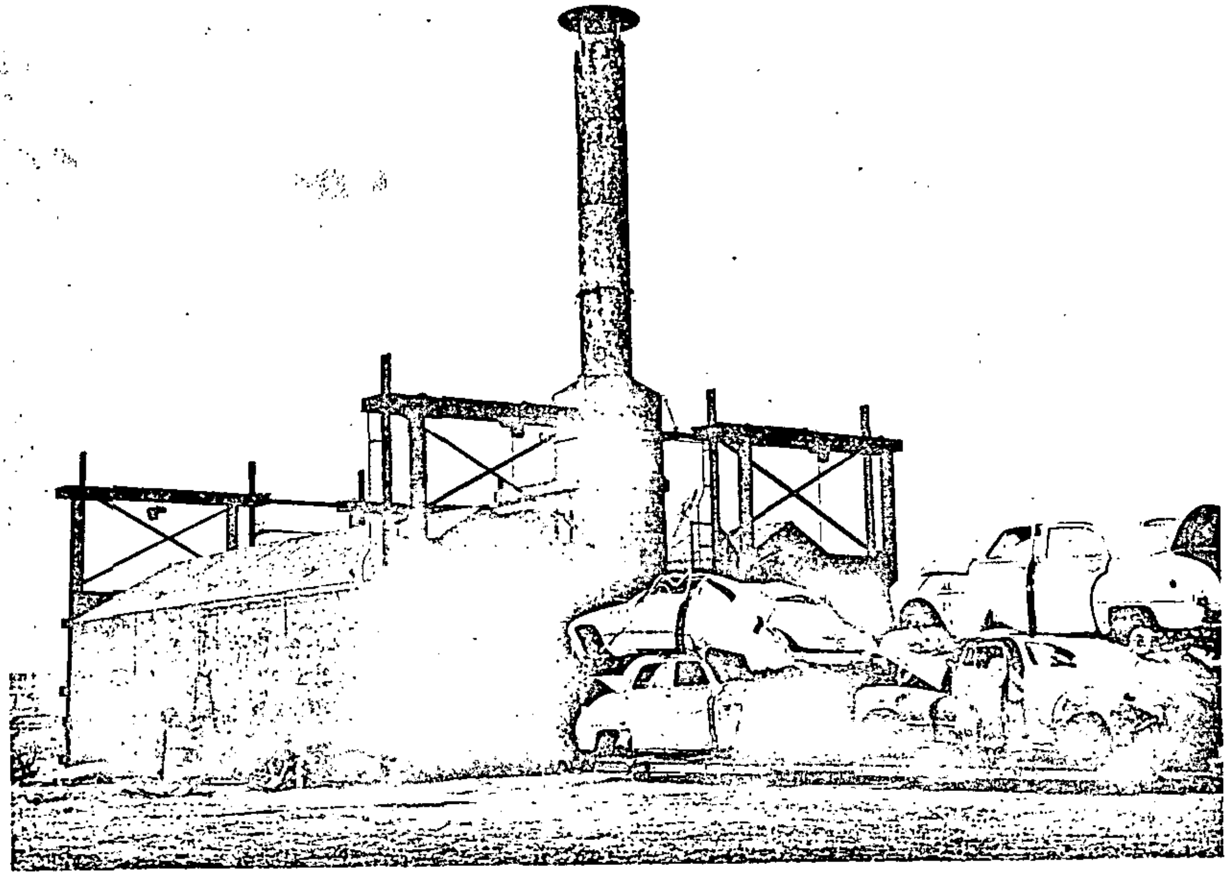

Figure 3. Harris Twin-Kiln Incinerator.

Present Program

After gathering experience from numerous sources, several designs of incinerators were created and evaluated. Smokelessness and low flyash emission were found to be relatively simpler to achieve than low-cost construction and operating economy.

The resultant prototype burner was built by the Michael Schiavone & Sons, Inc., 135 Front Street, New Haven, Conn. during the fall of 1960. Tests were conducted by the University staff on automobile bodies, insulated copper wire, and mixed municipal refuse. Although this report is limited to automobile bodies, the versatility of the furnace to burn a wide variety of smoke-producing combustibles successfully was established.

BASIC FACTORS

Combustion

The four requirements for complete and smokeless combustion are ample oxygen (air), sufficient temperature, turbulence or mixing of the fuel and air, and time. All four requirements must be met to achieve the desired result.

Smoke is produced during the burning of auto bodies in the open because of insufficient temperature to complete the combustion of the volatized combustibles. Too much heat is dissipated by radiation to the surroundings and by convection to a large excess of air. In addition to smoke, the cooling effect is also evidenced by unburned paint and plastics near the ends of the fenders. Exterior die castings and lead are not melted off as desired.

By burning the bodies in a furnace the air supply can be controlled and directed to the best advantage. Wind effects are eliminated. Mild turbulence in the flames can be provided by jets of air from a blower which are directed into the body through the windows and open trunk compartment. The design factors for air jets are well understood[5]. Turbulence can be controlled in a furnace so as not to raise excessive dust from the ash remaining after combustion. A chimney can provide controlled draft for withdrawing the combustion gases from the top of the combustion chamber while inducing more air below the burning bodies.

Compared with high radiation losses from open burning, the furnace walls and ceiling can retain heat from previous burns to radiate to the colder unburned bodies immediately after a new load enters the furnace.

Because of the inherently limited furnace temperature, some smoke must be expected from the primary chamber, although less than from open burning. For that reason it is necessary to treat the smoky gases before discharging them from the stack. A temperature of approximately 1450-1500F has been found necessary to burn the soot in smoke in the time available. The additional temperature can be obtained by burning fuel oil with the primary gases in a secondary chamber or afterburner.

The afterburner principle was selected in this application in preference to other methods of gas treatment for the following reasons:

1. Hydrocarbon gases and allied odors could be burned while burning visible smoke.

2. The temperature rise of the primary gases necessary to reach the 1450 to 1500 F for the burning of smoke could readily be obtained by burning heavy fuel oil with the excess air of the primary gases.

3. The afterburner would establish chimney draft promptly after overnight and week-end shutdowns.

4. No disposal problem as with devices that trap particulate matter from gases.

5. Lower investment cost than other suitable devices.

6. Simplicity of operation.

Basic Equipment Features

The following criteria and considerations were instrumental in the design of the prototype burner:

1. A furnace producing 15 to 25 clean bodies a day would satisfy a majority of auto wreckers.

2. Two bodies, one piled on the other, can be burned in the same period of time as one body. As the furnace for two superimposed bodies would have the same plan area but only 4 ft additional height, the output could be doubled at a minor increase in furnace cost.

3. Inspection of all-steel auto-burning furnaces showed warpage from the heat, fracture of welds, and rapid oxidation of some portions. A refractory-lined furnace was deemed advisable for increased service life and heat conservation. Standard firebrick backed by concrete block, red brick or light steel were favored. Concrete block particularly offers wall stability at low cost.

4. Hinged doors of plate steel with angle framing and bracing on the outside were selected as most practical, yet sufficiently heat resistant for auto burning. At only slight extra cost, steel mesh and two inches of mineral insulation could be added on the inside surfaces.

5. The afterburner should be of firebrick construction and can be fired by a single oil burner using No. 4 oil. The afterburner should also provide heat storage and combustion turbulence. Loose firebrick laid in a checkerbrick design could provide both of the latter features.

Because of its weight, and the convenience of having an oil burner within easy reach of the operator, it is advantageous to locate the afterburner directly on the main foundation.

6. The refractory ceiling for primary and afterburner chambers could be of arched construction, or flat. In the latter case there is the choice of a cast ceiling or blocks with T-slots suspended from light beams. The flat ceiling of block design was found to be least expensive, largely because of the saving in construction labor.

7. A steel chimney supported on a concrete base poses no special problems. A used chimney would be suitable, as would one fabricated from old tanks, transformer housings, etc.

8. For ease of moving the auto bodies in and out of the furnace, a 4-wheeled cart on rails has numerous advantages. The cart elevates the bodies above the dirt floor of the furnace and allows air to reach the undercoating through the open steelwork of the cart. Cold air from below also keeps the cart relatively cool.

9. The rails can be anchored to ties or imbedded in concrete. Steel ties must be used inside the furnace unless the rails are set in concrete, but wood ties would be suitable outside. The use of a concrete apron in the loading area outside the furnace is optional.

10. The use of secondhand steel when available and suitable is particularly advantageous in the scrap industry. Many local contractors and builders who could construct the body burners are skillful in adapting available steel to a given design.

DESCRIPTION OF AUTO-BODY BURNER

As the results of tests on a furnace with basically the same features and dimensions, as will be described later, the design illustrated in Figure 4 was evolved. The primary furnace has doors at both ends. By using two carts on rails, one load of two bodies can be burning, while the other cart is being unloaded and reloaded. Loading and unloading by fork-lift truck would take place alternately on each apron. Based on a morning warmup period of 30 minutes, a burning period of 30 minutes, and a cart-transfer period of 5 minutes, the throughput in 8 hours would be 28 bodies. Preparations for the first burn can be made during the warmup period. The last load can burn out after quitting time.

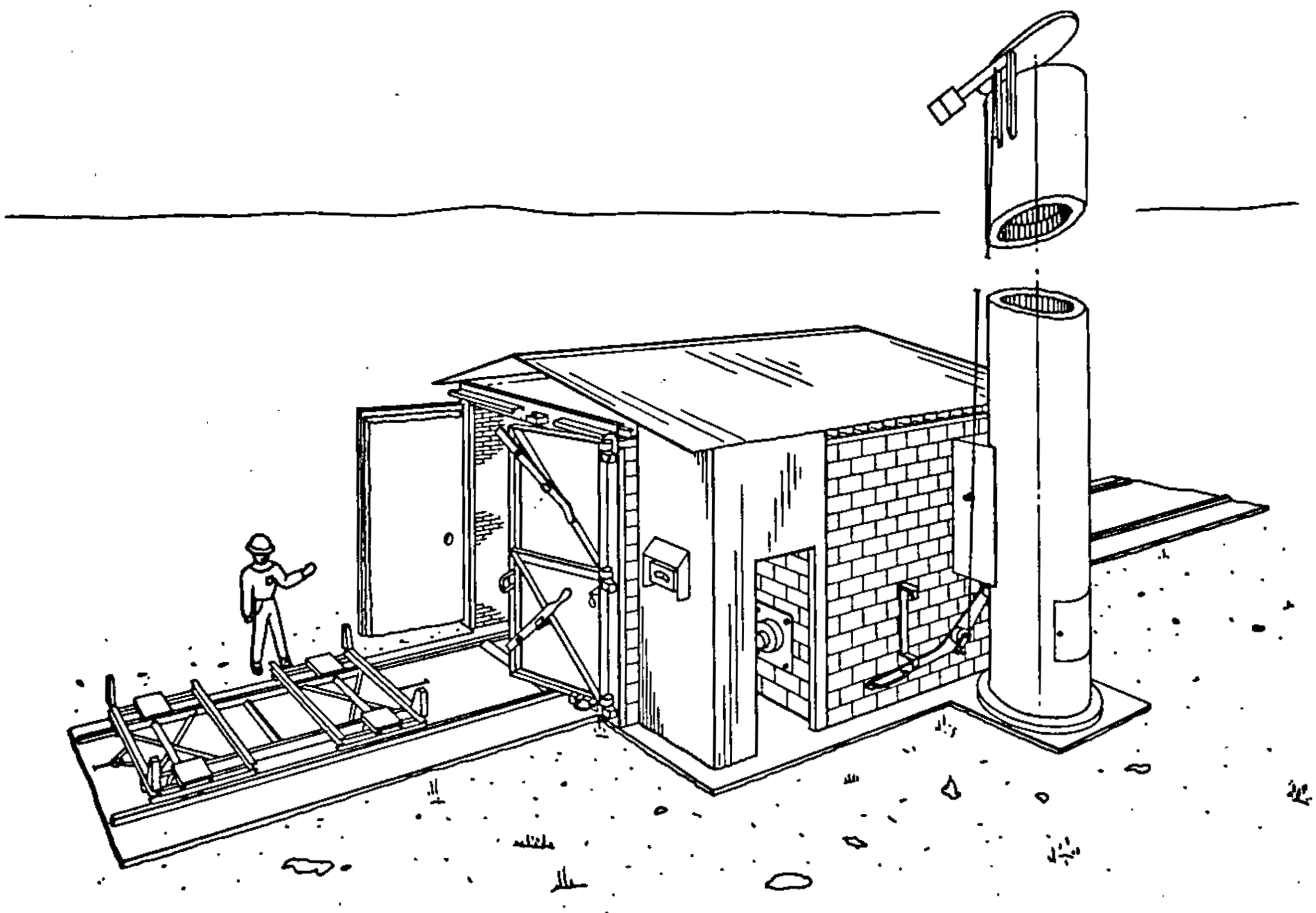

Figure 4. Double-Ended Auto-Body Burner with Afterburner. Capacity: 28 bodies a day.

The primary furnace is 10 ft wide, 10 ft 11 in. high and 20 ft long inside. The side walls are built of concrete blocks, 8 in. thick. The walls are lined with $4\frac{1}{2}$ inches of firebrick tied with steel strips to the concrete blocks. The walls rest on concrete footers and have horizontal steel reinforcement on the outside. Depending on soil conditions, piling may be required. The furnace floor may be earth or concrete covered by sand or ash.

The afterburner is along one side wall of the primary furnace. The oil burner, oil pump, burner blower, and switches are mounted in the small shed at the front end of the afterburner. A short steel breeching lined with firebrick connects the afterburner to the steel stack.

Figure 5 shows a vertical section along the afterburner, illustrating the construction and directions of gas flow. The walls are of 9-inch refractory with a concrete-block exterior. Auxiliary heat is supplied by a 35 gph oil burner (5,000,000 Btu/hr) with 5:1 turndown ratio for No. 4 fuel oil. An equivalent gas burner would be satisfactory, depending on costs. Natural gas with a heating value of 1000 Btu per cu ft, and costing 81 cents per 1000 cu ft, is approximately the fuel equivalent of No. 4 fuel oil with a heating value of 148,000 Btu per gal, costing 12 cents a gallon.

The checkerbrick is shown in outline in Figure 5, and in detail in Figure 6. A total of 250 fire bricks, each $2\frac{1}{2}$x$4\frac{1}{2}$x9 inches, is required. Mortar is not necessary. The temperature of the gases leaving the checkerbrick can be monitored by an indicating pyrometer with a 0-2400 F range.

The ceiling over the primary furnace and afterburner chambers is composed of refractory blocks suspended under steel beams that support the blocks through T-slots. The I-beams rest on the concrete-block walls. A simple corrugated steel roof provides protection from rain and snow.

The steel stack of 55 to 60 ft height should be lined with $4\frac{1}{2}$ inches of firebrick, at least for the first 20 ft above the base. The diameter inside the lining may be 36 to 48 inches.

The damper at the top of the stack is an important fuel-saving feature. The damper is adjusted for a restricted opening by cable and hand winch, its position during warmup and transfer periods. During the burn the damper is held full open by a lever arrangement.

Sidewall air jets to blow air into the burning bodies are provided by four nozzles in the wall of the primary furnace opposite the afterburner side.

Construction drawings and equipment details are available at $5 per set from the authors for those interested in building these furnaces. Checks should be made payable to "New York University".

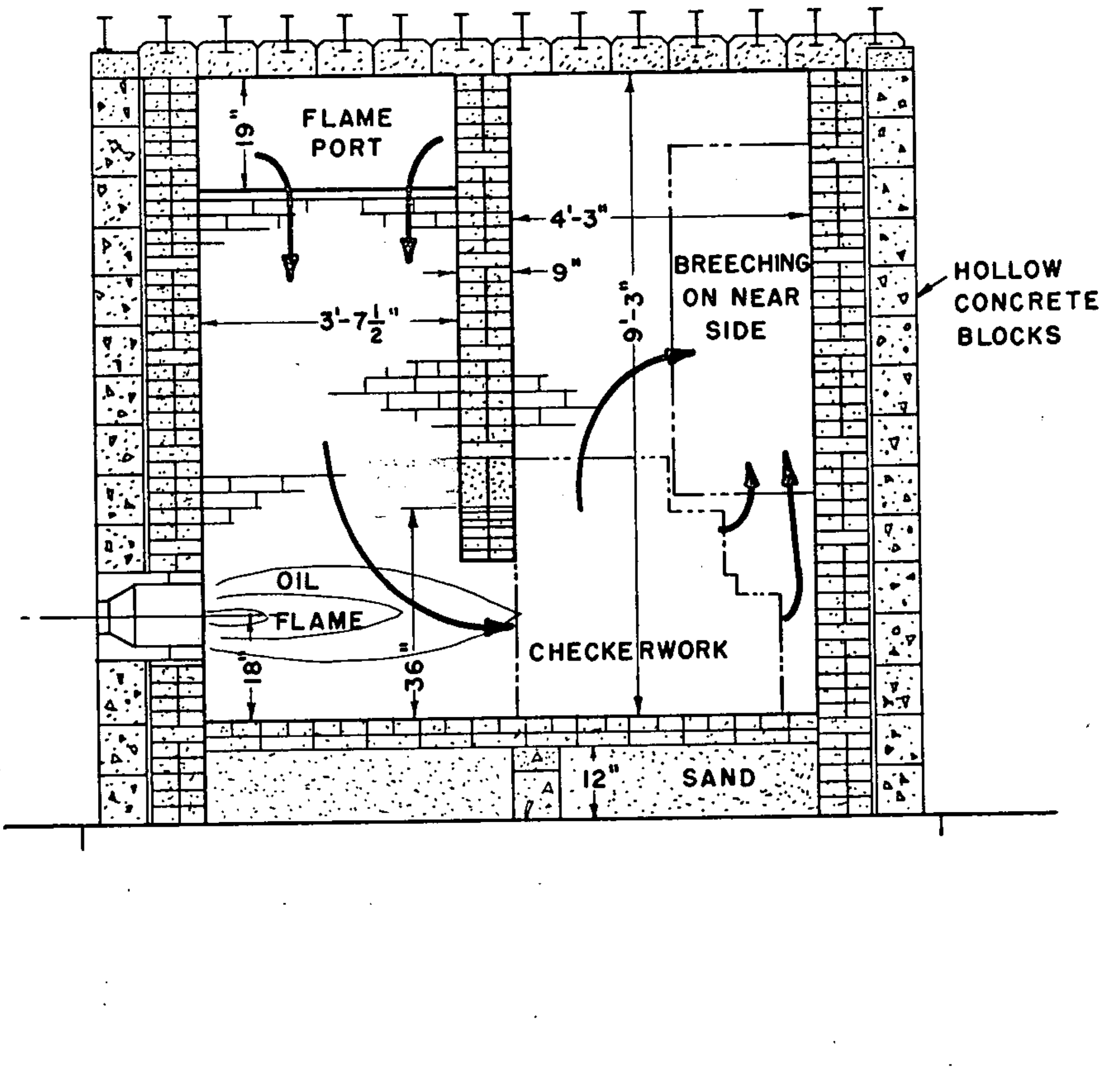

Figure 5. Cross Section of Afterburner.

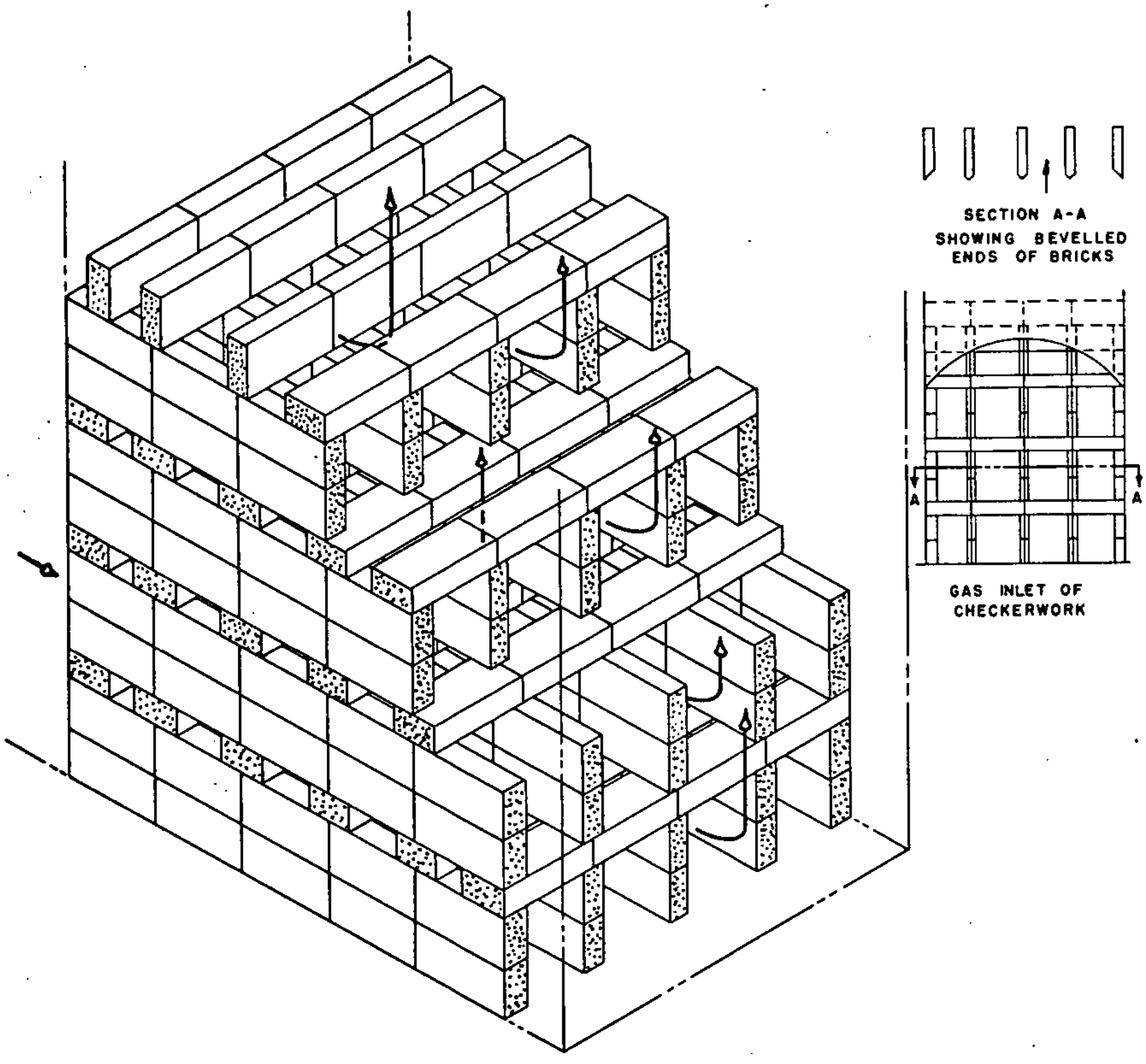

Figure 6. Arrangement of Checker Brick.

Test Furnace

The prototype furnace in New Haven, Conn., is shown in Figure 7. This furnace has doors at only one end and only one cart is used. The afterburner chambers were located at the far end of the furnace, with the burner shed located on the side.

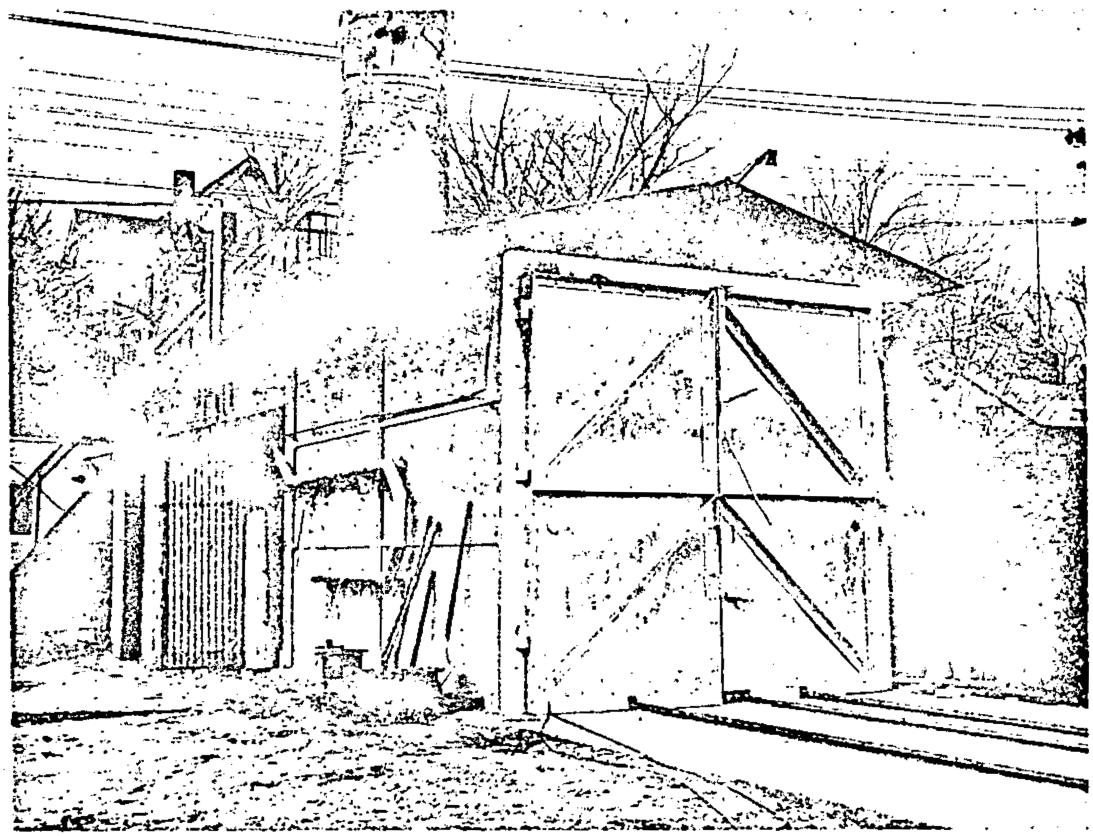

Figure 7. Single-ended Test Furnace.

Because of its availability from scrap, a steel chimney measuring 56-in. I.D. and 57 ft 4 in. in height was fabricated from scrap transformer casings. The stack was lined to mid-height with $4\frac{1}{2}$ inches of firebrick leaving an inside diameter of 47 inches. A conical rain cap was added to protect the lining from rain and snow during shutdown.

No damper was installed in the stack or breeching. The stack draft can be reduced to a limited degree by opening the door at the base of the stack (check damper). The door opening is 20 x 22 inches, or 3.06 sq ft. The ingress of air to the furnace is limited by closing hanging flaps under the main doors. The gas flow from the main furance to the afterburner is restricted by the flame port. The draft in the flame chamber of the afterburner is, in turn, affected by the configuration of the checkerwork. The final flame-port area and checkerbrick arrangement were established by the results of the preliminary tests.

Instrumentation

A laboratory trailer was moved to the site and positioned near the breeching and afterburner. Measurements of temperatures, drafts, gas composition, and particulate matter in the exit gases were made aboard the trailer. Continuous temperature measurements were made with chromel-alumel thermocouples in alloy steel sleeves located in the following places:

1. Outdoor air.
2. In primary furnace 3 inches below center of ceiling.
3. At center of the flame-port between the primary furnace and afterburner.
4. At center of the breeching.
5. At mid-height of stack-- bare couple.
6. Auto-body metal near rear window-- bare couple.

Static pressures at the following locations were transmitted through copper tubing to draft gages in the trailer for draft measurements relative to ambient air.

1. Primary chamber at floor level.
2. Primary chamber at flame-port level.
3. Breeching at mid-height.

Pitot tubes measured gas-velocity heads in the breeching and at the mid-point of the stack. A water-cooled probe with a 3/4-in. dia. nozzle sampled dust from the breeching at nearly isokinetic conditions. The sample stream was aspirated through three sets of wet and dry impinger bottles in parallel and a dry gas meter. The impingers collected moisture and dust from the gases. A paper thimble filter collected particulate matter successfully on only one test. The gases had sufficient moisture to rupture the thimble on other tests.

The carbon dioxide and oxygen content of the breeching gas was determined by the Orsat apparatus from gas samples collected continuously over saturated brine. Carbon monoxide in the flue gas was determined by the MSA colorimetric analyzer. Smoke was observed visually against both a black and a sky background.

No tests were made for the aldehydes, organic acids, ammonia, esters and phenols as negligible amounts of these contaminants would be expected under the favorable combustion conditions prevailing.

The auto bodies were weighed on the yard scale before and after burning. The bodies were received without chassis, but they contained the full upholstery. Virtually all of the glass was present. Two steel station wagons but no compacts nor unusually large bodies were included in the 30 cars burned during the test program.

Preparation of Bodies

After initial weighing, the trunks were opened to facilitate air admission for burning. Spare tires were removed since they increase the burning period by 15 to 20 minutes. Gasoline tanks had generally been removed by the wrecking yard, but they were punctured if still attached. The windshields, side and rear glass were smashed inward to admit air for combustion. The doors were left ajar but were wired through the windows to prevent their opening wide either during burning or loading.

The bodies were lifted on the cart by crane. A fork-lift truck would be more suitable for commercial operation. The second body was mounted on the first as shown in Figure 8. No fastening was used to secure the upper body.

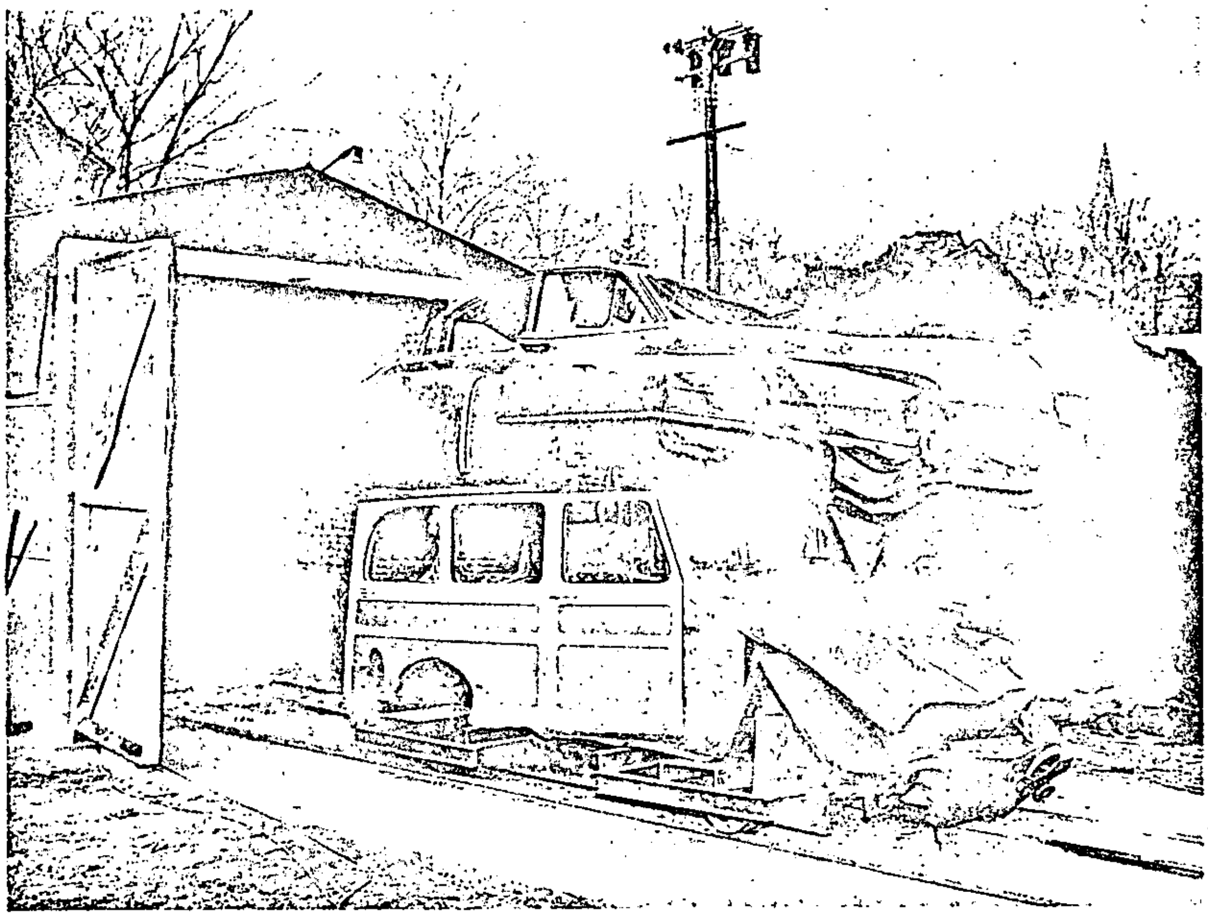

Figure 8. Bodies on Cart before Burning.

Two to three quarts of No. 2 fuel oil were then spilled on the upholstery of each body. The oil expedited ignition and was particularly helpful with wet upholstery. After the cart was moved into the primary furnace, the upholstery was ignited by a small hand torch.

Burning cycle

Prior to a burn the afterburner bricks were preheated by the oil burner until the breeching temperature was at least 1250F. Shortly after igniting the auto bodies, the heat from the main furnace and the afterburner caused the temperature of the breeching gas to rise above 1500F. The air jet blower was started as soon as the bodies were well ignited. To conserve oil, the oil burner was set back to a low rate while the bodies were burning briskly. Once regular production is established, a constant rate of oil firing can be set for both body-burning and transfer periods.

For test purposes, the burns were continued until the flames burned out. However, in commercial practice the cart could be withdrawn a few minutes earlier.

GENERAL TEST RESULTS

Weight and Time

The bodies were weighed in pairs before and after burning. The initial weights of pairs ranged from 2700 to 3400 lb. The final weights of pairs ranged from 2160 to 2650 lb. Corrections were applied for tires and offal.

The burning of the bodies separated the components into the categories listed in Table I. This breakdown compares closely with published data [6,7] after allowance is made for the absence of chassis.

Table I. Average Composition of Auto Bodies Burned

Item		Lb per body	Per cent
Body steel		1100	73.5
Non-ferrous metal		10	0.7
Glass and ash		133	8.9
Combustible and moisture		254	16.9
Initial wgt, avg. body	Total	1497 lb	100.0

A cartload of two bodies before light-off is shown in Figure 8. The same bodies after the burn are shown in Figure 9. The heat was not sufficient to cause the bodies to slump.

The average burning time was 38 minutes until the last flame died out. As very little burning took place during the last 8 minutes, the bodies could have been removed at the end of 30 minutes and the last flames extinguished with a small water spray without creating smoke.

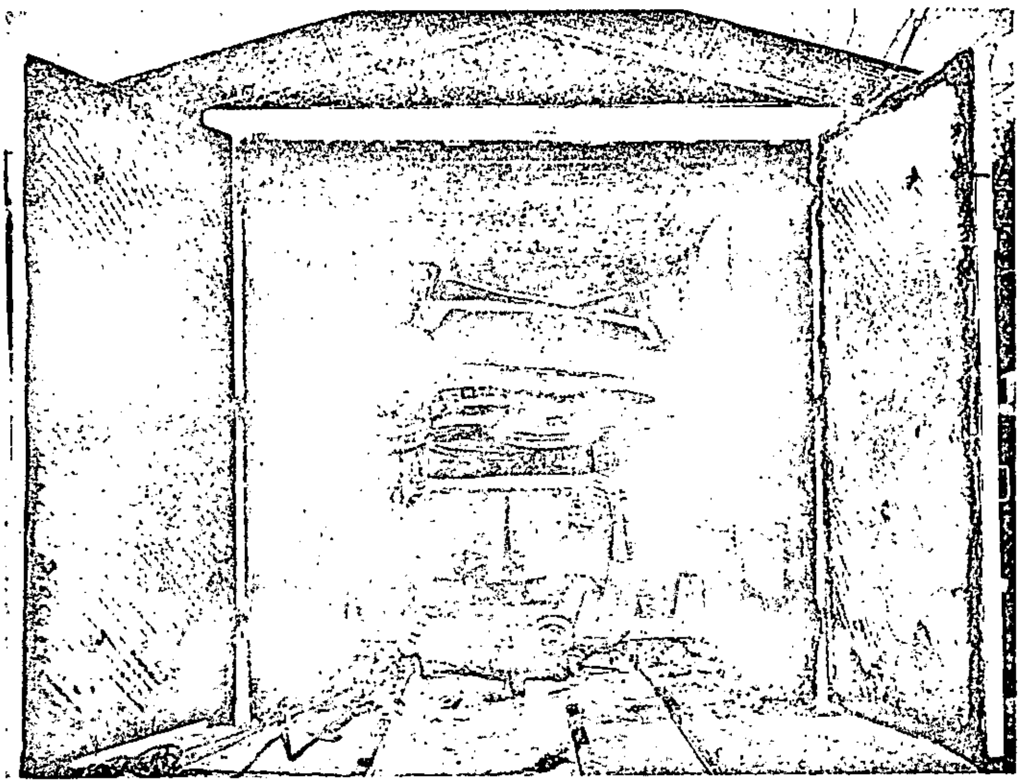

Figure 9. Interior of Furnace with Same Bodies After Burning.

Sidewall Air Jets

Twelve horizontal air nozzles were used, three on each side of both bodies. The air was supplied through pipe manifolds connected to a blower in the burner shed, as shown in Figure 7.

The effectiveness of the jets in producing a brighter fire was evident visually and photographically.

The experimental and temporary arrangement of 2-in. jet piping is shown in Figure 9. The lower jet nozzles were 50 inches above the floor and spaced 3 ft apart horizontally. The upper nozzles were 93 inches above the floor. The deck of the cart was 18 inches above the floor, a governing factor in the heights of the nozzles.

The total air delivery per nozzle was 770 cfm or an average of 64 cfm per nozzle. The static pressure in the 4-in. manifolds was 5.3 in., water gage.

A preferred arrangement recommended for future installations is a set of 4 straight nozzles flush with each sidewall and inclined downward at 45 degrees. Inclined jets would blow toward the seats, which contain the greatest amount of combustibles. The required penetration or jet throw of 7 ft, and delivery of 150 cfm per nozzle, could be achieved with a manifold pressure of 3.5 in. water gage (5). The jets should, of course, be positioned to direct the air through the windows. The velocities should provide penetration into the body cavity. Stronger jets can reduce the burning time, possibly to 15 minutes, but the dust raised thereby would likely exceed the legal limits for dust emissions.

While air jets can also be directed into the trunk space by nozzles mounted to the furnace door, and having flexible connections to the manifold, no trial of the idea was attempted. A paperboard partition usually separates the luggage compartment from the rear seats. Simultaneous burning in both areas would consume the combustibles more rapidly.

Temperatures

The average temperature history and gas analyses of four typical burns totalling 8 bodies, are plotted in Figure 10. Four to five minutes after body ignition it was possible to reduce the rate of oil firing by one-half without risking smoke emission. As the temperatures were measured by industrial-type thermocouples encased in metal sleeves, some lag in response occurred. The thermocouple located 3 inches below the center of the ceiling was particularly affected by radiation exchange with the ceiling and with the top of the upper body, about 6 to 12 inches below the couple.

The metal temperatures near the front and rear windows of the lower bodies, shown in Figure 10, are indicative of general body temperature and are probably not far from the average. The upper body became somewhat hotter than the lower body. Oxidation of the steel was not observed. When the dusty paint minerals which protected the steel were brushed off after a burn, clean gray steel was exposed.

The temperatures were high enough to melt off the zinc-base die castings in the ornamental trim, as well as the lead and solder.

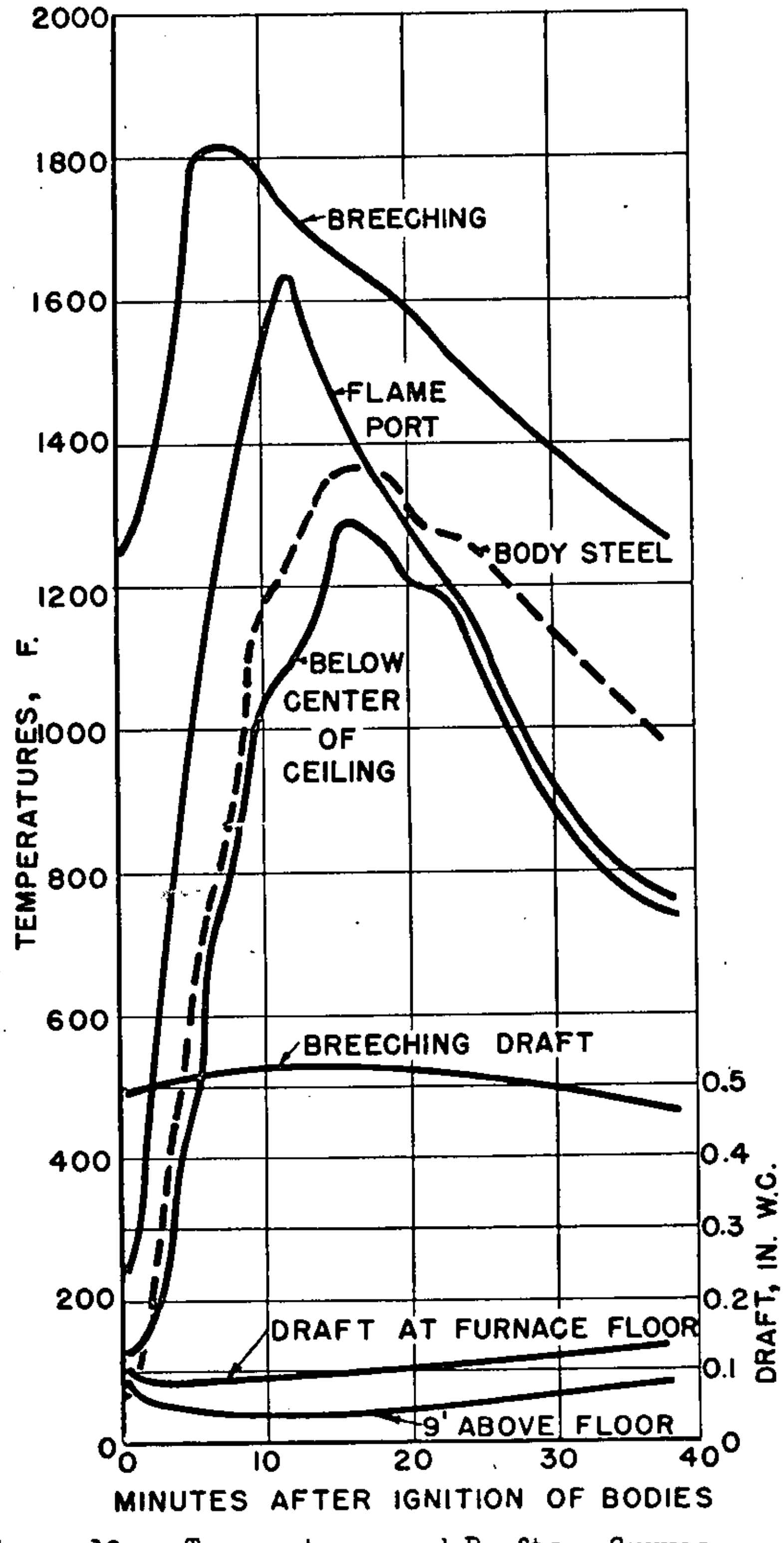

Figure 10. Temperatures and Drafts. Curves are average of 4 burns, including 8 bodies.

Gas Analyses

The carbon dioxide in the breeching flue gas, the principal product of combustion, increased in per cent volume from a base value of 4% (during the oil firing of the afterburner) to 12.5%. Eight minutes after light-off, the percentage of carbon dioxide diminished as shown in Figure 11. The maximum burning rate occurred 7 to 8 minutes after the start of the burn.

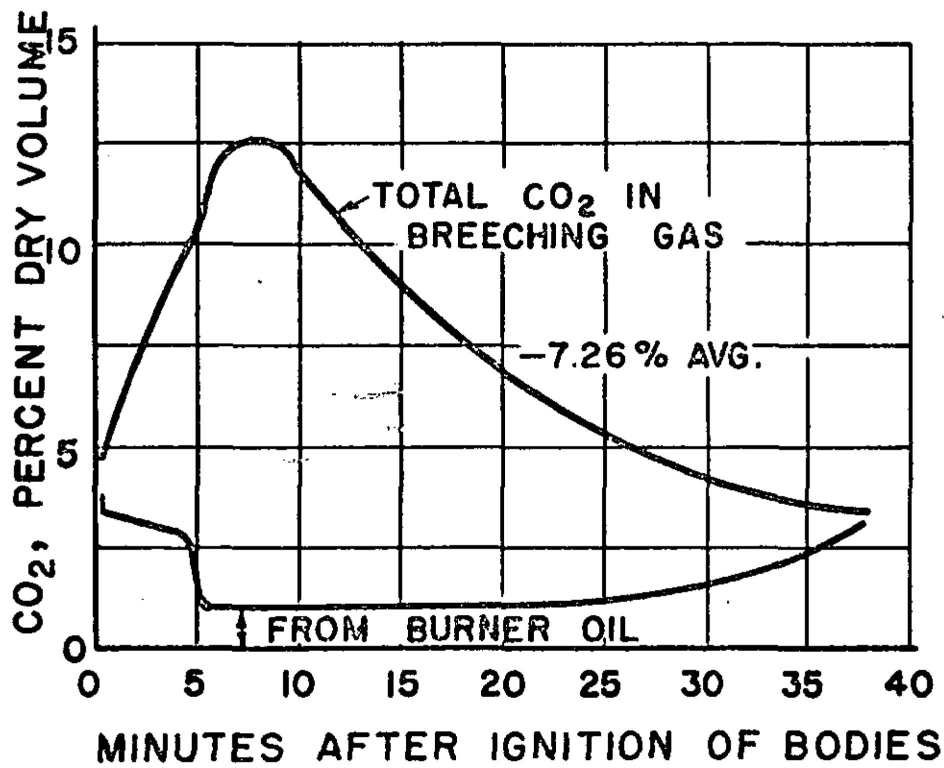

Figure 11. Carbon Dioxide in Breeching Gas.

The carbon monoxide determinations of the breeching gas were all in the range of 0.01 to 0.03%.

The water vapor produced by the combustion of hydrogen was determined by evaluating the gas analyses and by measuring the condensate in the impinger bottles. In general, the carbon:hydrogen ratio in the net combustible, as determined by gas analysis, was 8:1 or 11% hydrogen. Allowing for the 13.7% hydrogen in the oil, the net combustible in the auto bodies was 90% carbon and 10% hydrogen.

Drafts

With the check damper open and the flaps on the main doors closed, the breeching draft rose to 0.35 in. w.c. during the warmup period. By closing the check damper at body light-off, the breeching draft increased to 0.50 in. w.c. The drafts in the breeching and main furnace are plotted in Figure 10. Seventy-five per cent of the draft loss between the breeching and main chamber occurred in the checkers, and 25% in the flame-port. Had the stack draft been less, it would have been necessary to enlarge the flame-port or to enlarge the checker passages. The latter change would have affected smoke control and heat storage adversely.

To prevent smoke leakage from the main chamber, a slight negative pressure was maintained under the ceiling by limiting the flow of air under the main doors. The draft at floor level was essentially 0.10 in. w.c. when the draft near the ceiling was 0.03 in. w.c. or less. In other words, the stack effect which occurs in the main chamber must be considered in the design and operation of the furnace.

Gas Velocities

During the peak of the body-burning cycle, the air rate was quite near optimum. The minimum percentage of excess air was reached at that time and was only 29.7%. Even when the flue gas contained 10% CO_2 by dry volume, the percentage excess air was only 57.5%. On the average, excess air was 115%, which corresponds to 7.26% CO_2. It is likely that smoke and increased loss of unburned carbon as particulate matter would result if the air flow were restricted further in this type of furnace. A stack height of 55 to 60 ft would therefore be satisfactory for future installations.

The average gas velocity in the breeching was 1940 fpm at 1532F., the average temperature. In a stack of 48-in. O.D. (39-in. I.D.) the gas velocity would have been about 2170 fpm avg., a satisfactory rate. The stack diameter actually used (47 in. I.D. brick lining) was therefore larger than necessary.

Material and Heat Balances

The material and heat balances for the burning of the bodies are given in Tables IV and V respectively in the Appendix. The data provided in these tables will enable the reader to make numerous calculations for the design of continuous body burners and larger batch operations.

AIR-POLLUTION TEST RESULTS

Smoke

Smoke of hydrocarbon origin was produced in the primary chamber, but the emission of black and gray smoke to the atmosphere was prevented at will by maintaining sufficient temperature in the afterburner. Hence the stack gases were virtually clear at all times and would meet the requirements of all smoke ordinances. A light gray smoke (0.5 Ringelmann max.) was produced when wet bodies and insufficient oil firing in the afterburner caused the breeching gas temperature to remain below 1450F during the early part of a burn. This temperature was not necessary for smokelessness during the latter part of the burn when the body combustibles were largely devolatilized.

When viewing the flue gas during the first third of a burn, a faint whitish-gray haze could be observed against the black background under the rain cap. This emission was not visible against the sky.

On one test the two bodies were burned with an initial afterburner temperature of 580F and the oil burner shut off after the bodies were ignited. Smoke grayness increased to No. 2 Ringelmann, which persisted for 5 minutes, and gradually declined. The breeching temperature never exceeded 1210F on this run.

Dust Loadings

The particulate matter in the flue gas during the burns was determined after the furnace had been in daily use burning auto bodies and insulated copper wire for 4 months. Dust was sampled during the burning of 10 bodies; 3.231 gm of dust was collected. The average dust loading was 0.357 lb of dry dust per 1000 lb for flue gas of 7.26% avg. CO_2, or 115% excess air. Corrected to 50% excess air (ASME), the dust loading was 0.512 lb per 1000 lb of flue gas. The usual dust limit specified in ordinances is 0.85 lb per 1000 lb of gas corrected to 50% excess air.

The dust was 33% ash and 67% combustible, the latter being almost entirely carbon.

Depending upon wind velocities, flakes and dust of undetermined but minor amounts were blown off the burned bodies as they were removed from the furnace. The nuisance was largely confined to the unloading area.

Stack-Gas Odor

The odor of the breeching gas was noted during all tests by sniffing the gas directly. A faint burnt odor was detected, the character and concentration of which are not expected to cause complaint under normal circumstances.

AFTERBURNER OIL CONSUMPTION AND DAMPERING

The preliminary warmup period and the operation of the afterburner between burns can be wasteful of oil unless the flow of air through the afterburner is restricted during those periods. A hinged cap for the stack is recommended for the dual purpose of flow control and weather protection.

Preceding Test 12, for example, the afterburner was preheated on the following schedule without the benefit of adequate air restriction. The stack base was open to check the stack draft and the flaps under the main doors were closed, but leakage air entered around the doors and from other sources.

	Minutes	Oil rate, gph	Oil Consumpt., gal.
	First 25	21.0	8.75
	Next 47	31.0	24.25
	Next 76	36.5	46.25
Totals	148 min.		79.25 gal.

The breeching temperature rose to 1250F in 148 minutes after the consumption of 79.25 gal. of oil. The excess air was 258% of that theoretically required to burn the oil when the CO_2 in the breeching gas reached 4.0% during the period of highest oil flow rate. The total air rate was 253 lb per minute through the afterburner.

By dampering the air flow at the flame port during the preheating for Test 15, the breeching the temperature was raised to 1250F by the following firing schedule:

Minutes	Oil Rate, gph	Oil Consumpt., gal	CO_2 %
First 11	21.0	3.85	3.4
Next 12	27.5	5.50	5.8
Next 11	36.5	6.70	7.0
34		16.05	

The air rate was reduced to 132-147 lb per minute through the afterburner without causing smoke. The excess air during the last period was only 108%. The oil consumption had been reduced to only 20.3% of the previous amount. The preheat time was reduced to 23.0% of the previous preheat time.

Some further improvement could undoubtedly be made in reducing oil consumption by a further restriction in air flow. However, it would not be advisable to reduce the preheat time below 30 minutes as a gradual warmup increases refractory life.

To meet the requirements the flow damper should be nearly closed during initial warmup and between burns, and be full open while the cars are burning. The oil firing rate between burns and during burning of cars could be held at a constant rate of 20 gph. The afterburner would thus consume 16 gal during the first 30 minutes, 150 gal during the remaining 7½ hr of the 8-hr working day, and 10 gal during the 30-min. lunch period, for a total of 175 gal per day.

COSTS AND THROUGHPUT

Cost of Construction

The initial cost for the single- and double-ended furnaces are given in Table II on two bases; (1) normal conditions of soil, level ground, availability of second-hand structural steel, and (2) added costs where these factors are not favorable. The actual costs in any case will depend on local conditions, labor rates, etc., as reflected in contractor's bids. It is conceivable that the costs under the normal conditions will be reduced in some cases, as with a second-hand oil burner, existing fuel tank, etc. The costs are exclusive of land.

The contractor's supervision and profit is included in the items and does not appear as a separate item.

Table II. Cost of Construction

Item	Single-Ended Furnace Normal Costs	Single-Ended Furnace Possible Extras	Double-Ended Furnace Normal Costs	Double-Ended Furnace Possible Extras
Excavation and filling	300		400	
Piling		700		800
Footers	400		500	
Concrete floor and apron(s), stackbase	800	475	1050	475
Rails and ties	100		160	
Concrete blocks and mortar	800		800	
Firebricks and mortar	1800		1800	
Ceiling, refractories and insulation	815		815	
Structural steel	250	250	300	300
Doors, insulated	600	100	1200	200
Roof, burner shed, erected	1450		1300	
Stack erected	1200	2000	1200	2000
Oil burner, installed	1600		1600	
Oil tank installed	800	200	800	200
Overfire jets, blower	1000		800	
Steel cart(s) fabricated	200	300	400	600
Mason labor	2000		2000	
Welding labor, misc.	350		375	
Electric wiring	425	300	425	300
Winches	335	300	375	300
Painting	200		200	
Pyrometer, installed	300		300	
Fees for permits	25	50	25	50
Normal cost	$15,750		$16,825	
Possible extras		$4675		$5225
Normal cost plus possible extras	$20,425		$22,050	

Annual and Unit Costs

The cost of operation will vary with labor rates and the cost of oil, as well as with the productivity achieved. Table III is offered for guidance with the expectation that the reader will make his own adjustments.

As potential users of the burner will be interested in the added cost of preparing auto bodies by the smokeless burner, all costs are incremental to open burning. Delivery of bodies to the burning site, and removal to the press will be considered the same in each case. Some oil will be used to ignite the bodies in either case, and has been omitted in Table III.

It is assumed that one man and fork-lift truck will be required for the burner beyond that for open burning. Daily operation for 8 hr is assumed, with $\frac{1}{2}$ hr for lunch. Production is assumed 5 days a week and 48 weeks a year to allow for holidays, vacations and maintenance. Daily warmup of $\frac{1}{2}$ hr is offset by time to unload bodies left overnight, reloading, and other preparations. The double-ended furnace would have a 5-min. period between burns while the single-ended furnace would require 20 min.

The daily throughput of the double-ended furnace on the above basis would be 28 bodies maximum, with the last cars left to burn out unattended. Similarly, the single-ended furnace would have a daily maximum throughput of 20 bodies.

On an annual basis the production is assumed at 90% of the theoretical, which is equivalent to 1 day lost time per 10 working days during a 48-wk work year.

The investments assumed in Table III are the "Normal Costs" plus one-half of the "Possible Extras". Depending on circumstances, the actual capital outlay may be more or less. In any case, the capital cost is relatively minor on an annual basis.

Table III. Annual Capital and Operating Cost

	Single-Ended Burner	Double-Ended Burner
Amortization in 10 years		
$18,088 for single-ended burner	1809	
19,438 for double-ended burner		1944
Interest @ 6% for unamortized balance	543	583
Direct labor	8000	8000
Oil @ 175 gpd x 240 x $0.12	5040	5040
Fork-lift truck @ $2.50/hr	4800	4800
Electric power, 7.5 hp.	550	550
Maintenance	1000	1200
Miscellaneous	400	600
	$22142	$22717
Value of non-ferrous metals assumed equal to cost of cleaning	0	0
Total	$22142	$22717
Annual output		
28 x 240 x 0.90		6048 bodies
20 x 240 x 0.90	4320 bodies	
Steel @ 1100 lb	2376 tons	3326 tons
Annual cost per ton of steel above cost of open burning.	$9.32	$6.83
Annual cost per body burned above cost of open burning.	$5.13	$3.76

SUMMARY AND CONCLUSIONS

1. Large furnaces for burning scrapped automobile bodies have been developed by several firms to meet the requirements of local and state air-pollution ordinances. Smokelessness is achieved by the use of afterburner chambers or electrostatic precipitators for eliminating the smoke generated from the burning bodies.

2. A double-ended shed-type furnace with a smokeless afterburner was designed by the authors for burning up to 28 auto bodies a day in an auto-wrecking or scrap yard. The furnace may be constructed from concrete blocks, firebrick and used or new steel by local contractors. A single-ended proto-type furnace was used to develop and prove the design.

3. The transfer of auto bodies into and out of the furnace is readily accomplished on simple rail-supported carts. While one cartload of two bodies, one atop the other, is burning in the double-ended furnace, the operator can unload and reload the second cart by means of a large fork-lift truck. The burning time is 30 minutes and the shuttling of the two carts can be done in 5 minutes by a winch.

4. Smoke emission from the stack can be controlled at will to the faintest visible fume by maintaining 1500F in the afterburner and over 30% excess air.

5. A daily consumption of 175 gal. of No. 4 fuel oil in the afterburner, or the equivalent in natural gas, would suffice for smoke control. A draft-control damper, preferable on the stack, must be used to achieve fuel economy.

6. The total particulate matter (dust) in the exhaust gas was determined as 0.51 lb per 1000 lb of flue gas corrected to 50% excess air. The dust was 33% ash and 67% carbon. Although this dust loading is well within the common legal limit of 0.85 lb per 1000 lb of flue gas, some further reduction may be made by a higher temperature in the afterburner, so as to burn the carbon that escaped at 1532F avg. breeching temperature.

7. The complete cost of construction for the double-ended furnace, ready to operate, should range between $17,000 and $22,000. The single-ended furnace would cost only about $600 less.

8. The double-ended furnace has an annual capacity of 6048 bodies when operated 216 full days a year. On the same basis, the single-ended furnace has a capacity of only 4320 bodies. At 1100 lb of clean steel per body, the respective tonnages would be 3326 and 2376 a year.

9. The capital and operating cost of the double-ended furnace is estimated at $3.76 per body or $6.83 per net ton of steel above the cost of open burning. Similarly, the cost of burning would be $5.13 per body or $9.32 per net ton with the single-ended furnace.

10. Plans of the body burners are available at $5 a set by written request to the authors, with checks made payable to "New York University". Local codes and conditions may require the services of consulting engineers to specify foundations and to submit plans for approval by local authorities.

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APPENDIX

The average material balance for the tests, exclusive of the warm-up periods, is given in Table IV.

Table IV. Material Balance During Test Burns, Avg.

Input		Lb/Burn	Lb/Body
2 Auto bodies		2993	1497
Afterburner and ignition oil, 16.75 gal.		132	66
Dry air		13979	6989
Air moisture		76	38
Total lb		17,180	8590
Output			
2 Burned auto bodies		2461	1230
Ash and metal on floor		10	5
Dry flue gas		13982	6991
CO_2	1459 lb		
O_2	1780		
N_2	10,743		
Flue dust		5	3
Moisture in flue gas		722	361
Total lb		17,180	8590

The average heat balance is given in Table V . Because the primary furnace was cold at the beginning of most tests and had only partially warmed in a few burns, the heat loss from the furnace and the oil consumption were both higher than would prevail with more continuous production.

A heating value of 17,000 Btu per lb of combustible C and H was assumed on the basis of carbon and hydrogen available for combustion in cellulose, rubber, cellulose nitrate paint and plastics.

Table V . Heat Balance During Test Burns, Avg.

	Btu/Burn	Btu/Body
Calorific value of oil, 16.75 gal x 146,370	2,450,000	1,225,000
Calorific value of body combustible, 315 x 17000	5,350,000	2,675,000
Total	7,800,000	3,900,000
Output		
Sensible heat to auto bodies	275,000	137,500
Sensible heat to offal	800	400
Sensible heat to cart	60,000	30,000
Sensible heat to dry flue gas	5,420,000	2,710,000
Sensible and latent heat to moisture	1,169,000	584,500
Heat loss from furnace and unacct. for	875,200	437,600
Total	7,800,000	3,900,000