AGRO-INDUSTRIAL REPORT

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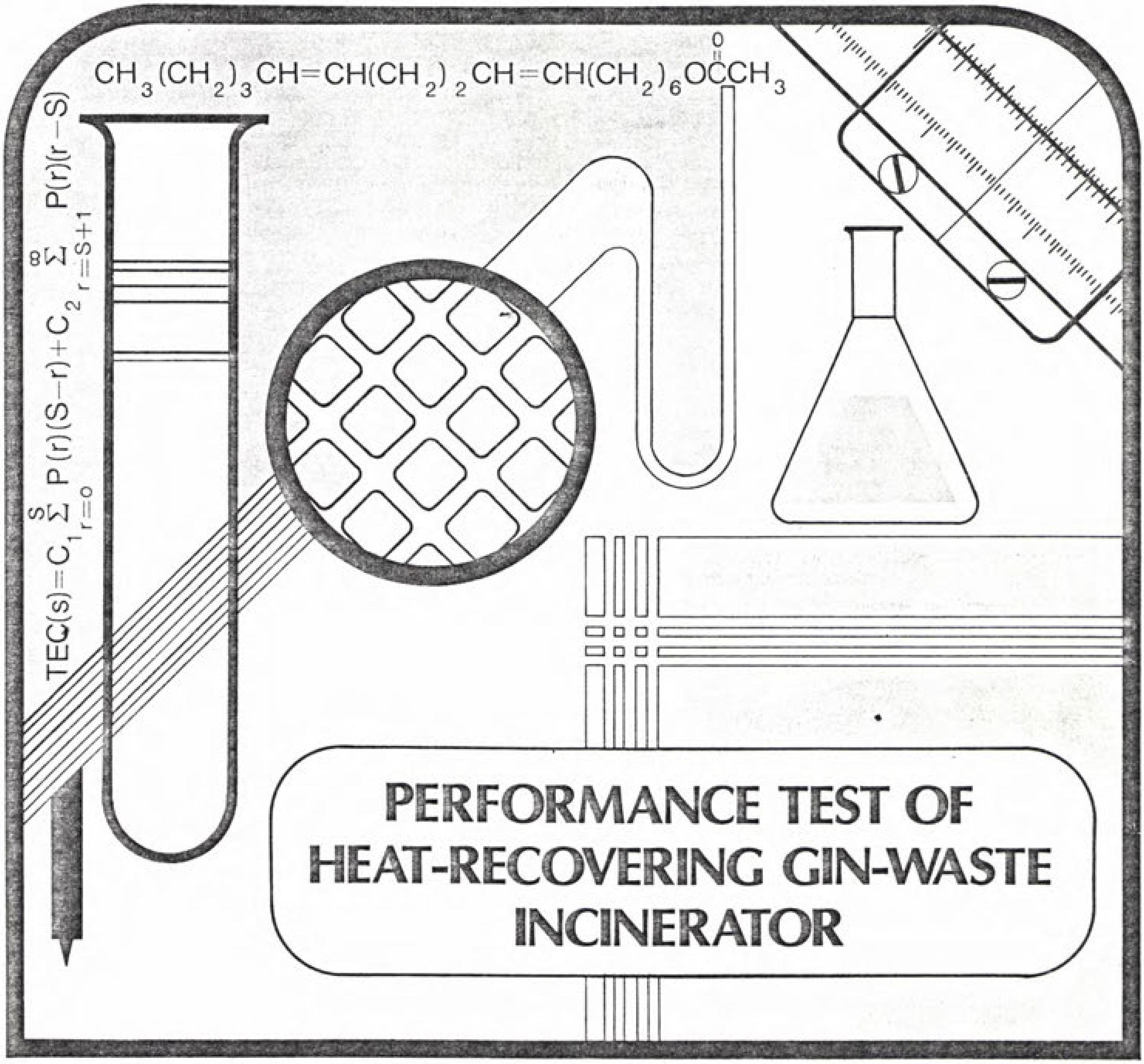

PERFORMANCE TEST OF HEAT-RECOVERING GIN-WASTE INCINERATOR

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Performance Test of Heat-Recovering Gin-Waste Incinerator

By W.F. LALOR, J.K. JONES and G.A. SLATER

Introduction

During the 1975 ginning season, Cotton Incorporated made an operational study of a heat-recovering incinerator at the Kiech-Shauver Gin at Monette, Arkansas. Approximately 8,200 bales of cotton were ginned during the season. Most of the drying heat was supplied by recovering heat from burning gin trash in the incinerator.

This Agro-Industrial Report is an account of our findings. The equipment involved is described and its performance evaluated. The problems encountered are discussed, and we give recommendations about how to lessen some of them.

The manufacturer of the heat-recovering incinerator is Ecology Enterprises, Dadeville, Alabama. This incinerator is the only one we know of that has been tested and that performed well when coupled to a modern, high-speed gin.

Description of the Installation

The Gin. The Kiech-Shauver Gin Company operates a four-stand, split-overhead gin with a capacity of 24 bales per hour. The seed cotton stream splits immediately after the first tower dryer, each stream then passing to the overhead cleaning equipment and to a second tower dryer. Two stages of lint cleaning are operated behind each gin stand. *The lint cleaner waste is not kept separated from the overhead cleaning and other waste materials.*

The dryer control system consists of a temperature sensor at the outlet of each tower drying stage. Signals from that sensor control the heat input from the natural gas burners.

The Incinerator. The installation consists of a pair of identical incinerators, each capable of handling the trash from a 12-bale per hour gin. Figure 1 is a photograph of the installation. The incinerator design was based on a trash production of 240 pounds per bale. While this trash content is unusually high for picked cotton, the Ecology Enterprises design anticipated the worst possible conditions.

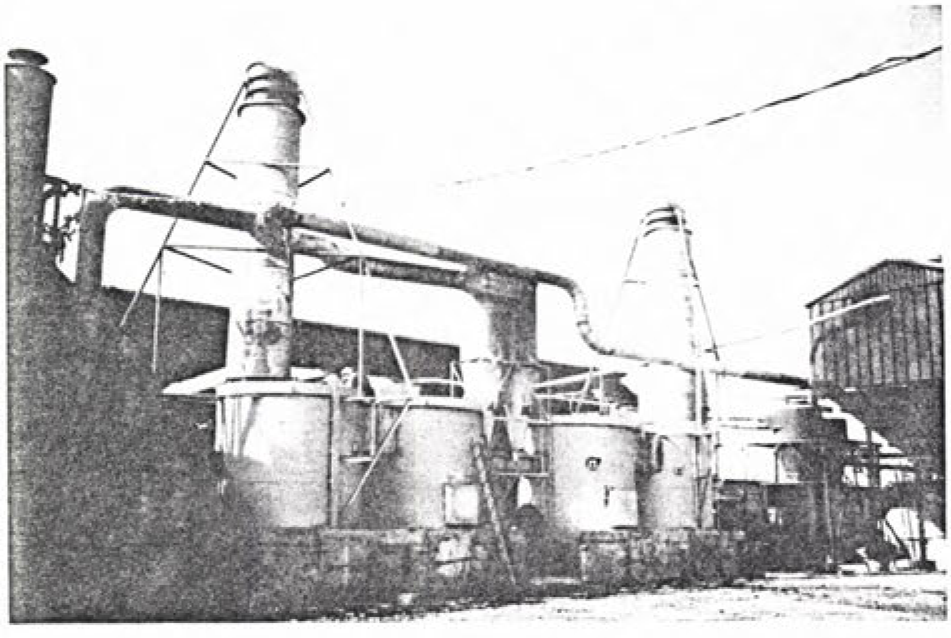

Figure 1. Heat recovering incinerator at the Kiech-Shauver Gin Company, Monette, Arkansas.

Figure 2 (Page 6) is a schematic diagram of the system. Each incinerator consists of two cells, or chambers. The trash is conveyed by auger into the first, or primary, cell, where combustion begins. By far the largest portion of the ash settles to the bottom of this cell.

The combusting gases then pass through a throat into a second cell. The gas velocity is reduced in the second chamber, allowing suspended ash material to settle out. The settling-out process is aided by a system of baffles.

The hot flue gases then pass up through the stack. The stack itself is stainless steel and it is surrounded by a stainless steel, insulated jacket.

Air for drying the cotton is drawn in at the top of the jacket by suction from the hot-air fans. It passes down through the annular space between the jacket and the stack, where it is warmed by heat transfer from the stack gases through the stainless steel stack wall. The heated air is then ducted into the hot-air fan just upstream from the gas burners.

A bell housing and air-bleed valve are provided upstream from the hot-air fan. These allow the control system to mix cool air with the incinerator-heated air to produce the desired temperatures at the dryer. Figure 3 (Page 7) shows the air bleed arrangement.

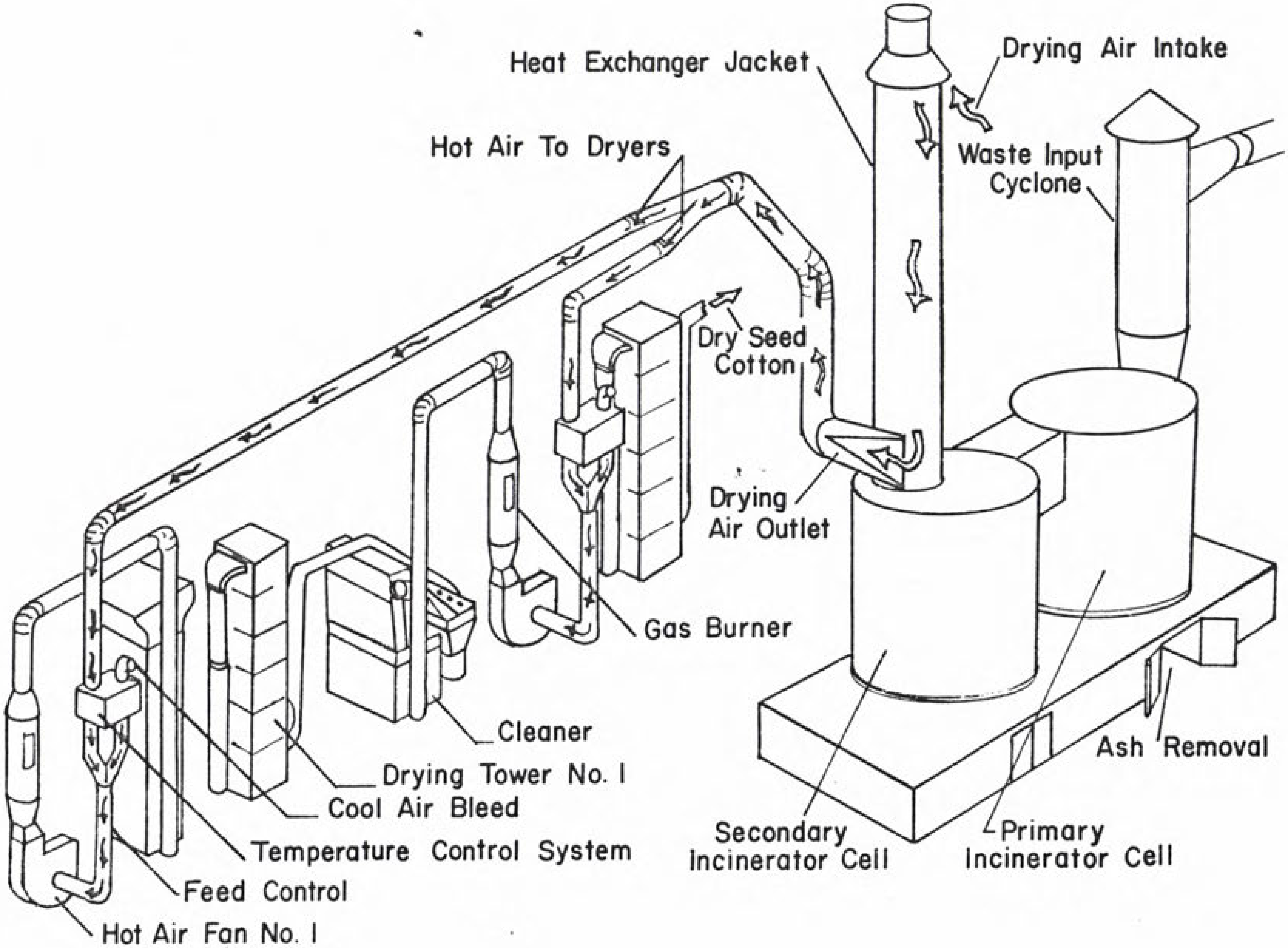

Figure 2. Schematic diagram explaining the operating principles of the heat-recovering incinerator.

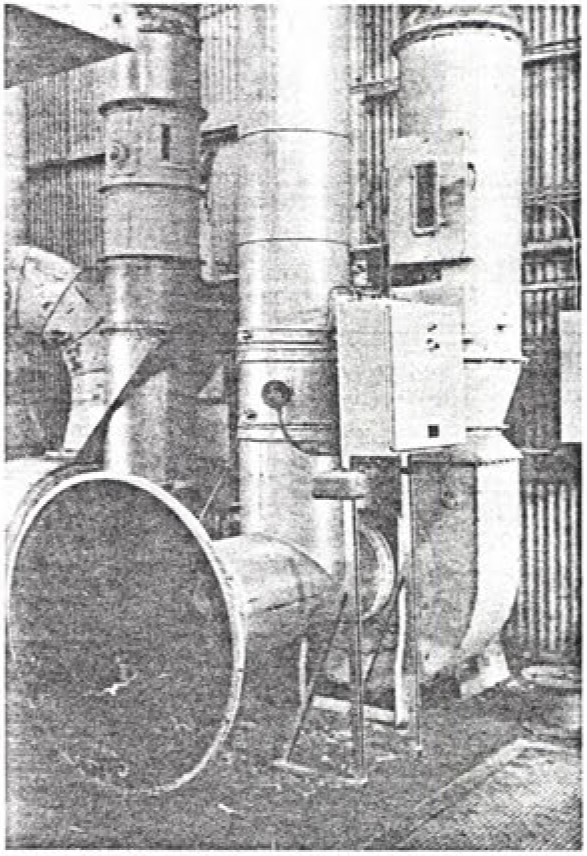

Figure 3. Air bleed arrangement for mixing hot and cool air to produce the desired drying temperatures.

The gas burners are maintained in a usable condition because the heat recovery system is not intended to replace 100 per cent of the gas heat. The control system is designed to draw all available heat from the incinerator, then to supplement it with gas heat when necessary.

The trash comes from the various gin fans. It enters a bank of cyclones in the usual manner. It is then conveyed by an auger to a trash fan, which conveys it through a split stream to two cyclone separators--one for each of the two incinerators. The trash passes from these separators into two auger conveyors, which convey it into the primary incinerator chambers.

Previous Trash Handling System. Until 1975, the Kiech-Shauver Gin Company burned the trash from the gin in a teepee burner. The bank of cyclone separators and the trash-conveying auger and fan located beneath them were a part of the teepee disposal system. Only the necessary ducting and the cyclone separators above the incinerator feed augers were added to accommodate the new incinerator.

Clean-air legislation prevented the continued use of the teepee burner. The alternative to burning the trash was to haul it to locations where it could be dumped--if suitable locations could be found.

Dryer Fuel Supply. During recent years, the gas supply to the gin was interrupted during periods of cold weather. This interrupted ginning. In turn, cotton harvesting was halted when all trailers were filled.

The gin management considered installing storage for sufficient LP gas to avoid having to shut down during periods of natural-gas interruption. This would have cost approximately $40,000, with no guarantee of a supply of LP gas.

The installation of an incinerator to burn the gin trash and, at the same time, supply drying heat to the gin was, therefore, an attractive alternative. It would take care of both the trash disposal and the gas interruption problems.

Operation and Performance

Ginning Rate. The Kiech-Shauver Gin has the rated capacity to operate at 24 bales per hour. We observed ginning rates of just over 25 bales per hour. The rates were sustained for as much as one hour. The normal ginning rate from trailers was 18 bales per hour and from modules, 23 bales per hour.

Cotton was ginned direct from trailers and from modules that had been stored for up to six weeks.

Turnout and Trash Content. Turnout was observed to vary from 31 per cent to over 37 per cent, figured on a moist basis. (Turnout is the ratio of lint ginned to seed cotton entering the gin.)

We observed trash contents varying from 140 to over 260 pounds per 480-lb bale of lint when calculated on a moist basis. On a dry weight basis, this corresponds to trash contents of 80-200 pounds per bale. High trash content was associated with low turnout.

About 760 pounds of seed were produced per bale of lint, based on a seed moisture content of 12-15 per cent. *Table 1* (Page 10) shows turnout analysis on a moist basis, and *Table 2* (Page 11) shows turnout analysis on a dry-matter basis. In all cases, trash content was determined by arithmetical subtraction of weights--that is, trash weight is seed cotton weight, minus lint weight, minus seed weight.

True trash content per bale must be expressed on a dry weight basis. When the trash calculation is made by using wet weight differences, the trash content per bale can be overestimated by as much as 80 pounds--the weight of moisture removed in the dryers.

Because this was a commercially operating gin, it was difficult to make observations of moisture content and trash content of single bales in order to make bale-by-bale comparisons. Because there were no seed scales, cottonseed was not weighed until it had been loaded on the truck. We could not justify altering the seed handling system to allow the seed from each bale to be weighed.

Table 1. Turnout Analysis (moist basis)

Sample Date	Weight of Fractions (lb/480-lb bale) Seed Cotton	Lint	Seed	Trash*	Turnout %
10/2/75	1353	480	730	143	35.5
10/9/75	1387	480	726	181	34.6
10/9/75	1508	480	760	268	31.8
10/10/75	1428	480	750	198	33.6
10/10/75	1438	480	750	208	33.4
10/11/75	1388	480	737	171	34.6
10/12/75	1427	480	765	182	33.6
10/15/75	1354	480	765	109	35.5
10/22/75	1411	480	739	192	34.0
10/29/75	1492	480	767	245	32.2
10/30/75	1523	480	787	256	31.5
11/1/75	1448	480	747	221	33.1
11/1/75	1513	480	764	268	31.7
Mean	1436	480	753	203	33.5

*Trash weight per bale includes weight of moisture removed by the dryers. See *Table 2* for trash weight per bale when moisture contents have been compensated for.

Table 2. Turnout Analysis (dry-matter basis)

Sample Date	Weight of Fractions (lb/480-lb bale) Seed Cotton	Lint	Seed	Trash	Trash Moisture Content (%)*
10/17/75	1160	459	617	84	13.62
10/30/75	1273	452	668	153	17.56
11/1/75	1257	456	660	141	12.77
11/1/75	1225	456	649	121	12.77
11/1/75	1313	456	674	184	12.77
Mean	1246	456	654	136	13.90

Trash contents in *Table 2* were determined from lots of about 60 bales. Moisture contents were determined from samples within the 60-bale lots; the results were used to estimate the quantities of dry matter in seed cotton, lint, seed and trash. This procedure allowed us to estimate the average dry weight of trash per bale; we realize that some small errors are involved.

Moisture Content. Moisture contents of seed cotton, lint, cottonseed and trash were determined by the oven drying method. *Table 3* (Page 12) is a list of some of the moisture contents we found. The selection shown gives an idea of the range involved. Cotton was not normally defoliated in the Monette area; hence the high seed-cotton moisture contents, even with good harvesting weather.

Heat Recovery. We installed temperature measuring instruments at the locations necessary to allow us to evaluate the performance of the system.

*Samples collected at trash fan.

We also installed air flow measuring equipment which, combined with the temperature data, permitted us to calculate the amount of heat per bale recovered from the incinerator stacks. *Table 4* (Page 13) shows examples of the heat-recovery rates per bale and of some of the associated temperatures.

Table 3. Moisture Content of Material at Different Locations in the Gin (%)

Sample	Sample Location				
Date	Suction Pipe	Feeder Apron	Lint Slide	Trash Fan	Seed Belt
10/8/75	13.01	-	-	17.99	-
10/9/75	16.86	-	-	19.86	-
10/9/75	17.32	14.21	-	16.78	-
10/10/75	19.36	14.39	-	17.48	-
10/12/75	15.03	14.44	-	20.68	-
10/12/75	19.83	14.97	5.90	20.70	-
10/14/75	11.22	8.62	5.30	11.54	-
10/15/75	12.25	9.94	5.80	12.65	-
10/17/75	17.77	11.43	4.47	13.62	16.54
10/30/75	16.40	12.38	5.73	17.56	15.22
11/1/75	13.21	10.67	5.08	12.77	11.66
Mean	15.66	12.34	5.38	16.51	14.47

Gas Consumption. We installed a flow-rate measuring instrument in the gas line. Gas flow to all three burners was measured by one instrument. The maximum gas flow to the burners was about 110 cubic feet per minute. This means that the gas burners were capable of supplying as much as one-half million BTUs per bale if the cotton was very damp. For the 1975 crop conditions, about 200,000 BTUs per bale were supplied by the burners in the absence of incinerator heat during a one-week period in mid-season.

Table 4. Heat Recovery per Bale and Drying Air Temperatures

Ginning Rate (Bales/hr)	BTU Recovered per Bale	Heated Air Temp (F)*		Drying Air Temp (F)**	
		Dryer 1	Dryer 2	Dryer 1	Dryer 2
23	158,298	400	480	290	170
23	98,974	220	320	190	160
23	105,037	220	320	190	160
20	100,617	300	340	190	150
20	107,345	340	360	190	150
20	118,080	340	380	190	170
20	134,857	350	390	200	170
25	109,217	290	340	240	190
25	103,416	260	330	230	190
23	132,481	275	240	230	220
20	124,589	250	340	250	190
24	89,806	260	360	190	160
24	96,565	280	380	190	170
24	116,816	310	450	210	190
24	137,145	370	500	230	210
Mean 22.5	115,549	298	369	214	177

*Temperature of air before cool air was blended with it by action of the control system.

**Temperature of drying air at seed cotton pick-up points. No gas heat was used.

Heat input from the burners was used during warm-up periods each morning.

When cotton was too wet to be dryed with the heat produced from the incinerators, gas heat was used. Gas heat was commonly needed on cool, damp days. The average gas consumption per bale over the entire ginning season was about 50 cubic feet, or six cents' worth.

During the first few days of ginning, all the drying heat was supplied from the incinerator because the gas burners were inoperative.

No gas was used as a combustion aid in the incinerator. Most of the gas used was to supply heat during warm-up periods.

Lighting the Incinerator

The incinerator is lighted from a cold start by burning wood, discarded tires or other available material in the primary incinerator chamber until temperatures of 700 F to 800 F are consistently observed at the base of the stacks. Gin waste can then be fed into the incinerators. Combustion will proceed without problems as the temperatures continue to rise. This start-up procedure takes about two hours. It is needed only after shutdown periods greater than 24 hours.

The Kiech-Shauver Gin operated on a one-shift, 16-hour per day basis. This means that the incinerator was without fuel for at least eight hours per day.

Start-up each morning was a very simple matter. Lint tags collected from the lint cleaners were saved and soaked in diesel fuel. When trash began to enter the primary incinerator cells, the diesel-soaked lint was ignited in the primary cells and the ash removal doors were left ajar to provide the extra draft to get the fire started. (See Figure 4 on Page 15.) This daily start-up routine required a maximum of ten minutes.

Figure 4. Lighting the incinerator fire with diesel-soaked lint tags.

Occasionally, a fire went out after we thought it had been well started. This was an unusual occurrence. It probably could have been prevented by leaving the ash-removal doors open longer. When the fire goes out, it creates a problem because unburned trash continues to accumulate in the incinerator. Ginning must be stopped while the fire is relighted and the accumulated trash consumed. Hence the need for the warning devices we discuss later in this report.

The gin shut down for meal breaks. No special procedure was needed to re-start the incinerator system after one or two hours of downtime. The high residual temperatures in the primary cells and the smoldering trash residue in the ash pit provided all the heat necessary to burn the new trash as it entered the incinerator.

Ash Clean-out

Figure 5 (Page 16) shows the ash being removed from the ash pit of one of the primary incinerator cells. The front-end shovel arrangement, designed by

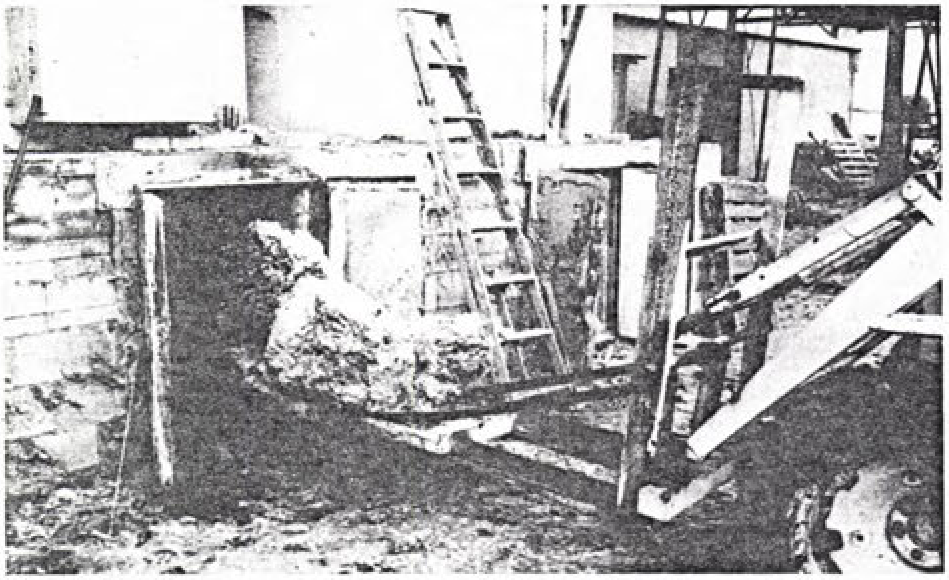

Figure 5. Ash removal from primary-cell ash pit took 10-15 minutes each morning.

the gin manager, served its purpose very well. To use this ash removal method, it is necessary to allow the incinerator to cool for 3-4 hours. Ash was removed each morning before start-up.

We did not measure the quantities of ash removed. Figure 6 (Page 17) shows the ash pile from about 5,000 bales. Ash accumulation in the secondary chambers was so small that cleaning was not necessary until the ginning season was over.

Temperatures During Warm-up

The system took 1-1½ hours to reach steady operating temperature each morning. During warm-up time, gas was used to supplement the incinerator heat. Figure 7 (Page 17) shows start-up temperatures after eight hours of downtime. The two traces represent temperature variations in the drying air at the point where seed cotton is dropped into the hot-air line.

The undulating portion of the traces was generated when natural gas was in use to supplement incinerator heat. Because the drying-air temperature-control sensor was located at the outlet of the tower dryer, we know from

Figure 6. Ash disposal created no problems; this is the ash pile from 5,000 bales of spindle-picked cotton.

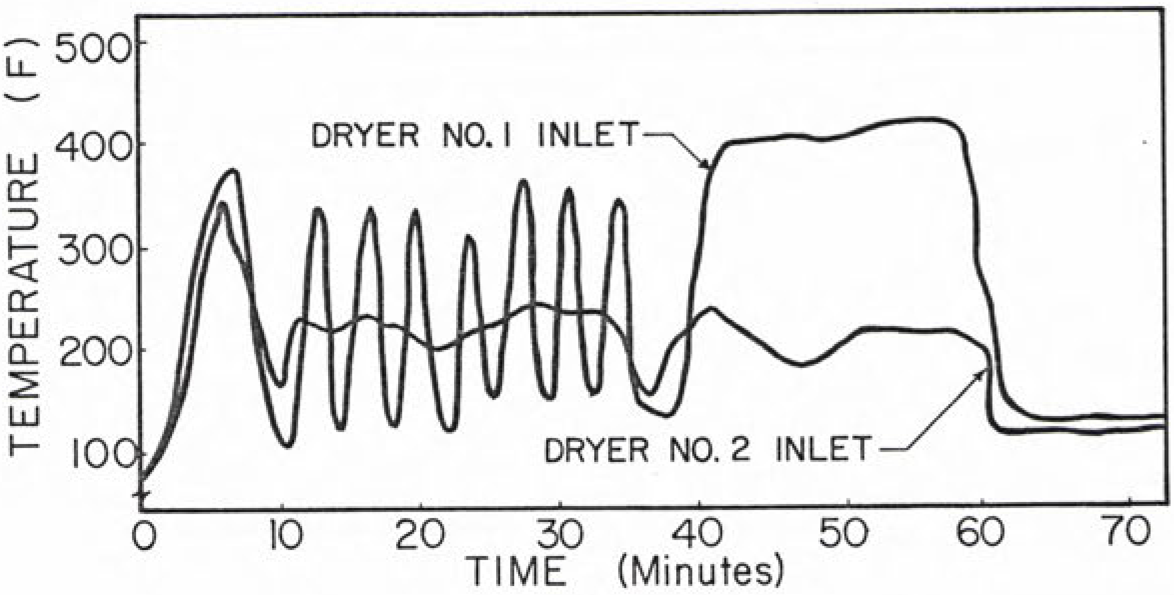

Figure 7. Sufficient heat to dry cotton was recovered after 1-1½ hours each morning. On the day when this temperature chart was recorded, gas was used to supplement incinerator heat for the first 60 minutes after start-up.

experience that the dryer outlet temperature remained fairly constant and that this type of temperature variation at the dryer inlet is common.*

The gas utilization in Figure 7 stopped after one hour. Figure 8 (Page 19) shows another start-up period. (Note that the temperature scales in Figures 7 and 8 are different.) In Figure 8 we see that gas utilization had not stopped at the end of the 70-minute period shown. Our records show that, in this particular case, gas consumption ceased at 80 minutes from start-up. The ginner often overrode the automatic temperature controls. This accounts for some of the start-up time variability.

Figure 8 also shows the flue gas temperatures at the base of each incinerator stack during the warm-up period. Normal operating temperatures after steady state has been reached are 1,500 F and 1,800 F.

Start-up after a 60-minute downtime required little or no gas utilization. Figure 9 (Page 19) shows one such start-up period during which gas was utilized in each of the dryers for a brief period. More often than not, no gas was used during a start-up after downtime for meals.

Figure 10 (Page 20) shows how drying air temperatures varied with time during steady operating conditions. The two dips in the dryer No. 2 temperature trace were probably due to breaks in ginning between modules. The temperature traces in Figure 10 were generated when incinerator heat only was being used.

Figure 11 (Page 20) shows steady-state operating temperatures when gas heat alone was used for drying. The characteristic temperature variations at the pick-up points are evident. Note that maximum temperature was about 350 F in dryer No. 1. The temperature in dryer No. 2 was less variable.

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*_Handbook for Cotton Ginners_, Agricultural Handbook No. 260, ARS, USDA, February 1964, p. 27.

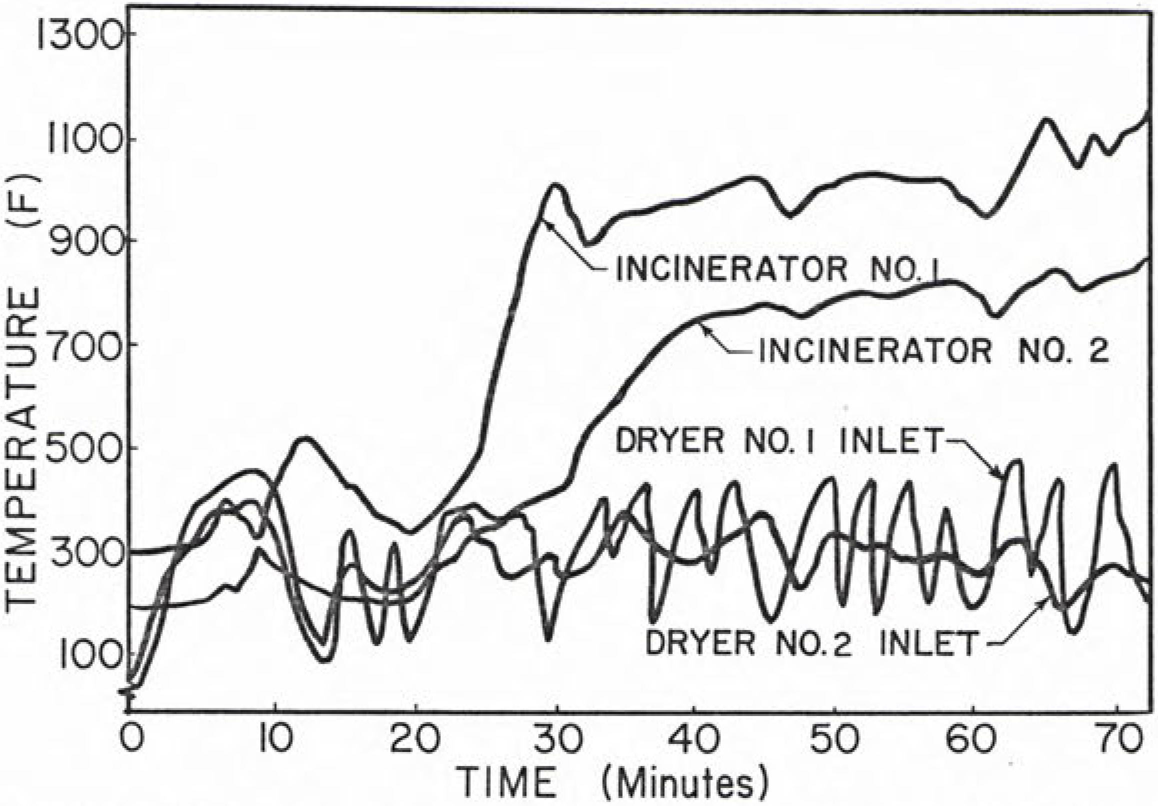

Figure 8. This record shows how flue-gas temperature increased after a morning start-up; the gin had been down overnight (8 hours). Drying-air temperature variation indicates that gas was in use for the entire period shown.

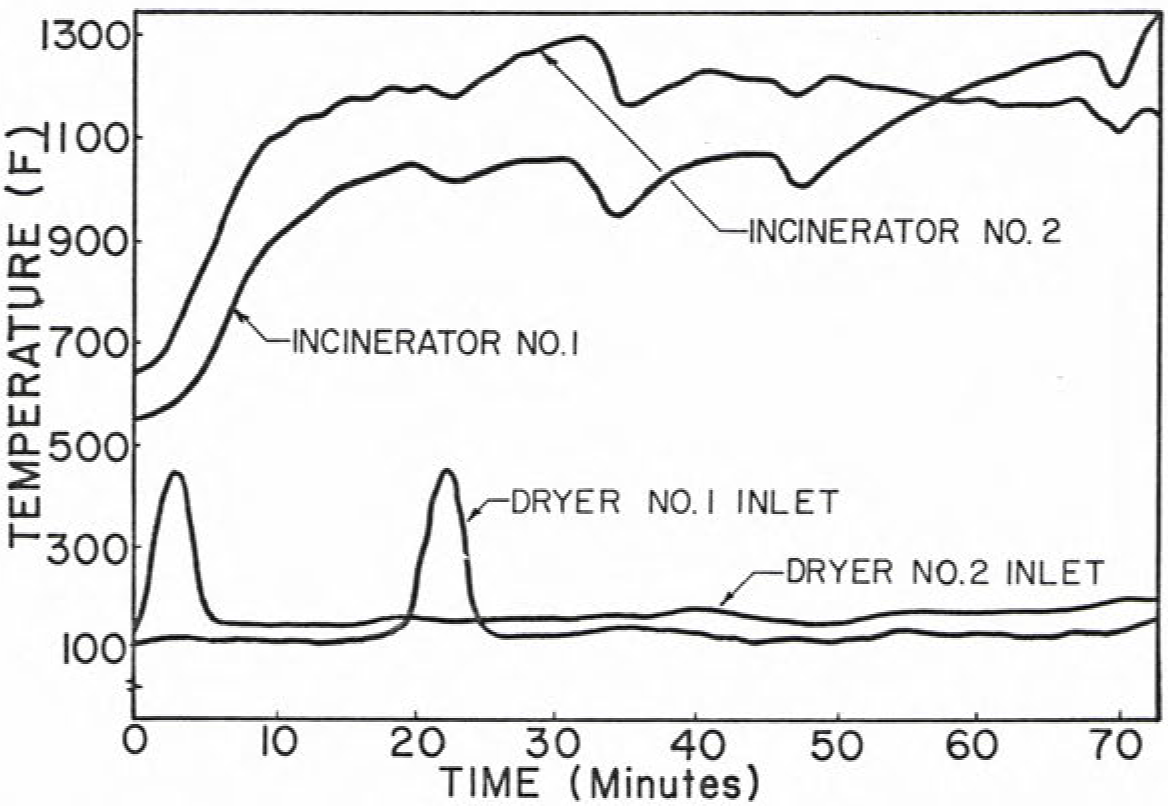

Figure 9. Little or no gas was used during the warm-up period after short breaks in ginning; the period after a dinner break is shown in this record. Stack gas temperatures rapidly increased toward the normal operating range of 1,500 F to 1,800 F.

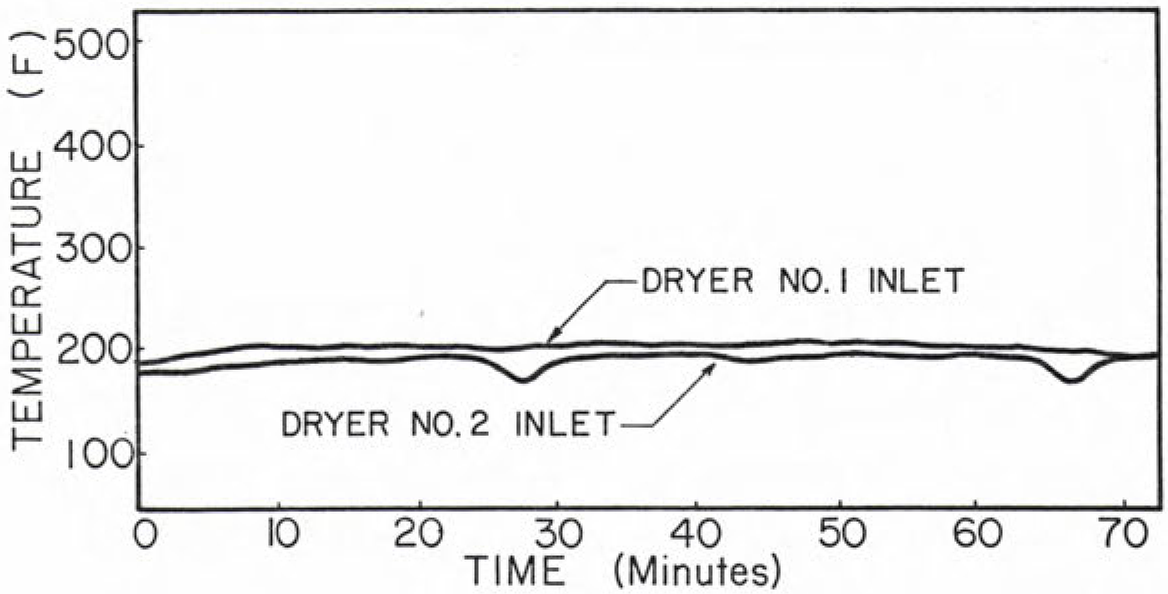

Figure 10. When full operating temperature has been reached, no gas heat is used, and drying air at relatively constant temperatures is supplied from the incinerators. The temperatures shown here were measured at the points where seed cotton was dropped into the hot-air line.

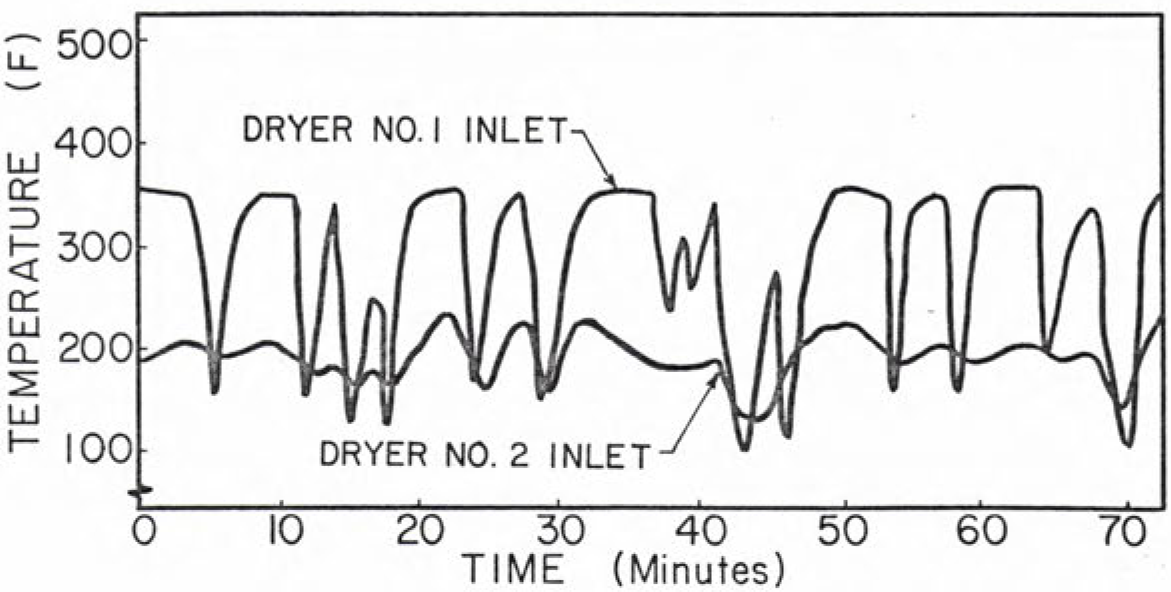

Figure 11. When gas heat alone was used to heat drying air, temperatures varied widely. Compare the records in this figure to those in Figure 10.

Figure 12 (Page 22) shows the pick-up air temperature traces for a period during which incinerator heat was supplemented by gas heat. During this period dryer No. 2 operated with incinerator heat only; in dryer No. 1 the gas burner supplemented the incinerator.

In Figure 12, the varying temperature in dryer No. 1 contrasts sharply with the steady temperature at the inlet of dryer No. 2. We have no reason to believe that the seed cotton moisture content variability justified the temperature variations. Furthermore, the heat produced by the gas burner appears to have been added on to the heat already in the air from the incinerator. As a result, the cotton was exposed to excessively high temperatures.

Temperature above 350 F at any point in the drying system is known to cause irreversible quality loss in the lint.* For example, damage normally associated with overdrying cannot be reversed by addition of moisture if overdrying is due to temperature above 350 F. The excessively high temperatures shown in Figure 12 are evidently the result of inadequacies in the temperature-control system.

Stack Temperatures. We measured the temperatures of the flue gases entering the stack from the secondary incinerator cell. These temperatures far exceeded the temperatures we had expected to find. The 2,300 F sheathing on our iron-constantan thermocouples failed; so we conclude that the temperatures reached 2,300 F on a number of occasions. Normal operating temperatures were the 1,500 F to 1,800 F range, depending on the ginning rate and the

*Private communication with A.C. Griffin, research physicist, ARS, USDA, Stoneville Ginning Laboratory, February 2, 1976.

amount of trash per bale. The stainless steel stacks and the brick refractory lining of the incinerators showed no adverse effects from the high temperatures.

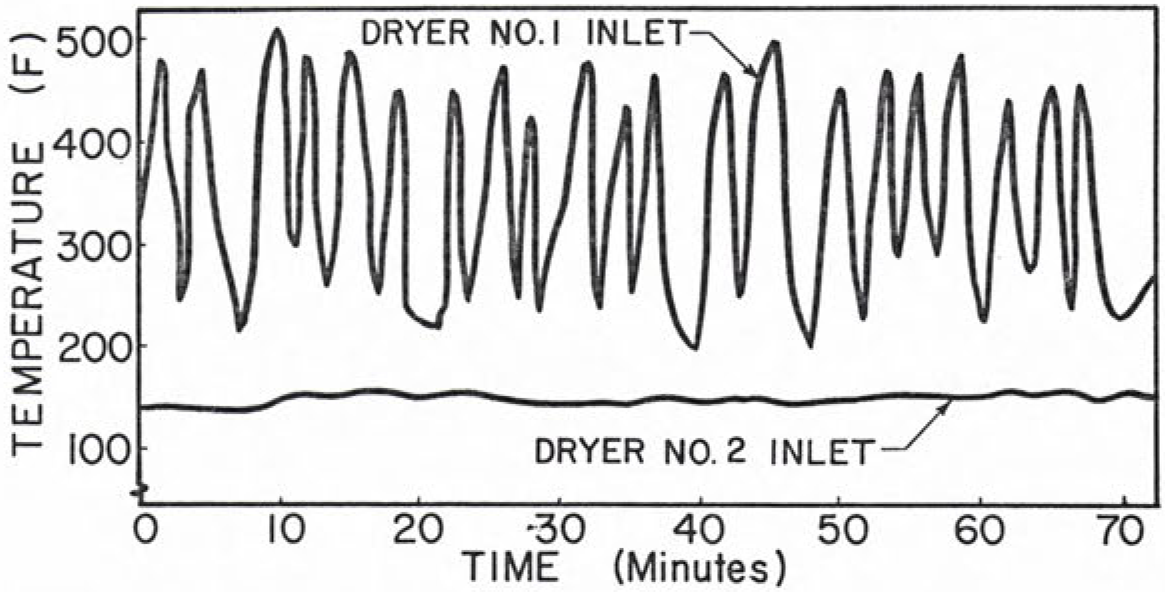

Figure 12. When incinerator heat was supplemented with gas heat, seed cotton was exposed to excessively high temperature, as shown by the record for dryer No. 1; incinerator heat only was used in dryer No. 2. Improved temperature controls would prevent the excessive temperatures.

Problems and Recommendations

We encountered no major difficulties; however, we did have to cope with a series of minor problems. In the discussion of those minor problems that follows, we have combined our experiences with those of Raymond Miller, the gin manager. We hope that our joint recommendations will be of some value to designers of heat-recovering incinerators at cotton gins.

Division of Trash. The trash was supposed to be divided equally between each of the two incinerators; but the distribution was not even.

Air flow rates handled by the trash fan probably varied slightly, due to the different trash production rates. The splitting device was located a short distance downstream from an elbow. Together, these two factors caused intermittently uneven splitting of the trash between the two incinerators.

Whenever a tag of linty material became lodged on the splitting device, unequal division also occurred.

We are confident that the trash stream splitter can be redesigned to improve its performance considerably.

We believe that the excessively high temperatures attained in the incinerator stacks were due to unequal splitting of the trash between the two incinerators; therefore, we strongly recommend that a temperature indicating device coupled to a warning signal of some type be installed to sense the temperatures at the base of each stack. Unusual temperature situations (either too high or too low) could be detected and their causes remedied before damage or time loss occurs.

Feed Screw. The trash was augered into the primary incinerator cells by a feed screw. On one of the two feed screws, the end of the auger flight was not securely welded to the auger shaft. This eventually caused the end of the auger flight to bend. It had to be replaced. This was a very minor problem, and no change in the screw feed is recommended.

Refractory. The refractory brick installed in the incinerators withstood the temperatures very well and showed no signs of deterioration. Castable refractory was used in some locations, but this material was deficient under the temperatures generated in the incinerator. The refractory parts of the incinerator carry a five-year warrantee from Ecology Enterprises; the defects will be made good before the next ginning season.

Heat Dump. When dry cotton is being ginned, not all the available heat is removed from the flue gas. The heat nevertheless tends to transfer into the jacket and produce high temperatures. This occurs because the air flow rate through the jacket is reduced when less than maximum heat is required in the gin. The slow moving air can reach very high temperatures as it passes through the jacket. This can have two undesirable results.

First, the temperatures of the duct work between the incinerator and the hot air fan can reach the point at which lint fly that may settle on top of the ducts begins to smolder. This could be a fire hazard.

Second, the temperatures in the jacket and stack could reach excessively high levels because air flow is insufficient to produce cooling. We saw no evidence of damage due to this heat build-up, but we believe it should be avoided.

If fans moving air through the heat exchangers are shut down with the rest of the gin, overheating can occur because the last of the trash is still burning.

A system should therefore be provided whereby air can be kept moving through the jackets at all times to provide the necessary cooling. The heated air not needed in the gin can be dumped into the atmosphere.*

*Such a dump system has been designed by Oliver McCaskill, USDA, ARS, Stoneville Ginning Laboratory. It incorporates a drying-air temperature control. Valves actuated by the temperature sensor in the dryer are located on the duct at the base of the incinerator stack. McCaskill's valve arrangement allows cool air to be drawn into the duct leading to the dryer. The valve arrangement also allows hot air to be exhausted into the atmosphere. The combination of incinerator-heated air and cool atmospheric air required to produce the desired drying temperatures is made possible by these valves.

Heat Recovery Efficiency. The overall heat recovery efficiency of the incinerator system was 10-15 per cent.

If 140 pounds of dry trash are produced when one bale of lint is ginned, about one million BTUs of heat will be released when the trash is burned. If we assume that 350,000 BTUs of heat per bale would meet most of the drying situations encountered in ginning,* we then need to have the capability to extract 35 per cent of the trash heat and duct it to the dryers in a controlled manner.

We had expected the heat recovery efficiency of the system to be higher than the 10-15 per cent observed. Our engineering analysis shows that the addition of extra heat-exchange surface and the creation of turbulence on the flue-gas side of the exchanger would increase the heat recovery to near the desired 30-35 per cent level. Ecology Enterprises intends to make the needed changes. We believe the additional cost involved would not be excessive. (NOTE: Our engineering analysis is available upon request. *See address on Page 35.*)

If 30-35 per cent of the gin trash heat can be recovered, the system will be capable of drying all but the very wettest cotton, once normal operating temperatures have been attained. *Insufficient trash production to supply the needed heat would rarely, if ever, be a problem, even with spindle-picked cotton.*

An important difference between incinerator heat and gas heat lies in the fact that gas heat is available as a steady input of heat that does not have to vary from one minute to the next and is independent of the rate at which trash enters the incinerator. On the other hand, heat recovered from

**Cost of Electric Power and Fuel for Dryers in Cotton Gins in Arkansas and Missouri* (ERS 138), by Shelby H. Holder and Oliver McCaskill, October 1963.

the incinerator is directly dependent on the rate at which trash is being put into the incinerator and burned.

When ginning rate is reduced due to excessively wet cotton, the rate of burning trash will be reduced; consequently, the drying heat will be reduced. The reduction in drying heat availability will necessitate further slowing of the ginning rate until eventually the system must be shut down or supplemented with heat from the gas burners. *Except for start-up, conditions requiring supplementary gas heat will occur very infrequently if 30-35 per cent of the incinerator heat can be ducted into the dryers.*

A surge hopper would ensure a reserve supply of trash to produce full drying heat for every moisture-content situation and would thereby lessen the need for supplementary gas heating. But the extra investment for the hopper does not seem justifiable to us.

If the heat extraction efficiency of the heat exchanger is increased to desired levels, the need to provide a heat dump, as described earlier, becomes compelling.

Ash Removal. No problems were encountered, but a method of removing the ash during a brief interruption of ginning is needed for gins that operate around the clock. Although we have no experimental evidence to prove it, we believe that particulate stack emissions are increased when a large ash accumulation is present.* A cleaning out operation every eight hours therefore might be worth the extra expense.

*Ecology Enterprises, manufacturer of the incinerator, claims to have data in support of this belief.

Stack Emissions. An independent consultant analyzed the stack emissions in accordance with EPA-approved methods. The concentration of the particulate emissions was 1.2 grains per standard cubic foot.* The maximum allowable under Arkansas anti-pollution regulations is 0.2 grains per standard cubic foot. The emissions level from the stack was clearly several times higher than the legal maximum. The state of Arkansas is permitting operation of the equipment because of its experimental nature and because of the energy savings achieved.

We had further analysis done on the particulate matter collected. We found that no combustible material was present and that most of the particles appeared to be soil-derived. We draw two conclusions from this.

First, the use of an after burner in the stack will not solve the problem because no combustible material was emitted.

Second, removing as much soil as possible from the trash would reduce particulate emissions from the stacks. One immediate beneficial measure would be to prevent material from the unloading-air cyclone from entering the trash system. We believe that soil separation is an area where experimentation is required.

The technology by which stack emissions can be lowered to anti-pollution standards already exists, but all such equipment with which we are familiar would increase the cost considerably.

Judging from the appearance of the stack emission plumes, we believe that particulate concentrations are highest when large ash accumulations

*Ecology Enterprises installed a ceramic filter in the stack and stack emissions data were collected. The data collection was done by the test crew that collected our data. The particulate concentration observed when the filter was present was 0.67 grains per standard cubic foot.

occupy some combustion space. As suggested earlier, a method that allows quick ash removal from a hot incinerator would probably help lower the particulate concentrations in the stack gas.

NOTE: The results of the stack emissions test are available by request. See address on Page 35.

<u>*Costs and Savings*</u>

All equipment is new. We have almost no information about the cost of repairs and maintenance, nor can we predict what the initial cost of the equipment will be a year or two from now. The heat-recovery principle, though old, is only now being adapted for use at cotton gins, and we are likely to see several changes within the next few years.

<u>*Initial Cost*</u>. The contract price on the incinerator we studied was $65,000. The gin incurred initial on-site installation expenses of approximately $17,000, bringing the total initial cost to $82,000.

<u>*Operating Costs per Bale*</u>. Like any other business, a gin will want to recover its initial investment in incinerator equipment, plus interest on the unrecovered portion of the investment. Because everyone's tax situation is different from everybody else's, it is not possible for us to present cost estimates that apply to all situations.

Calculations for our experience at Monette are based on before-tax figures. In the paragraphs that follow, we show how we determined the cost estimates. This information should enable you to make your own calculations. You should consult with your accountant or attorney to determine the cost reduction you might expect from tax deductions applicable in your case.

Table 5 (Page 29) shows our estimates of what it cost the Kiech-Shauver Gin to operate the incinerator for 8,200 bales. Our estimates are for two different pay-off periods.

Calculation of Annual Costs. The useful life of the incinerator may be 10-15 years. You may not want to wait 15 years to recover your investment with interest. The minimum interest rate you will accept on the unreturned portion of your investment will depend on your other investment alternatives.

Table 5. Cost of Using Heat-Recovering Incinerator

Pay-off Period (Years)	Cost ($/Bale)			
	Capital Recovery Plus Repairs	Labor	Gas	Total
5	3.24	.01	.06	3.31
10	2.23	.01	.06	2.30

Table 6 (Page 30) is a chart of capital recovery factors. When you decide on the number of years over which you want the investment returned and on an interest rate you want to receive on the outstanding balance of your investment, you can choose a capital recovery factor from *Table 6*. We used the chart in *Table 6* to arrive at the numbers in *Table 5*. We assumed that we wanted the investment returned with ten per cent interest over a period of five years. We also assumed that the equipment would have no salvage value at any time. We then pinpointed the ten per cent interest rate column in *Table 6* and moved down to the five-year pay-off period line. Here we found that the capital recovery factor is 0.264.

We multiplied the initial cost of $82,000 by 0.264. The resulting figure of $21,631.39 is the annual cost of recovering the investment, plus ten per cent interest on the unrecovered balance over a five-year period.

Table 6. Capital Recovery Factors

Pay-off Period (Years)	Interest Rate (%)						
	6	7	8	9	10	11	12
3	.374	.381	.388	.395	.402	.409	.416
4	.289	.295	.302	.309	.315	.322	.329
5	.237	.244	.250	.257	.264	.271	.277
6	.203	.210	.216	.223	.230	.236	.243
7	.179	.186	.192	.199	.205	.212	.219
8	.161	.167	.174	.181	.187	.194	.201
9	.147	.153	.160	.167	.174	.181	.188
10	.136	.142	.149	.156	.163	.170	.177
11	.127	.133	.140	.147	.154	.161	.168
12	.119	.126	.133	.140	.147	.154	.161

For any other pay-off period and interest rate you might choose, you will find a corresponding capital recovery factor in *Table 6*. When the initial cost is multiplied by this factor, it always gives the annual cost of recovering the investment, plus interest on the unrecovered portion.

In our calculation, we assumed that annual repair costs would be six per cent of the initial investment. The six per cent figure is an opinion, for we have no experience with the equipment. Six per cent of $82,000 is $4,920. The $4,920 repair cost, plus the $21,631.39 capital recovery cost, are added together to give a total of $26,551.39. When this annual cost is spread over 8,200 bales, we get the capital recovery and repair cost of $3.24 shown in *Table 5* in the five-year pay-off period line.

This is a before-tax calculation. You should now figure your avoided tax dollars on a per-bale basis and subtract them from this figure. We reiterate the importance of tax considerations, especially since special tax breaks are often available on equipment that must be installed for environmental protection purposes.

The labor cost was calculated at the rate of $3 per hour.

The gas costs we used in *Table 5* were the actual costs calculated from bills received at the gin.

It should be evident by now that the major costs of the incinerator system are fixed. We had only seven cents per bale variable cost. This means that if the gin's annual volume were 16,000 bales instead of 8,200, the per-bale cost of operating the incinerator would be halved.

Savings per Bale. With a good heat recovery system, you will save up to 90 per cent of your present gas costs, whether they be LP gas or natural gas. From gas bills received at the gin, we calculate that the gas savings were 34 cents per bale. This calculation is based on an assumed* gas need of 333 cubic feet per bale for the entire season and on an actual gas cost of six cents per bale. (See Page 12 for actual gas consumption at mid season. Gas costs $1.20 per 1,000 cubic feet [MCF], or 40 cents per bale to meet the assumed need.)

The heat-recovering incinerator system is also a disposal method. You would have to choose another disposal method if the trash were not incinerated.

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*See footnote on Page 25.

The cost of your disposal method will vary. The alternative disposal method available to the Kiech-Shauver Gin was to haul the trash by truck. We estimated that this would cost approximately $1 per bale since a trash house would have to be erected and a truck purchased.

Table 7 shows our estimate of what it would have cost the Kiech-Shauver Gin in 1975 to haul trash and to use either natural gas or LP gas as a heat source. Although the incinerator was the more expensive choice for 1975, the gin management expects it to be the less expensive in the long run.

Table 7. Estimated Cost of Trash Hauling and Gas Heat in 1975

	Cost ($/Bale)		
	Gas	Trash Hauling	Total
Natural Gas	0.40	1.00	1.40
LP Gas	1.40	1.00	2.40

Conclusions

1. Sufficient heat was recovered from the incinerator to eliminate the need for about 85 per cent of the gas that otherwise would have been used.

2. The stack heat exchanger was able to extract about 10-15 per cent of the heat released when the trash was burned.

3. To provide the amount of heat per bale required to meet most needs, the heat extraction should be 30-35 per cent of the total heat released by burning. Insulation of incinerator and ducts would help achieve this. Additional heat exchange capacity could be designed into the stack at minimal cost.

4. The extracted heat should be continuously removed from the heat exchanger on the stack by maintaining air movement through the jacket.

5. A means of dumping or exhausting unwanted heat should be provided.

6. The drying-air temperature control system should be improved.

7. Temperature measuring and indicating instruments should be installed in the incinerator and coupled to a warning light or horn to warm of excessively high or low temperatures in the incinerator cells.

8. Provision should be made for removing ash without having to cool the incinerator.

9. Investigation of how to reduce particulate emissions from the stacks is required.

10. The heat-recovering incinerator performed well in every way except for particulate concentrations in the stack gas. It is ironic that our clean air policy is in conflict with our energy-independence goal. We hope the ginning industry and the pollution-control agencies can work toward a compromise with the help of the Federal Energy Research and Development Administration. The heat-recovering incinerator is an immediately applicable principle that can save 90 per cent or more of the valuable natural or LP gas that would otherwise be needed at gins.

11. The number of inquiries we have received and the number of visitors at the gin testify to the widespread interest generated by the system. Ginners are ready to use it whenever environmental questions are settled.

12. In view of the short ginning season, the need for such stringent air pollution regulations should be re-examined--especially since we found that combustion was 100 per cent complete.

Future Studies

We believe this study confirms the correctness of our contention that, at many gins, heat recovery from gin trash is feasible from both engineering and economic standpoints. The feasibility will increase as technology improves and as gas costs increase. Other industries (such as vegetable dehydration) will be able to use gin trash heat because it will cost less than heat from other sources.

Transportation and storage of gin trash so that it can be used as a fuel at times other than during the ginning season will be needed. We intend to continue our studies to make this economically feasible.

The 1975 cotton harvesting weather in the Monette, Arkansas area was unusually favorable. We intend to continue our data collection at Monette for at least one more year to broaden our experience. We will let you know whether our 1975 experience was confirmed or contradicted.

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Further Information

We welcome any inquiries you may have about this study. Please address inquiries to Dr. Bill Lalor, Manager, Systems and Cost Engineering, Cotton Incorporated, P.O. Box 30067, Raleigh, North Carolina 27612. Telephone if you prefer: 919/782-6330.

COTTON INCORPORATED

Cotton Incorporated is the research and marketing company of American cotton growers.

Through research Cotton Incorporated works to improve cotton fiber and cottonseed, to develop more efficient techniques for growing, harvesting, ginning and processing the crop, and to find new fiber and food products—all so that producers will enjoy the maximum net returns on their investments and labor.

Through marketing, Cotton Incorporated gives cotton farmers direct interface with cotton customers and consumers. Marketing experts and professional salesmen represent growers in the competitive marketplaces all over the world in efforts to create new markets for cotton products, and thus to create increased demand for cotton fiber and other products.

Cotton Incorporated represents only the interests of American cotton producers. Cotton producers only sit on the board of directors, elected by cotton producer organizations in the 19 states in which American upland cotton is grown.

Cotton producers guide and govern the operations of Cotton Incorporated, and cotton producers fund the company's operations through a voluntary contribution for every bale of cotton sold.

Sales-marketing activities are centered in New York City, where agents of cotton growers work directly with the mills that spin, weave, knit, dye, print, and finish cotton, with the manufacturers that make wearing apparel and other consumer products from cotton cloth, and with mass volume chain stores and independent shops that sell cotton products to consumers.

In addition, the sales-marketing division operates "Cottonworks" facilities in New York, Dallas and Los Angeles. In these private showrooms, manufacturers and fashion designers can choose in privacy the latest cotton fabrics offered by American mills.

At the Cotton Incorporated Research Center at Raleigh, N. C., three research divisions work to improve the quality and marketability of cotton fiber and cottonseed products.

The textile research and development division explores new fabric constructions and finishes in efforts to develop new and profitable products for the industries that consume cotton fiber.

In economic research and development, economists, marketing men and computer scientists seek techniques for marketing cotton that will bring equilibrium to factors affecting supply and demand so that cotton producers and cotton customers alike can earn maximum profits.

In agricultural research, scientists in many disciplines conduct research on new and improved cotton varieties, on more efficient production systems, and on more effective insect, disease and weed controls. Engineers look for ways of applying modern technology to the harvesting, handling, ginning and processing operations.

Agricultural research scientists and engineers seek to make cotton a true agro-industrial product, not subject to the vagaries of pestilence and weather. The primary objective always is to give the producer the highest possible profit for every acre he plants to cotton.

This agro-industrial report contains the findings in one agricultural research area.