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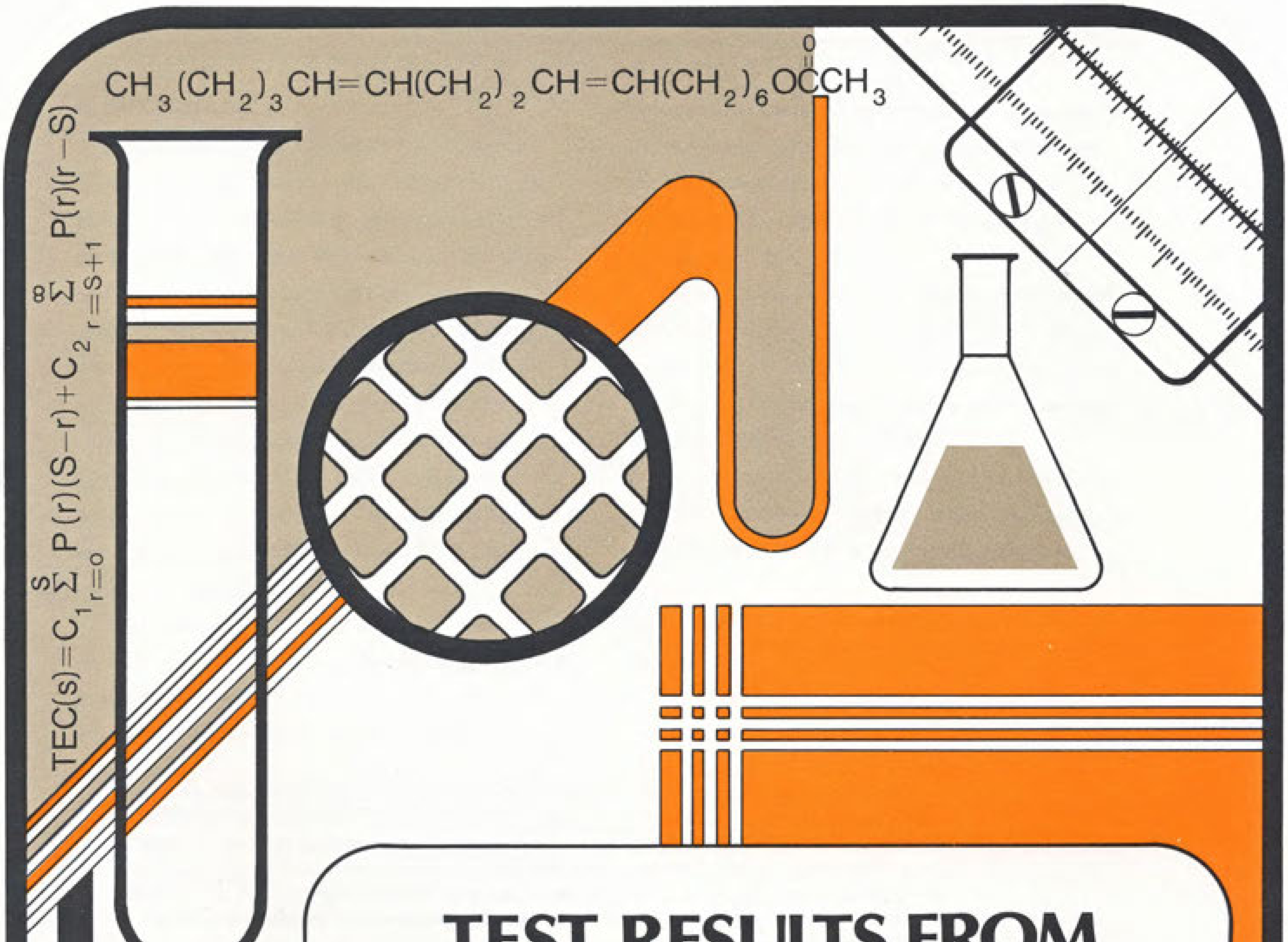

TEST RESULTS FROM WASTE-FIRED GIN DRYERS

Volume 4: Number 7 (GP-4) June 1977

NEW YORK • LOS ANGELES • DALLAS

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TEST RESULTS FROM WASTE-FIRED GIN DRYERS

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

INTRODUCTION

In April 1976, we published an Agro-Industrial Report on our experience with a heat-recovering incinerator[1**]. It was based on the results of tests at the Kiech-Shauver Gin in Monette, Arkansas, where a heat-recovering incinerator had been installed in 1975 to supply drying heat to the cotton gin. At that gin, natural gas supply had become unreliable and LP gas was unavailable (even as a standby fuel) for new customers. Hauling away the gin waste was the only disposal option available to the gin management. An incinerator was thus seen as a way to eliminate the cost and aggravation of waste disposal and to ensure a supply of drying heat at all times.

The incinerator at Monette supplied about 85 per cent of the drying heat needed in the gin in 1975. In so doing, 10 to 15 per cent of the available heat was extracted from the incinerator stack gas by the heat exchanger.

Waste production per bale varied from about 84 to 184 pounds and averaged about 136 pounds per bale, including motes.

Gas consumed during start-up, and as supplementary dryer heat (when needed), averaged 50 cubic feet per bale. This was 13 per cent of the total expected gas consumption[2] and 27 per cent of the previous year's actual consumption (when gas was the only source of drying heat). For the most part, the heat recovered in 1975 was adequate for drying needs, and, from time to time, an excess of drying heat was available.

The tests were continued in Monette in 1976 and were also initiated at a California gin. The incinerator at the California gin is different from the one in Monette. Furthermore, cotton is grown, harvested, and ginned differently in California from in the mid-South. Our 1976 studies, therefore, broadened our experience with heat-recovering incinerators. This Agro-Industrial Report is a record of our new insights.

THE MONETTE GIN IN 1976

Experiments

The incinerator-heat-recovery system at Monette was essentially unchanged from that described in our previous report.[1] The heat supplied to the dryers from the incinerator was manually controlled and was occasionally supplemented with natural-gas heat while gas was available. Beginning on November 5, the gas supply was interrupted, and the incinerator was the only source of drying heat.

The data collection system was not as elaborate as the one we used in the 1975 study. Instead of per-

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**Superscript numbers refer to references given on page 16.

manently placed temperature and air-flow measuring instruments, we used a hand-held Pitot tube to which we attached a thermocouple to sense the temperature. We ran tests of several hours' duration on four different dates. Data enabling us to calculate gas consumption and incinerator heat supplied to the dryers were collected. We also collected the data to estimate the amount of waste per bale. We did not maintain a record of incinerator stack temperatures, but we know from observations by the gin manager that they were similar to 1975 levels.

Heat Recovery

Table 1 presents the data from the heat recovery measurements. The seed cotton moisture content (taken from wagon samples) is also presented so as to contrast heat use with drying needs.

Heat recovered from the incinerator and used in the dryers is the sum of the heat flows measured upstream from the temperature controls in the ducts that lead to the first and second drying stages (see Figure 1). In this gin, the second stage was in a split-overhead system consisting of two dryers. We measured the combined heat flow to these dryers. In taking the air-flow and temperature data, we made measurements at 20 points across each duct according to recommended practice.[3] We averaged the air flows and calculated the heat flow. In our calculations, we used ambient temperature as a base level and computed

Table 1. Heat used in the Kiech-Shauver Gin in 1976

Time	Ginning Rate (bales/hr)	S/C Moisture Content	Drying Heat (BTU/bale)		
			From Incinerator	From Gas	Total
			October 14, 1976		
9:52 am	21	14.2%	52,934	94,545	147,479
11:15 am	21	13.8%	75,683	0	75,683
2:05 pm	19	17.1%	70,396	0	70,396
4:25 pm	19	15.5%	73,282	0	73,282
Average	20		68,074	23,636	91,710
			October 15, 1976		
9:00 am	19	--	0	121,770	121,770
10:00 am	23	--	0	97,218	97,218
12:30 pm	16	--	0	95,238	95,238
1:40 pm	18	--	0	106,524	106,524
Average	19		0	105,188	105,188
			October 19, 1976		
10:33 am*	14	14.2%	63,452	35,244	98,696
2:15 pm	21	13.1%	60,842	29,700	90,542
4:03 pm**	19	12.3%	72,651	27,720	100,371
7:30 pm**	16	15.6%	81,445	109,890	191,335
9:40 pm**	10	12.9%	126,185	264,471	390,656
Average	16		80,915	93,405	174,320
			November 5, 1976* **		
8:05 am	17	12.2%	48,768	0	48,768
9:10 am	16	13.8%	89,075	0	89,075
10:00 am	15	11.4%	118,870	0	118,870
10:35 am	15	10.9%	123,019	0	123,019
10:50 am	15	12.9%	139,020	0	139,020
Average	16		103,750	0	103,750

*Three out of four stands operating.
**Rain, 50°F, 80-90% RH.
***Natural gas supply interrupted, outside temperature 30-40°F.

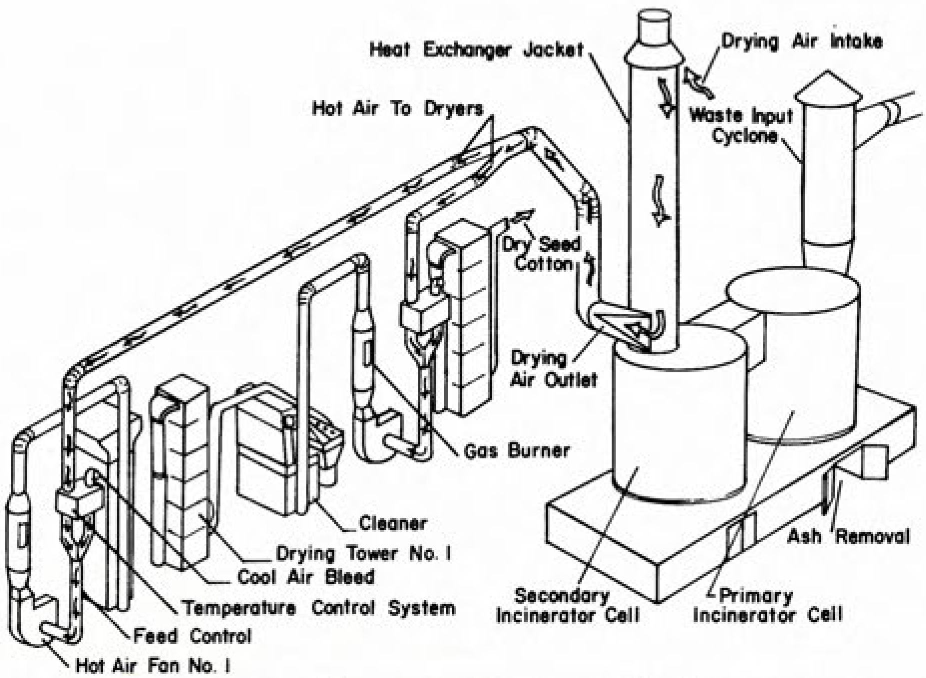

FIGURE 1. Schematic diagram of Ecology Enterprises heat-recovering gin-waste incinerator.

the heat needed to raise the drying air from ambient temperature to the temperatures we observed.

The heat recovered per bale was about 27 per cent lower than the levels we observed in 1975. Two factors possibly contributed to this. First, the air flow across one heat exchanger was reduced below the 1975 level because of a bent rain shield on the inlet atop one stack. Second, accumulation of a layer of ash on the inside of the stacks reduced the rate of heat flow outward to the air in the heat exchanger jacket which surrounded the stack. Ecology Enterprises, manufacturer of the equipment, suggested that this might explain the reduced heat recovery.

Temperature data for the air flowing to the dryers from the incinerator, along with ambient temperature and relative humidity, are shown in Table 2.

Table 2. Air temperature in ducts leading to dryers

Time	First-Stage Dryer (°F)	Second-Stage Dryer (°F)	Ambient Temp. (°F)	Relative Humidity (%)
		October 14, 1976		
9:52 am	231	234	67	53
11:15 am	290	250	74	30
2:05 pm	234	267	80	31
4:25 pm	244	302	84	28
		October 19, 1976		
10:33 am	154	169	60	67
2:15 pm	213	226	57	60
4:03 pm	229	238	54	79
7:30 pm	189	192	50	94
9:40 pm	192	184	52	82
		November 5, 1976		
8:05 am	93	134	34	---
9:10 am	168	194	37	58
10:00 am	149	358	42	58
10:35 am	205	286	41	57
10:50 am	245	304	43	---

Because of the throttling effect of the heat exchanger jackets and the added ducting on the intake side of the hot-air fans, air velocity was not sufficient to ensure positive transport of seed cotton in the drying system when the cool air bleeds were closed (see Figure 1).

The bleeds, therefore, were partially open virtually all the time to avoid choke-ups. This was particularly true for the second drying stage where two hot-air fans were attempting to draw air from the heat exchanger through one 20-inch duct. Static pressure in the duct with air bleeds closed (a negative 16-inches water column) is a sign of the severe throttling. We did not measure static pressure at the fan inlet, but we estimate that it would be a negative 18 inches water column.

The drying system was designed to operate with near-zero static pressure at the fan intake, so it is not surprising that caution had to be exercised to prevent choke-ups in dryers and the overhead equipment. The appropriate caution was to allow some cool air to enter the bleed openings, thereby ensuring adequate air for transport in the drying system. This reduced the airflow through the heat exchangers and thus reduced the amount of heat that could be recovered. Consequently, supplementary heat had to be generated by burning natural gas from time to time.

Based on estimated heat content of the available waste, about 10 per cent of the flue-gas heat was ducted to the dryers. This is consistent with 1975 results.

Gas Consumption

Our observation of gas consumption spanned the ginning of 3,610 bales of cotton. Rates of heat generation from gas, shown in Table 1, were observed during our test runs. The average gas consumption in ginning 3,610 bales was 118 cubic feet per bale. This corresponds to 116,820 Btu per bale, allowing for 10 per cent burner inefficiency. Consumption of gas at this rate costs about 21 cents per bale. (The price of gas was about $1.75/MCF.) The average gas consumption (118 ft^3/bale) accounts for all gas used, whether during warm-up periods, during periods when drying was unusually difficult, or during periods when the incinerator was not in use.

As in 1975, gas was used for one to two hours each morning during warm-up. This is amply documented in our previous report.[1]

Difficult drying conditions caused high gas consumption as indicated by the data in Table 1 for October 19. Rain was falling, the temperature was in the low 50s, and the relative humidity was in the 80s. Some trailers had received rain, although our moisture-content samples were purposely chosen so as not to reflect rain wetting of the cotton at the top of the load. Under these circumstances, gas use reached almost 270 cubic feet per bale—well above the 1974 average of 185 cubic feet per bale with no incinerator. Gas use, however, was well below the average of 381 cubic feet per bale reported by Holder and McCaskill[2] as typical for the Arkansas and Missouri areas.

Gas consumption of 270 cubic feet per bale during the rain on October 19 was about 2.25 times the average for the season. When the heat supplied by the incinerator is added to this gas heat, the total is equivalent to heat from 395 cubic feet of natural gas per bale used to dry seed cotton in the 12 to 15 per cent moisture range. At other times, such as on October 14, less than one-third as much heat was used to dry similarly damp cotton when outside temperatures were in the 70s and 80s and relative humidity was in the 50s. This is a quantitative illustration of what ginners already know to be the effects of cool, wet weather and a slowed ginning rate because of rain-dampened loads of seed cotton. It is also a quantitative illustration of the flexibility a heat-recovering incinerator requires if it is to supply all, or almost all, the heat needed at gins in the rainbelt cotton-growing areas.

On one occasion, the incinerator was down for repairs for almost a week. The data for October 15, taken during that week, reflect gas consumption

Table 3. Turnout analysis at the Kiech-Shauver Gin (dry pounds/480-lb bale)

Date	Seed Cotton		Lint		Seed		Waste	
	Wt.	MC	Wt.	MC	Wt.	MC	Wt.	MC
10/14	*1566*	*15.5%*	*454*	*5.3%*	*703*	*14.2%*	*166*	*21.9%*
10/19	*1256*	*13.7%*	*449*	*6.5%*	*701*	*14.5%*	*106*	*10.6%*
11/5	*1263*	*12.2%*	*450*	*6.4%*	*695*	*12.3%*	*48*	*18.6%*

rates when no incinerator heat was available (see Table 1).

Turnout Analysis

Measurements to obtain data for the turnout analysis presented in Table 3 were made in the same manner as in 1975. Waste output per bale is shown on a dry basis in Table 3. The true weight of waste per bale *cannot* be reliably calculated from wet weights of seed cotton, seed and lint.

The range of dry waste weight per bale was 48 to 166 pounds. In 1975, it was 84 to 184 pounds.[1] The range is important because the incinerator at Monette is of the direct-on-line type (meaning that it is designed to consume the waste at whatever rate it receives it). Direct-on-line incinerator-heat-exchanger combinations must recover enough drying heat when waste output per bale is low and, on the other hand, they must consume all the waste without overheating when waste output per bale is high.

If we assume that recovery of 300,000 Btu per bale will accomplish drying under almost all conditions, 43 per cent of available heat will have to be recovered from the flue gas when waste output is 100 dry pounds per bale. But at a waste output of 180 dry pounds per bale, only 24 per cent of the heat has to be recovered. The remainder must be discharged to avoid overheating the equipment. This shows the need for an efficient heat exchanger and heat-dump system as discussed in last year's report.[1]

THE INCINERATOR IN CALIFORNIA

Description

The incinerator we studied in California was designed by Agrotherm Company of Los Angeles.* It is quite different from the one at Monette in that it is not a direct-on-line incinerator but has a surge bin from which the incinerator proper is fed at a controlled rate. Figure 2 is a schematic diagram to explain the operation of the system. The surge bin and feed system were designed by the gin owners and are not a part of the Agrotherm system.

The Agrotherm incinerator is known as a dispersion burner. Waste is introduced into a combustion space where highly turbulent, excess air permits complete burning in the shortest possible time. The incinerator we studied is a vertical, refractory-lined cylinder nine feet in diameter with a conical top. The waste inlet is tangential to the cylinder so as to create a vortex in the combustion space. Part of the combustion air is used to convey the waste into the unit. The remainder is added through another tangential inlet later in the burning process.

The hot refractory and the combustion zone design cause waste to ignite and burn spontaneously once the unit has reached operating temperature.

*In California we were joined by Robert G. Curley and George E. Miller, Extension Agricultural Engineers, University of California, Davis, and by O. D. McCutcheon, Farm Advisor, Kings Co., California. We acknowledge their equal partnership with us in this part of our study, and we thank them for their help and interest.

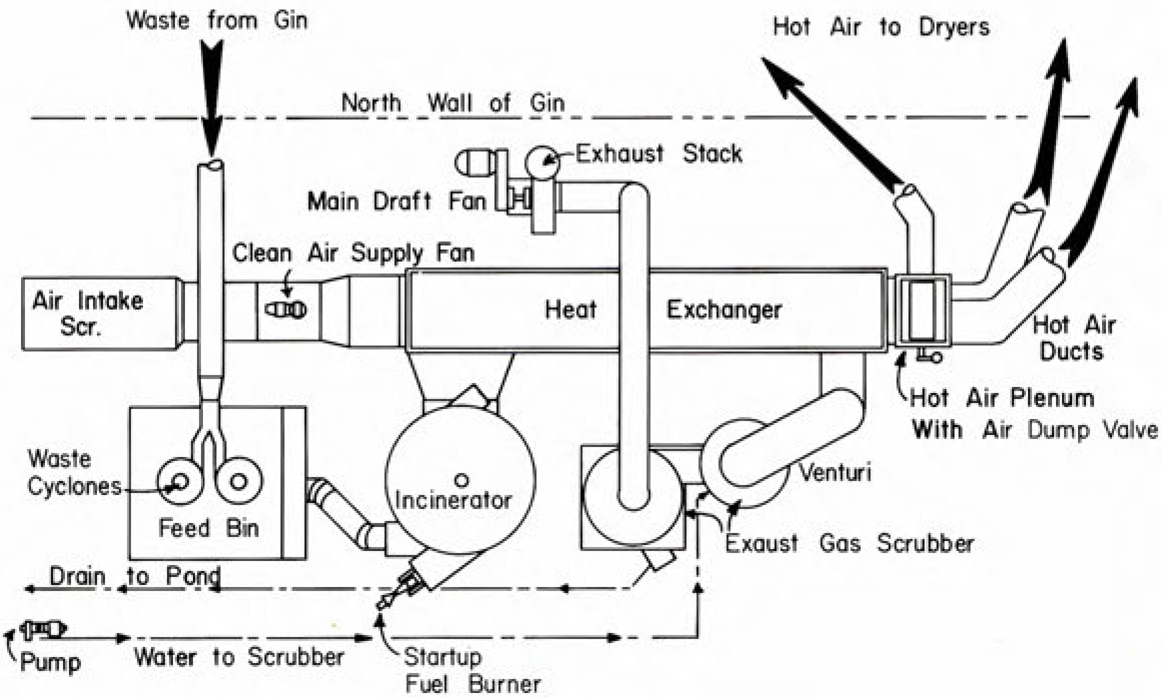

FIGURE 2. Schematic diagram of the Agrotherm heat-recovering gin-waste incinerator.

Before operating temperature is reached, a propane-fired gas burner provides ignition heat.

The non-combustible material remains suspended in the turbulent mixture of air and combustion products and is carried through the heat exchanger to a wet-venturi scrubber where solids are separated from the stack gas before it is exhausted. Provision is made for some heavy particles to drop out of the flue-gas stream and to be removed through access doors.

The rate at which the incinerator consumes waste is related to the temperature in the combustion zone. This temperature can be set within a range from 1500°F to 1800°F and will be maintained at the set point by the automatic feed control. The incinerator can consume more waste at higher set-point temperatures than at lower set-point temperatures. It has a nominal rating of about 4,500 pounds of gin waste an hour.

The surge bin was designed to hold a 2-hour supply of waste. This permitted a constant rate of feed to the incinerator even during ginning interruptions. On the other hand, the system can be shut down so as not to use up waste stored in the bin if a long interruption is anticipated. The surge bin should accommodate several hours, over-supply or under-supply of waste relative to the incinerator burning rate. Ultimately, however, the incinerator hourly capacity would have to be adjusted up or down (within design limits) to match the gin output of waste. This is done by changing the set-point temperature in the combustion zone.

When output of waste is higher over an extended period than the maximum incinerator capacity, waste is diverted to a pile in the conventional way. When the waste output is too low over long periods to keep the incinerator temperature at minimum set point, the start-up burner will eventually ignite to correct the situation. If economical, a way could be devised to move waste from an accumulated pile (if such exists) to the incinerator during prolonged periods of shortfall. However, no such provision now exists.

Heat Exchanger

The heat exchanger is of a channel-type design with a large surface area for heat transfer. It is a separate component in contrast to the heat exchanger in Monette which was on the stack. Stainless steel is used in the heat transfer surface.

A constant flow of cool, ambient air is forced into the heat exchanger by an axial-flow fan. This air is heated as it passes through the heat exchanger and is used as needed by the dryers. The heated air not needed by the dryers is vented outside the gin. The axial-flow fan ensures a supply of air to carry the heat away from the heat-transfer surfaces at all times, thus preventing overheating and possible damage.

The temperature of the air entering each dryer is varied in response to the dryer-outlet temperature variation relative to its set point. The existing dryer-temperature sensors are used to control the system. Motorized dampers allow cool air to enter and blend with the hot air going to the dryers, thus reducing its temperature to a level appropriate for the drying effect needed.

made in the ducts leading to each of the three dryers and also at the inlet to the axial-flow clean-air fan. By knowing how much air entered the system and how much was ducted to the dryers, it was possible, by subtraction, to calculate the amount vented. This assumed that there were no leaks across the heat exchanger—an assumption which turned out to be questionable (see below).

Table 4 shows the heat used by the dryers during the two tests when the incinerator was operating. The amount of heat drawn from the incinerator by the dryers was 69 per cent and 76 per cent, respectively, of the total recovered heat during the first and second tests. This means that more than enough drying heat was always available. The LP gas equivalent of the incinerator heat used by the dryers is shown in parentheses below the "weighted-average" lines in Table 4.

Based on our calculations, the LP gas equivalent of the total heat recovered was 7.1 gallons per bale during both tests. Some air leakage from the clean-air side to the flue-gas side of the heat exchanger developed during the season. This is a problem that can easily be rectified, but it tends to exaggerate

Table 4. Incinerator heat used for drying

Time	Ginning Rate (Bales/hour)	Seed Cotton Moisture	Drying Heat (BTU/bale)		
			From Incinerator	From Propane	Total
			November 9, 1976		
4:40--5:10 pm	*25*	*9.1*	*345,035*	*0*	*345,035*
5:25--5:55 pm	*24*	*8.3*	*353,323*	*0*	*353,323*
5:55--6:34 pm	*20*	*8.4*	*437,884*	*0*	*437,884*
Weighted Average	*23*	*8.6*	*378,534 (4.9 gal propane)**	*0*	*378,534*
			November 17, 1976		
5:10--5:35 pm	*26*	*8.5*	*328,829*	*0*	*328,829*
5:55--6:15 pm	*21*	*9.5*	*422,485*	*0*	*422,485*
6:25--6:50 pm	*17*	*8.8*	*536,640*	*0*	*536,640*
7:20--7:55 pm	*22*	*9.2*	*416,641*	*0*	*416,641*
Weighted Average	*22*	*9.0*	*414,403 (5.4 gal propane)**	*0*	*414,403*

**Propane equivalent of incinerator heat used by dryers.*

Heat Recovered

Using the measuring procedure employed in Monette, we collected data to calculate heat flow to the dryers. Tests of about two hours' duration were made on five dates. Airflow measurements were the amount of heat we calculated to have been recovered. (It was probably less than 7.1 gallon equivalents per bale.) Nevertheless, when the incinerator ran at full operating temperature, all the heat needed by the three dryers was available. The seed cotton moisture content and the ginning rate are given in the table to indicate the drying effect needed.

Table 5 shows data for periods when the incinerator was not in use. A comparison of the data in Tables 4 and 5, on the basis of Btu used per bale, would indicate that the incinerator supplied more heat than was supplied from gas. But that is not the whole picture. First, the ginning rates were lower with the incinerator running. Low ginning rate almost always leads to high heat consumption and wastes heat. Second, seed cotton moisture was considerably higher for the material dried with incinerator heat and thus would be expected to result in a higher heat consumption. Third, when the heat input to the dryers is converted to Btu/hr, the incinerator input averages 8,934,384 Btu/hr and the gas input averages 8,758,249 Btu/hr. Much of the seeming heat-consumption difference between the two heat sources, therefore, can be explained on closer examination of the data.

Table 5. Propane heat used for drying

Date	Ginning Rate (Bales/hour)	Seed Cotton Moisture	Drying Heat (BTU/bale)			Propane (gal/bale)
			From Incinerator	From Propane	Total	
11/11	*24*	*6.96*	*0*	*283,872*	*283,872*	*3.7*
12/6	*32*	*8.1*	*0*	*299,216*	*299,216*	*3.9*
12/9	*29*	*7.4*	*0*	*360,594*	*360,594*	*4.7*
Weighted Average	*28*	*7.5*	*0*	*305,113*	*305,113*	*4.0*

Gas Consumption

Propane was the fuel used at the gin. Besides the dryers, a humidifier and the start-up burner in the incinerator also used propane. Table 6 shows the propane consumption of each gin component. Data to determine the humidifier consumption were collected during periods when the incinerator was operating and the only burners in use were in the humidifier and in the incinerator. Total gas consumption and the gas consumption by the start-up burner in the incinerator could each be monitored. Their difference was the gas consumed by the humidifier.

The start-up burner seldom ignited once operating temperature had been reached, and we believe that the consumption observed on November 9 is what should be expected under normal operating circumstances. The high gas consumption by the start-up burner on November 17 resulted from experimentation with the set-point temperature in the combustion space.

The gas used by the start-up burner during warm-up

Table 6. Propane consumption by gin components (gal/bale)

Date	Ginning Rate (bales/hour)	Gin Component			
		Humidifier	Dryers	Incinerator Start-up	Total
11/9	*23*	*0.6*	*0.0*	*0.2*	*0.8*
11/11	*24*	*0.6*	*3.7*	*0.0*	*4.3*
11/17	*22*	*0.7*	*0.0*	*1.2*	*1.9*
12/6	*32*	*0.6*	*3.9*	*0.0*	*4.5*
12/9	*29*	*0.6*	*4.7*	*0.0*	*5.3*

Table 7. Turnout analysis at the California gin (dry pounds/480-lb bale)

Date	Seed Cotton		Lint		Seed		Motes		Waste	
	Wt.	MC	Wt.	MC	Wt.	MC	Wt.	MC	Wt.	MC
11/9	1396	8.6%	460	4.1%	792	7.7%	26	7.0%	117	7.4%
11/11	1388	8.6%	455	4.1%	801	7.7%	29	7.0%	103	7.4%
11/17	1463	8.6%	455	4.1%	785	7.7%	29	7.0%	195	7.4%
12/6	1413	8.6%	463	4.1%	782	7.7%	30	7.0%	139	7.4%
12/9	1501	8.6%	460	4.1%	779	7.7%	26	7.0%	236	7.4%

Table 8. Moisture content percentage of seed cotton and its components during ginning

Date	Location					
	Wagon	Feed Apron	Lint Slide*	Seed	Motes	Waste
11/8	8.6	6.5	4.1	7.7	7.0	7.4
11/11	7.0	5.6	5.2	6.7	7.0	----
11/17	9.0	7.5	5.3	8.6	7.6	7.0
12/6	8.1	6.7	3.6	8.9	4.9	----
12/9	7.4	7.0	4.2	9.2	5.9	6.1

After rehumidification.

varied from about 5 gallons per bale at the start to less than 0.5 gallons per bale 90 minutes after a cold start. Operating temperature was reached in the incinerator at the end of the first 90 minutes. Because the system was designed to operate continuously, start-up cycles would be expected infrequently and gas consumption of the incinerator and dryers would likely not be more than 0.2 gallon (7 cents worth) per bale unless the waste production was unusually low or erratic.

Turnout Analysis

Table 7 shows the turnout analysis for the five tests. Moisture contents were determined by the oven-drying method, but an error in laboratory procedure may have caused lint moisture contents to be underestimated. We adjusted these lint moisture contents to obtain the data shown in Table 7. They correspond well to similar measurements taken at the same time in a comparable gin.* Lint was sampled after being rehumidified, so the moisture content shown probably is higher than it was at the gin stand. Measurements at the gin stand with an electronic moisture meter indicated lint moisture of two to three per cent.

The weight of dry waste per bale varied from 103 to 236 pounds. We were surprised to find the range extending as high as 236 pounds and we believe that unusually high soil content was responsible. We found up to 20 per cent soil (by dry weight) in waste samples collected on December 9. The effects of soil-derived materials on incinerator performance is discussed in the next section.

The moisture contents at various points in the ginning process are presented in Table 8. We have no

*Leonard, Clarence, Southwest Cotton Ginning Research Laboratory, Mesilla Park, New Mexico. Private communication, January 1977.

explanation for the relatively high seed moisture on December 6 and 9. According to the work of Chapman,[4] seed cotton with 7.4 per cent moisture would contain seed of about 8.3 per cent moisture at equilibrium state. Because this seed cotton was stored for 10 days before ginning, we can safely assume equilibrium conditions, but this does not fully explain the inconsistency in the December 9 data. The December 6 seed moisture content is more believable in view of Chapman's work but is still inconsistent with the data obtained during November.

Operating Performance

This incinerator principle has been used in other applications but never before at a cotton gin. It is not surprising, therefore, that some difficulties and problems were encountered. The manufacturer now believes that the shortcomings have been corrected and that the equipment can operate as designed.

Two difficulties stood out: first, it was difficult to feed the incinerator as uniformly as was needed and, second, soil-derived, noncombustible material accumulated unexpectedly within the system. It is probably true that almost all the other problems were a result of these two conditions.

This incinerator should be fed at a uniform rate. According to an Agrotherm official, slugging will result in poor ignition and rough burning which tends to produce momentary surges of pressure in the combustion space and periodic occurrences of blow-back. Starving the system causes the temperature to drop and results in poor ignition of the next fuel to be fed and/or unnecessary use of the start-up burner. Slugging and starving often tend to be alternating phases of a non-uniform feed rate and their effects on the system are compounded.

The first feeding arrangement consisted of a live bottom bin with screws moving the material toward a cross conveyor which dropped it into an airline going directly to the furnace. This arrangement produced slugging. The slugging was eliminated by dropping the waste into the inlet of a small materials-handling fan which fed the incinerator. Passage through the fan caused breaking up of the slugs, and Agrotherm claims that the feeding system now seems to be satisfactory.

Excessive accumulation of non-combustible material sometimes restricted the flow of air through the incinerator. This caused overheating because the airflow through the incinerator should carry the heat with it and the diminished airflow was incapable of removing sufficient heat. A system has now been devised to prevent non-combustibles from accumulating.

The wet-venturi scrubber was also new to this application and needed adjustment to make it perform as desired. Tests were under way in March 1977 to verify that proposed adjustments would produce the desired effect and enable the equipment to meet the clean-air standards.

As the equipment was originally designed, no provision for routine ash clean-out was made. Experience in 1976 led to the conclusion that a device for continuous ash clean-out might be desirable, and the system is being modified accordingly.

We detected up to 30 per cent non-combustibles in some samples of waste. When ginning at 30 bales an hour, this would result in up to 18 tons of this residue a day. This could develop into a disposal problem which ginners should consider when planning to install an incincerator system. The wet-venturi scrubber on the Agrotherm system should remove virtually all the non-combustibles from the flue gas. Non-combustibles are transported in the scrubber water to a settling pond and water from the settling pond is recirculated to the scrubber.

We hope to include the results of a study of the various problem-causing characteristics of gin waste in another Agro-Industrial Report. That report will also deal with experiments to determine how best to screen some of the fine material, including the soil.

Cost Aspects of Heat-Recovering Incinerators

The ginning rate (bales per hour) determines the first cost of an incinerator system. The annual volume (bales per year) determines the operating cost per bale. When gas for drying does not have to be purchased or waste disposal paid for, a part of the gin's revenue becomes available to pay for the costs of the incinerator. These include recovery of first cost with interest, gas to fuel an auxiliary burner, labor to operate the system, and repairs, power, taxes and insurance.

The cost of natural gas at gins now varies from about $1.25 to $3.60 a thousand cubic feet (MCF). Based on an estimate of the range of gas consumption by dryers, this translates into costs shown in Figure 3 (left). Propane varies from about 28 cents to 38 cents a gallon. Its estimated cost is also shown in Figure 3 (right). In the near future, the cost of gas fuels is expected to increase with drying costs increasing accordingly.

Examination of Figure 3 shows that, with natural gas costing $1.25/MCF, even high-volume gins can free very little revenue to pay for an incinerator that totally eliminates the need for gas. When gas costs $3.60/MCF, considerable revenue becomes available to pay for an incinerator to replace gas purchases. When propane is the fuel used, it is much easier to save the revenue needed to pay for an incinerator. The cost of gas to most gins will lie somewhere in the shaded areas of Figure 3. The upper boundary of the shaded areas is the cost at gins where consumption per bale is high and gas is expensive. The lower boundary is where gas is inexpensive and consumption is low. The shaded areas in each side of Figure 3 correspond to similar amounts of heat at the dryers (within the limits of gas-composition variability).

If a gin manager wishes to recover investments with interest in 5 years, savings of about one-fourth

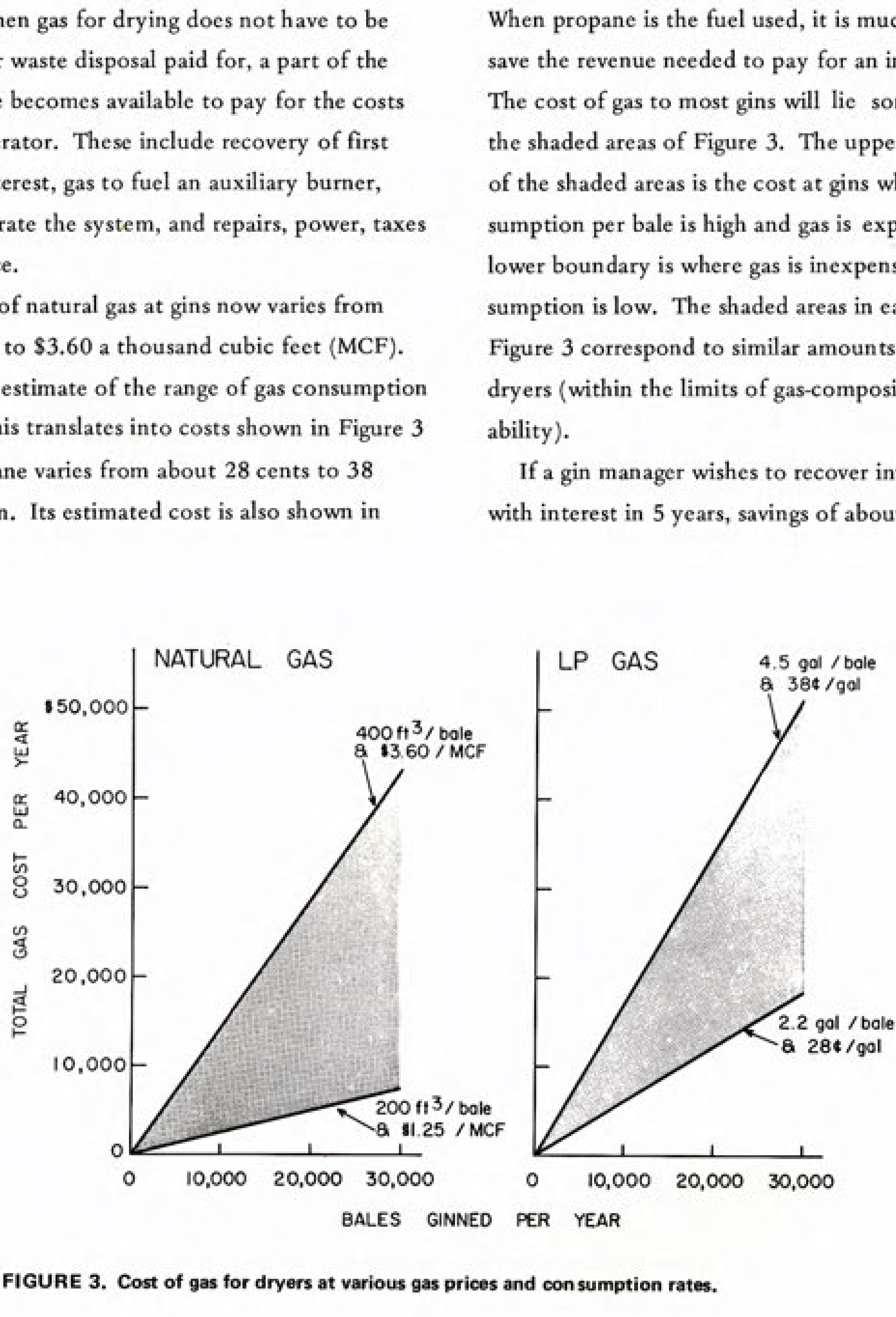

FIGURE 3. Cost of gas for dryers at various gas prices and consumption rates.

of the first cost of the installation will have to be realized annually when interest rate is 10 per cent. Reduction in tax liability (where applicable) due to investment credit, depreciation allowance, and other provisions will reduce the savings needed to meet the capital-recovery objective. Gin managers should consult tax specialists if they have questions about how their tax liability would change.

If a 10-year capital-recovery goal is acceptable, only one-sixth of the initial cost need be covered annually by savings.

Additional savings must be realized to pay for labor, repairs, power and others costs. The cost of power to operate wet-venturi scrubbers is typically high, corresponding to as much as 150 HP for a 30-bale-an-hour gin.

We would like to be able to give a clear-cut estimate of what an incinerator installation would cost, but this is not possible because of the variability in circumstances from one gin to another. Furthermore, it would probably be misleading. Table 9 is a list of existing incinerators with information about their location and manufacturers. By consulting the manufacturers, one can obtain current prices and estimates of repair costs and other expenses. By inquiring from gas suppliers about the likely cost of gas in future years, he can estimate his savings. Savings resulting from not having to haul gin waste should be

Table 9. Heat-recovering incineration systems located at U. S. cotton gins*

Gin, Location & Manufacturer	Date Installed	Performance of Heat Exchanger	Stack Samplings Results
USDA Cotton Ginning Research Laboratory Gin, Stoneville, Mississippi, Consumat Systems Inc., Richmond, Virginia (USDA designed heat exchanger)	*1973*	*Air-to-air heat exchange system delivered about 30 per cent of overall available heat to the seed cotton drying system.*	*Particulates: 0.36 grains/d.scf**.* *Standard = 0.2 grains/d.scf**.* *Opacity: Not recorded.*
A. J. Buffler Gin, Oakland, Alabama; Ecology Enterprises Dadeville, Alabama	*1974*	*Air-to-air heat recovery system reduced gas consumption for drying by approximately 65 per cent.*	*Particulates: 1974: average 1.91 pounds/100 pounds of charge. (2328 pounds per hour = charge rate.)* *1975: average 1.94 pounds/100 pounds of charge.* *Standard = 0.4 pounds/100 pounds of charge.* *Opacity: Range = 20 to 40 per cent. Estimated average = 25 per cent.*
Wynnburg Cotton Co., Wynnburg Tennessee; Meyer Incincerator Co., Pine Bluff, Arkansas	*1974*	*Original sheet-metal heat exchanger being replaced with 26-foot refractory lined tunnel type air-to-air heat recovery system. No data on performance available.*	*Not sampled.*
Schugtown Co-op, Schugtown, Arkansas; Meyer Incinerator Co. Pine Bluff, Arkansas	*1975*	*Air-to-air system of heat recovery reduced normal gas consumption by approximately 80 per cent.*	*Particulates: Average of two tests = 0.73 grains/d.scf**.* *Standard = 0.2 grains/d.scf**.* *Opacity: Not recorded.*

We are indebted to Dr. B. G. Reeves, Extension Agricultural Engineer, Federal Extension Service, Memphis, TN, for the information in this table.

***d.scf as used here means dry standard cubic foot corrected to 12% CO_2*

Table 9 (continued)

Kiech-Shauver Gin Co., Monette, Arkansas; Ecology Enterprises, Dadeville, Alabama	*1975*	*Air-to-air system recovered up to 15 per cent of available heat of incineration. This reduced gas consumption for drying approximately 90 per cent. Performance is described in this report.*	*Particulates: Average = 1.19 grains/d.scf*** *Average: 0.67 grains/d.scf** with ceramic filter in stack.* *Standard: 0.2 grains/d.scf*** *Opacity: Not recorded.*
Frank Murchison Gin Co., Coy, Arkansas; Mechanical Equipment Co., Little Rock, Arkansas	*1975*	*Early 1976, direct fire heating of drying system was concept used. No performance data available. Later 1976, air-to-air exchange used, no results available.*	*Average particulate emissions of 0.0325 grains/d.scf**.* *Standard = 0.2 grains/d.scf***
Drake Ginnery, Blenheim, South Carolina, Ecology Enterprises, Dadeville, Alabama	*1976*	*Air-to-air system. Fuel cost reduced to 5 to 10 per cent of 1975 level.*	*Particulates: 0.3496 grains/d.scf**.* *Or, 0.29 pounds/100 pounds charge.* *Or, 0.21 pounds/million BTU.* *Standard = 0.5 pounds/million BTU.*
J. G. Boswell Co., Corcoran, California; Agrotherm, Los Angeles, California	*1976*	*Air-to-air system. Supplied 100 per cent of drying heat. Performance is described in this report.*	*Not yet tested.*
West Valley Cotton Growers Gin, Riverdale, California; Valley Fabrication Engineers, Fowler, California	*1976*	*Air-to-air system. Gin manager reports that 100 per cent of heat needs were supplied. Not yet a commercial design.*	*Not yet tested.*
Mounds, Neighbors Gin, Rector Arkansas; Mechanical Equipment Co., Little Rock, Arkansas.	*1977*	*Direct firing under consideration.*	*Under construction, April 1977*

included where appropriate. Comparing the costs with the savings will show which gins can afford the system.

CONCLUSIONS

o The findings of our 1975 study were confirmed.

o A heat exchanger that is 30 to 40 per cent efficient can extract enough heat from burning gin waste to dry cotton under virtually any conditions.

o The non-combustible matter in gin waste is a serious problem in incinerators and warrants an investigation. (This investigation is now in progress.)

o The design of a feeding mechanism to produce an appropriately uniform feed rate for suspension-type incinerators, such as the Agrotherm unit, requires careful planning.

o Warning devices that alert operators to dangerously high temperatures should be a part of the system.

o Reduced airflow on account of extra piping and difficulty of moving heated air can be a problem. Hot-air fan capacity may have to be increased.

o No change in lint grades because of drying method was noticed, but the crews at both gins expressed preference for incinerator heat over gas heat.

o In view of current trends in energy prices, more gins will be able to justify the investment in heat-recovering incinerator systems.

o Experience with existing installations will inevitably lead to improvements that will make the system increasingly attractive to ginners.

FURTHER INFORMATION

Further information about matters discussed in this report may be obtained by contacting Dr. William F. Lalor, Cotton Incorporated, P. O. Box 30067, 4505 Creedmoor Road, Raleigh, North Carolina 27612.

ACKNOWLEDGEMENTS

The part of this study done in California is the result of close collaboration with personnel of the Cooperative Extension Service of the University of California. They are: Robert G. Curley, George E. Miller and O. D. McCutcheon and their supporting staffs. Professor Robert Kepner, Department of Agricultural Engineering, University of California, Davis, also contributed. The J. G. Boswell Company granted us access to the gin where the study was made. In particular, John Baker, Larry Chrisco, Joe Compagno, Jim Mackey and John Rodriques were most helpful. So were the staffs at the gin and at the Boswell central packaging facility.

Dr. Veon Kiech and Raymond Miller were most cooperative in helping us collect the data at the Kiech-Shauver Gin. We wish especially to acknowledge the help we got from the gin staff and the office staff. This was the second ginning season for us to have been permitted to collect data at the Kiech-Shauver Gin.

Oliver McCaskill, USDA, ARS, Stoneville Ginning Laboratory, and Dr. Beverly Reeves, Federal Extension Service, Memphis, Tennessee, made themselves freely available for consultation which was valuable to us.

The manufacturers of the two incinerators helped us in every possible way both in planning and executing of our work. They are Agrotherm Company of Los Angeles, California (Webb Nimick and Norman Pitt), and Ecology Enterprises of Dadeville, Alabama (Taylor Headley).

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ERRATUM: Page 11, Table 7 should read as follows:

Table 7. Turnout analysis at the California gin (dry pounds/480-lb bale)

Date	Seed Cotton		Lint		Seed		Motes		Waste	
	Wt.	MC	Wt.	MC	Wt.	MC	Wt.	MC	Wt.	MC
11/9	*1396*	*8.6%*	*460*	*4.1%*	*792*	*7.7%*	*26*	*7.0%*	*117*	*7.4%*
11/11	*1388*	*7.0%*	*455*	*5.2%*	*801*	*6.7%*	*29*	*7.0%*	*103*	----
11/17	*1463*	*9.0%*	*455*	*5.3%*	*785*	*8.6%*	*29*	*7.6%*	*195*	*7.0%*
12/6	*1413*	*8.1%*	*463*	*3.6%*	*782*	*8.9%*	*30*	*4.9%*	*139*	----
12/9	*1501*	*7.4%*	*460*	*4.2%*	*779*	*9.2%*	*26*	*5.9%*	*236*	*6.1%*