A-2464

FINAL REPORT
PROJECT A–2464

GEORGIA POULTRY INDUSTRY RESEARCH

PROGRAM MANAGER

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Prepared for
GEORGIA DEPARTMENT OF AGRICULTURE

AUGUST 1980

GEORGIA INSTITUTE OF TECHNOLOGY

Engineering Experiment Station
Atlanta, Georgia 30332

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by

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SUMMARY

The poultry industry in Georgia is currently the state's largest agribusiness with respect to gross annual revenues. An industry this large and competitive has both problems and opportunities before it. Most of the problems and opportunities have arisen because of the loss of productivity and because of the increase in the price of energy. The United States has fallen behind many other countries in the area of productivity. Although the U.S. as a whole is reducing its energy usage on a per unit basis the total energy usage is still increasing because of growth.

The future holds more stringent energy conservation ideas and better use of labor and resources if the poultry industry is to remain a viable entity. Many of the poultry companies are realizing this and are hiring individuals who are helping them, such as engineers, personnel and productivity people. It is important to have this new breed of people in the poultry industry, so that they can take research that is being done and use it to the companies' best advantage.

The research reported on here is an attempt to address and to focus on some of the problems of productivity and energy in the poultry industry. Specifically, in the energy area: 1) particular material degradation problems have been overcome in the solar poultry growout houses, and data collection which has been a continuing problem has been improved by the installation of a digital data acquistion system. 2) demonstrations for industrial heat recovery- a hatchery and an egg processor were chosen for installation of heat exchangers. These are very indicative of how heat

recovery systems can be cost effective in food processing plants. 3) The wood heated poultry house functioned very favorably for another winter season.

In the systems area: 1) A pilot plant for wastewater in an egg processing plant was designed and built to remove solids before going into the sewer. 2) With regard to productivity the yield data system made some good strides toward begin completely operational in the industrial environment. After many logistics problems were overcome, the scales were installed and made functional.

I. INTRODUCTION

Events similar to what happened this year worldwide appear to be indicative of an uncertain future for energy supplies, both for industrial and residential users. If the poultry industry is to maintain itself in the marketplace it must continue to endeavor to conserve energy and utilize alternate energy sources wherever it can.

As a continuing effort to combat these problems which undermine the industry the Georgia Poultry Federation has helped identify problem areas that exist and has aided the Georgia Tech Experiment Station in securing research funds through the Georgia Department of Agriculture.

This report covers research performed during the period September 15, 1979 - July 30, 1980. The research program addresses the following areas:

A. Wood Heated Growout House

Data was taken on this wood heated poultry growout house for another winter. The results are very good. Some modifications were made which enhanced the operation of the air duct system. In order to do an economic analysis which would denote a realistic price of wood some wood was bought and used in the firebox. Samples of the wood were taken for combustion analysis.

B. Solar Energy Applications

It was decided after some initial tests of a modified system at the Cumming solar poultry house that in order for it to be energy and cost efficient it would have to undergo some severe design changes.

The Villa Rica solar growout house absorber surface was replaced because the surface had become ineffective due to buckling and movement from high temperature stagnation and water vapor. The new sheet metal absorber surface is expected to have a much greater life expectancy and give much better results.

C. Electronic Yield Evaluation

Within the processing plant there is much turmoil because of the various types of inspection that were in effect this year. This constant flux has made it difficult to install weigh scales on the evisceration line. However during the contract period, four weigh stations were installed and are operating with data collection.

D. Noise Evaluation and Control in Poultry Plants

This report furthers the development of this NASA/Georgia Department of Agriculture study of Poultry plant noise. The noise sources have been identified and this report attempts to describe efforts to control it.

F. Energy Conservation

The energy consumption survey has taken been again this year and the results were sent out to the companies so they could see where they rank in relation to other companies.

Two energy conservation demonstration projects were also undertaken this year. 1) The first is a heat exchanger installed in an egg processing plant. The heat exchanger would take exhaust heat from a refrigeration compressor used in the egg cooler and preheat water going to the hot water heater and egg washers. 2) The project in an egg hatchery is using an air-to-air heat exchanger which is using the exhaust air to warm incoming fresh air which is necessary for the proper operation of the setters.

G. Poultry Engineering Progress Newsletter

The P.E.P. has been in existance for about three years now and is one of Georgia Tech's best means of communicating new ideas and results of current research to the poultry industry. We are continually updating our mailing list to make sure the appropriate people are receiving it. It is published on a monthly basis.

II. Wood Energy Applications

by
Bill Nolte

A. Introduction

In 1973, the Middle Eastern nations banned together, formed an organization called OPEC, and began what has since been called the "energy crisis." As supplies of petroleum became more restricted, usage of other fuels increased. In the winter of 1976 through 1977, a natural and lp gas shortage developed. This shortage made it obvious that gas dependent industries must find alternate as well as economical fuels. One of the major industries in Georgia that is gas dependent is the poultry industry. Of the total industry energy consumption, broiler growout operations use 1/3, and of this 1/3, 71% is for brooder heat.

Virtually all of the 4,500 active growout operations in Georgia have direct access to forested areas, making wood very practical as an alternate fuel. As part of the state's fiscal year '78 energy conservation program, a wood fired warm air brooding system was designed to demonstrate the practicality of wood as a fuel. Of those that were interested in the project, the farm of Mr. George Key of Carrollton, Georgia, was selected for the demonstration site. The installation of the warm air system was completed during the winter of 1977-78, with the first flock of chickens to be brooded with the warm air system being placed in June of 1978. Data has been collected continuously since that time and now represents 2 full years.

B. Site Description--Wood Heated House

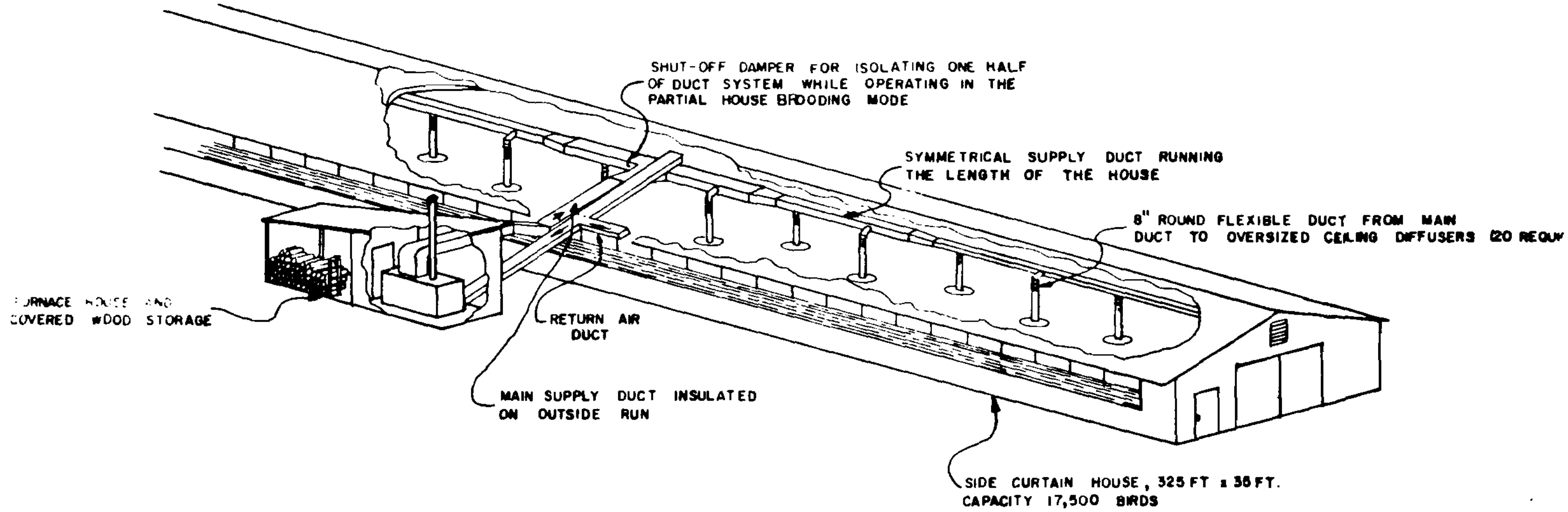
The farm has two identical growout houses which are physically located on a flat area approximately 100 feet apart and in an east-west orientation. They are approximately 3 years old and are of wood frame construction with a sheet metal roof and roll mineral siding, having 3½" of fiberglass insulation with a tri-ply vapor barrier installed in the ceiling, are 325 feet long by 36 feet wide and have a nominal capacity of 15,000 birds at a density of 0.8 square foot per bird.

Each house has manually controlled, full length side curtains that employ a safety device to open the curtains in the event of a power outage. Feed for the chickens is supplied to both houses from a single hopper located between the two buildings. Once in the house, 2 feeders running the full length of the building supply the birds. Cup-type waterers are installed adjacent to each feed line. House temperature is regulated by five 36" swingout belt-driven exhaust fans. Two of these are controlled by timers while the remaining 3 are controlled by thermostats.

The southernmost house is used as a control and has 20 conventional lp gas brooders with a heating capability of 30,000 Btu's per hour each. Although the other house has the same quantity and size lp brooders installed, they are used only as a backup system with the primary heat source being from a 350,000 Btu per hour wood-fired furnace.

C. System Description

Figure 2.1 depicts the main elements of the wood-fired warm air brooding system. A separate structure is provided



WOOD FIRED WARM AIR BROODING SYSTEM

STRAIN POULTRY FARMS, INC.
GEORGE L. KEY, GROWER

DRAWING IS NOT TO SCALE

FIGURE 2.1

to house the furnace and wood supply. A concrete pad, about 6" thick, is required to support the 3,100 lb wood furnace. The furnace house is located at the midpoint of the growout house to allow a symmetrical and naturally balanced air distribution system as well as to provide ready access to the farm's 40 acres of mature timberland. Exposed ducting from the furnace to the house is insulated and weatherproofed to reduce potential heat losses that can occur during inclement weather conditions. The side curtain is cut appropriately to allow the duct to enter the house. Following the inclined roof to the ceiling, the duct branches out into two long runs down the length of the house. Flexible 8" diameter ducts are located at approximately 15 foot intervals to supply warm air to ground level. The air is distributed parallel to the ground by means of slightly oversized concentric ceiling diffusers.

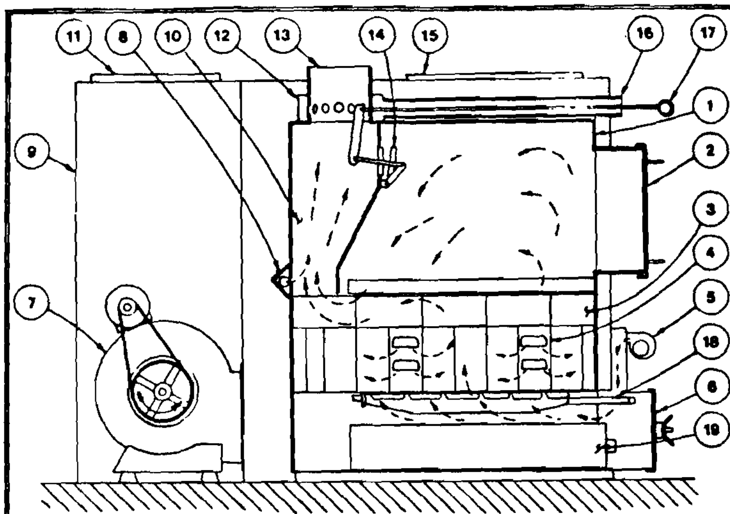
The entire duct system was sized using a static regain method as described in the ASHRAE Handbook of Fundamentals. As Mr. Key practices partial house brooding, there are times when only half of the duct system is utilized. A damper is installed to block off either half of the house as necessary. Both sides of the system are sized generously in order to accommodate an increased air flow. This also allows symmetry and natural balancing for ease of installation and operation.

The environmental requirements of young chickens are quite strict with regard to temperature and humidity. Normal propane fired brooders generated substantial quantities of water vapor as one of the products of combustion. The wood fired brooding system does not utilize the heating system medium in the combustion process and as a result dry air is provided. The ideal relative humidity condition for the litter ranges from 20% to 30%. Provision has been made in the design to allow for the installation of a humidifier in the duct system to control the moisture content of the supply of air if necessary.

The furnace selected for this program was Model 1007 designed and built by the Lynndale Manufacturing Company of Harrison, Arkansas. Figure 2.2 shows a schematic drawing and a list of the specifications for the furnace. The furnace has a 47 cu ft firebox and is rated at 350,000 Btu per hour. Air for combustion of the wood is supplied by a forced draft fan which operates when heat is required from the furnace. When heat is not required, the fan is turned off and the air supply to the firebox is minimized, thus slowing the burning process.

The brooding area is heated by being blown around the outside of the furnace firebox by a 4,140 cfm fan, Figure 2.3. It is then directed into the chicken house. The blower is controlled by the house thermostat; in addition, the blower will not operate if the temperature of the air entering the duct system is not above a set point temperature.

Construction and installation of the furnace and air distribution system was completed during the winter of 1977-78, and the first flock of chickens to be brooded with the wood-fired warm air system was placed in June of 1978. Prior to this, temperature in relative humidity data were recorded on a continuous basis using Rustrak Model 225 hygrothermographs. From the resulting charts, Figure 2.4, it is apparent that the test and control houses possessed parallel environmental characteristics and the control house can be considered an accurate data base with which to compare the performance of the wood-fired house.



1. BLACK IRON FIRE BOX CASING
2. 3/8" PLATE FEED DOOR
3. 2 1/2" THICK FIRE BRICK
4. CAST IRON DRAFT LOUVERS
5. FORCED DRAFT FAN
6. 3/8" PLATE ASH PIT DOOR
7. BLOWER AND MOTOR
8. OXYGEN INTAKE
9. 24 GA. METAL CABINET
10. SECONDARY HEAT EXCHANGER
11. RETURN AIR DUCT OPENING
12. SUPPLEMENTAL AIR INTAKE
13. VENT
14. BYPASS SMOKE DAMPER
15. SUPPLY DUCT OPENING
16. SLEEVE FOR BYPASS SMOKE DAMPER
17. CONTROL ROD FOR BYPASS DAMPER
18. CAST IRON GRATES
19. ASH PAN

APPLICATIONS:

●RESIDENTIAL
BASEMENT, GARAGE, WORKSHOP, OR ABUILDING OF ITS OWN. THE LYNNDALE SYSTEM EVEN WORKS IN A MOBILE HOME.

●COMMERCIAL
FACTORIES, SHOPS, WAREHOUSES, RETAIL SHOWROOMS, SCHOOLS, WHEREVER HEAT IS NEEDED AT A REASONABLE COST, OR WHERE CURTAILMENTS ARE A PROBLEM, THE LYNNDALE SYSTEM WORKS!

●AGRICULTURAL
THE LYNNDALE SYSTEM IS HEATING CATTLE, HOGS, AND EVEN WORMS.• BUT TWO APPLICATIONS SEEM TO STAND OUT AS THE MOST POPULAR:

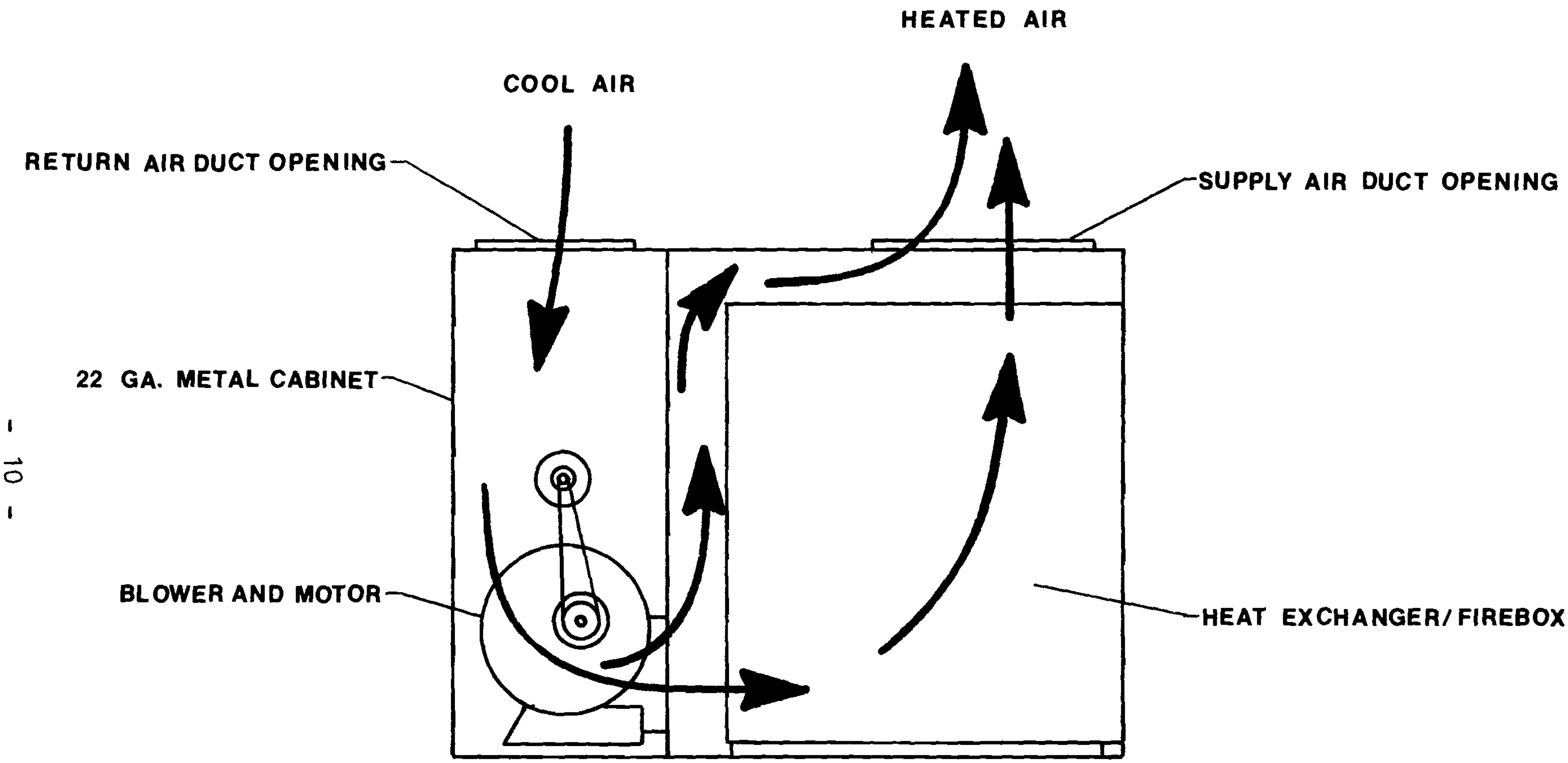
●POULTRY
THE BROODER HOUSE APPLICATION ALLOWS THE GROWER TO OPERATE PROFITABLY REGARDLESS OF THE HIGH COST OF HEATING WITH CONVENTIONAL FUELS.

●COMMERCIAL GREENHOUSES
HEAVY HEAT DEMANDS ARE NO PROBLEM WHEN YOU HAVE THE ECONOMY AND EFFICIENCY OF A LYNNDALE SYSTEM.

SPECIFICATIONS

MODEL	810	910	1007
BTU OUTPUT	125,000	200,000	350,000
FIREBOX (CU. FT.)	15	18	47
SHIPPING WT. (3 PC. SHIPPING)	1200 LBS.	1300 LBS.	3100 LBS.
UNASSEMBLED WIDTH	31"	34"	44"
ASSEMBLED WIDTH	34"	39"	46"
LENGTH	68"	73"	96"
HEIGHT	51"	51"	64"
FIREBOX METAL THICKNESS	10 GA.	10 GA.	7 GA.
FLUE SIZE	7"	7"	9"
BLOWER CFM	1600	2000	4140
MOTOR	1/3 HP 115V	1/2 HP 115V	1 HP 115V

FIGURE 2.2



FIREBOX AIR FLOW

FIG. 2.3

POULTRY HOUSE CONTROL QUALIFICATION TEST
GEORGE KEY POULTRY FARM
CARROLLTON, GEORGIA

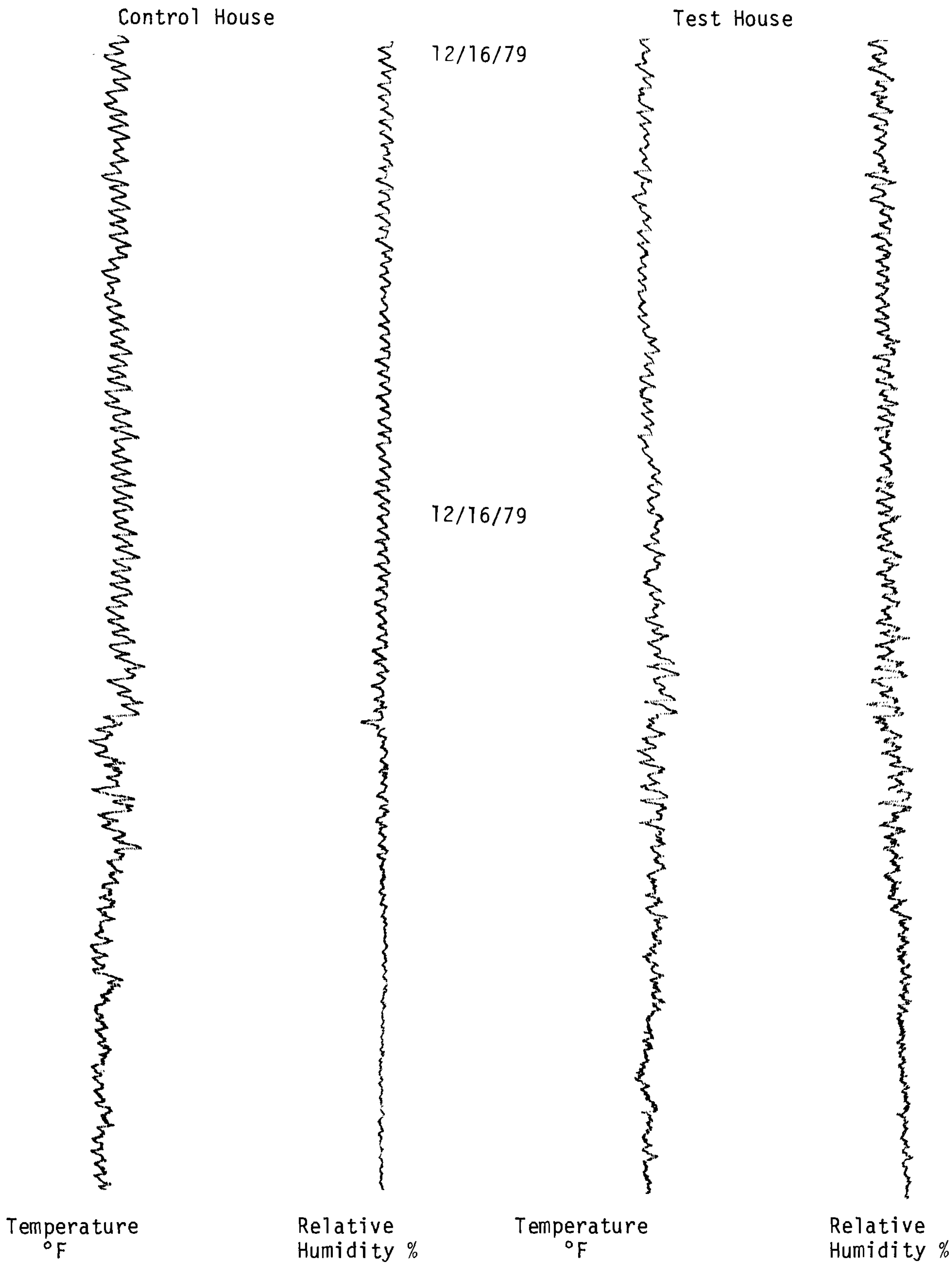


FIGURE 2.4

In order to insure survival of the first group of chickens brooded with the test system, the propane brooders were left in place with pilot lights burning so environmental conditions would be maintained in the event of some unforeseen failure of experimental system. Gas meters were installed on both the control and experimental house. Previous weather data had indicated that a 350,000 Btu/hr furnace would be adequate to maintain 70°F at the lowest average temperature the Carrollton area had experienced. However, one to three-day old chickens must have a minimum of 85°F temperature. Should the timing be such that day-old chicks were in the house and the minimum night-time temperature should be less than the average minimum temperature, the furnace would then not have sufficient capacity. Therefore, as a precaution, when chicks are placed during the months of November through March, the gas brooders are lowered into place the first week that the chicks are in the house. Although the gas brooders were not used at all in the winter of 1978, they were used twice in the winter of 1979.

The system has now been in operation for 2 years and has performed very reliably during this time. The reserve capability of this system was impressively demonstrated in the winter of 1978 when a storm caused an electrical power disruption to the poultry house. The chickens were approximately 6 weeks old at the time and, consequently, the gas brooders had been turned off. A safety device that insured adequate ventilation in the event of a power failure had been installed. When the set length of time passed, the mechanism actuated dropping the side curtains to a fully open position.

There is no device to automatically raise the curtains, thus when the power was restored, the side curtains remained lowered and the 3 timer controlled ventilating fans became operative. The situation was discovered approximately 4 hours after the power outage, and although the outside temperature was 16°F, the temperature inside the house had stabilized at 40°F.

D. Results and Discussion

1. Benefits of a warm air system. Qualitative measures of broiler production such as mortality, feed conversion, yield, and downgrading have been about the same for each house although the statistics favor the wood burner somewhat. It should be noted that these two houses have excellent management. In houses with average management, the inherent benefits of the warm air system (i.e., lower relative humidity and the absence of combustion products) might be more pronounced in the quality of the bird.

2. Heat value of wood. At this point, it seems appropriate to comment on the heat energy available from a cord of wood. Table 2.1 was a 1978 publication by the State of Vermont. Table 2.2 was extracted from the USDA Bulletin No. 753. Table 2.3 is from the Northeastern Regional Agricultural Engineering Services book, "Burning Wood." When the heat value of a single type of wood is compared, each table lists a different value. Tables from other sources show still different values.

A standard cord is defined as a stack of wood whose volume is 128 cu ft. The volume of the solid wood against standard wood, though, can vary from 60 to 110 cu ft. Size and shape of the wood as well as care in stacking are all factors of the variance.

PECIES	Specific Gravity (As Compared To Water)	B.T.U.'s Per Air-Dry Cord In Millions Of B.T.U.'s	Equivalent Value Of Heating Cost (In Gallons Per Cord)
ickory	.70 - .74	32.3	230.6
ed Oak	.60 - .73	28.8	205.7
eech	.64 - .66	29.3	209.5
ard Maple	.58 - .65	30.6	218.5
ellow Birch	.55 - .64	27.6	197.4
sh	.57 - .61	27.0	192.9
lm	.50 - .59	25.8	184.6
oft Maple	.47 - .54	25.3	180.8
marack	.49 - .53	25.3	180.8
erry	.50 - .52	24.8	177.0
ruce	.41 - .44	19.1	136.4
mlock	.40 - .42	18.9	134.8
pen (Poplar)	.37 - .39	18.7	133.4
sswood	.37 - .39	17.9	128.1
ite Pine	.35 - .37	18.0	128.8

sumptions: The above data is based on 95 cubic feet of solid wood in a cord as might be expected in a carefully stacked wood pile of split, 16 inch pieces. It is also assumed that the wood is air-dried to 20% moisture content.

The above figures represent total B.T.U. potential. However, efficiencies of present firing systems vary. Oil furnaces have efficiences near 70% while modern wood burning devices vary from 50% to 60% efficient.

eful Energy Data

1 Therm = 100 cu. ft. gas	=	100,000 BTU
1 KWH	=	3,412 BTU
Propane Gas	=	21,650 BTU per lb. (4.24 pounds = 1 gallon)
		2,500 BTU per cu. ft.
Butane Gas	=	21,500 BTU per lb. (4.8 pounds = 1 gallon)
		3,200 BTU per cu. ft.
Natural Gas	=	1,000 BTU per cu. ft.
Fuel Oil #1 Domestic	=	132,908 - 138,800 BTU per gallon
Fuel Oil #2 Domestic	=	135,800 - 144,300 BTU per gallon
Coal 80 Lb.	∿	1,000,000 BTU

COMPARATIVE HEATING VALUES OF WOOD

TABLE 2.1

Variety of Wood	Weight Per Cord, Lb.		Available Heat Units Per Cord Million B.T.U.		Equivalent in Heat Value to Tons of Coal+	
	Green	Air Dry	Green	Air Dry	Green	Air Dry
Ash, white	4300	3800	19.9	20.5	0.77	0.79
Beech	5000	3900	19.7	20.9	.76	.80
Birch Yellow	5100	4000	19.4	20.9	.75	.80
Chestnut	4900	2700	12.9	15.6	.50	.60
Cottonwood	4200	2500	12.7	15.0	.49	.58
Elm White	4400	3100	15.8	17.7	.61	.68
Hickory	5700	4600	23.1	24.8	.89	.95
Maple Sugar	5000	3900	20.4	21.8	.78	.84
Maple Red	4700	3200	17.6	19.1	.68	.73
Oak Red	5800	3900	19.6	21.7	.75	.83
Oak White	5600	4300	22.4	23.9	.86	.92
Pine Yellow	----	----	21.1	22.0	.81	.85
Pine White	----	----	12.9	14.2	.50	.55
Walnut Black	----	----	18.6	20.8	.72	.80
Willow	4600	2800	10.9	13.5	.42	.52

*The Use of Wood for Fuel, U.S. Department of Agriculture Bull. 753

+Short ton (2000 lb.) of coal having a heating value of 13,000 BTU/lb.

APPROXIMATE WEIGHTS AND HEATING VALUES PER CORD OF FUEL WOOD

TABLE 2.2

A Cord of Air-Dry Wood Equals	Tons Of Coal	Gallons Of Fuel Oil	Therms Of Natural Gas	Kilowatt Hours Of Electricity
Hickory, Hop hornbeam (ironwood), Black locust, White Oak, Apple =	0.9	146	174	3800
Beech, Sugar Maple, Red Oak, Yellow Birch, White Ash =	0.8	133	160	3500
Gray and Paper Birch, Black Walnut, Black Cherry, Red Maple, Tamarack (Larch), Pitch Pine =	0.7	144	136	3000
American Elm, Black and Green Ash, Sweet Gum, Silver and Bigleaf Maple, Red Cedar, Red Pine =	0.6	103	123	2700
Poplar, Cottonwood, Black Willow Aspen, Butternut, Hemlock, Spruce =	0.5	86	102	2200
Basswood, White Pine, Balsam Fir, White Cedar =	0.4	73	87	1900

AMOUNT OF OTHER FUELS EQUIVALENT TO A CORD OF AIR-DRY WOOD

TABLE 2.3

Weight of the wood is probably a better basis, but there is a pitfall here also. How much water does the wood contain? Not only is the weight of the fuel decreased by the amount of water present, but the energy available is lowered by the amount required to evaporate the water. From a temperature of 32°F, approximately 1,200 Btu's* are required for each lb of water.

The environmental conditions to which the tree has been subjected are also a factor. These conditions cause the density of wood within a given species to vary. Consequently, the heat produced by a cu ft of wood will vary from tree to tree although the trees are of the same specie.

3. Combustion analysis. In the original concept of the project, fuelwood was cut from Mr. Key's farm--typically oak, hickory, elm, poplar, and yellow pine were available. Random samples were selected from the cut wood and were used for a combustion analysis, the results of which are shown in Table 2.4.

The average of the heat values obtained in the analysis was 8,034 Btu's per lb. A commonly accepted value for hardwoods is 7,950 Btu's per lb. Using other commonly accepted criteria, this should have yielded 19.3 million Btu's required for the fuelwood used.

Although aware of the inherent inaccuracies of volume measurement, this method was deemed the most practical for the demonstration. Special bins were constructed, each con

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* Btu is the amount of energy required to raise the temperature of one pound of water one degree Fahrenheit.

SAMPLE	PERCENT MOISTURE	PERCENT ASH	HEATING VALUE(BTU/LB)
1103A(1)	9.94	4.18	7,682
(2)	-	4.16	7,636
(ave)	-	4.17	7,659
1117A(1)	22.89	2.69	7,810
(2)	-	2.74	7,818
(ave)	-	2.72	7,814
1117B(1)	25.85	1.28	8,037
(2)	-	0.97	8,102
(ave)	-	1.13	8,020
1117C(1)	19.41	1.67	8,132
(2)	-	1.55	8,112
(ave)	-	1.61	8,122
1117D(1)	28.64	1.43	8,037
(2)	-	1.55	8,013
(ave)	-	1.49	8,025
1117E(1)	15.60	0.42	8,296
(2)	-	0.40	8,343
(ave)	-	0.41	8,320
1117G(1)	18.69	1.08	8,214
(2)	-	1.08	8,166
(ave)	-	1.08	8,188
1207A(1)	15.44	3.40	8,036
(2)	-	3.31	8,076
(ave)	-	3.36	8,056
1207B(1)	26.49	2.27	7,890
(2)	-	2.46	7,905
(ave)	-	2.37	7,898
1214B(1)	34.35	0.92	8,203
(2)	-	1.06	8,207
(ave)	-	0.99	8,205
1117Ash(1)	-	-	263
(2)	-	-	235
(ave)	-	-	249
1207Ash(1)	-	-	499
(2)	-	-	546
(ave)	-	-	523

COMBUSTION ANALYSIS

TABLE 2.4

taining 27.4 cu ft per bin. From the records of bin usage, the annual fuelwood consumption for the experimental house was 29 cords for May of 1978 to May of 1979, and 24 cords for May of 1979 to May of 1980, or an average of 26½ cords per year. Equating this quantity to the heating value of propane used by the control house (an average of 3,433 gallons per year), the resulting value is 12.4 million Btu's per cord. If the furnace is assumed to be 50% efficient, this value then compares favorably with published data for this mix of wood.

Part of the phenomena of modern poultry meat production is that the grower's operation has become a part-time job. Although the chickens require attention periodically each day, the average time consumed will average 2 to 4 hours. As a result, many growers have full-time jobs elsewhere and raise chickens on the side. This leaves little time for cutting the wood required for a wood burning brooder house.

A more realistic approach then might be that the wood would be purchased rather than cut from the farmowner's land. A number of dealers and suppliers in the Carrollton/Carroll county area were contacted, and it was found that firewood was considered to be a home item and was priced accordingly. To be economically viable, it was found that wood would have to be purchased in pulpwood lengths and then cut in half at the site. Quoted prices for this wood varied from $25 to $40 per cord with the splitting fee averaging $5 per cord.

Since pulpwood length is 5'6", cutting such a log in half reduces the length to 2'9", or 33", which can readily be accepted by the Lynndale furnace. The furnace can also accept logs up to 15" in diameter which reduces the splitting required to a minimum.

Bids to purchase 11 cords of wood were issued by Georgia Tech in November 1979. Unfortunately, the lengthy forms required by Tech deterred a number of dealers and suppliers from responding. The lowest bid received was $42 per cord delivered and split in half at the site.

One load of purchased wood representing 3.67 cords was weighed prior to delivery. This load was isolated and random samples were selected for a combustion analysis--the results of which appear in Table 2.5. This analysis showed the samples to have an overall average of 43% moisture by weight and a heating value of 8,244 Btu's per lb of oven dry wood. After reducing the gross energy by the heat necessary to evaporate the moisture in the wood, this load of wood had a net available energy of 94.8 million or 26.2 million Btu's per cord. This further reduces to an output energy value of 13.1 million Btu's per cord when burned in a 50% efficient furnace, or 15.7 million Btu's per cord when burned in a 60% efficient furnace.

It might be further noted that had the wood been purchased in the spring, stacked, and allowed to air dry through the summer to a moisture content of 20%, the annual usage would have been decreased by 2.1 cords or a cost savings of $88 with wood priced at $42 per cord, or $63 with wood at $30 per cord.

4. Economic Analysis. Tables 2.6 and 2.7 show an economic analysis of 20-year life cycles for the gas-fired and wood-fired systems. In 1980 dollars, the wood-fired system shows a cost advantage of $2,494.00 per year. Note that this is based on a wood price of $30 per cord. From the price quotes Tech received from the dealers when first contacted, we feel that a private owner can readily obtain wood at this price.

Sample Number	Percent Moisture	Heating Value (Btu/lb)
1	48.7	8251
	52.0	8169
(Avg)	50.4	8210
2	54.1	8300
	50.7	8399
(Avg)	52.4	8349
3	34.7	8228
	33.5	8216
(Avg)	34.1	8222
4	32.8	8155
	39.1	8233
(Avg)	36.0	8194

COMBUSTION ANALYSIS OF PURCHASED WOOD

TABLE 2.5

Item	November 1979 $
) 20 Brooders (20 x $5/brooder)/t=0,10	$ 3,000
) Propane (3750 gal/yr) ($.56/gal) / t=0,1,2,...,18,19	$ 42,000
Fuel tank, piping, regulator t=0	$ 1,200
	$ 46,200

Amortized Annual Cost @ 10% for 20 yr. is:

(46,200) (.1175) = $5428.50

Legend	
t=0	20 year life
t=0,5,10,15	replace every 5 years
t=0,1,2,...,18,19	replace every year

ECONOMIC ANALYSIS GAS-FIRED SYSTEM

TABLE 2.6

Item		November 1979 $
200,000 BTU Furnace	t = 0	$ 2,000
100,000 BTU Heat Reclaimer	t = 0	500
ducts & installation	t = 0	1,500
Furnace Flue $150/t = 0,5,10,15		600
Air Filter Media $180/t= 0,1,2,...,18,19		3,600
Air Filter	t = 0	600
Electricity $80/t=0,1,2,...,18,19		1,600
Wood 29 cords x $30/t=0,1,2,...,18,19		17,400
		$ 27,800

Amortized Annual Cost @ 10% for 20 Years is:

($27,800) (.1175) = $3266.50

Legend

t=0 20 year life

t=0,5,10,15 replace energy 5 years

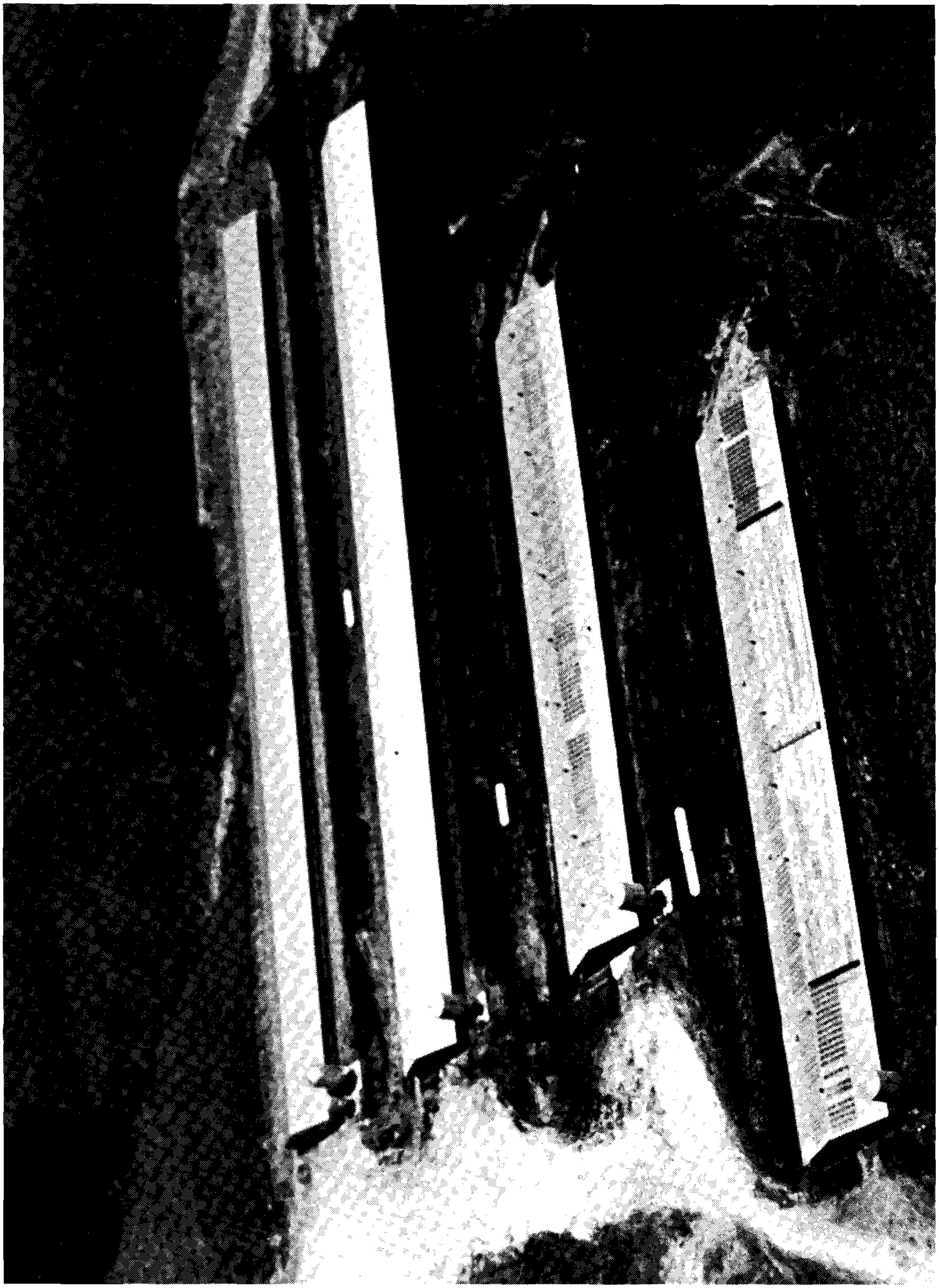
t=0,1,2,...,18,19 replace energy every year

ECONOMIC ANALYSIS WOOD-FIRED SYSTEM

TABLE 2.7

E. Conclusion

During the past two years, the cost of propane has risen from 56¢ per gallon to 65¢ per gallon, and government sources predict this upward price trend to continue. Although the cost of wood will surely rise, it is felt the lag will produce an even greater cost advantage for wood in the future.



III. Solar Energy Applications

by
Wiley Holcombe
Steve Robertson

A. Introduction

There are a number of ways to collect and use solar energy. Solar energy can be used directly as thermal energy through the use of flat plate solar collectors. Solar energy can also be harnessed in the form of falling water.

The Georgia Tech Engineering Experiment Station, funded through the Georgia Department of Agriculture, began investigating the utilization of poultry manure as an energy source in 1974. An anaerobic digester which produces methane from manure was designed and constructed on an egg laying farm near Cumming, Georgia. In 1975, studies were begun to determine the feasibility of directly utilizing solar thermal energy on a broiler farm. Since then, two low cost solar air heating systems have beem built and operated. In 1978, a wood fired heating system was added to a broiler house near Carrollton, Georgia. This system was discussed in Section II.

Work is continuing on the two solar heated broiler growout houses. Modifications were completed on the solar collector at the Villa Rica site to correct problems caused by material degradation. Drawings and specifications were prepared for a series of modifications to the Cumming passive solar heating system. These modifications will allow an investigation of the important parameters affecting a remote passive collector. Also, the results of the hydro-biomass survey, started during the last fiscal year, were compiled. These topics are discussed in the following section.

B. Active Solar Heating System

1. Description

A low cost, active solar heating system was built on Mr. William Waddell's farm near Villa Rica, Georgia in April 1978, to augment the propane fired brooders in one of his growout houses. Figure 3.1 is a photograph of the solar collector on the roof of the chicken house. Figure 3.2 shows the distribution ducts inside the house. Figure 3.3 is a cutaway view of the system. Outside air is pulled from each end of the collector through five parallel channels between the collector glazing and absorber surface to a central plenum. A duct fan pulls air from this plenum and distribuutes it to the house through polyethylene ducts which run the length of the house. The system was operated and monitored during the 1978-1979 heating season.

Cost was a major consideration in the design and material selection process. The 2950 square foot collector was built on site using Kalwall fiberglass sheet for the glazing and a black foil faced insulation board to absorb the solar energy and reduce heat loss from the collector. The system was built for about $2.45 per square foot of collector in 1978.

A number of things were learned in operating the system. The forced air system was designed to pull make-up air either from the house or from the outside. It was

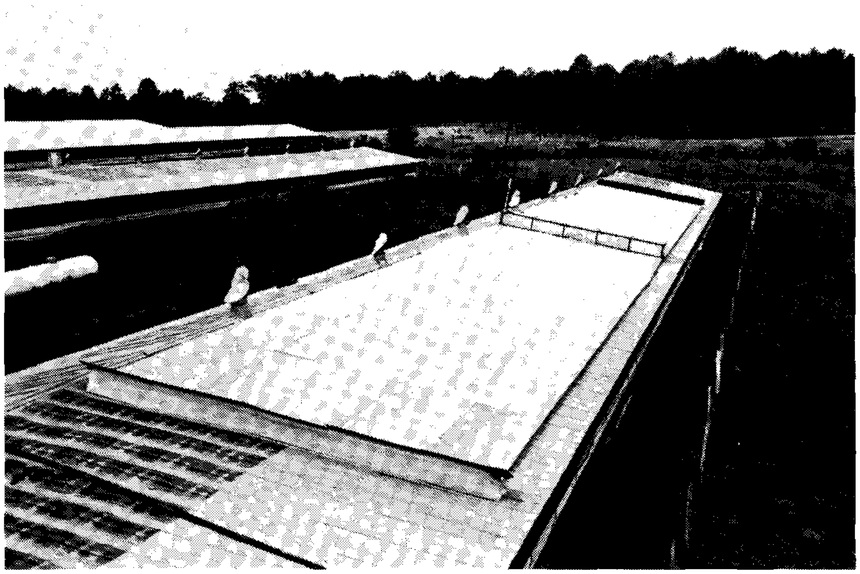


FIGURE 3.1 ACTIVE SOLAR COLLECTOR

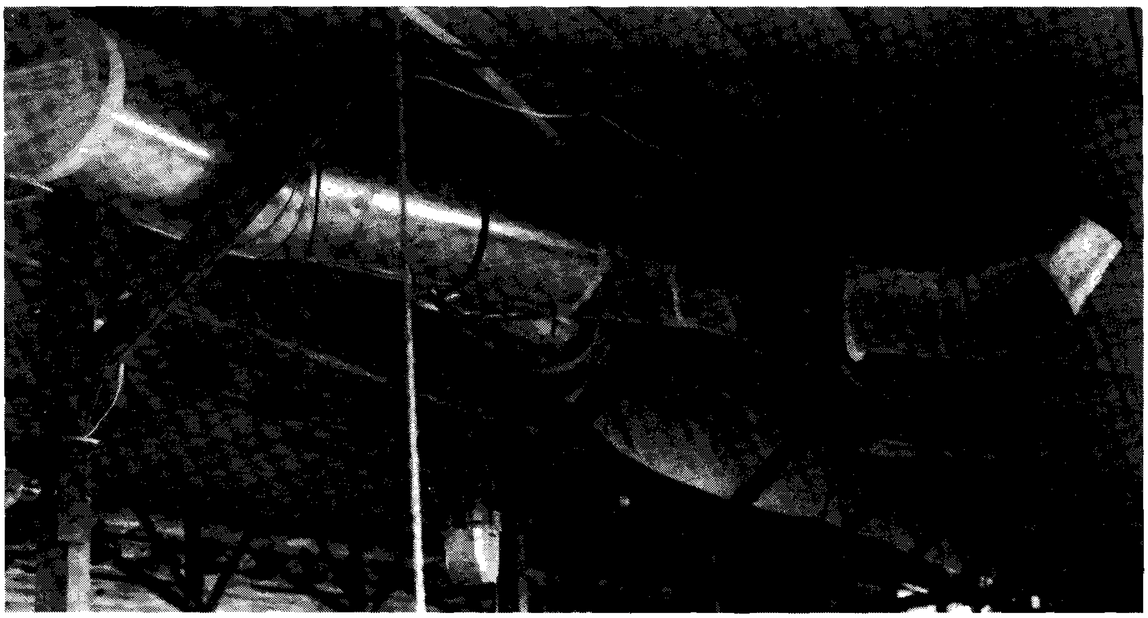
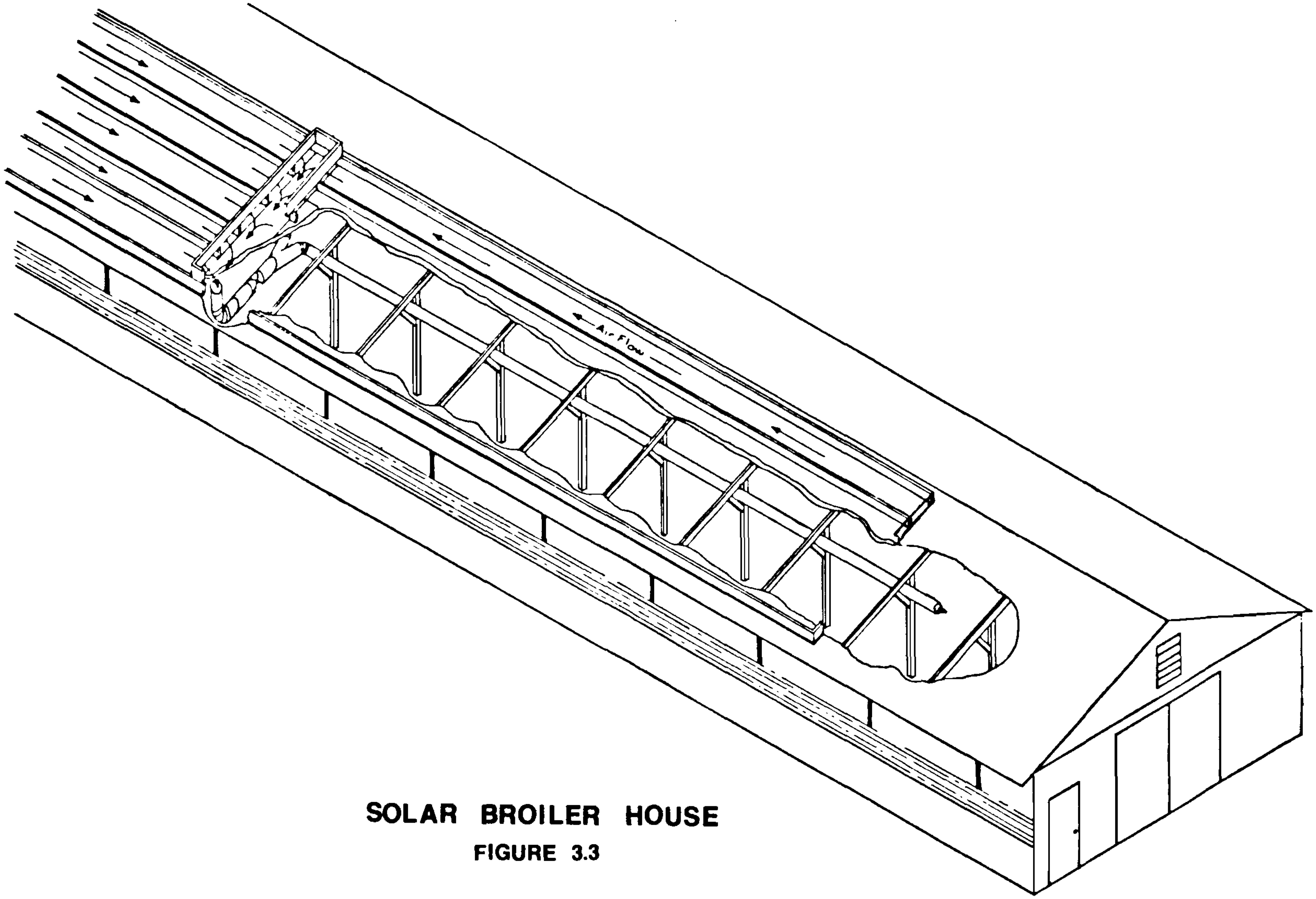


FIGURE 3.2 FAN AND DISTRIBUTION DUCTS



SOLAR BROILER HOUSE

FIGURE 3.3

apparent from soon after start-up that the house air was too dirty to be pulled directly through the collector. The system was operated using ambient air as make-up. The volume flow of air was small enough to be below the minimum ventilation requirement during most operating periods. It is possible that the house air could be filtered and recirculated, as evidenced by the installation of a filter at the Georgia Tech wood heated growout site.

2. Problems

As reported in Reference 1, a number of problems have arisen which serve to reduce the efficiency of the collector. Dust from the chicken house has been a major problem. Dust is carried into the collector by the ambient air which is being heated during normal collector operation. Dust is also carried into the collector by warm air from the house which backflows the collector at night by natural convection. Much of this dust settles out on the black absorber surface thereby reducing its absorptivity. In addition, the dust also settles out on the surface of the glazing, thereby reducing its transmissivity. The glazing itself has deteriorated, resulting in a loss in transmissivity. A test made at Georgia Tech indicated that the transmissivity of the glazing had dropped from 78% down to approximately 56%. A sample of this glazing was returned to the glazing manufacturer. A representative of the manufacturer indicated that the transmissivity of this sample was approximately 69%.

The original absorber surface was foilfaced Celotex® insulation board which was painted black. The black paint, although covered by dust, has held up well. The foil face, however, has begun to crack and peel off the foam board as shown in Figure 3.4. In addition, data taken at the site during their 1978-1979 heating season indicated that the controller was not operating the fan properly. The controller sometimes provided air from the collector to the house that was cooler than the house temperature.

These problems combined to reduce the efficiency of this solar air heater far below its potential. Experience with his system has shown that materials must be carefully selected with consideration given to material life as well as initial cost. Dust should be an important design consideration in any application located in a dirty environment.

3. System Rebuild

An effort was begun to rebuild the system to alleviate some of the problems discussed above. This effort included selecting the method to correct these problems, selecting the required materials, and physically rebuilding the system.

The problem of the absorber surface peeling up was solved by placing a new absorber surface on top of the old absorber surface. For an air collector which flows air between the absorber surface and the glazing, the absorber surface does not have to act as a fin as in a typical tube and plate liquid collector. Consequently, a very thin, thermally nonconducting material can be used if it can withstand the 100-200°F operating temperatures of a typical absorber surface. Other factors to consider are the cost and the weight of the absorber surface which increases the roof loading and increases the installation time.

Considering all these factors, the new absorber surface was selected to be .021 inch-thick, galvanized steel sheet. Steel was selected over a plastic because a metal can withstand the 100-200°F operating temperatures. Also steel sheet has a lower cost than that of other commercially available sheet metal such as aluminum or copper. The galvanized steel sheet that was purchased also has a phosphate coating. The phosphate coating treatment provides a better suface for paint adhesion than untreated galvanized steel. Paint adhesion is important because the sheet steel is painted flat black to inhance its ability to absorb solar radiation.

For an air collector, the absorber surface paint must be able to withstand the combination of 200°F temperatures and high humidities. Also, to keep with the design philosophy of having a low cost, site-built collector, the paint should be commercially available and relatively inexpensive. Presently, performance data on paints for absorber sufaces is limited. Therefore, after reading the available literature on paints, other solar collector manufacturers were consulted and asked for their recommendations. This lead to the selection of Rust-Oleum 412 flat black paint as the absorber surface paint. This paint is used by several collector manufacturers, is readily available, and is considerably cheaper than other paints which are being used by some collector manufacturers.

The original wooden battens used to seal the glazing were replaced by aluminum battens. The advantage of aluminum over wood is that aluminum does not require painting to protect it from outdoor exposure. The disadvantage of aluminum is that the holes for the hold-down screws have to be predrilled. For wood though, the hold-down screws can be screwed directly through the wood. The cost of aluminum batten including drilling the holes is more expensive initially than the painted wood batten. However since aluminum has a longer life than wood, it was selected for use as the batten.

An important consideration with aluminum is its greater thermal expansion as compared to wood. Room for thermal expansion must be provided to prevent the aluminum from buckling. Expansion room can be provided by drilling the hold-down screw holes larger than the screw diameter and by leaving a gap between the adjacent batten strips.

The hold-down screws used in the initial installation of the glazing in 1978 were cadmium plated steel screws. The majority of these screws were severely rusted and as a result had lost some of their holding strength. The hold down screws used to replace the glazing were cadmium plated stainless steel screws. More specifically the screws were #14x2-inch, hex head, self-tapping sheet metal screws. Brass screws were considered; however, they were not available with a hex head. Installing hex head screws is much faster than installing Phillips head or slotted head screws. These new screws also have an aluminum backed EPDM dished washer on them which helps to seal the hole.

In the initial installation of the glazing, too few supports were used and the glazing sagged in the middle. To solve this problem, 1/16 inch diameter stainless steel wire was stretched across the collector to support the glazing every 30 inches. This helped some, but the glazing still sags with the wire stretched as tight as possible.

After the materials were selected, the individual tasks involved in the rebuild were identified. These tasks were listed in the order that they were to be done. Estimates were made for the amount of time, amount of labor, and amount of material cost required for each of these tasks. The task that required by far the longest lead time was obtaining the new absorber surface. It required approximately one month from the time the order was placed for this material to be delivered.

Work was begun at the site soon after the new absorber surface was ordered. The fiberglass glazing was removed from the collector and stacked at the site. The glazing was later returned to the Georgia Tech campus where it was washed using soap and water and a floor scrubber. New aluminum batten strips were attained and predrilled to speed reinstallation of the glazing. Also, stainless steel, hex-head lag screws were obtained for installation of the glazing.

Removal of the glazing revealed that the collector was in worse condition than had been previously thought. The foil surface was cracking and peeling over much of the collector (See Figure 3.4). The foam board had buckled up in many places, partially blocking the airflow passages (See Figure 3.5). Sap from the 2x4 structure had run down across the absorber surface, removing some of the paint (See Figure 3.6). Many of the 2x4's were badly warped. Dust build-up was heavy at the collector inlets and at the plenum, indicating that house air was backflowing the collector when the fan was off,(See Figure 3.7).

It proved difficult to remove the dust and loose foil from the collector. The large debris was removed from the collector and sections of foam were cut out to allow the buckled areas to lay down. The new absorber surface was

FIGURE 3.4 TWO–YEAR OLD FOIL ABSORBER SURFACE

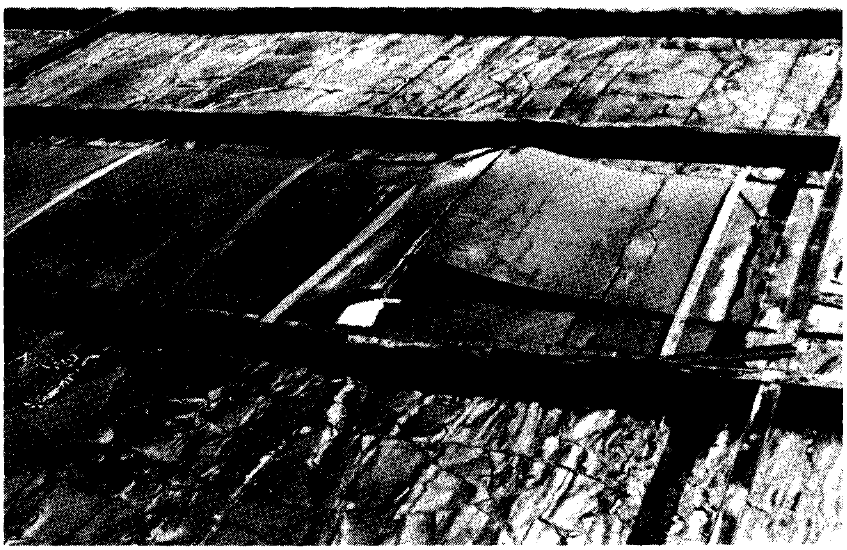


FIGURE 3.5 BUCKLED FOAM INSULATION BOARD

FIGURE 3.6 ABSORBER SURFACE DAMAGE CAUSED BY TREE SAP

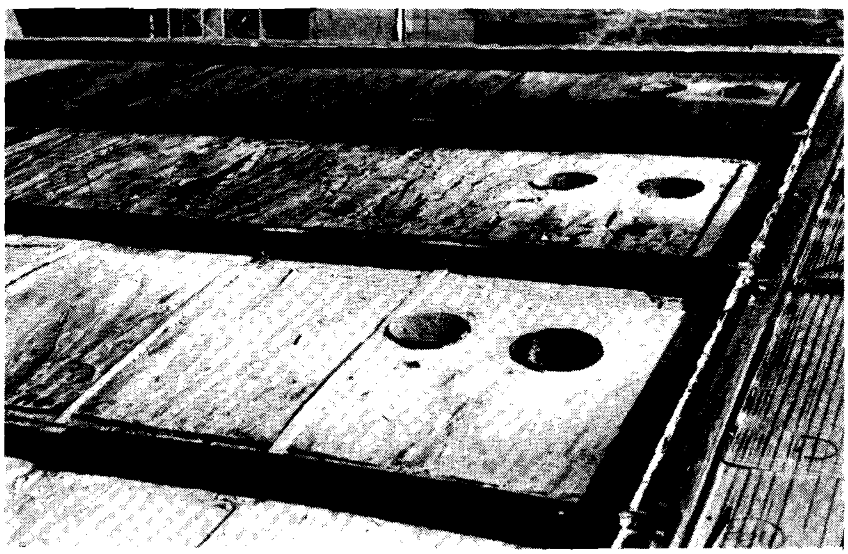


FIGURE 3.7 DUST BUILDUP ON ABSORBER SURFACE

then delivered to the site and installed in the collector in approximately two days. The new absorber surface is shown in Figure 3.8. Broken glazing supports were repaired and a section of rotten 2x4 was replaced. Stainless steel wire was strung every three feet across the collector channels to provide additional support for the fiberglass glazing. Reinstallation of the glazing was then begun. The glazing was installed over a period of approximately two weeks. During this time, dust began to accumulate on the new absorber surface. New thermocouples were installed in the collector as the glazing was put back down. Also, the temperature sensors for the new controller were installed in the collector.

It is apparent that dust is going to continue to be a problem for this solar collector. Therefore, a filter has been added at each end of the collector. Structures were built to hold the roll filter media. These structures provide for a twelve inch tall filtered inlet opening and provide a sixteen inch overhang to protect the filter material from rain. Two-inch-thick, roll fiberglass filter material was installed on these structures. The completed filter is shown in Figure 3.9.

4. Instrumentation

The instrumentation and data collection system at the Villa Rica site has been improved. A cassette digital data recorder along with a data reader was obtained in July of 1979. The digital data recorder was interfaced with the existing Esterline Angus 24-channel chart recorder. This interface involved modifications to the Esterline Angus chart recorder and design and construction of sample/hold circuits. These sample/hold circuits store the temperature

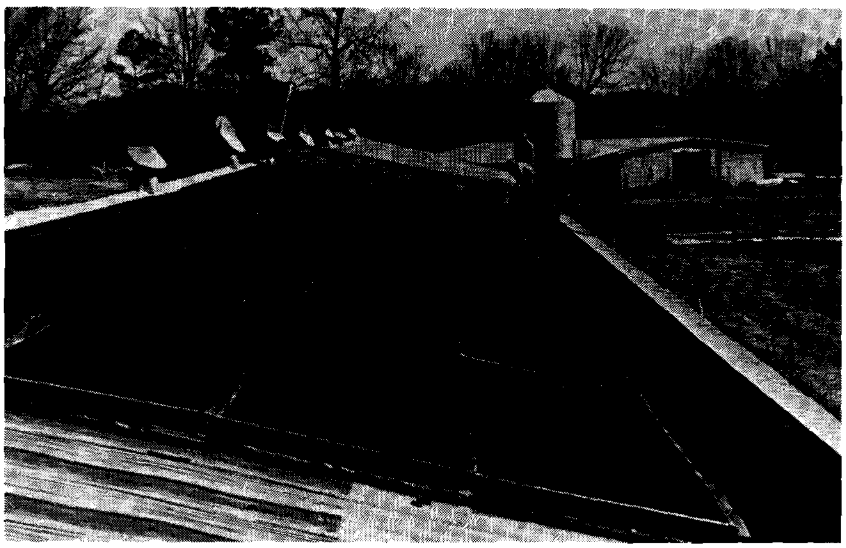


FIGURE 3.8 NEW STEEL ABSORBER SURFACE

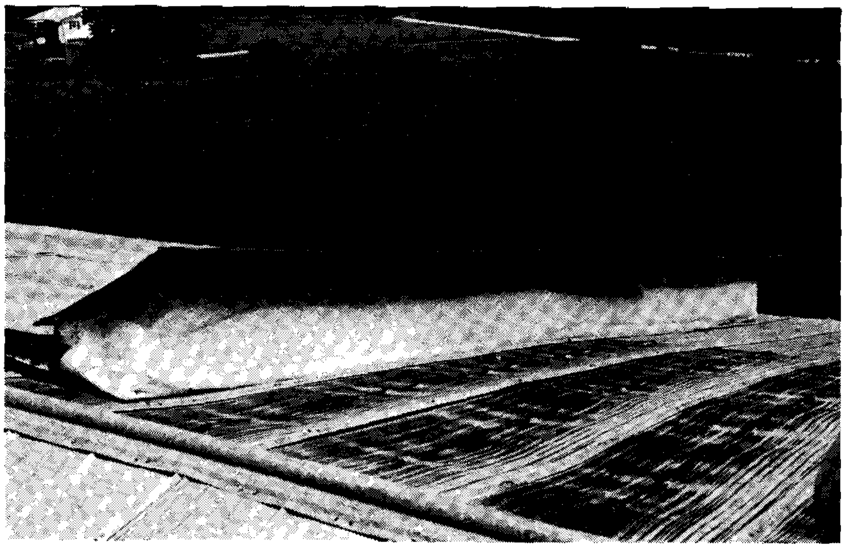


FIGURE 3.9 NEW COLLECTOR INLET AIR FILTER

measurements taken by the Esterline Angus recorder. The digital data recorder then reads this information stored by the sample/hold circuits. This permits the thermocouple reference circuitry of the Esterline Angus recorder and the digital data recorder to cycle at different cycle rates. The Esterline Angus chart recorder, the digital data recorder, and the solar radiation integrater have been mounted in a nineteen-inch electronics cabinet which has been sealed to protect the equipment from the dusty environment of the chicken house. A manual has been written to document the sample/hold circuits and their interface to the chart recorder and digital data recorder. This manual is included as Appendix A. New thermocouples, installed as the collector was rebuilt, will provide temperature profiles along the top flow channels and will measure the exit temperature for each of the ten collector channels. These thermocouples along with existing thermocouples and instruments will be used to monitor the system during the 1980-1981 heating season.

5. Results and New Problems

The collector rebuild was completed in early March 1980, at the end of the winter heating season. The improved data collection system was completed and installed in May 1980. Consequently, no winter data was taken. However, much was learned from the collector rebuild. The variations in dimension common in a site built collector can be a problem. The sealing of the collector glazing was a problem. Thermal expansion of the new aluminum batten strips has caused them to buckle and pull out screws. Dust is a continuing problem.

6. Future Monitoring

The system rebuild was not completed in time for the 1979-1980 heating season. However some data was obtained during June of 1980. The system will be used during the summer months when heat is required for new chicks. During the summer, software will be developed for data reduction of the digital data. The system will then be operated and monitored during the 1980-1981 heating season.

C. Passive Solar Heating System

In May, 1976 a solar heating system was built on Lamar Hick's poultry farm near Cumming, Georgia. The system provides part of the heat needed in one of his broiler growout houses. Conventional gas brooders provide the remainder of the heat. The two main design objectives for the system were that it be low cost and be easily built by a poultry farmer.

One solar heating system that meets these objectives is a passive solar air collector. The reason for choosing a passive type collector over an active type collector is that no pumps, fans, or controls are needed. Although, an active system will usually have a higher efficiency, these extra components will also increase the cost. Furthermore, skilled labor may be needed to install the pumps, fans and controls. An air heating collector was chosen over a water heating collector because air heating collectors are typically less costly and need less maintenance.

Low cost materials were used in the construction of the passive solar air heater. A six inch deep, granite rock bed was used as the absorber surface. The average diameter of the granite rocks is four inches and about eighty tons of granite rock were used. To increase the absorbitivity of the rockbed, it was spray painted black. The glazing for the collector is two layers of six mil thick, clear polyethylene, treated to prevent ultraviolet degradation. Thirteen outlet ducts, made of eight inch diameter concrete pipes, connect the collector to the growout house. The collector is built on a 30° hillside behind the broiler growout house and faces 30° east of south. A schematic of the system is shown in Figure 3.10.

Basically, the radiation from the sun heats the rockbed thus raising its temperature. Air in the collector is then heated by the rockbed. As the air is heated, it will rise naturally through the collector and into the broiler growout house. The total cost to build this 3328 square foot collector was about $6600, in 1976.

Evaluation of performance data over the past winters showed the collector was not operating as effectively as expected. The major causes of the low efficiency were:

1) no insulation on the outlet ducts,

2) no plenum to direct the heated air from the collector to the outlet duct,

3) improper ratio of collector area to outlet duct area, and

4) material degradation.

Because of these problems, an experimental program was undertaken to determine the effect of various design changes

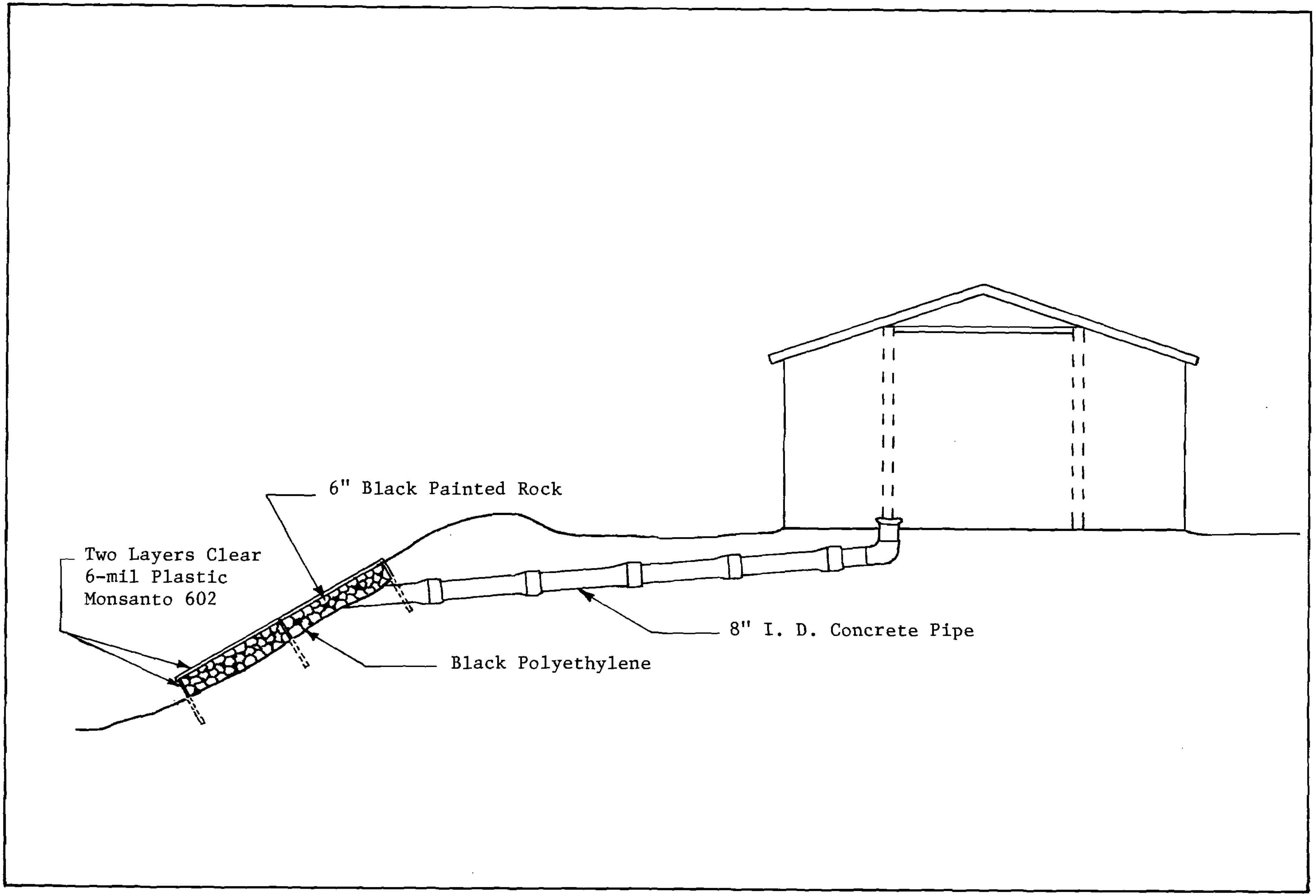

6" Black Painted Rock
Two Layers Clear
6-mil Plastic
Monsanto 602
8" I. D. Concrete Pipe
Black Polyethylene

FIGURE 3.10

on collector performance. In this program a sixteen foot by sixteen foot section of the collector was sealed off from the rest of the collector. This section was modified by

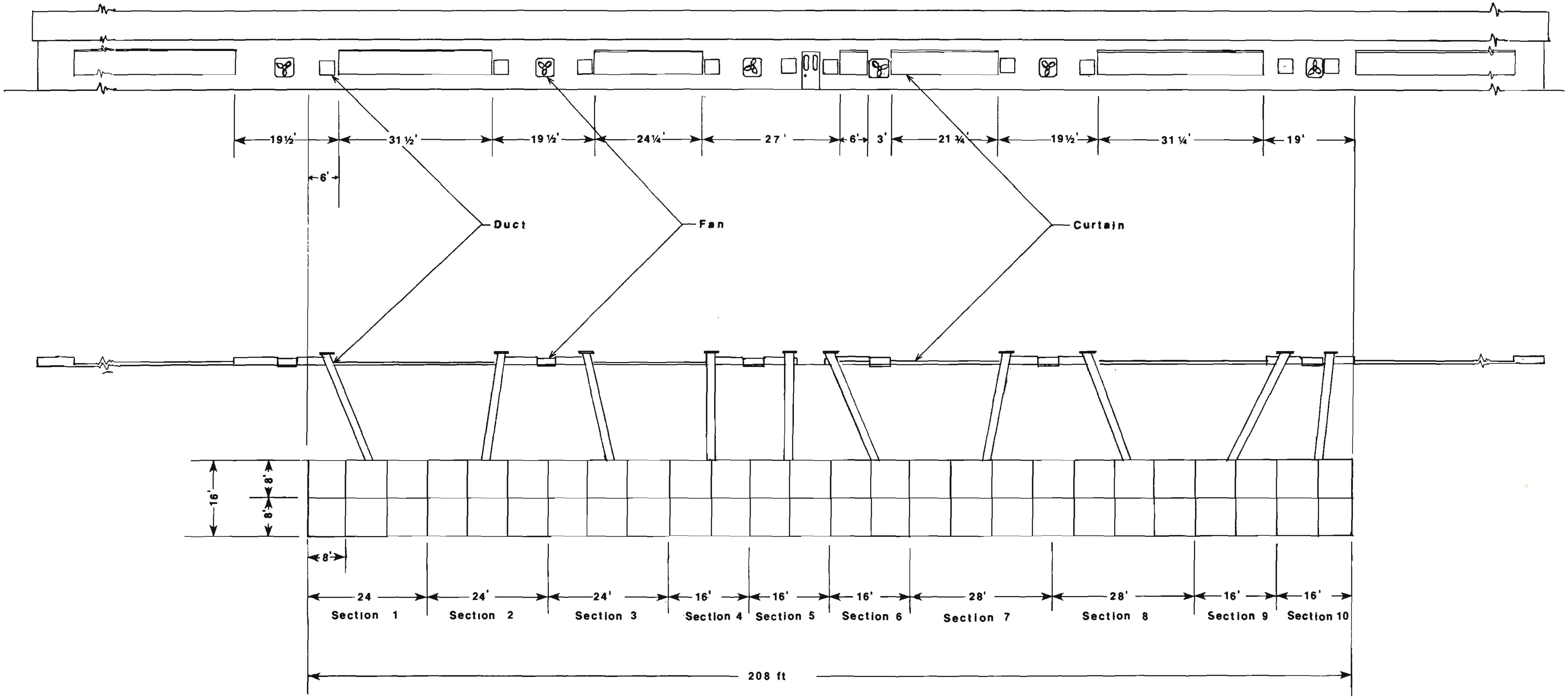
1) increasing both the inlet area and outlet area to to four square feet

2) adding an above ground outlet duct

3) adding a plenum to direct the airflow from the collector to the outlet duct, and

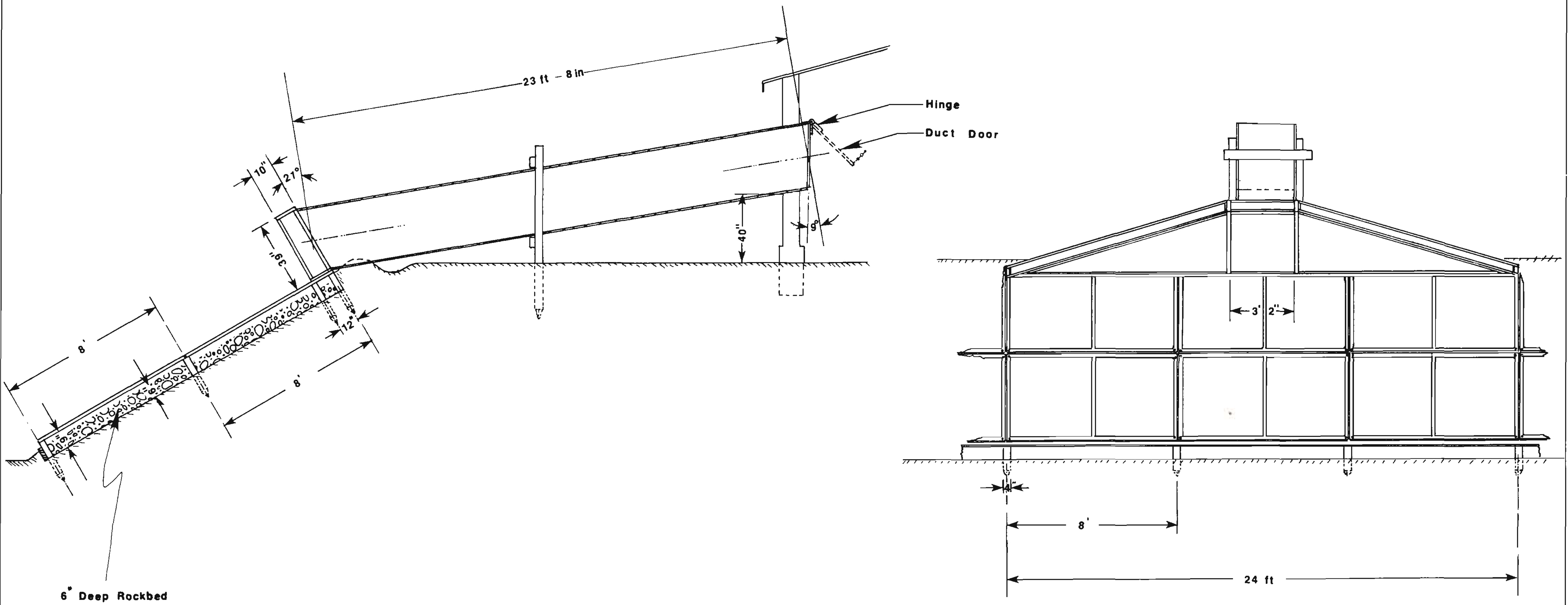
4) installing new polyethylene glazing.

The results of this test program showed that these changes increased the efficiency of the collector. Therefore, a plan was proposed to divide the entire collector into ten individual test sections. In this way, the effect of certain design parameters on the collector's performance can be determined. The approach is to change a specified design parameter on each section thereby making it different from the other sections. Each section will then be monitored to determine the amount of useful heat energy it adds to the growout house. The performance results for each section will be compared to determine which design parameters significantly affect the collector efficiency. Also, this testing will show how the collector efficiency changes with respect to each design parameter. The end result of the test program will be a more efficient passive solar air heater for poultry growout houses. A plan view of the proposed test section is shown in Figure 3.11. Also, Figure 3.12 shows two elevation views of one of the test sections.



PROPOSED TEST SECTIONS

FIGURE 3.11



TEST SECTION ELEVATIONS

FIGURE 3.12

The design changes to be made to the collector include:

1) above ground outlet ducts for all sections

2) different ratios of collector area to outlet area

3) different air gap heights, which is the distance between the rockbed absorber surface and the lower glazing, and

4) different glazing materials which have a longer expected life than polyethylene.

The specifications for each test section are shown in Table 3.1. Initially, the air gap height for all sections will be three inches.

A list of deliverables and drawings detailing the modifications to be made to the collector has been prepared. This information was sent to two contractors for bid. Both contractors responded with considerably different estimates. One estimate was for about $19,000 and the other was for about $10,000. Since both of these estimates were greater than the amount budgeted for the Cumming demonstration project, the proposed collector modifications were postponed until the start of FY '81. Consequently, more time and money was devoted to rebuilding the active solar energy system at Villa Rica, Georgia.

D. Alternative Energy Survey

A survey of Georgia poultry farmers was conducted to determine the potential for hydropower and biomass as alter

TABLE 3.1

TEST SECTION SPECIFICATIONS

SECTION	GLAZING	LENGTH FT.	COLLECTION AREA / OUTLET AREA	OUTLET AREA (SQ. FT)
1.	Single Kalwall Sunlite .060"	24	64	6
2.	Single Mylar	24	128	3
3.	Single Llumar .005"	24	128	3
4.	Double Monsanto 602	16	64	4
5.	Double Polyethylene .006"	16	64	4
6.	Single Lexan .040" Polycarbonate	16	64	4
7.	Single Mylar	28	256	1.7
8.	Single Llumar .005"	28	256	1.7
9.	Single Filon 556 (corrogated)	16	64	4
10.	Single Filon 550 (flat)	16	64	4

native energy sources on poultry farms. Representatives of approximately fifteen integrators were contacted. Eleven of these people agreed to furnish Georgia Tech with a confidential mailing list of their growers. Five mailing lists were received which contained a total of 907 growers, including 835 broiler farms and 72 egglayer farms. This represents approximately 18% and 9% of the broiler and layer farms respectively in Georgia. Figure 3.13 shows the location of the farms receiving surveys by county. Copies of the survey form and the cover letter are included in Appendix B.

Response to the survey was very good. One-hundred and forty-eight survey forms were received, approximately 16% of the farmers surveyed returned the survey form. The results of the survey are summarized in Table 3.2. All of the respondents have a potential for using chicken manure as a fuel source. The great majority of them presently use this chicken manure as fertilizer on pasture land. Also, approximately 68 farmers or 46% of the replys indicated that they owned stands of timber that could be used for fuel. The survey forms indicated that 44 of the farms or 30% of the replys have a potential for generating hydroelectric power. These farms have streams that will provide approximately one kilowatt or more of electricity.

The distribution of the survey was limited to the areas covered by the five integrators that provided Georgia Tech with mailing lists. These lists did, however, cover the most important broiler producing counties in North and South Georgia. Layer farms are not as concentrated as broiler farms, consequently the survey cannot be considered representative of layer farms. The survey was slightly biased towards north Georgia which may exaggerate the potential for hydropower on poultry farms. Even so, small hydropower

TABLE 3.2

ALTERNATIVE ENERGY SURVEY RESULTS

S/NO.	COUNTY	SURVEY Broiler/Layer	BIOMASS RESPONSE	WOOD	HYDRO
1.	Atkinson	8	0/1	1	-
2.	Bacon	2	-	-	-
3.	Banks	37/4	2/2	3	1
4.	Barrow	42/3	6/2	5	3
5.	Bartow	33	4	2	3
6.	Berrien	1	-	-	-
7.	Chattooga	-	-	-	-
8.	Cherokee	8	1	1	-
9.	Clarke	11/1	-	-	-
10.	Coffee	23	1/1	2	1
11.	Colquitt	1	-	-	-
12.	Dawson	46/1	6	4	2
13.	Floyd	2	-	-	-
14.	Forsyth	68	17	6	3
15.	Franklin	50/5	5/5	3	7
16.	Fulton	5/2	3	-	1
17.	Giler	27	2	1	-
18.	Gordon	33	6	3	3
19.	Gwinnett	11/1	-	-	-
20.	Habersham	26/2	1/1	-	-
21.	Hall	77/28	10/4	5	6
22.	Hart	3	2	1	-
23.	Jackson	145/10	14/7	9	3
24.	Jeff Davis	4	-	-	-
25.	Lanier	4	-	-	-
26.	Lumpkin	12/6	7	2	2
27.	Madison	34	15	9	-
28.	Morgan	4/1	-	-	-
29.	Murray	1	-	-	-
30.	Newton	1	-	-	-
31.	Oconee	1	2	2	1
32.	Otlethorpe	15	6	3	2
33.	Pickens	27	7	2	3
34.	Stephens	17/2	1	1	1
35.	Telfair	6	0/1	-	1
36.	Walton	4/1	2	1	-
37.	Ware	4	-	-	-
38.	White	43/5	5	1/2	1
		835/72	121/27	68	46

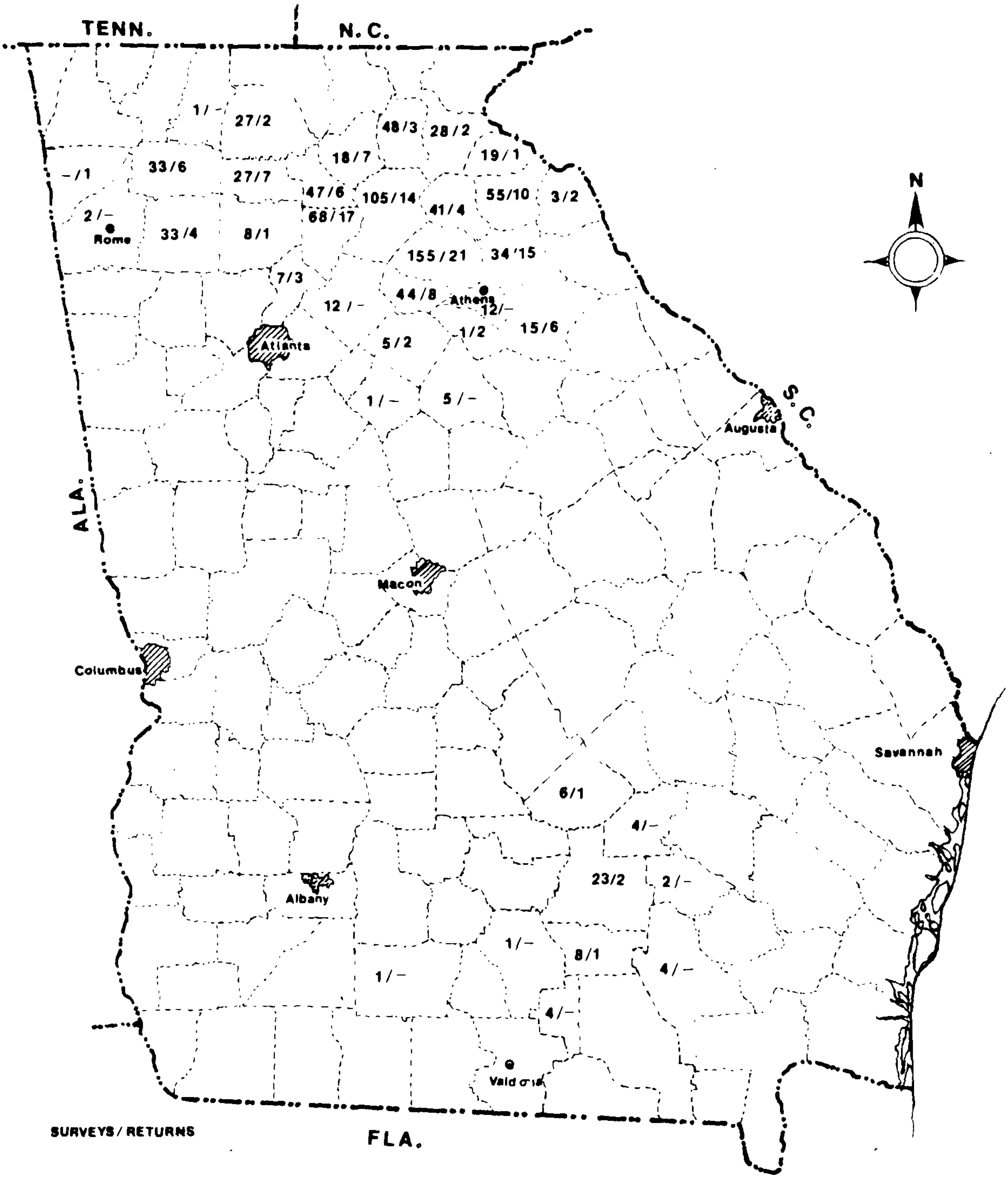

TENN.
N.C.
S.C.
ALA.
FLA.
N
1/-
27/2
48/3
28/2
18/7
19/1
-/1
33/6
27/7
47/6
105/14
55/10
3/2
68/17
41/4
2/-
Rome
33/4
8/1
155/21
34/15
7/3
44/8
Athens
12/-
12/-
Atlanta
5/2
1/2
15/6
1/-
5/-
Augusta
Macon
Columbus
Savannah
6/1
4/-
23/2
2/-
Albany
1/-
8/1
4/-
1/-
4/-
SURVEYS/RETURNS

FIGURE 3.13

appears to have a good potential as an alternative energy source on poultry farms in the state.

Approximately twenty replies included requests for additional information on alternative energy sources. Comments on those and other returned survey forms indicated that there is much interest among poultry farmers in alternative energy sources. The requests for information included eight on methane conversion, five on solar energy, nine on small hydropower, and one on wood energy. Copies of Agricultural Energy Management Tips and "Engineering Research for Agriculture at Georgia Tech" were mailed to the people that requested information.

E. Technology Transfer

An effort was made to pass along the information learned from the past years of research in solar energy for agriculture at Georgia Tech. A manual entitled Agricultural Energy Mananagement Tips was prepared by researchers at Georgia Tech. This manual includes a section on solar heated shelters for livestock. It provides some basic information about collecting solar energy. It also discusses the solar heating demonstrations at Villa Rica and Cumming, Georgia. This manual is included as Appendix C. The Engineering Experiment Station had a booth at the Southeastern Agricultural Exposition held at Moultrie, Georgia, in October,1979. A display featured photographs and models of the two solar heated growout houses. Information sheets on the two growout houses and copies of Agricultural Energy Management Tips were distributed. An article on the two solar growout houses was published in the January, 1980 issue of Broiler Industry. The article, entitled "Georgia Broiler House Solar Study Shows Promise," discusses the two solar heating systems and emphasizes the importance of material selection. The article discusses the problems encountered by Georgia Tech using low cost materials for the solar energy system construction. An open house was held at the Villa Rica demonstration site on April 5, 1980. The open house was announced in the Market News Bulletin and in the form of a press release.

REFERENCES

1. Technology Application Laboratory. Georgia Poultry Industry Research Final Report, Atlanta, Ga., Georgia Institute of Technology, EES, 1979 pp.27-40

IV. YIELD EVALUATION PROJECT

by

Larry J. Moriarty, P.E.

A. Introduction

For the past two and one half years the Agricultural Technology Branch of Georgia Tech's Engineering Experiment Station has been working on developing a computer-based system to monitor and evaluate poultry processing plant eviscerating line performance. Knowledge of how well the eviscerating lines are operating is especially important to poultry processors because line performance, as measured by plant yield, is a direct measure of plant productivity. Because poultry processing plants operate under high volume and low profit margin conditions, a small change in line yield can have a dramatic effect on plant profitability. With the continually increasing performance and reliability and decreasing cost of electronic systems, the time seems right for the introduction of computer-based measurement systems into poultry processing plants. An electronic yield evaluation system is especially attractive because conservative estimates indicate that the time required for such a system to pay for itself would be less than one year.

B. System Description

The operating principle of the eviscerating line yield evaluation system is quite simple. In its basic form the system consists of two weigh scales and a small computer.

One scale is installed at the hanging station, while the other is located at the bird unloader. Weight readings from these scales are input to the computer, which periodically calculates and displays the line yield, line yield being defined as the fraction of bird weight at the hanging station that is dropped at the unloader. Because line yield is being displayed as it is occurring, problems can be quickly identified and corrected. In fact if the yield drops below a minimum acceptable value, an alarm can be made to sound, thus alerting plant personnel that immediate corrective action is required.

To the basic system just described, several improvements can be made to provide more information. Total birds processed, as well as total and average weights and weight distributions, can readily be calculated and displayed or printed. Additional scales could be installed at intermediate positions along the line to evaluate individual processing operations. For example, weigh scales installed before and after the neck cutter would make it possible to keep track of the total neck weight being processed as well as the percentage of neck weight to bird weight. This information could be used to keep the neck cutter adjusted for best performance. With some additional hardware, line stoppage by inspector also could be monitored and a record made of the number of times and the total time each inspector had stopped the line.

By carrying these ideas a bit further, it is easy to visualize the operation of a processing plant with instrumentation installed at all important processing locations. Data could be collected and input to a minicomputer and the complete plant operating performance could be displayed at one central location. Computer-generated graphs could easily be provided at the end of the day's production to give a summary of the entire plant operation for the day.

The Georgia Tech yield evaluation system in its present state of development can be thought of as the first step toward a completely instrumented processing plant. The system, as installed on an eviscerating line at the Mar-Jac poultry plant in Gainesville, Georgia, presently consists of a small desk-top computer, computer interfaces, a video display terminal, and four weigh scales using modified line shackles. Photographs of the system are shown in Figures 4.1 to 4.3. The overall operation of the system can probably be best understood by referring to Figure 4.4, which shows the locations of the weigh scales on the eviscerating line. As the figure shows, one scale is installed at the hanging station, one scale is located just prior to the neck cutter, and the remaining two scales are located close together before the bird unloader. With this arrangement, overall line performance, as well as the operation of the neck cutter, can be evaluated. Also by installing the last two scales close together, the accuracy of the weigh scales can be determined.

The system, which has been in operation for several months, is operating fairly satisfactorily. Some problems with shackle tracking over the scales still need to be solved, and more modified shackles need to be assembled and installed on the line. There are presently six modified shackles on the line, and with 750 total birds on the line, this gives less than one percent sample size. From results obtained so far, it appears that it will be necessary to weigh between 25 to 50 birds during each production cycle to obtain good results.

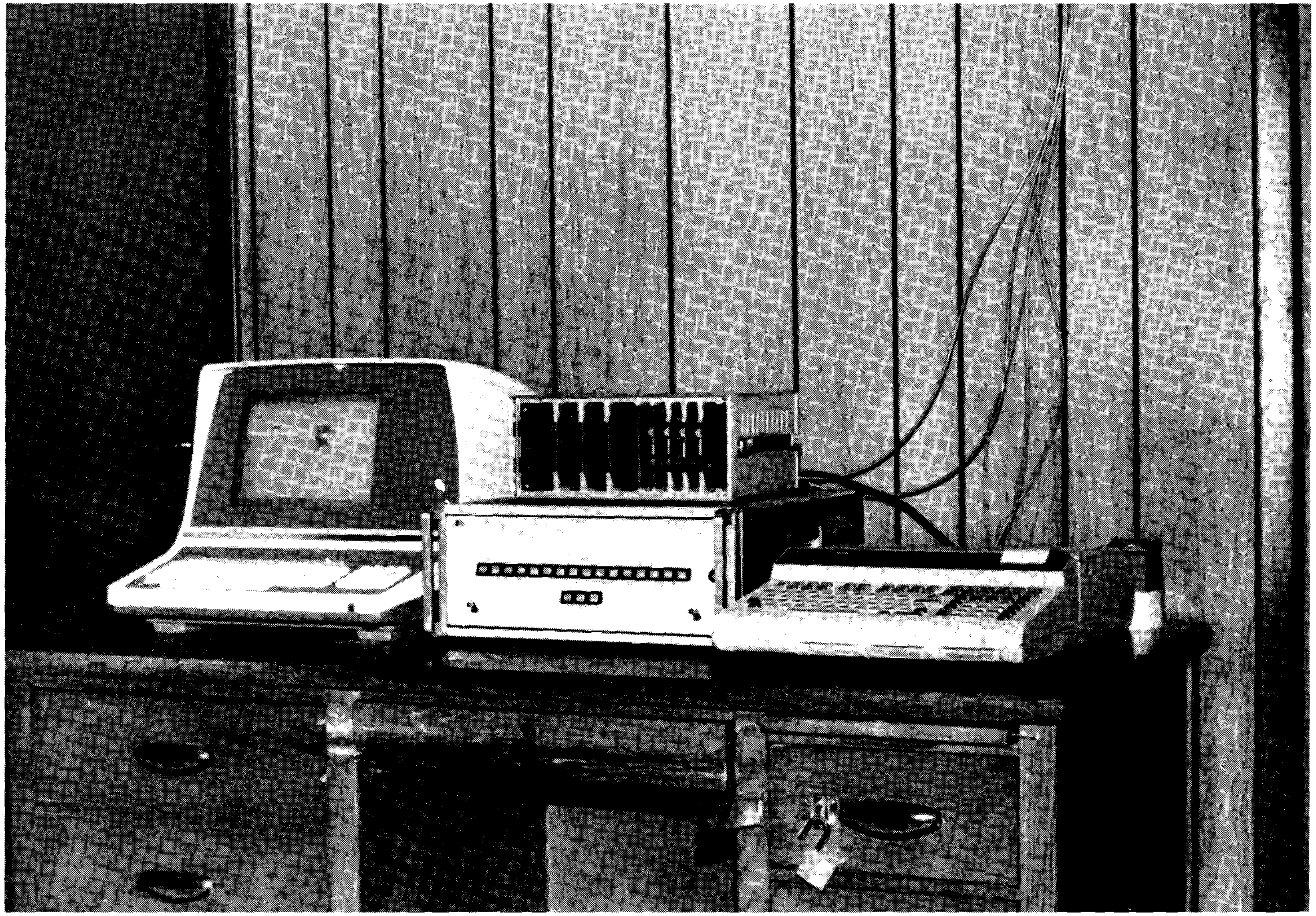


FIGURE 4.1 COMPUTER EQUIPMENT AND VIDEO DISPLAY TERMINAL

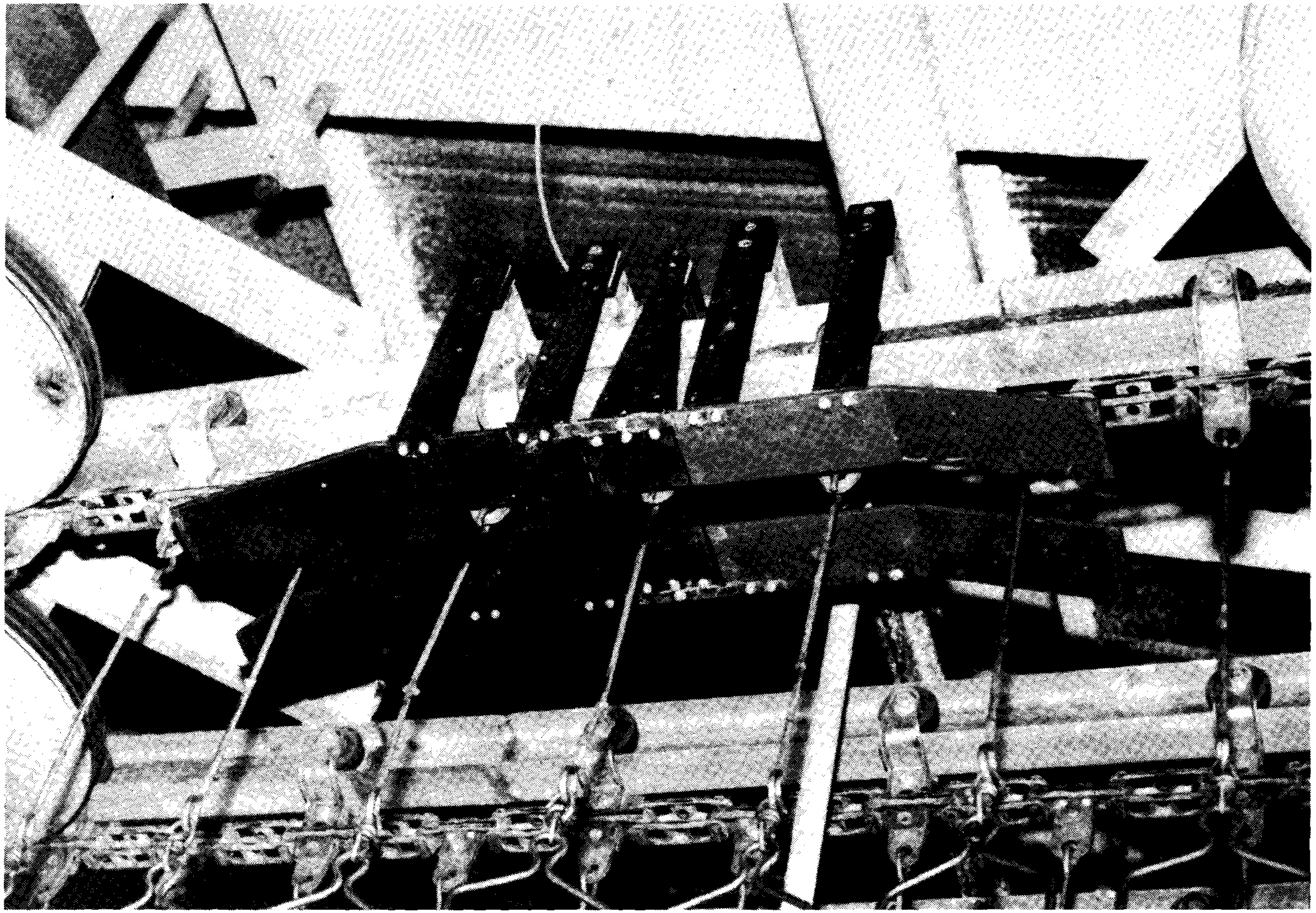


FIGURE 4.2 NECK CUTTER SCALE

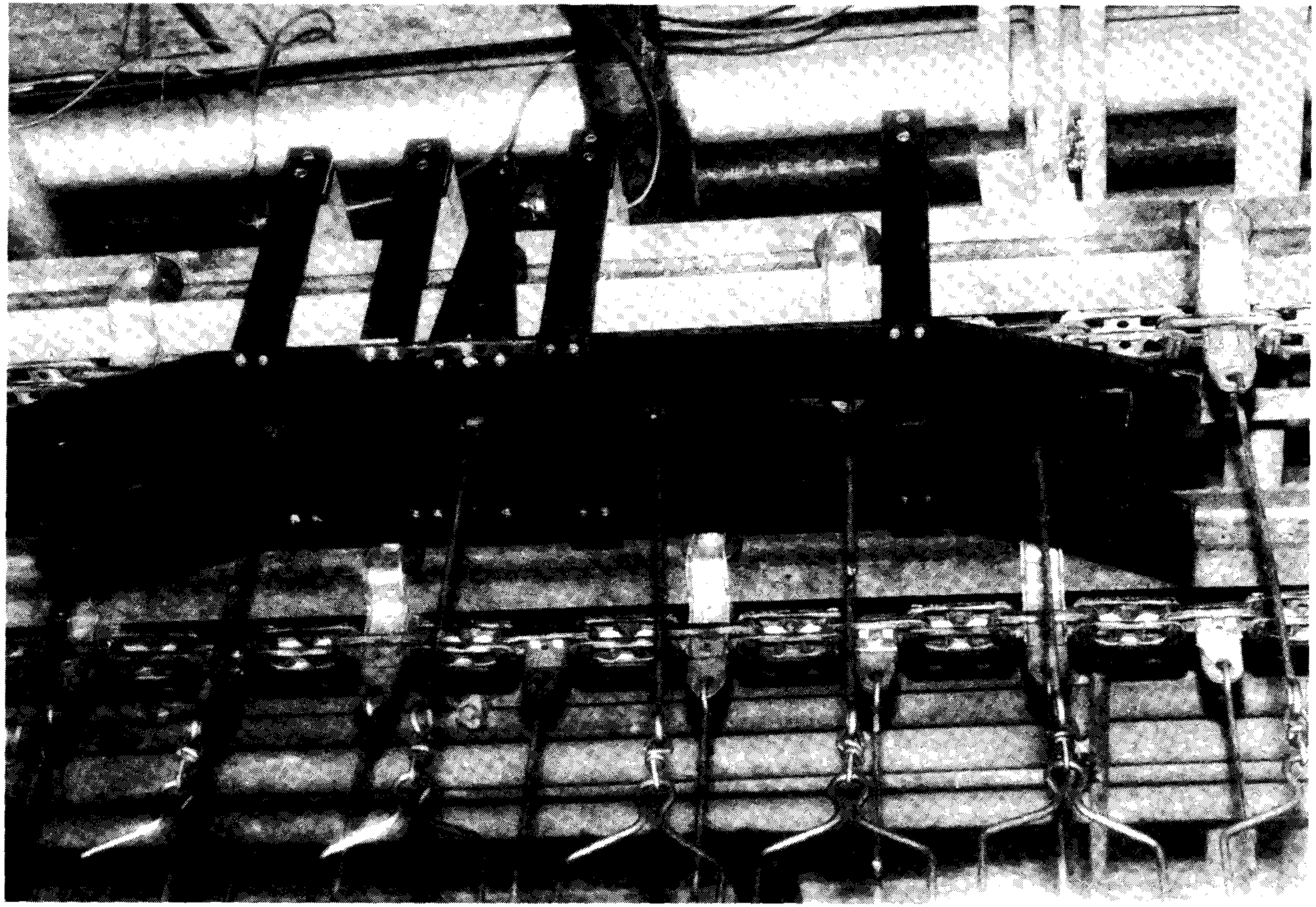
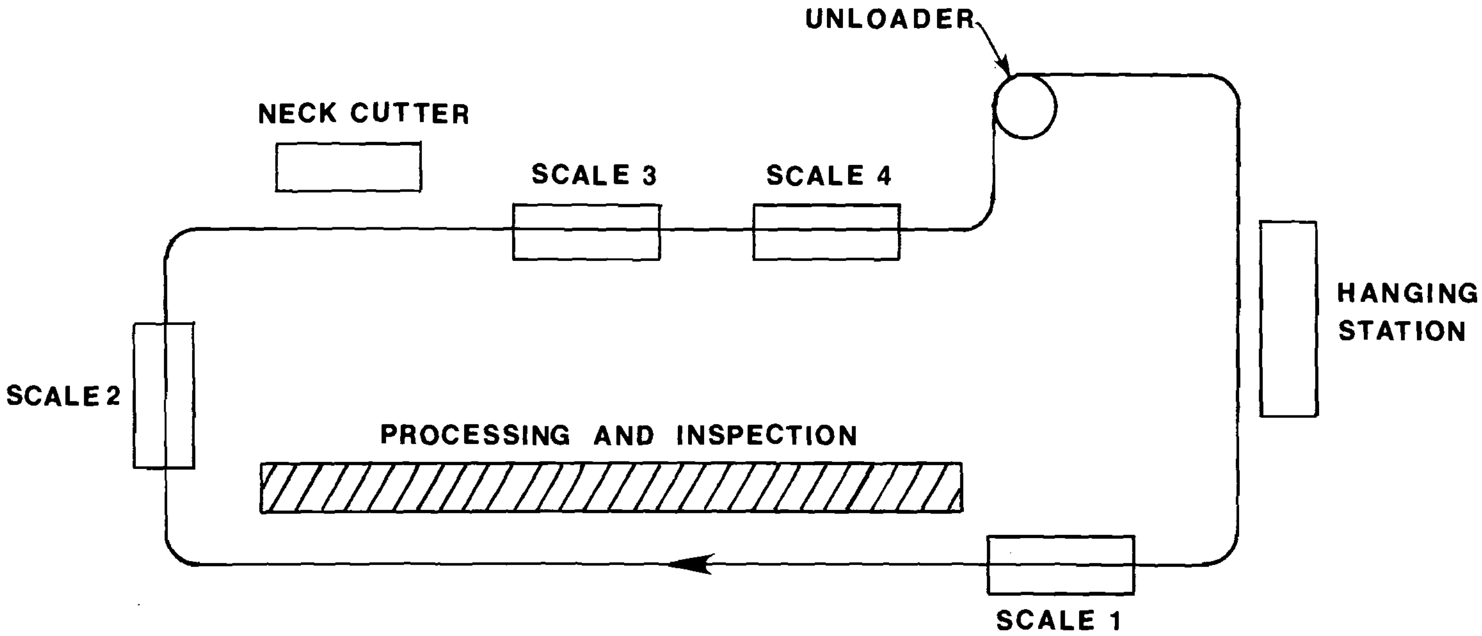


FIGURE 4.3 UNLOADER SCALE



NUMBER 4 EVISCERATING LINE
MAR-JAC POULTRY PLANT
GAINSEVILLE, GEORGIA

FIGURE 4.4 WEIGH SCALE LOCATIONS

As the system is now operating, about every 10 minutes the weight readings are processed by the computer and the results are displayed on the video display terminal and printed on the computer printer. The line yield and average weight at the unloader are printed for the production cycle just completed, while the video display is updated to show running totals and averages. Total birds and total weight processed are several of the items shown on the video display terminal. Figures 4.5 shows typical results as they appear on the video display terminal.

The weight readings are also stored on magnetic tape cartridges for later analysis. Periodically, this data is output to a computer plotter and daily yield and average weight summaries are obtained. Figures 4.6 and 4.7 show typical examples of such plots. By acquiring large amounts of data, we hope to be able to determine the effects of such variables as time of day, bird type and weight, as well as seasonal variation on the line yield. Although the system in its present form has yet to reach its potential of long-term reliable operation, the results obtained so far of are quite promising, and we feel that with continuing work we will have a practical and cost-effective system for poultry processing plant use.

C. System Design

This section describes in some detail how the technical aspects of the system design evolved as more was learned about operating in a poultry processing plant environment. As with many development projects, decisions involving design philosophy were sometimes based on incomplete, or even erroneous information. As this project developed, several unappreciated factors relating to poultry

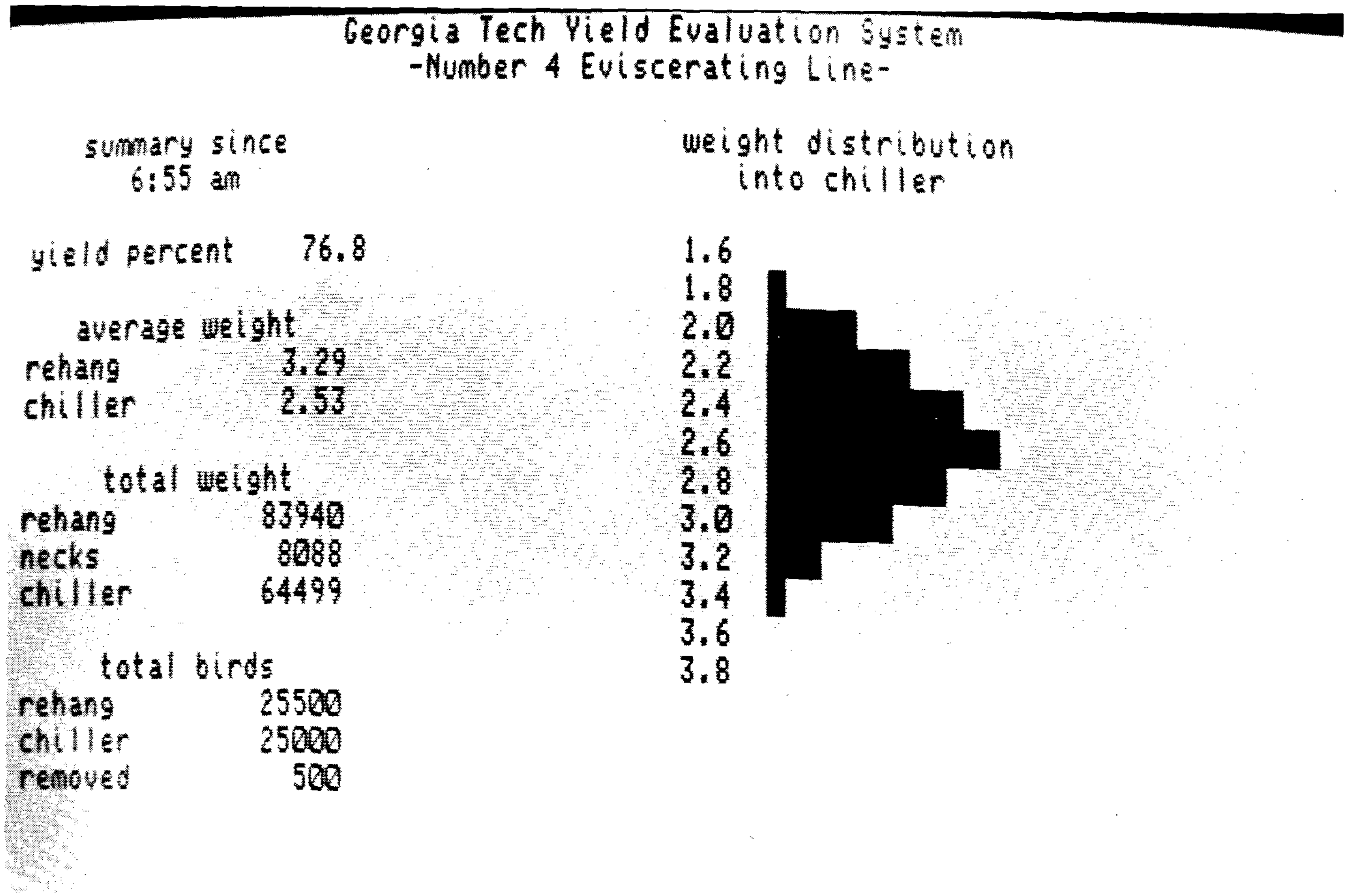


FIGURE 4.5 VIDEO DISPLAY OUTPUT

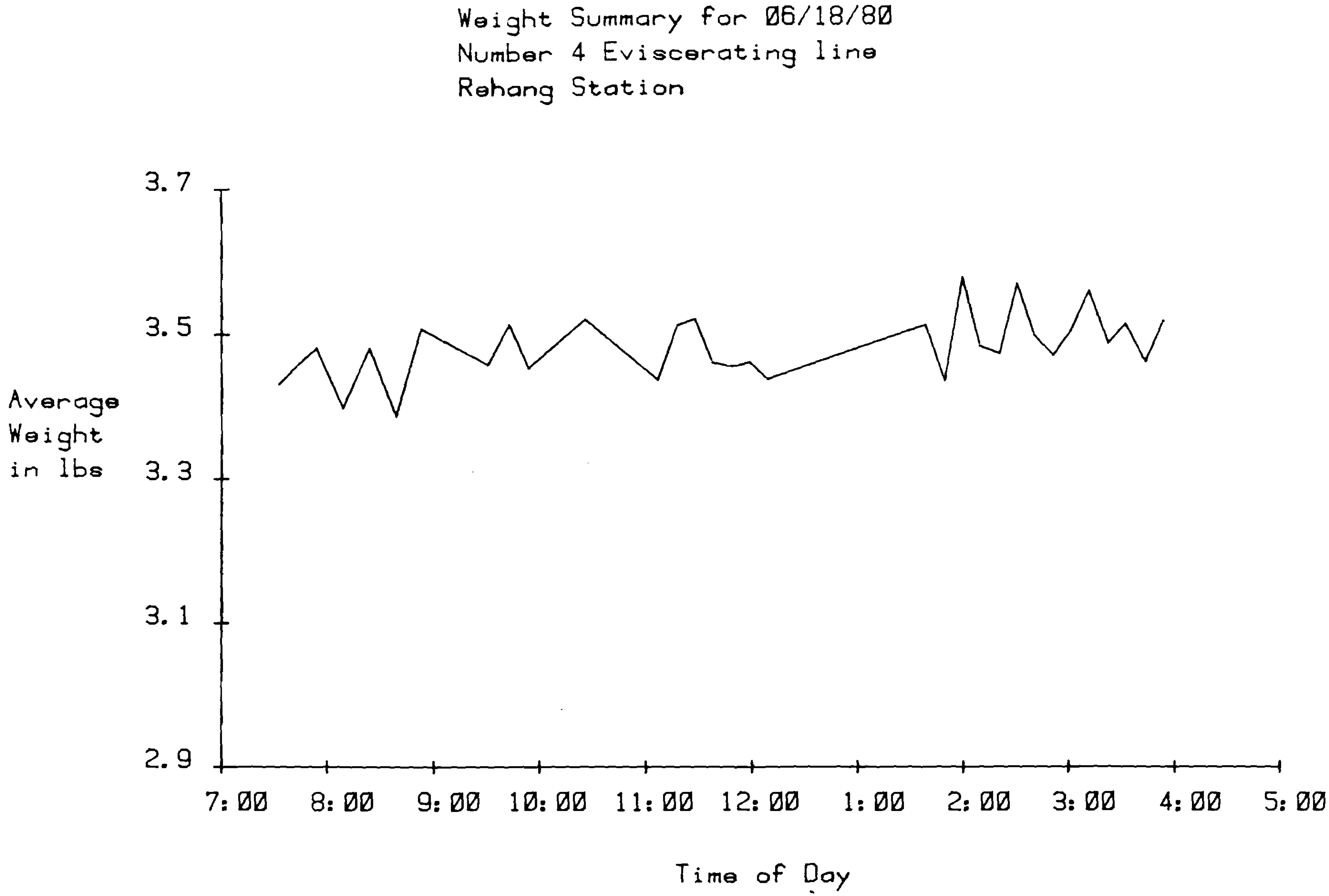


FIGURE 4.6 AVERAGE WEIGHT SUMMARY

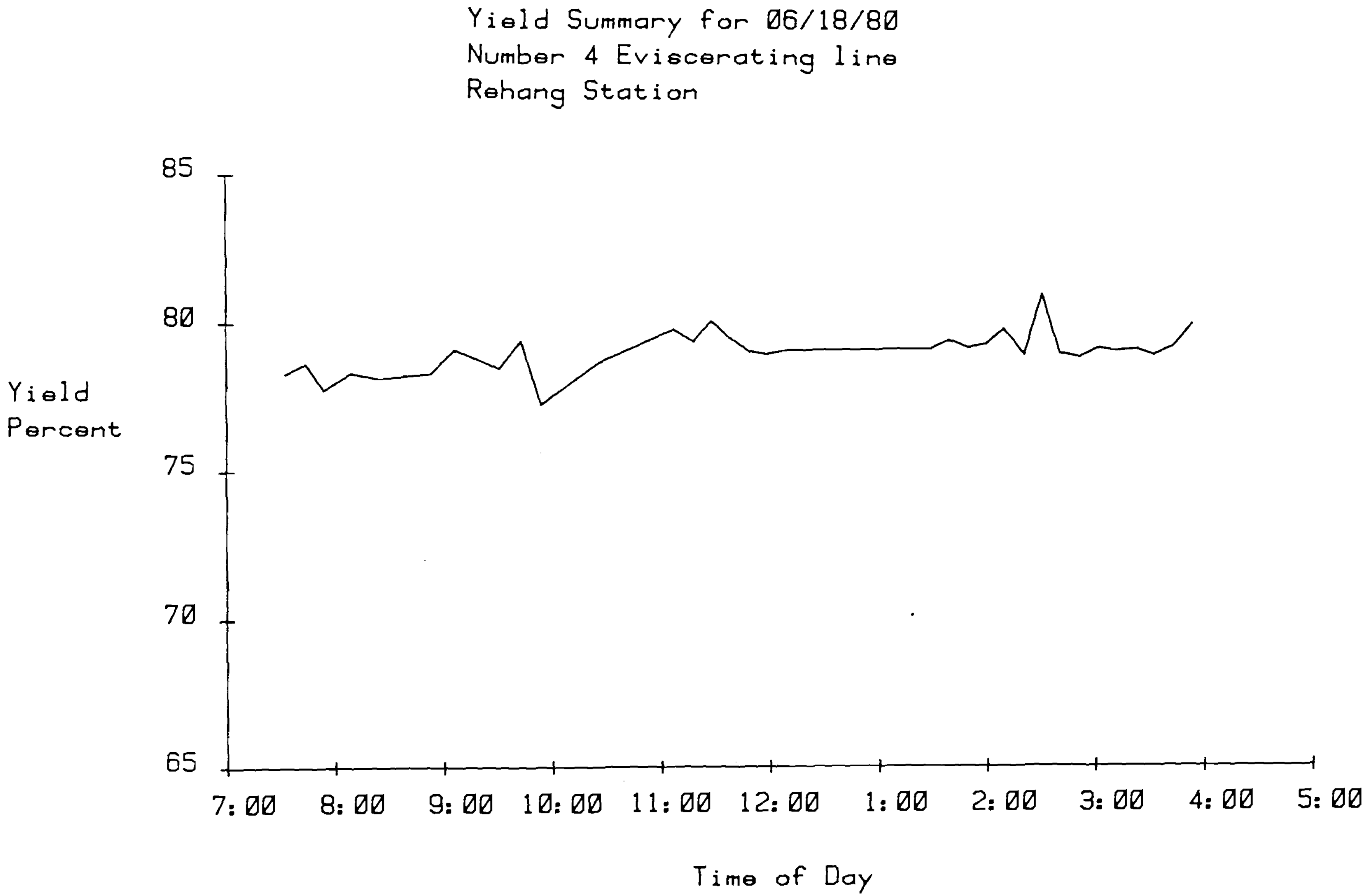


FIGURE 4.7 YIELD PERCENT SUMMARY

processing plant operation became apparent. For example, the severe electrical noise environment in the plant created havoc with the very low level electrical signals generated by the weigh scale transducers. Very careful attention to the design of the amplifier circuits was required to reduce these effects. Other problems occured because mechanical vibrations in the plant caused mechanical resonances of the weigh scales that also severely contaminated the weight readings. The extremely high relative humidity of the plant corroded the scales and caused transducer malfunctions. The presentation and display of the data changed often as the capabilities of the system became known to the plant personnel. In all, the problems encountered were more difficult than had been anticipated and did cause some delay in the development of the system.

The overall organization of the system is shown in Figure 4.8. As this figure shows, the system is composed of five main elements: the weigh scales; an electronics interface; a computer interface; a system controller; and a video display terminal. The single most important element of the system is the HP9825A desk-top computer, used as the system controller. The HP9825A is a small, portable, self-contained, yet powerful microprocessor-based system controller. Although a fairly expensive computer, it is a good choice for use in systems development because of its easy programmability, internal printer, display, and magnetic tape drive and powerful input/output capabilities, as well as the availability of special features, such as a time of day clock and specialized programming modules. For production systems, though, a less expensive system controller would be appropriate.

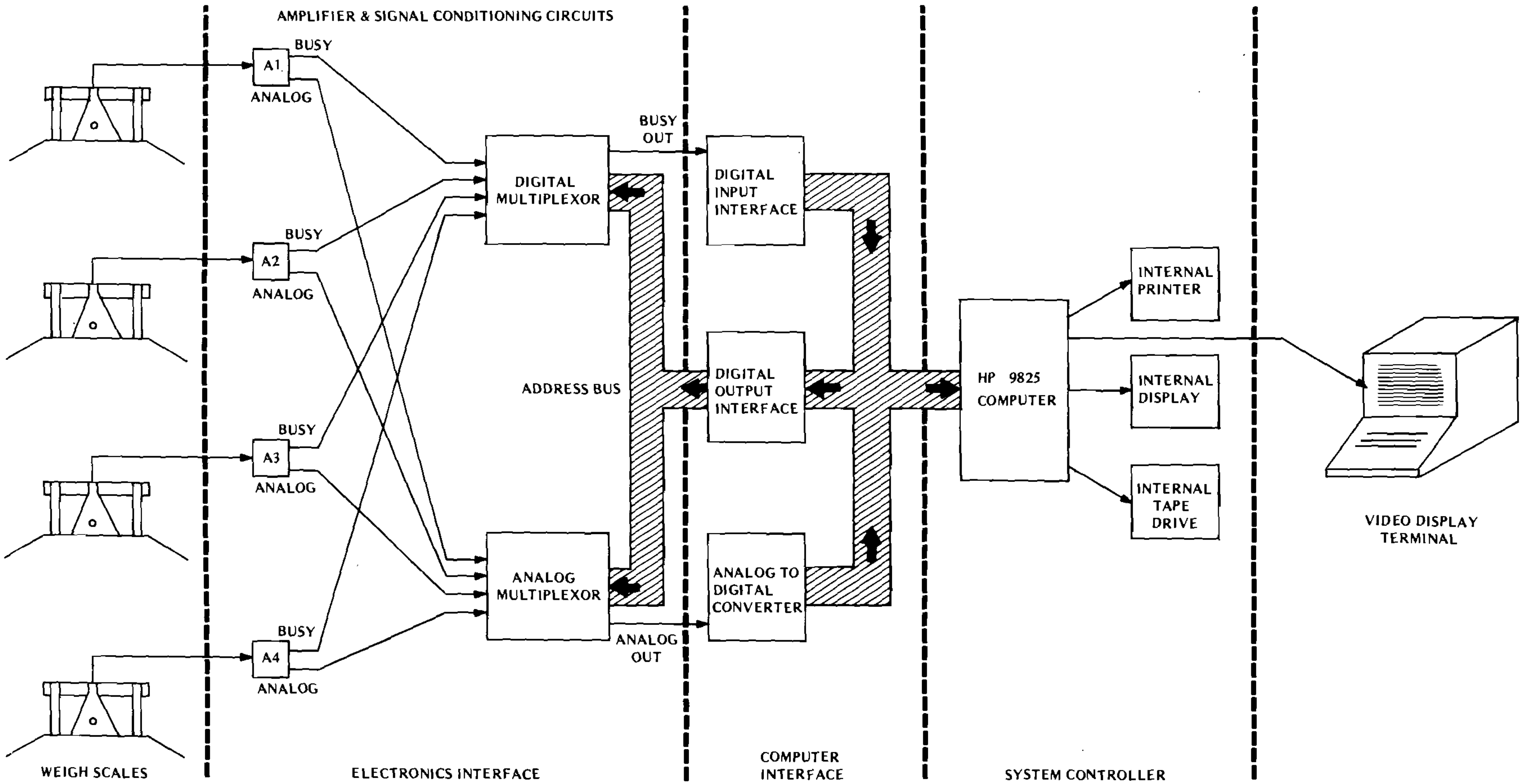


FIGURE 4.8 SYSTEM BLOCK DIAGRAM

Interfaced to the system controller is an Adds Regent 40 Video display terminal. This particular terminal was selected mainly because it has some graphics capabilities that greatly enhance the data display. Also interfaced to the system controller is an HP6940B multiprogrammer containing an analog to digital converter and digital input and output cards. The function of the multiprogrammer is to serve as an interface between the analog circuits and the system controller.

The components just described are all commercially available and need only be wired together and driven with appropriate software. The electronics interface, however, was designed and built in-house because no suitable commercial interface was available. The function of this interface is to amplify and perform signal conditioning of the weigh scale outputs and to multiplex these signals for input to the multiprogrammer. The weigh scales also were designed and built in-house because of the very high cost of commercial scales. Figure 4.9 shows the weigh scale as it is attached to the production line.

The need for signal conditioning is clearly shown in Figure 4.10, which shows a typical amplified scale output voltage signal as a bird passes over the weigh scale. Two problems are apparent: (1) the initial transient response as contact is first made with the weigh pan; and (2) the continuing high vibration levels due to resonant excitation of the scale as the bird is on the weigh pan. The first approach taken was to wait until the initial transient response was over, then take as many readings as possible while the bird was on the weigh pan, and average these results. This worked well enough as long as only one scale was active at any given time. However, with several scales

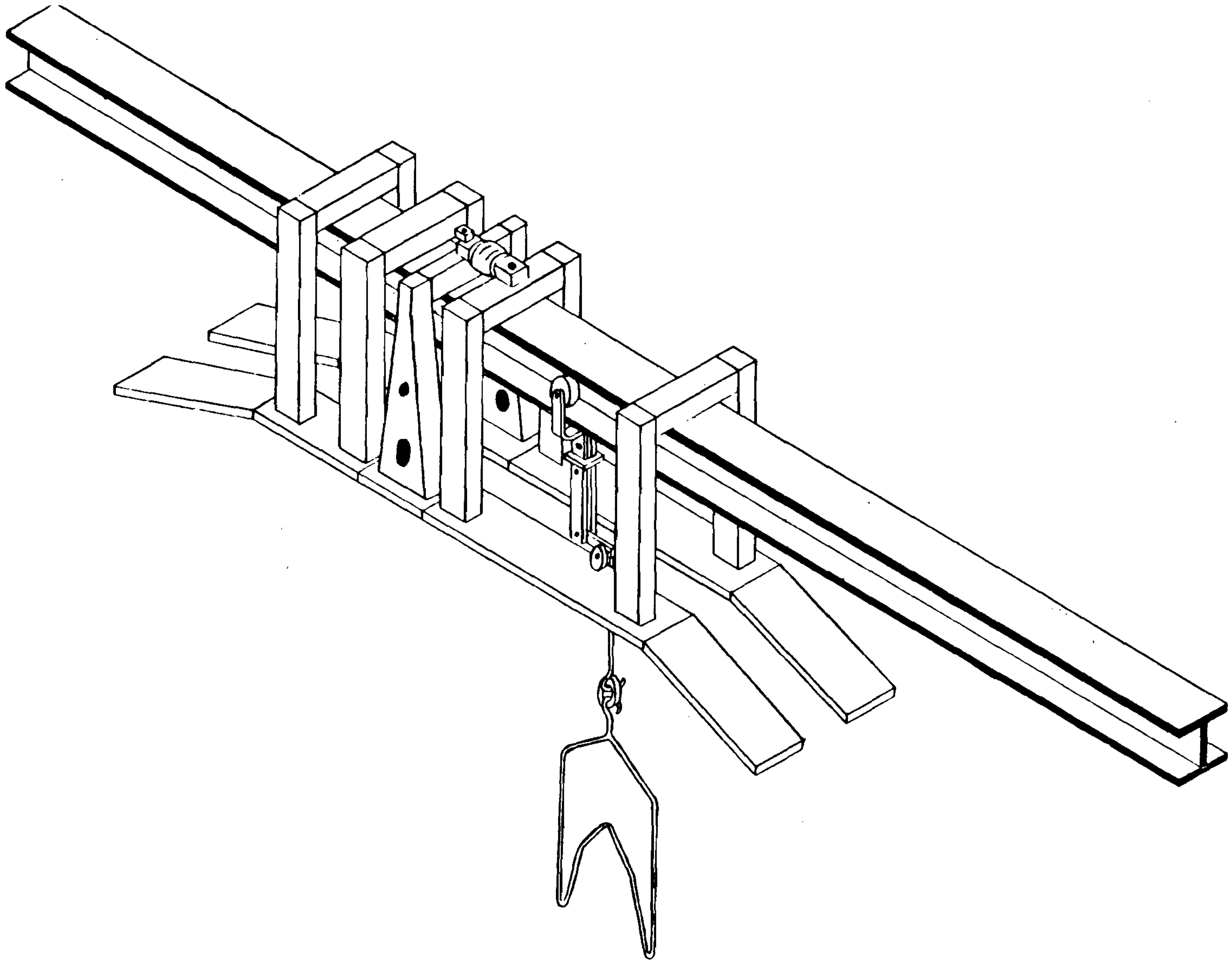


FIGURE 4.9 WEIGH SCALE

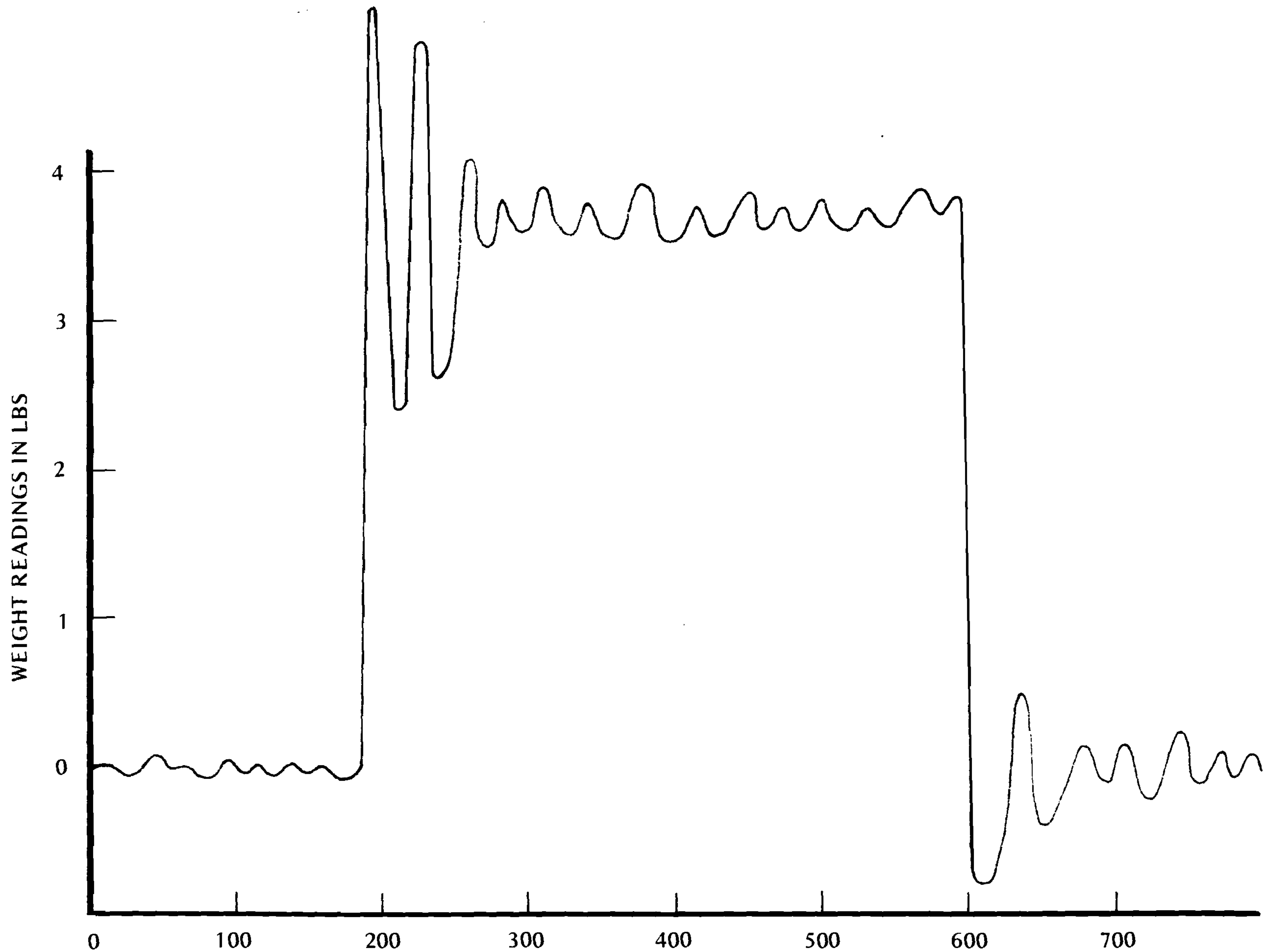


FIGURE 4.10 WEIGH SCALE OUTPUT

simultaneously active, it was not possible to acquire a sufficient number of samples to obtain an accurate weight reading. This approach was abandoned in favor of using hardware to integrate the weight readings, thus relieving the computer of the signal averaging task.

An understanding of this operation can be obtained from Figures 4.11 and 4.12. Figure 4.11 is a block diagram of the signal conditioning circuits, while Figure 4.12 shows the sequence of steps that occur when a bird is weighed. The zero crossing detector shown in the lower left-hand corner of Figure 4.11 is triggered whenever a bird passes either onto or off the weigh pans. The detector output activates the timer circuits and sets the "busy" line to prevent the system controller from taking a reading when the integration is in progress. The sequence of events that occurs when a bird passes onto a weigh pan is as follows: as the shackle roller contacts the leading edge of the weigh pans, the zero crossing detector is triggered and activates the delay timer. A delay time of 150 milliseconds (msec) was selected to allow the transient, mechanical vibrations to die out. Upon time out of the delay timer, the integration timer is activated for 250 msec, during which time the bird is passing over the weigh pan. The integration timer resets the integrator, connects the weight signal to the integrator input, sets the busy line high, and activates the sample/hold circuit, sampling while the integration is in progress and holding after the integrator has timed out.

Figure 4.12 shows a typical data acquisition sequence. An important feature of the circuitry is that because the zero crossing detector also is triggered when a bird passes off the weigh pan, a tare reading is taken after each weight

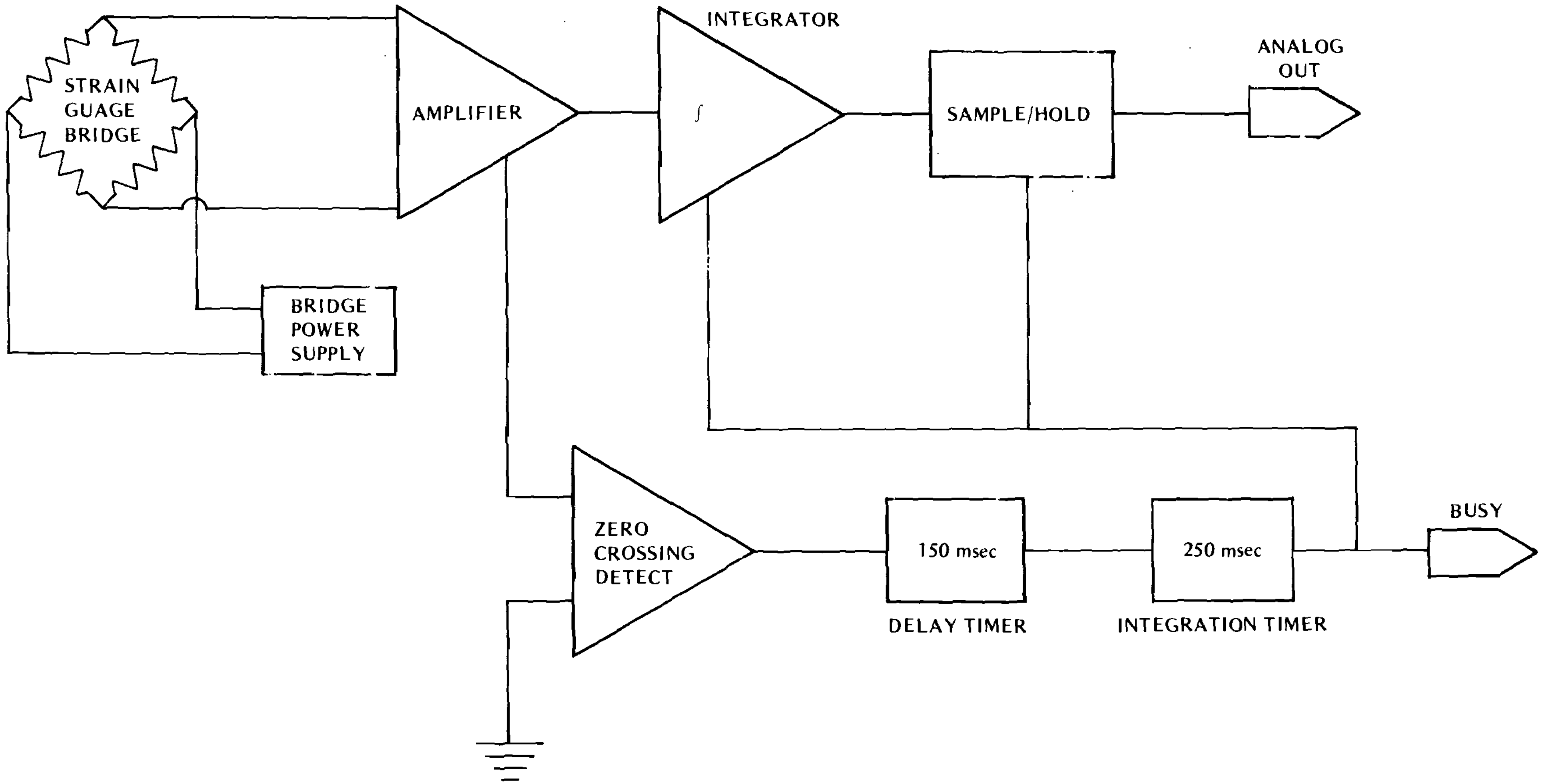


FIGURE 4.11 ELECTRONIC INTERFACE BLOCK DIAGRAM

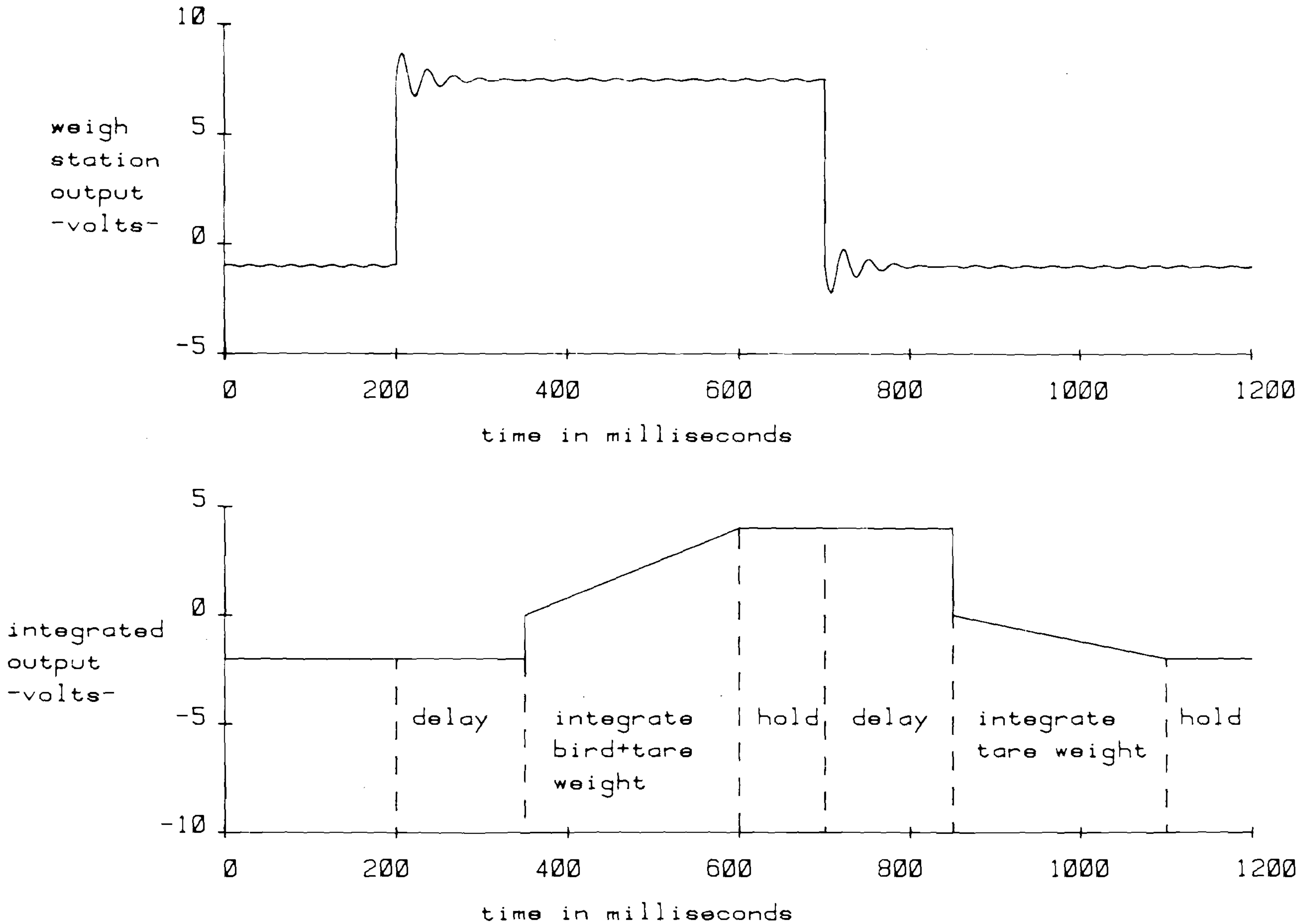


FIGURE 4.12 DATA ACQUISITION SEQUENCE

reading. This eliminates the effects of drift in the transducers, amplifiers, and integrator circuitry. The zero crossing detector also eliminates the need for a sensor at the scale to detect the presence of a bird ready to be weighed.

D. Results and Conclusions

When this project was initiated, the goals were to design, build, install, and demonstrate the usefulness of a system that would determine the operating performance of the line, as well as to provide the marketing department with information on bird weight distributions. We also planned to do some basic research into the causes of yield variations to determine the effects of such variables as block size, grower, time of day, as well as other parameters on the line yield.

Although all of the goals are yet to be accomplished, the results obtained so far clearly show that small computer technology can be effectively implemented in poultry processing plants. One lesson learned from the project is that the design and implementation of such systems is certainly not a trivial matter. Very careful consideration must be given to the high humidity, electrical noise, and mechanical vibration levels present in processing plants if a successful design is to be achieved. The effects of ever-changing USDA regulations also must be considered. In our case the change to modified traditional sequential inspection caused severe mechanical interface problems that required extensive redesign of the weigh scales and shackles.

Because of these and other problems, a sufficiently large data base has not yet been obtained to investigate the causes of yield variations. The current status of the project is that the system is operating reliably and collecting and displaying data, but because of some shackle tracking problems, the accuracy of the data is questionable. This problem, however, should be resolved with the installation of improved shackles. The plan for this year is to continue to obtain operating experience with the system, to obtain the data base required to analyze the causes of yield variations, and to provide technology transfer by inviting Georgia processors in for demonstrations.

V. NOISE ANALYSIS AND CONTROL

by
J.Craig Wyvill, P.E.

A. Introduction

In our final report entitled "An Analysis of Poultry Processing Plant Noise Characteristics and Potential Noise Control Techniques",[1] we determined that reverberation was a key factor in the extensiveness of excessive noise levels in poultry processing plants. We further pointed out that accoustical panels for reducing noise had been tried but were encountering durability problems due to the plastic covers tearing under normal use. Plastic covers it should be pointed out, are necessary to allow conventional absorbing materials to be used and yet allow the panels to be washable thereby meeting USDA cleanability requirements.

This report summarizes our effort to determine the cause of current panel failures and to develop designs of our own which appear capable of enduring the types of abuse typical to the poultry processing environment.

B. Current Technology

There are only a few companies today who have designed absorbing panels specifically for use as a hanging panel in the food processing industry. Of these designs none have established themselves as capable of withstanding the poultry environment. The standard design is typically a fiberous sheet covered with a plastic film which has been heat sealed and shrunk for a tight fit (see Figure 5.1).

The absorbing mediums found to date are fiberglass, mineral wool and foam. The plastic covers, all of the which are between 0.5 mil and 2 mil in thickness, are polyolefin or polyvinyl flouride (PVF). One design, which will be discussed later incorporates a perforated metal cover plate over the plastic covered core.

Two interesting incidents merit discussion regarding current technology:

In 1976, the Virginia Polytechnic Institute in Blacksburg, Virginia installed a urethane foam panel with a PVF cover in a Virginia poultry plant.[2] After installation the plant failed to continue their use. Our contact with the plant uncovered an attitude that the panels were too delicate. The covers had failed and therefore had to be removed.

In 1979, a commercial firm installed a mineral wool panel with a polyolefin cover in a Pennsylvania poultry plant. After a few months of usage, the panel covers began failing at a regular rate. The manufacturer went back to the drawing board and has since come out with a new cover on the same panel, this time using PVF film. The new results are not conclusive at this time.

Clearly, these experiences point out the need for developing a durable, absorbing panel. Every time an experiment

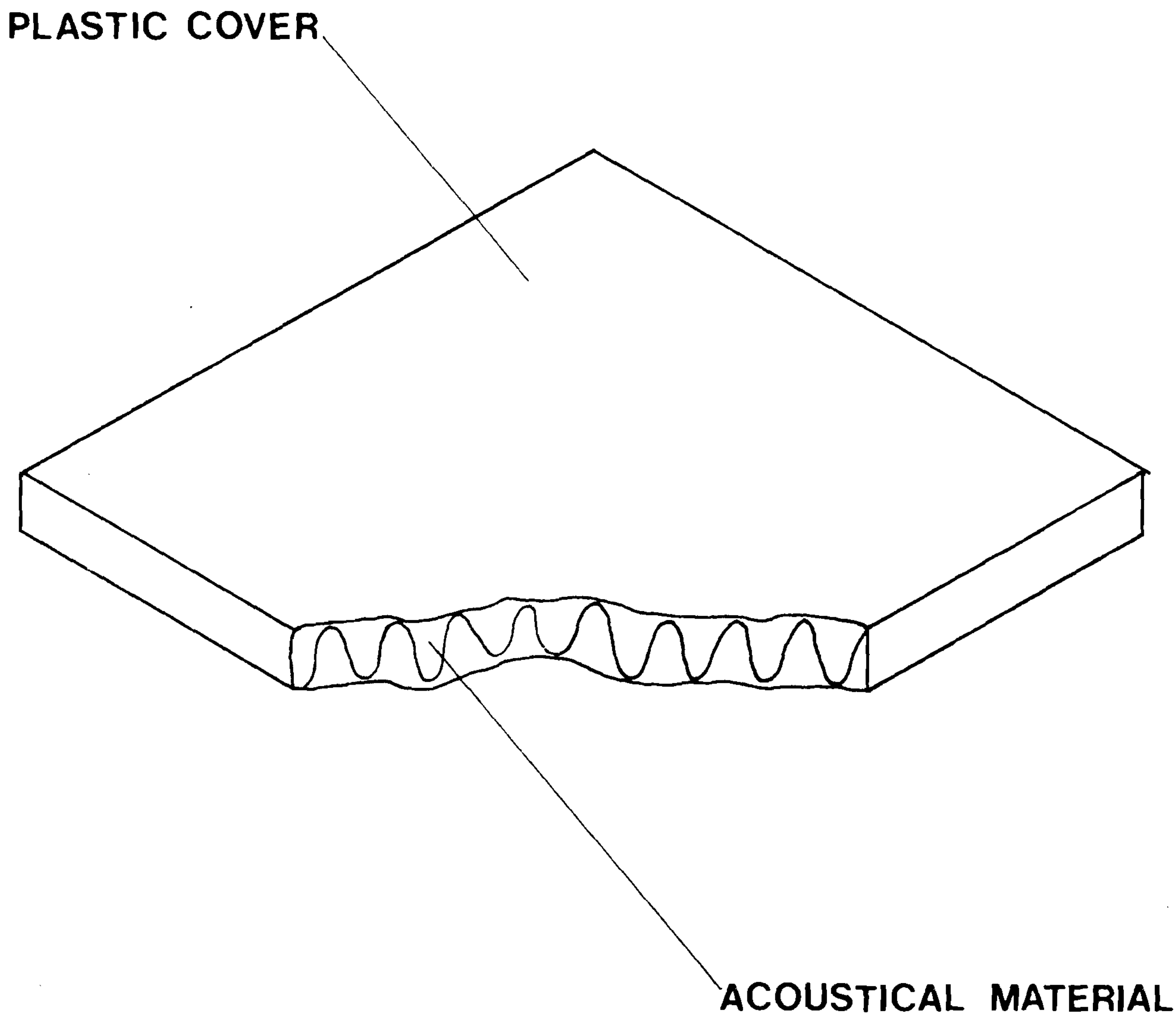


FIGURE 5.1 — TYPICAL DESIGN OF CURRENT ACOUSTICAL PANELS

fails it shakes the confidence of prospective users in any design working. Unfortunately, progress in developing new designs has been slow, and it appears doubtful, at this time, that any breakthroughs are imminent. However, if suitable designs are developed and tested which will work it appears certain producers will try to market such a product if a demand exists. We feel that demand development is merely a matter of instilling confidence in the durability and effectiveness of a panel design.

C. Design Development

In order to develop a durable design, we set out to evaluate a number of different design options. These options can be categorized as follows:

1) use a tougher film covering

2) reinforce existing film covers

3) eliminate the need for a film cover

Since a panels acoustical qualities are an essential element of its design, we also had to remodel a room on the Georgia Tech campus to serve as a reverberant room. This room will be used:

1) to test the absorption characteristics of both different panel designs and different panel orien tations

2) to provide a demonstration site for exhibiting our final design and its effectiveness.

To date, we have successfully identified several possible designs and are in the process of fabricating them. In addition, we are concluding tests on qualifying our

reverberant room in time for its use in testing panels.

D. Panel Design Considerations

We first focused our attention on developing a more durable panel by considering a tougher covering film. Upon reviewing the list of available plastic films, we found at least two which had superior qualities to those currently being tried.

Table 5.1 presents pertinent physical properties of the general film categories available today. Since polyvinyl flouride is already in use in current panel designs we began a search for a film with qualities superior to PVF. Polyester film, we found, had a superior tensile strength over PVF film while having comparable tear strength. Polyurethane film, on the other hand, has superior tearing strength to PVF film while having comparable tensile strength.

Both films, however, have drawbacks which will have to be addressed. Polyurethane, for instance, has a problem in handling sustained temperatures above 190 F and both films have questionable ultraviolet endurance. Nonetheless, we intend considering both films in a panel design since they clearly seem to offer an inexpensive alternative to current designs.

In addition to tougher materials, a tougher film may be achievable through a thicker film. This option will be reviewed for 2, 3, and 5 mil thick covers.

TABLE 5.1
General Film Properties*

	Polyethylene	PVC	PVF	Polyester	Polyurethane
Tensile Strength, (psi)	1,500,6,100	1,400-16,000	7,000-18,000	20,000-40,000	5,000-12,000
Tearing Strength					
Initial (lb/in)	65-575	110-490	997-1,400	1,000-3,000	350-600
Propagating (g/mil)	50-300	60-1,400	12-100	12-17	220-710
Resistance					
Grease & Oil	poor to good	good	good	good	good

*Source, reference 4

As a side note, we have observed that all current panel designs have a heat shrink cover. Because of this, the film is tightened over the core possibly weakening its ability to withstand an impact. We therefore intend to try PVF film which is only form fitted to a core, to see if this use of the film is more satisfactory.

Our next focus was on ways to reinforce the film covering. The three techniques researched were:

1) a protective screen

2) a cloth backing

3) a perforated cover plate

Of the three, using a protective screen seemed the most straightforward. Realizing the screen had to be none corrosive and inexpensive we researched plastics. We found a tough polypropylene screen which appeared suitable for this use. Our only concern now is whether the screen should be adhered to the film in order to satisfy USDA cleanability requirements

Cloth backed films are perhaps the most novel idea we have researched. There are a number of techniques available today but the two techniques considered most promising are:

1) film adhered to a thin cloth

2) calendered cloth using a waterproof liquid plastic film

Both techniques are novel to this type of application and promise to provide the kind of toughness, plastic films alone cannot. Our primary concern is getting the finished product thin enough to transmit significant portions of the pertinent sound frequency bands critical to reducing poultry processing noise.

We have also reviewed a technique called scrimming, whereby a netting is either adhered to the back of a film or sandwiched between two films. However, our concern is that the film still remains vulnerable, in the open areas of the netting, to contact with foreign objects and therefore we believe that a fine netting will be necessary to minimize the risk of puncture initiation making it comparable to a cloth-backed film.

The last film strengthening concept we focused on was covering the plastic film with a perforated plate. As mentioned earlier we are already aware of at least one panel design on the market which utilizes this technique. Unfortunately the design is a variation of panels used to build acoustical enclosures. Hence the firm making these items has not keyed on reducing weight or cost. Nonetheless, their concept is interesting and will be considered.

We lastly focused on a technique which would eliminate the need altogether for a plastic covering. In order for this to be realized, a fiberous core must not be used. We are aware of a concept developed by a Lockheed engineer for both aerospace and general application which utilizes an enclosed cavity of air designed with a graduated depth and having a perforated cover plate which appears to be quite effective as a broadband noise absorber. We intend to pursue this design further to discover is it can be used to reduce low frequency noise which must be dealt with in poultry processing plants.

E. Constructing a Reverberant Room

Our efforts to convert a storage room on the Georgia Tech campus into a suitable reverberant room were indeed ambitious. We first had to initiate a massive cleanup effort to empty the room of all attached and unattached objects. Since the room had been an instrumentation room, extensive removal of metal boxes and gages was required in addition to patching holes in the walls. Also the ceiling of the room was constructed of a sheetrock material which had become water logged from leaks in the roof. Therefore we had to use ½-inch plyboard to cover the ceiling for purposes of providing a suitable reflecting surface.

Our first acoustical qualifying tests showed the room was "hard" enough to be used in reverberation testing. Table 5.2 provides the surface absorption coefficients calculated from this test. Our guideline for qualifying the room was a standard procedure published by the American Society for Testing Materials.[3]

However, our enthusiasm was dampened slightly when we placed fiberglass panels, with a known absorption value in the room and attempted to reproduce these values. Our calculations provided values substantially below the manufacturer's values and our suspicion was that the absorbing panels lowered the diffuseness of the reverberant field in the room to an unsuitable level. A subsequent check of level variation in the room seemed to confirm this suspicion.

As of this writing, we are introducing diffusion panels into the room. Our hope is that this will result in a test chamber of sufficient quality to do comparative noise analysis.

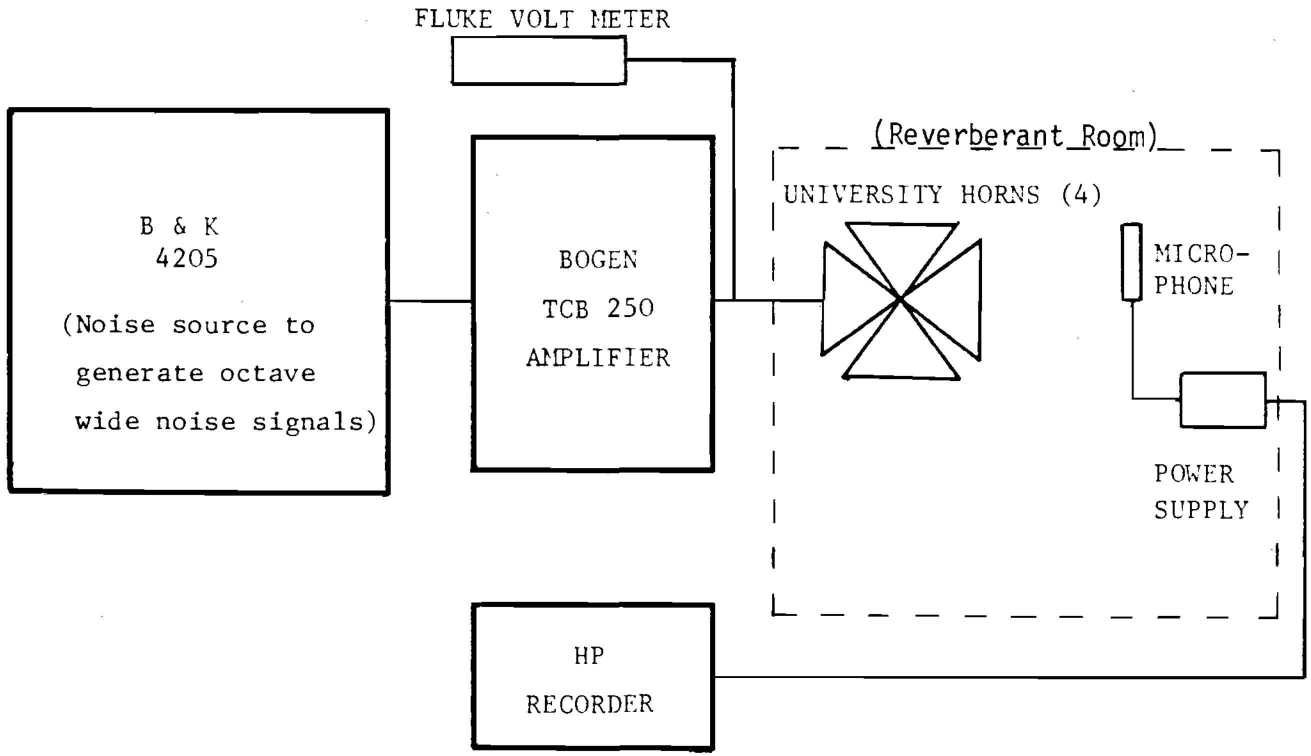
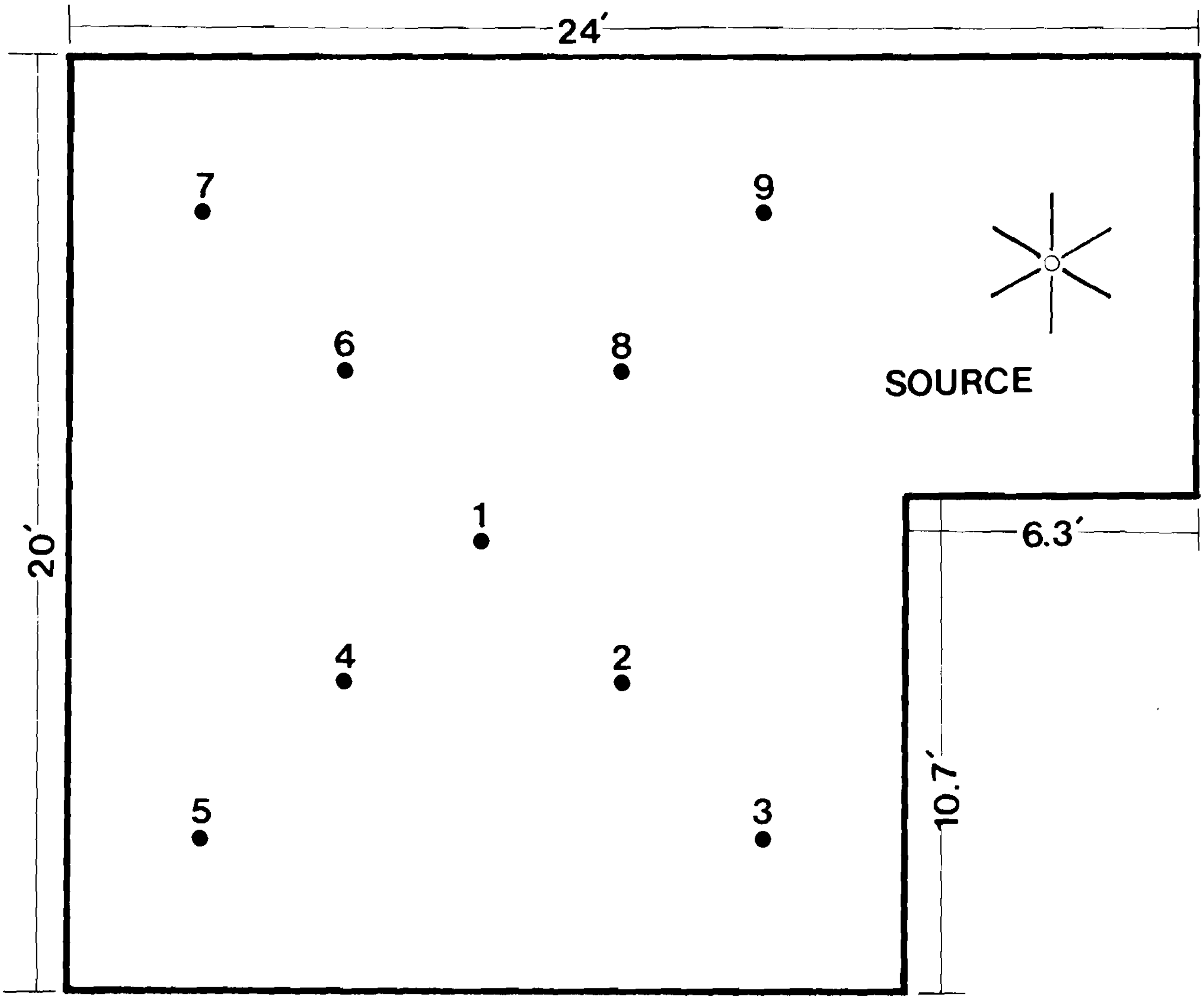


FIGURE 5.2

EQUIPMENT ARRANGEMENT



MICROPHONE HEIGHT – 3.4 ft

ROOM HEIGHT – 8.8 ft

FIGURE 5.3 – MEASUREMENT POINTS IN REVERBERANT ROOM

TABLE 5.2

Surface Absorption Coefficients For Reverberant Room*

Frequency Band	Octave Average Surface** Absorption Coefficient
250	.0456
500	.0452
1,000	.0503
2,000	.0566
4,000	.0621
8,000	.0618

*As determined by the decay method

**Values include any absorption by air.

F. Qualifying Test of Reverberant Room

The test used to qualify the reverberant room on the Georgia Tech campus for testing absorption coefficients of various material was the reverberant decay method. Using the equipment layout presented in Figure 5.2 we measured decay times at five different positions at the room using three bursts per position (see Figure 5.3).

The average surface absorption values obtained are presented in Table 5.3. Tables 5.4 through 5.8 show the specific decay times observed during our tests which were used in the construction of Table 5.3.

Table 5.3

Data Summary

Average SAB determined for Each Microphone Position*

	#1	#2	#4	#6	#8
250	.0460	.0451	.0450	.0462	.0456
500	.0460	.0436	.0456	.0462	.0448
1000	.0514	.0490	.0502	.0517	.0494
2000*	.0555	.0559	.0566	.0580	.0572
4000*	.0622	.0615	.0638	.0623	.0607
8000*	.0618	.0610	.0625	.0627	.0612

Average of all microphone positions #1,#2,#4,#6,and#8:

	SAB	Standard Deviation
250	.0456	.000531
500	.0452	.000106
1000	.0503	.00119
2000*	.0566	.00100
4000*	.0621	.00115
8000*	.0618	.000757

As shown on the frequency response chart of the University FID32-T horn loudspeakers used in this experiment, (see Figure 5.4), output in the 250 Hz octave is not adequate for valid results to be expected; likewise, output in the 8 KHz frequency octave is subject to question. It is felt, however, that octaves 500, 1000, 2000, and 4000 are valid. The values for these octaves are below the ASTM requirements. It should be cautioned that our measurements do not use the 1/3 octave wide source spectrum required in the standard but instead use a one octave wide frequency spectrum.

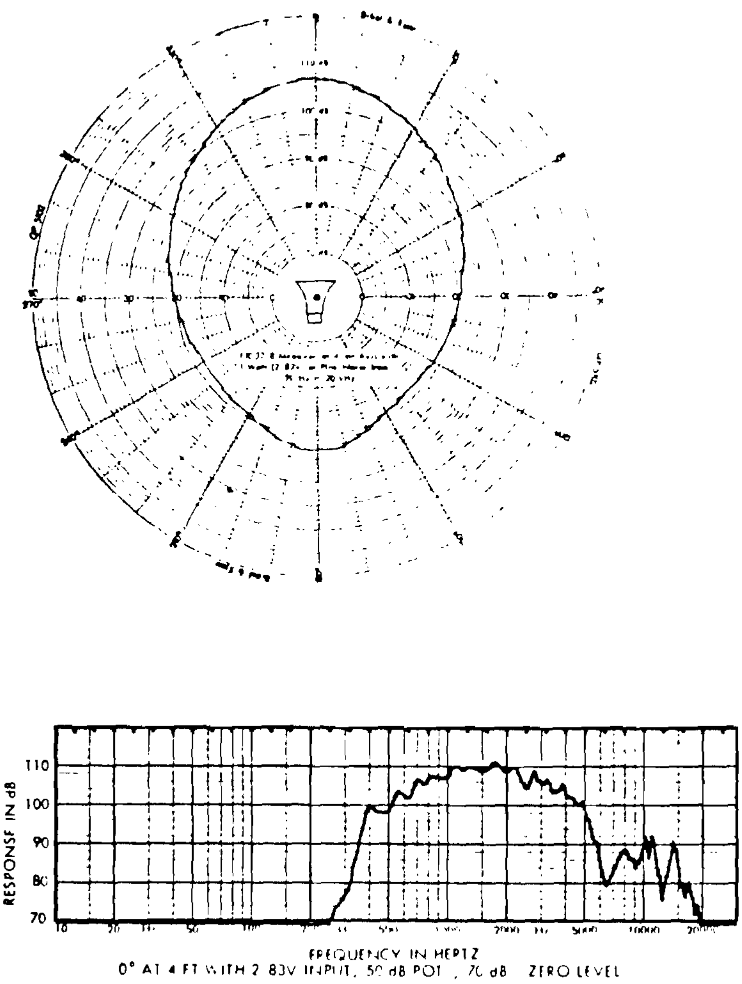


FIGURE 5.4 – FREQUENCY RESPONSE AND POLAR PATTERN OF UNIVERSITY FID32-T HORN LOUDSPEAKERS

TABLE 5.4
Microphone Position #1
Delay Time in Seconds

	Test Number			
	#1	#2	#3	Average α SAB
250HZ	2.469	2.39	2.403	.0460
500HZ	2.578	2.25	2.43	.0460
1000HZ	2.204	2.067	2.225	.0514
2000HZ	1.99	1.98	1.048	.0555
4000HZ	1.79	1.751	1.824	.0622
8000HZ	1.78	1.824	1.80	.0618

TABLE 5.5
Microphone Position #2
Delay Time in Seconds

	Test Number			
	#1	#2	#3	Average α SAB
250HZ	2.460	2.403	2.535	.0451
500HZ	2.542	2.517	2.596	.0436
1000HZ	2.262	2.288	2.256	.0490
2000HZ	1.980	2.029	1.958	.0559
4000HZ	1.769	1.822	1.8396	.0615
8000HZ	1.788	1.840	1.840	.0610

TABLE 5.6

Microphone Position #4

Delay Time in Seconds

Test Number

	#1	#2	#3	Average α SAB
250HZ	2.375	2.627	2.419	.0450
500HZ	2.508	2.410	2.402	.0456
1000HZ	2.269	2.220	2.163	.0502
2000HZ	1.981	1.915	1.995	.0566
4000HZ	1.742	1.765	1.725	.0638
8000HZ	1.791	1.778	1.769	.0625

TABLE 5.7

Microphone Position #6

Delay Time in Seconds

Test Number

	#1	#2	#3	Average α_{SAB}
250HZ	NULL	2.416	2.398	.0462
500HZ	2.464	2.332	2.420	.0462
1000HZ	2.134	2.148	2.174	.0517
2000HZ	1.831	1.976	1.950	.0580
4000HZ	1.774	1.782	1.804	.0623
8000HZ	1.778	1.774	1.774	.0627

TABLE 5.8
Microphone Position #8
Delay Time in Seconds
Test Number

	#1	#2	#3	Average$_{\alpha\ SAB}$
250HZ	2.377	2.556	2.379	.0456
500HZ	2.410	2.543	2.494	.0448
1000HZ	2.242	2.269	2.247	.0494
2000HZ	2.008	1.902	1.919	.0572
4000HZ	1.818	1.826	1.853	.0607
8000HZ	1.831	1.813	1.813	.0612

G. Retrospect

Since this project is jointly sponsored by the National Aeronautics and Space Administration, our schedule for final completion of the study runs through December. To date our initial approach to solving the reverberant noise problem in poultry processing plants has been to seek a tough, effective absorbing medium suitable for placement in the poultry processing environment. We have uncovered problems in current absorbing panel cover designs which we fee are solvable. At this time a number of concepts are being considered and will be tested for their suitability both acoustically and structurally. Our hope is that at least one design will be successful.

We also are beginning investigations aimed at quieting the three major sources in Poultry Processing Plants. Our primary thrust in this effort will focus on vibration identification and dampening/isolation techniques.

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VI. POULTRY WASTEWATER TREATMENT

by
George Battaglia

A. Introduction

In the state of Georgia in 1979 over $335,000,000 was generated by the egg processing industry. In Georgia this accounted for more than a third of all the revenue earned in the poultry industry.[1] Nationwide, the egg processing industry exceeds all other poultry operations in revenue produced. In any food processing industry water is used to clean the product before it is safe for human distribution. Naturally the bulk of this water ends up as discharge from the plant.

B. Background

As part of the increased public environmental awareness, new laws and regulations are being instituted to control all point sources of industrial wastes. Included under the Federal Water Pollution Act Amendments of 1972 are discharges resulting from egg processing operations. Egg processors are faced with four options of discharging their wastewaters in attempting to comply with existing legislation. First, they may obtain a permit to treat and discharge the wastewater directly to surface waters. Second, pretreatment may be utilized to decrease the pollutants to levels of domestic sewage for discharge to a municipal treatment system. A user charge will be assessed to industries adopting this alternative. The third option is to discharge untreated wastes directly to a municipality and pay a user's charge plus a surcharge which will be related to the egg processor's waste contribution. Finally the industry may consider reusing or no direct discharge by using land application.

Research reports indicate that about 3 to 6% of the shell eggs entering grading plants are broken during processing.[2,3] In addition because they are often located in small rural communities and because their wastewaters are highly contaminated they can create significant water quality degradation.

C. Processing System

Independent of the plants' size, it is not unusual that most plants' layout and mode of operation are nearly identical. Figure 6.1 shows a flow chart for an egg grading plant.

The first step in the operation is receiving the flats of eggs from the egg farms. The eggs are stored in a cool humid climate to maintain egg freshness and minimize evaporation of water from the egg contents. Upon reaching the washer, eggs are manually loaded onto a conveyor belt of rubber rollers. It is the duty of the person at this point of the operation to inspect the eggs and remove any "leakers" which are broken shells with contents exposed. Once a case of eggs has been loaded onto the washer, the empty flats are set aside to be returned to the egg distributors or bailed for sale as scrap paper. As the eggs move through the washer they are scrubbed by brushes moving in a

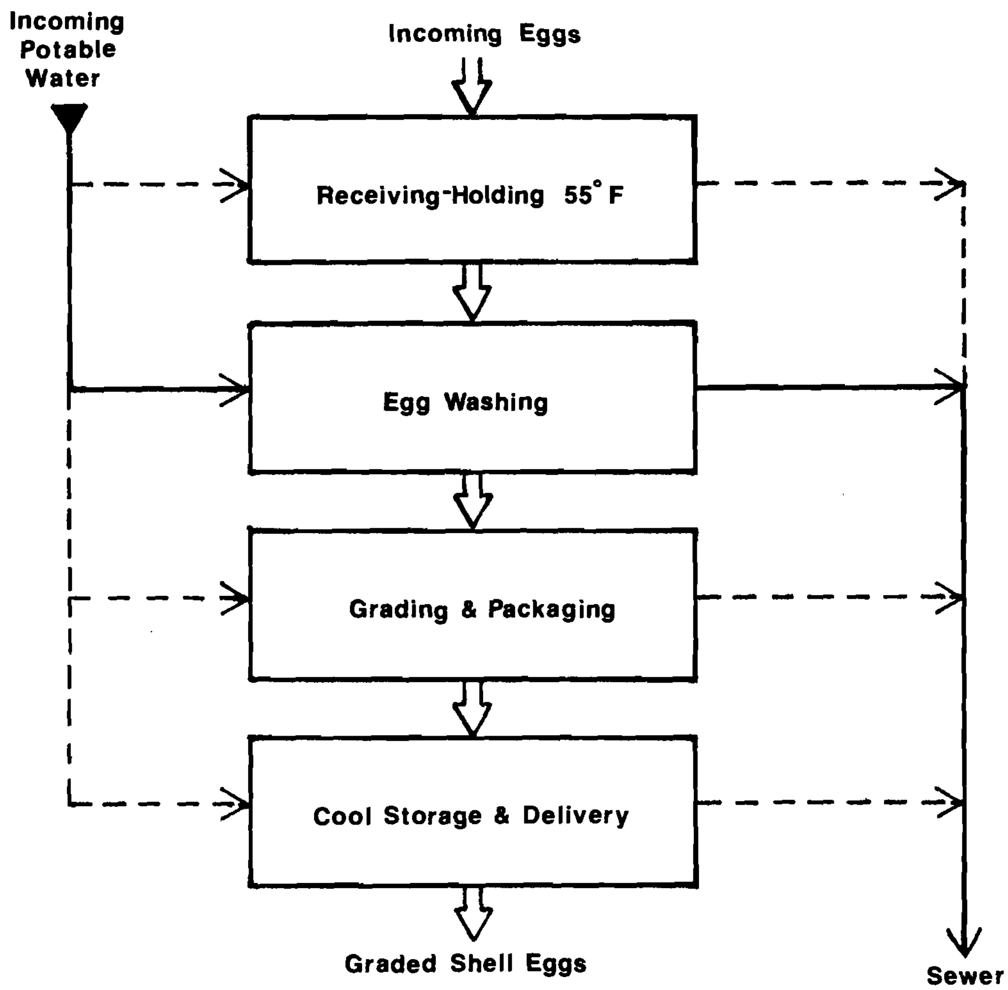

FIGURE 6.1

Flow chart of commercial egg grading plant. The only processing area with a constant demand for water is the washer. Other areas use water for clean up more or less on an as-needed basis which may be once daily or much less infrequent as in the cool rooms. (Constant flows are indicated by a solid line in figure, intermittant flow by a broken line.)

vertical direction. At the same time warm water is being pumped from the washer's holding tank and sprayed across the surface of the eggs. This water contains detergents, defoaming agents, egg solids, egg shells and foreign material removed from the shell surface. The washing equipment contains about 50-80 gallon volume which is continually recycled for a four-hour egg processing period. Once the eggs have passed through the scrub brushes they are rinsed with a warm chlorine spray containing 100-200 mg/l chlorine. This rinse along with a spray rinse which preceeds the scrub brushes constitute a continuous overflow of water from the washer. Figure 6.2 shows a simplified egg washing machine. The eggs are then conveyed above a series of brilliant lights for inspection in a candling operation. At this point inspectors remove leakers, blood spot, broken shells from eggs whose contents have been lost to the washer and eggs of poor interior quality. These inedible eggs are collected in segregated large containers for pet food products. It is also at the candling location that dirty eggs are removed to be rewashed. From the candler the eggs are sorted into their different sizes, put in dozen containers and then transferred into 15 or 30 dozen cartons. Once cartoned the boxes are moved by conveyor to the finished egg cool storage room to wait for shipping.

Normal production is from 8-10 hours per day. At the end of the processing day egg washer contents are again dumped into the sewer and the cleanup process begins. This is a final complete and intensive washdown which results in a substantial amount of water and egg solids (lost to floor spillage) reaching the sewer.

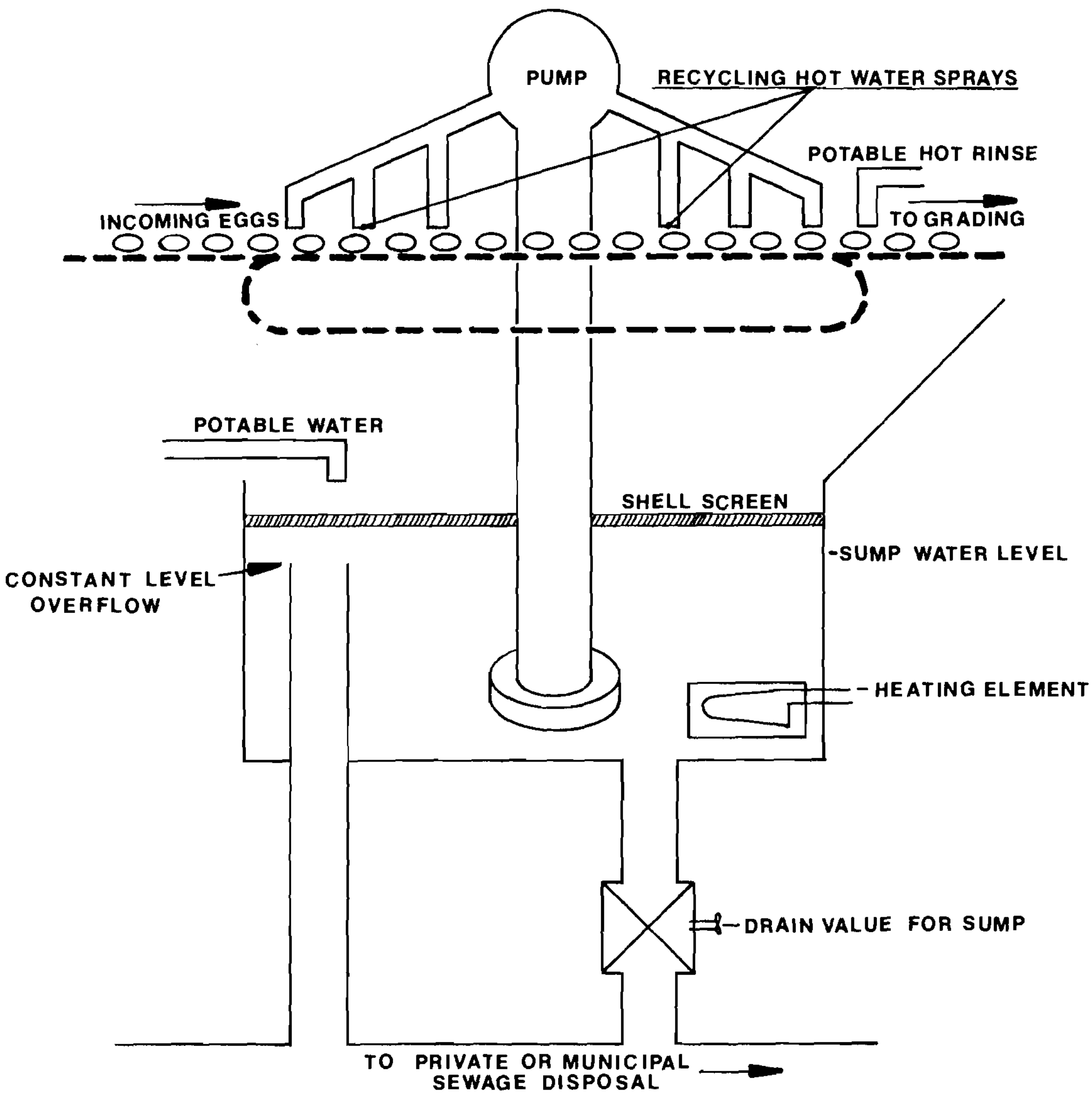

FIGURE 6.2

Schematic of in-line egg washers. This represents only the minimum basic design. Washer systems may incorporate brushes along with the hot water spray and blower-dryers after the final rinse. All systems use a detergent in the wash water.

D. Wastewater Characteristics

Typical egg processing wastewater flows are between 3000 gpd-9000 gpd. With large sewer surges every four hours due to wash water dumping, and during cleanup at the end of the day. This water contains egg shell, liquid egg contents, dirt and manure, detergent, defoaming agents, and miscellaneous other foreign matter. The wastewater has a pH in the range of 10.0-10.5 from the highly alkaline detergents used. Hamm et al tested various egg grading plants and came up with the following parameter concentrations, Table 6.1. Bulley et al came up with average values for various parameters as shown in Table 6.2.

E. Treatment Alternatives

Studies of wastewater problems in egg processing and egg breaking plants indicate that many facilities are presently experiencing difficulties in the treatment of their effluents.[5] It might also be estimated that a portion of those that are not aware of the problem will experience difficulties in conforming to new federal and state regulations in the near future.

Jewel et al have to date complied the best study on egg processing and egg breaking wastewater treatment. They looked at four types of treatment systems: aerated lagoons, activated sludge, anaerobic lagoons and rotating biological contactors.

An aerated lagoon is a dilute, completely mixed unit operating without solids recycle. The lagoon is often an earthen basin with elevated banks to minimize water losses

Table 6.1-- Wastewater characterization of egg grading plants

Egg grading plant[4]		COD	Fat[1]	Solids[2] Total (mg/l)	Solids[2] Residue	Solids[2] Volatile
	High	26,300	3,840	26,700	14,080	12,630
Washer overflow	Median	7,200	1,290	9,970	3,440	4,830
	Low	1,200	130	1,910	1,260	650
	High	17,300	3,840	20,440	11,540	8,900
Washer Sump	Median	7,400	1,280	9,730	4,140	4,030
	Low	1,200	210	1,910	1,260	530

1 Hexane Extractables
2 Dry matter obtained by drying at 103° C. to constant weight; residue=that remaining after firing at 600° C. for one hour.
3 By Micro-Kjehdahl method
4 Samples were drawn during full processing and represent only values for that specific time.

Table 6.2 Typical Egg Grading and Processing Wastewater Characteristics

Analysis	Mg/1
BOD_5	6300
COD	9780
T.S.	6950
Kjeldahl-N	537
NH_4 -N	48
NO_3 -N	2
PO_4 -P	144

due to wave action caused by aeration units.[6] Oxygen is supplied to the lagoon by either diffused aerators, surface aerators or sprayed air turbine systems. Aerated lagoons have been successful in the treatment of a number of food processing wastes including peaches, peas, apples, and dairy. This treatment process has experienced widespread use because it requires little operational control. Biological equilibrium will be established with time and will adjust automatically to absorb various change in loads. The absence of the need for complex mechanical maintenance other than lubrication and periodic inspection also makes the aerated lagoon an attractive treatment process. Results of their work on aerated lagoons showed the following results, Table 6.3. The aerated lagoons were capable of reducing a total effluent COD ranging from 4000-10,000 mg/l to a soluble effluent COD less than 1000 mg/l at all three hydraulic retention periods, 10, 20, 30 days. Even though these results indicate that aerated lagoons are capable of soluble COD removal efficiencies greater than 90%, the quality of effluent is not good enough to satisfy effluent discharge requirements. The units also had a strong pungent odor for aerobic lagoons.

It should be anticipated that treatment of egg processing wastewater with the activated sludge process will be difficult because of the high strength of the wastes. Effluent quality results from the above research were similar to those of the aerated lagoon.[5] The sludge produced in these units settled poorly and the high effluent turbidities indicated that this process would be a poor choice for the treatment of egg processing or egg breaking wastes. The activated sludge process was capable of producing an effluent suitable for discharge to a joint treatment system without resulting in a surcharge for excessive oxygen demand

Table 6.3 Summary Aerated Lagoon Characteristics and Removal Efficiencies

	Lagoon Characteristics					
	Plant A			Plant B		
	Hydraulic retention period, days					
Parameter	10	20	30	10	20	30
SS(mg/l)	1050	560	550	890	1,300	850
Oxygen uptake rate(mg/l/hr)	-	9.3	7.3	25.3	13.8	7.0
Removal effic.(%)						
COD,Total	59.8	72.3	81.1	69.2	66.1	76.5
COD,Soluble	89.7	88.3	96.2	86.9	93.7	94.3
TKN,Total	64.2	41.2	64.9	51.1	49.8	58.7

or suspended solids. However, problems with settleability of the sludge should be anticipated with this system.

The final aerobic treatment process investigated in the literature was the rotating biological contractor (RBC). The previous treatment schemes above, involved suspended growth systems whereas the RBC is an adhered growth treatment unit. This system is similar to the previous processes in that excess solids are produced by the oxidation of the substrate and have to be removed from the effluent. The results from the RBC treatment at a hydraulic retention period of nearly two days were very promising. Regardless of the loading rates used (#COD/ft^2) there was always a dissolved oxygen level in the RBC unit. The pH of the system remained between 7.2-7.7 and nitrification was higher than 50% efficient. The RBC units are capable of producing effluents suitable for further treatment without surcharge payments to municipalities and low loading rates can produce effluents with low turbidities. The question that must be answered for a particular egg processing plant is whether the capital cost for equipment and operating cost for power, maintenance and sludge handling are less than surcharges encountered if no treatment were applied.

When anaerobic lagoons are mentioned most people think of obnoxious odors, namely hydrogen sulfide or "rotten egg" odors. Contrary to this assumption, anaerobic lagoons properly maintained do not produce highly objectional odors when treating egg processing wastewater. However anaerobic lagoons by themselves would not be acceptable because of the oxygen demand associated with the discharge of wastes from anaerobic processes. Thus all anaerobic lagoons should be followed in series with aerobic lagoons operating at a six day detention period. Anaerobic-aerobic lagoon systems have operated with COD removal efficiencies between 80-91%. But perhaps the most impressive characteristics of the combination lagoon system is the high clarity and high flocculated nature of suspended materials in the effluent from the aerated unit. Since all solids settled rapidly BOD values of less than 10 mg/l are indicative of the efficiency that this treatment combination is capable of achieving with an influent COD varying between 5,000-10,000 mg/l.

F. Georgia Tech Treatment System

The treatment system Georgia Tech has been experimenting with was developed in the laboratory by Drs. W. A. Moats and C. E. Harris, food chemists with the U.S. Department of Agriculture. This system relys on physical-chemical treatment as opposed to biological decomposition of the wastewater. The highly alkaline egg wash water is first acidified to pH 4.7 by sulfuric acid addition. It is then heated to a range of 160-170°F for one half hour, with continuous stirring. At this point coagulation of the dissolved egg albumen takes place and a fine pin point floc begins to develop. Afterwards heating and stirring are ceased and the quiescent mixture is allowed to cool.

While cooling, the flocculated particles begin to grow in size, gravity settle, and eventually form a cloudy-white sludge blanket leaving behind a reasonably clear effluent. Moats and Harris found their process to reduce BOD in a range of 76 to 97%. However this experimentation showed that the efficiency of their physical-chemical treatment system increased as the strength of the egg wastewater increased. In other words, when egg processing wastewater had low BOD concentrations (below 1000 mg/l) their removal efficiencies were in the high 70% range, but when wastewater with high BOD concentrations (above 10,000 mg/l) was treated removal efficiencies greater than 90% were seen. The next two tables show this relationship. Georgia Tech's experimentation with this treatment process has yield data which corresponds quite closely to the results by Moats and Harris.

The table below shows typical concentrations of egg processing washwater effluent before and after treatment.

TABLE 6.4

TREATMENT WASHWATER CONCENTRATIONS

COD(mg/l)		BOD(mg/l)	
BEFORE	AFTER	BEFORE	AFTER
3760	520	1290	153
600	380	1150	150
1080	640	800	330
3620	600		

This experimentation was done at the Colonial egg processing plant in Douglas, Georgia. The plant processes an average of 1,250 cases (30 doz/case) of eggs per day. A small 100 liter batch treatment system was designed. A batch system was decided on because of the nature of the plant effluent flow. The bulk of the water flows occur at noon and again at the end of the day when the wash water is dumped.

Colonial Egg has a daily water consumption between 4,000-8,000 gals. During summer months the higher ranges result due to frequent washing of trucks and watering of the grass. The city of Douglas has been forced to apply industrial sewer surcharges based on an allowable BOD discharge limitation of 300 mg/l. The surcharge rate are determined by the following formula:

monthly avg. BOD (ppm)-alloted BOD (ppm)= BOD average

BOD (ppm) average x daily water usage (mgd) = lbs. per day BOD

lbs/day BOD x overage charge ($/lb) x number of operating days/month = surcharge amt.

From this formula it can be seen that there is only one way in which a plant can reduce its surcharge rate, it must lower its BOD concentration by either pretreating its wastes before discharge or taking in-plant procedures to lower the amount of plant wastes from entering the water. It should be pointed out that lowering the water consumption in the plant will also lower surcharge rates provided however that this lowering does not cause an increase in waste con centrations in the effluent. Ideally then all water consumption that is not directly related to the egg cleaning process should be kept to a minimum. Lowering water consumption will be talked about again later.

The physical-chemical treatment system discussed has at present a drawback which, although not seen during the laboratory testing, has appeared in the scaled up engineering phase. This is the problem of sludge separation. The flocculated egg albumen has a specific gravity very close to that of 1.0 and the combination of ionic charges at the molecular level cause the particles to settle very slowly. The following table shows COD (mg/l) concentrations taken at a number of time intervals after the heated and acidified effluent had been placed in a settling column.

TABLE 6.5
COD CONCENTRATIONS

Settling Time	COD(mg/l)*
0	3620
1/2	3050
1	2590
2	970
2 1/2	640
5	600

* samples taken from top of settling column

With gravity settling a quiescent time of 2.5-3.0 hours has been found to be most efficient. Due to the extremely fragile nature of the settled floc, or sludge, removal or separation from the clarified wastewater has so far proved most problematic. When agitation of the sludge blanket occurs from either the drawing off of the clarified supernatant or the direct removal of the sludge by pumping. The delicate blanket becomes sheared and immediately goes back into suspension. At present Georgia Tech is investigating the use of chemical or polymer addition to aid in strengthening the sludge. In addition, testing is almost underway using polypropylene sludge filtering bags. The idea here is to pump the heated and acidified wastewater into the bag, which is made of a slightly porous material. The low porosity of the bag will hopefully allow the supernatant to drain out while at the same time not allowing agitation or shearing of the settling sludge.

G. <u>Waste Control Modification</u>

In-plant waste control is an idea that until very recently was not practiced in the egg industry. Jewell et al showed that informing management of the weight of BOD5 lost in their operation does not give them a clear understanding of their losses. A much more effective approach is to relate BOD or COD losses to the loss of egg product, that can be easily translated to dollar losses. Although it is difficult to achieve, construction of a mass balance indicates the relationship of various losses to the final product. This type of data impresses management because it indicates that the egg loss in most plants represents greater than 5% of the plants edible product output. When converting this to dollar amounts it is in the range of more than a few hundred dollars per day. When it is noted that egg losses are substantial and result in decreased profit, plant managers are quick to understand the problem and anxious to implement suggested in-plant modifications.

The following steps if implemented would greatly reduce egg waste in processing plants.

1. minimize use of improper stacking of eggs in storage, or weak storage boxes.

2. minimize number of times eggs are handled and length of the conveyor system.

3. frequent adjustment of brushes in washers to minimize breakage.

4. efficient collection of discarded eggs.

5. maximize dry cleanup of plant at end of day.

In addition to these steps Georgia Tech has found that an integrated system to conserve water usage in the processing plant is also needed. The two areas where significant water savings can be earned is in the cleanup process and in the egg rinsing spray. Far too much water is used in washing down plant equipment and floors at the end of the working day. The possibility of a wet vacuum system for cleaning floors should be looked into. This would not only reduce water consumption but also eliminate egg waste from entering the sewer discharge.

The egg rinsing systems around the plant should be checked to make sure that the minimum amount of spray nozzles, to adequately rinse each egg, are being used. Too often more spray nozzles than necessary are used, actually causing a reduction in overall spray effectiveness. Also, water pressure in the spray lines should not be above the manufacturers recommendations. With the implementation of these water conserving techniques on their egg spray rinses Colonial Egg Processors was able to cut down their consumption by over 5% and improve the quality of their final product as well.

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VII. HEAT RECOVERY IN EGG PROCESSING PLANTS

by
William B. Boykin, P.E.

A. INTRODUCTION

Egg processing plants in Georgia are generally highly automated, similar in layout, and employ a common process for preparing the product, fresh whole eggs, for market. Typically, the egg preparation process involves successive steps of cooling and heating the product. Energy, in the form of natural gas and electricity is consumed by the plant equipment which, accomplishes the temperature changes required. The waste energy streams resulting can be reclaimed and reused in the process to reduce the overall plant requirements.

In the past, relatively abundant supplies of energy held down energy costs relative to other costs incurred in egg production. The rapid increases in energy costs currently being experienced by egg processors, however, has changed the situation. The rising costs and declining supply of energy resources, both domestic and foreign, has made all energy users, egg processors included, aware of the need to conserve energy and use it as efficiently as possible.

As a part of continuing efforts to assist Georgia's poultry industry through applied engineering research, the Georgia Tech Engineering Experiment Station conducted a research project to demonstrate the implementation of energy recovery technology in egg processing plants. Using information obtained through earlier energy surveys of several Georgia egg processing plants, EES engineers characterized the energy usage patterns of such plants and identified sources of waste energy economically recoverable by currently marketed equipment. With funds provided by the Georgia Department of Agriculture, EES engineers installed and monitored the performance of energy recovery equipment in the Crystal Farms, Inc., egg processing plant at Chestnut Mountain, Georgia. This report discusses the methodology involved and the results of the research effort.

B. EGG PREPARATION PROCESS

Preparing eggs for the commercial retail market involves a rather simple process beginning with transportation of fresh eggs from the layer faciity to the processing plant. At the plant, the eggs are received and stored temporarily in a room maintained at temperatures below ambient, usually 50-60°F.

Next, the eggs are automatically loaded onto machines which wash them with hot (110°) soapy water. After washing, the eggs are conveyed across an illuminated table where they are visually inspected for imperfections in a process known as "candling". The machine then automatically weighs each egg, sorts them into preset weight categories, and places them into labeled cartons. From this point, the cartons are manually loaded into boxes and again stored in a refrigerated room to await shipment to retail outlets or commercial users. Figure 7.1 shows the process schematically.

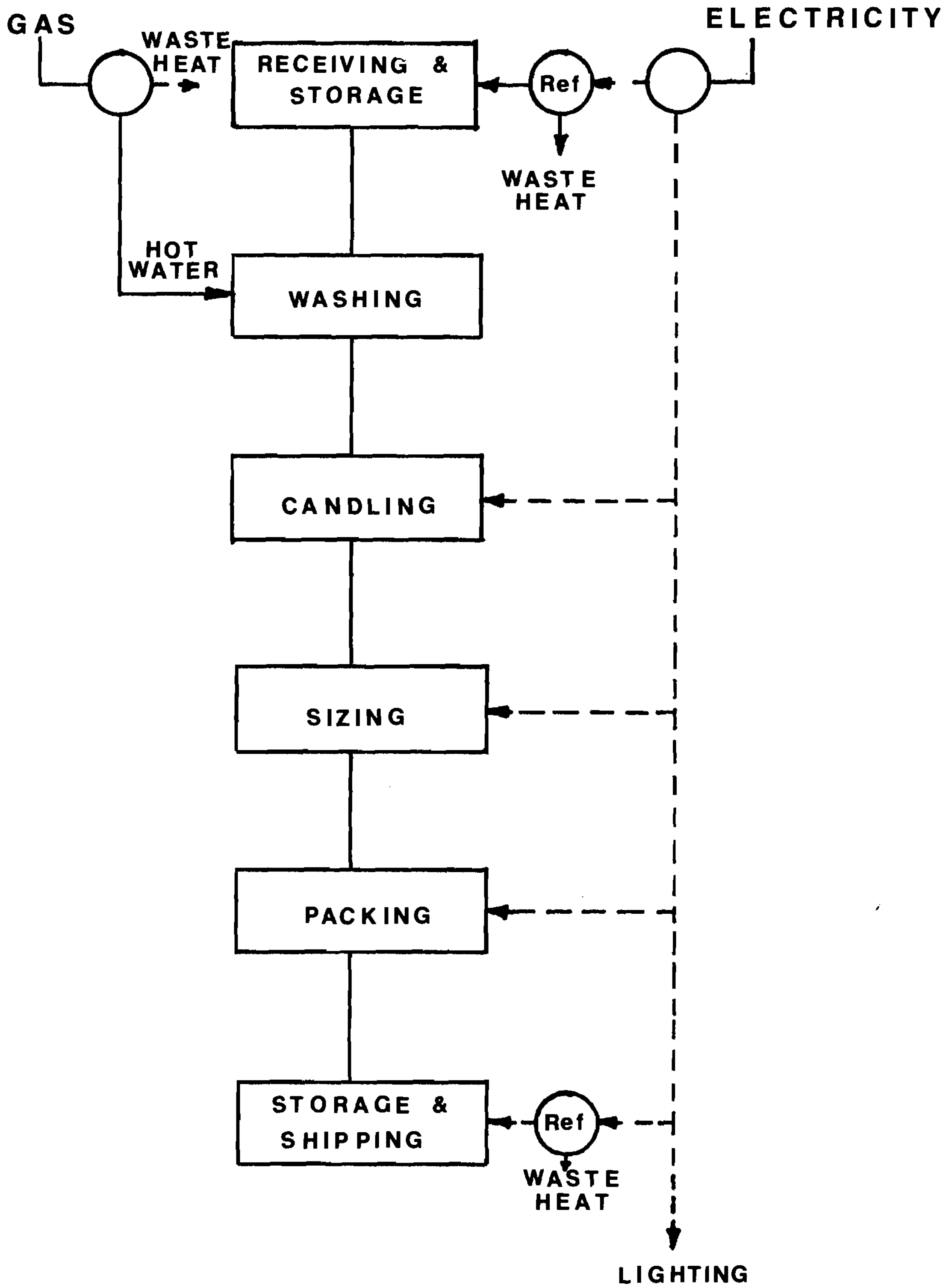


FIGURE 7.1

EGG PREPARATION PROCESS

The Crystal Farms plant operates four processing machines with two production shifts of 8 hours each per day. Production occurs 5 days per week throughout the year making this particular plant the state's largest with a total output of over 40 million dozen eggs per year.

C. ENERGY CONSUMPTION PATTERNS

The Crystal Farms plant consumes energy in two forms; electricity and natural gas. In addition to plant lighting, electrical energy is supplied to motors on space air-conditioning units, air compressors, vacuum pumps and egg cooler refrigeration units. Electrical consumption averages 97,000 KWH per month at an average monthly cost of $2500.

Natural gas, the primary fossil fuel used at Crystal Farms, is burned in four high temperature hot water heaters which supply both domestic hot water, makeup water to the egg washers, and heat energy to the egg washer reservoirs. Several roof-mounted space conditioning units also consume natural gas during the heating season.

The egg washers are part of the egg processing machines described earlier. They consist of rectangular covered tanks containing approximately 150 gallons of heated water-soap mixture. The water is pumped from the bottom of each tank and sprayed over the eggs which are transported through the unit by a conveyor belt. Since some water is lost by evaporation, continuous hot water make-up is required. In addition, the entire tank reservoir is discharged and refilled twice each operating shift in compliance with USDA regulations. To maintain the water-soap mixture in the tank at the desired 110°F, heat is required. It is supplied by circulating water from the heaters at 150°F through coils in the tank reservoir. The heating water is returned to the gas-fired heaters through a closed-loop pressurized piping system. Figure 7.2 presents a diagram of the egg washer heating system.

Total natural gas consumption for both the water heaters and space heating units averages 5,000 therms per month at a monthly cost of $800.

D. HEAT RECOVERY FROM REFRIGERATION SYSTEMS

The Crystal Farms plant has 5 egg storage rooms, or coolers, each of which is maintained at 50°-60°F by two 10 hp roof mounted refrigeration units. The units employ R-22 as a refrigerant and are responsible for a large percentage of plant electrical energy consumption.

The thermodynamic cycle utilized by refrigeration systems presents an economically attractive energy conservation opportunity due to the large quantities of energy rejected to the ambient environment. This phenomenon occurs because the refrigeration system "pumps" energy from the cooler space to the warmer outside air by taking advantage of the special properties of the refrigerant as described below.

Referring to Figure 7.3, the refrigerant in vapor form at low pressure and temperature (point 1) is compressed to a higher pressure and temperature (point 2) by the electric motor-driven compressor. The superheated vapor flows to the condenser (a finned coil) where it cools down to saturation temperature (110°F) and condenses at constant pressure (250 psia) and temperature. This process liberates heat which is transferred by the coil to ambient air forced by a fan across the outside coil surface. The resulting high pressure liquid

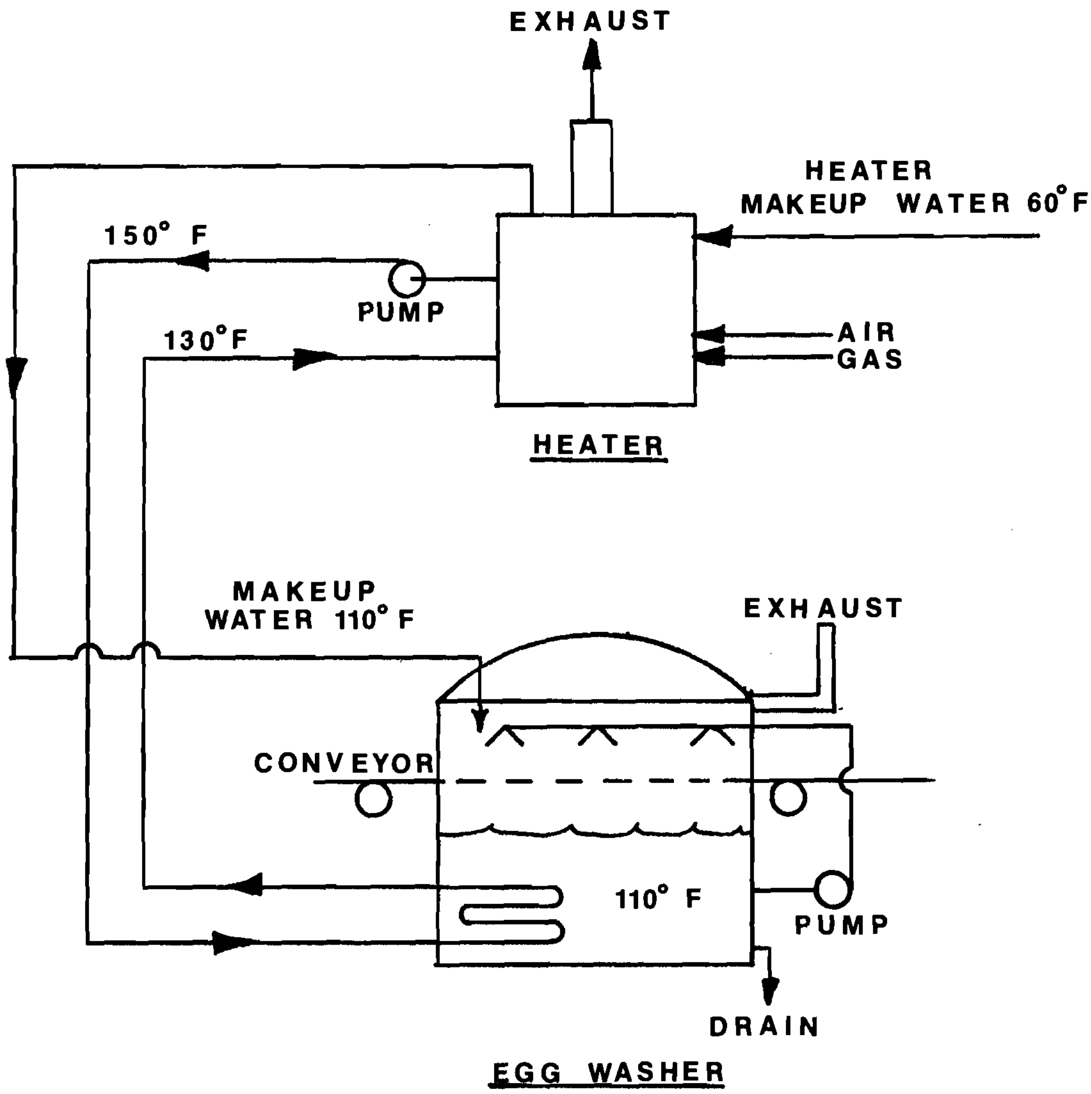


FIGURE 7.2

EGG WASHER HEATING SYSTEM

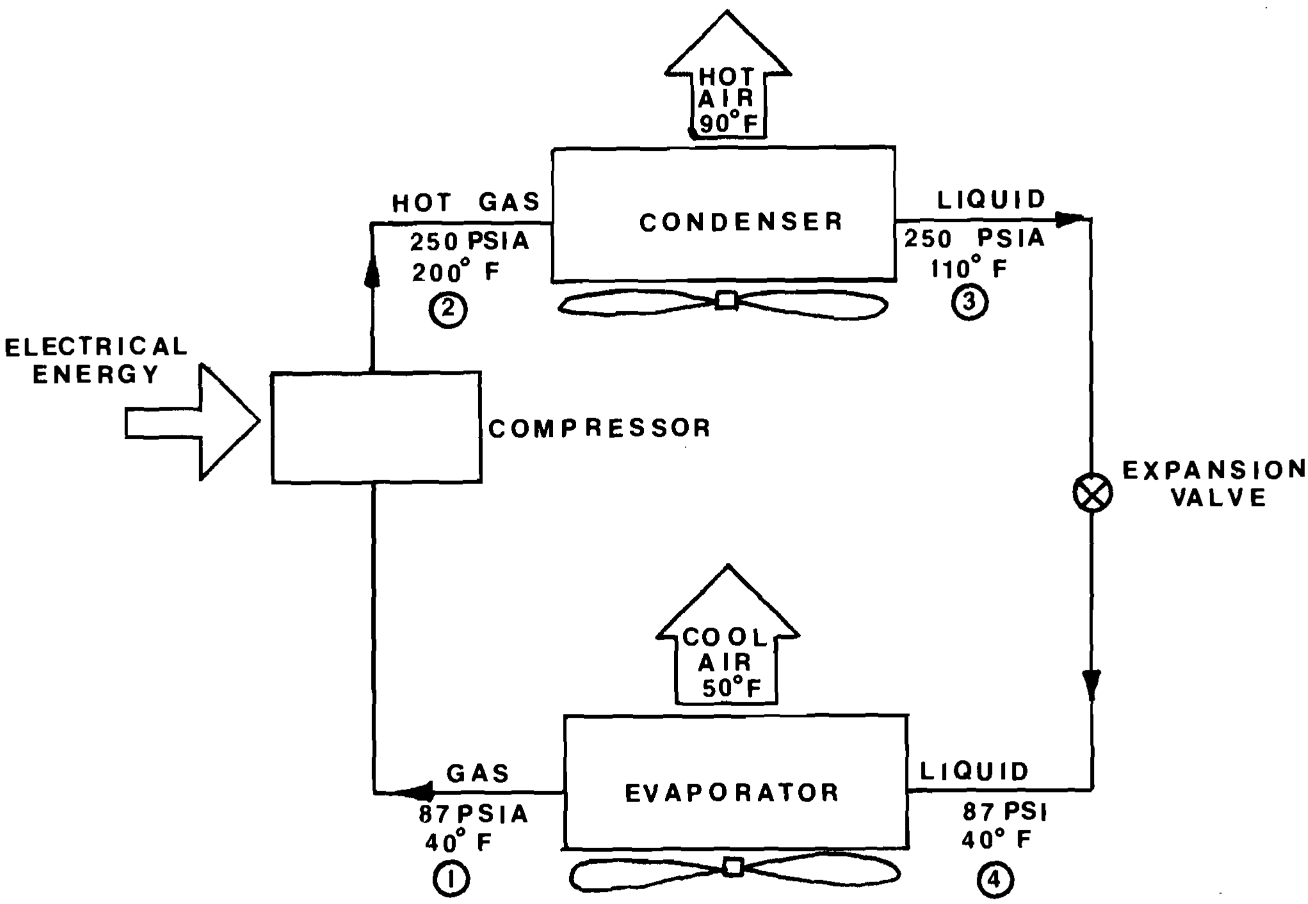


FIGURE 7.3

TYPICAL REFRIGERATION CYCLE

(point 3) flows across a specially designed valve which drops its pressure and temperature to lower values (point 4). The cold liquid refrigerant then receives heat from room air as it passes through the evaporator coil, and returns to the vapor phase (point 1), thus completing the cycle.

An idealized energy balance on the system shows that the total energy rejected by the condenser equals that removed from the room plus the electrical energy consumed by the compressor in motivating the whole process.

As one might conclude, the energy rejected by the condenser is "wasted" in rather large quantity, e.g., approximately 90,700 Btu/hr from the idealized cycle. This figure is larger, however, for a real system due to internal losses, such as friction.

Before the recovery of waste energy is feasible, however, a use for the low temperature heat (110°F-200°F) must exist within the plant. At Crystal Farms, hot water at 110°-120°F was required by the egg washers, thus the essence of the research effort was how to direct the waste energy to serve plant needs in an economically attractive manner.

E. HEAT RECOVERY SYSTEM INSTALLATION

It is possible to condense the hot refrigerant vapor and recover the resulting waste energy by transferring it to water rather then the outside air. This can be accomplished by specially designed water-cooled heat exchangers added to the system between the compressor and condenser.

There are currently several different heat exchanger designs being marketed by their respective manufacturers.

The unit selected for installation at Crystal Farms is manufactured by the Paul Mueller Company.

The Mueller heat recovery system consists of two refrigerant-to-water heat exchangers, two 150 gal. insulated water storage tanks, and interconnecting plumbing. The heat exchangers are designed to cool (desuperheat) the hot refrigerant gas to saturation and then condense it (remove the latent heat of condensation). The heat exchangers are connected in parallel, each unit condensing half the total refrigerant flow. Thermal storage capacity is furnished by the water tanks and flow from the tanks to the heat exchangers and back is induced by natural convection as depicted schematically by Figure 7.4.

Actual installation and startup of the heat recovery system was accomplished by a local heating and plumbing contractor whose services were procured via an open bidding process. H & R Mechanical Inc. of Gainesville, Ga., was selected as the contractor.

As mentioned earlier, the heat recovery system was connected to the existing roof mounted refrigeration system between the compressor and condenser. Hot water flow from the system was directed to the plant heaters for use as preheated make-up water. The arrangement is shown in Figure 7.5, while Figure 7.6 shows the system as actually installed in the plant. Under normal operation, with hot water being drawn from the system, all refrigerant flow condenses and the existing condenser fans, which are controlled by head pressure do not operate. However, when no hot water is required by the process no condensation occurs in the heat exchangers, and the refrigerant flow is then condensed by the existing fan cooled condenser.

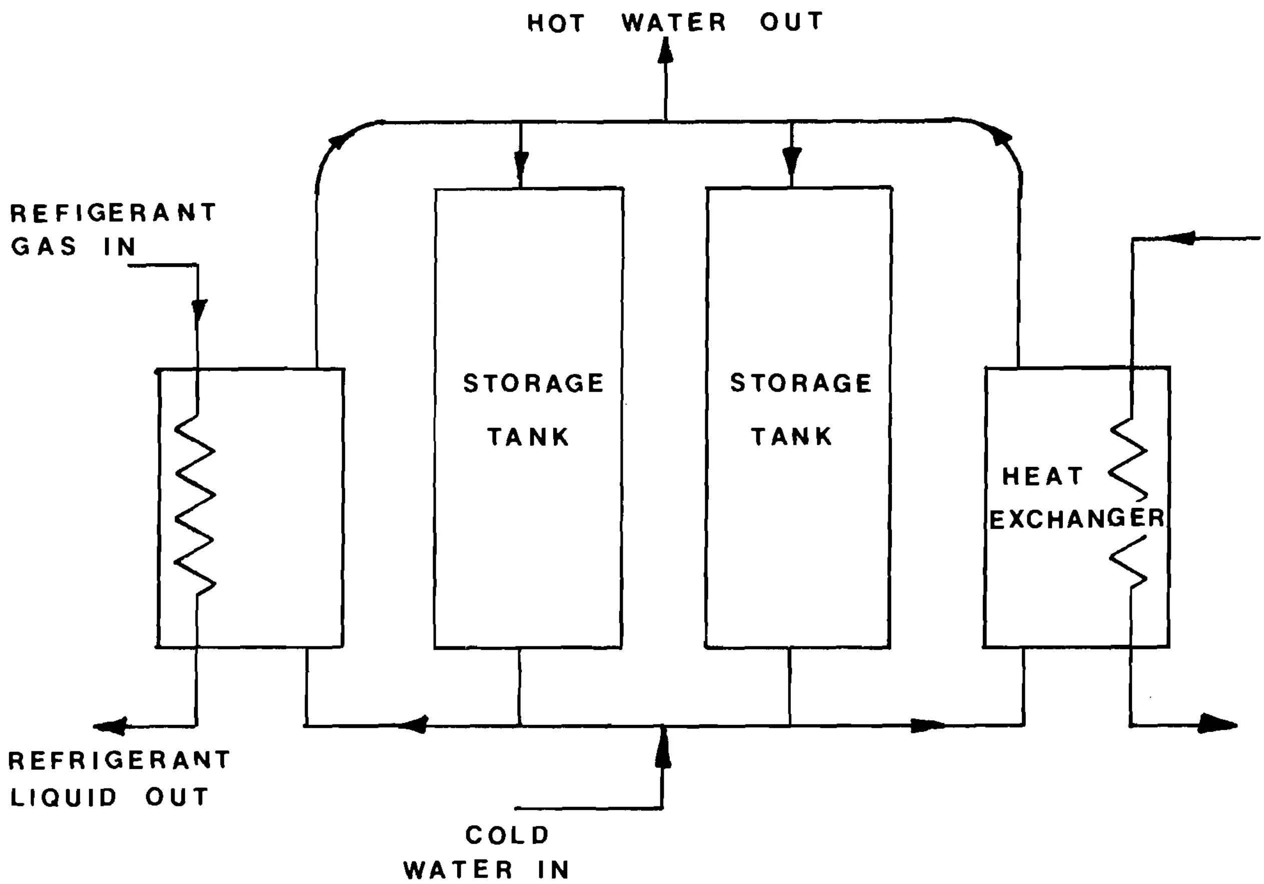


FIGURE 7.4

HEAT RECOVERY SYSTEM

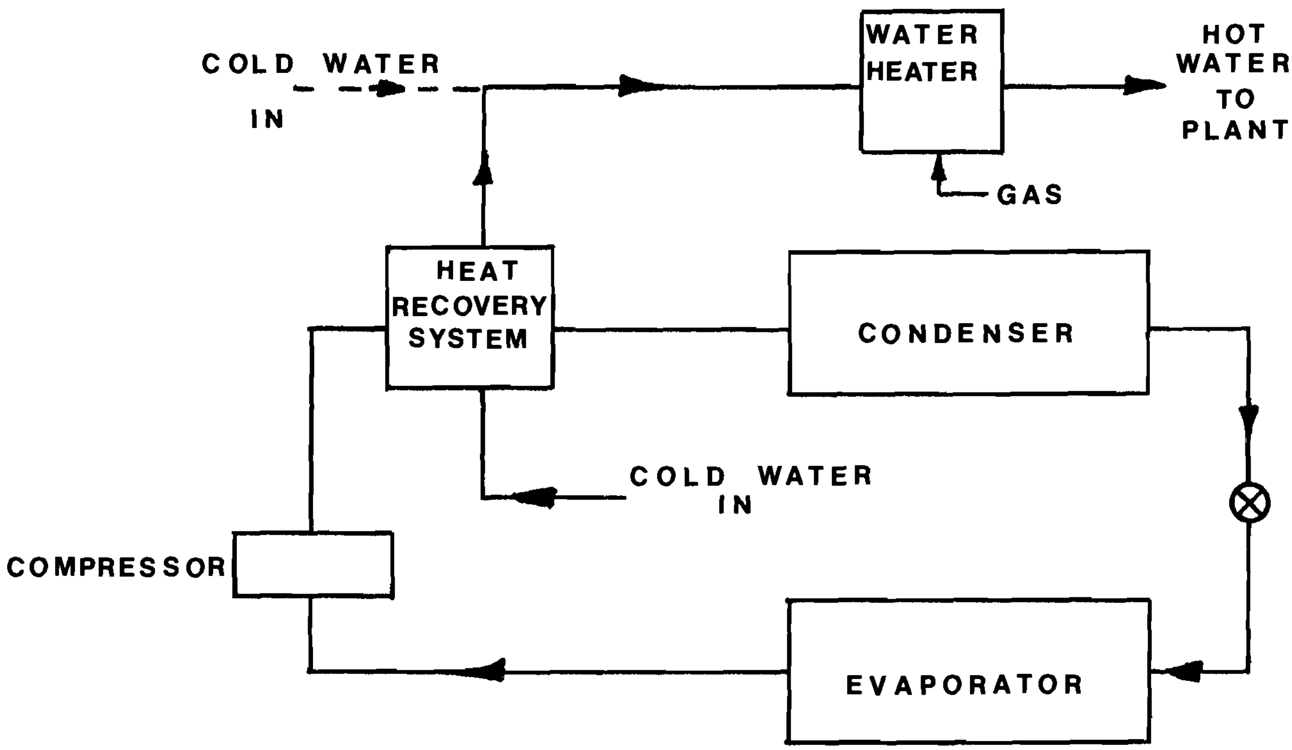


FIGURE 7.5

HEAT RECOVERY SYSTEM INSTALLATION SCHEMATIC

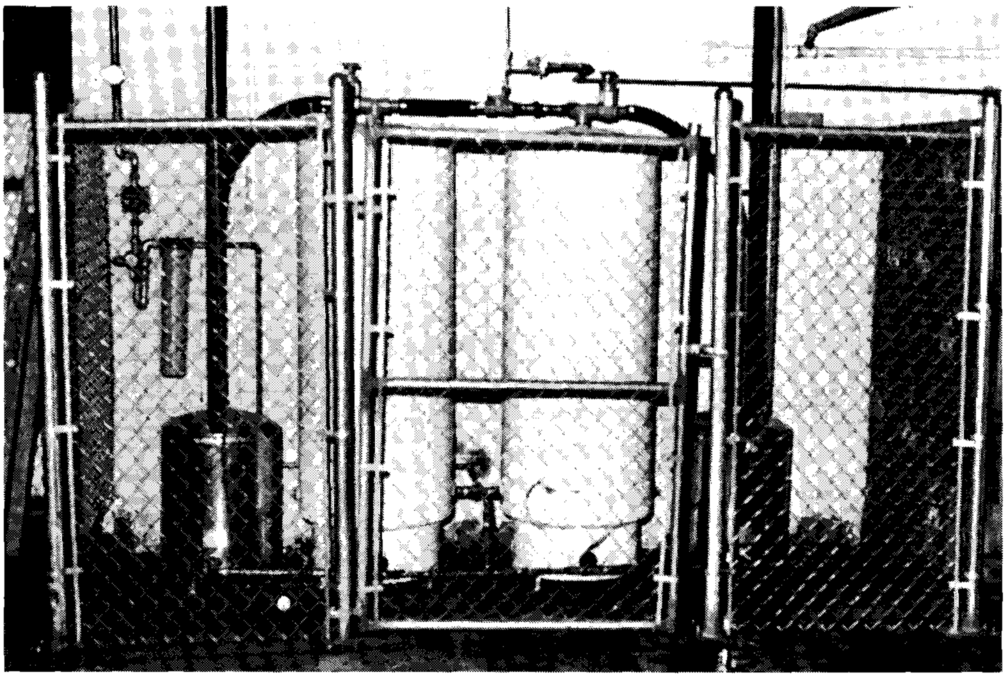


FIGURE 7.6

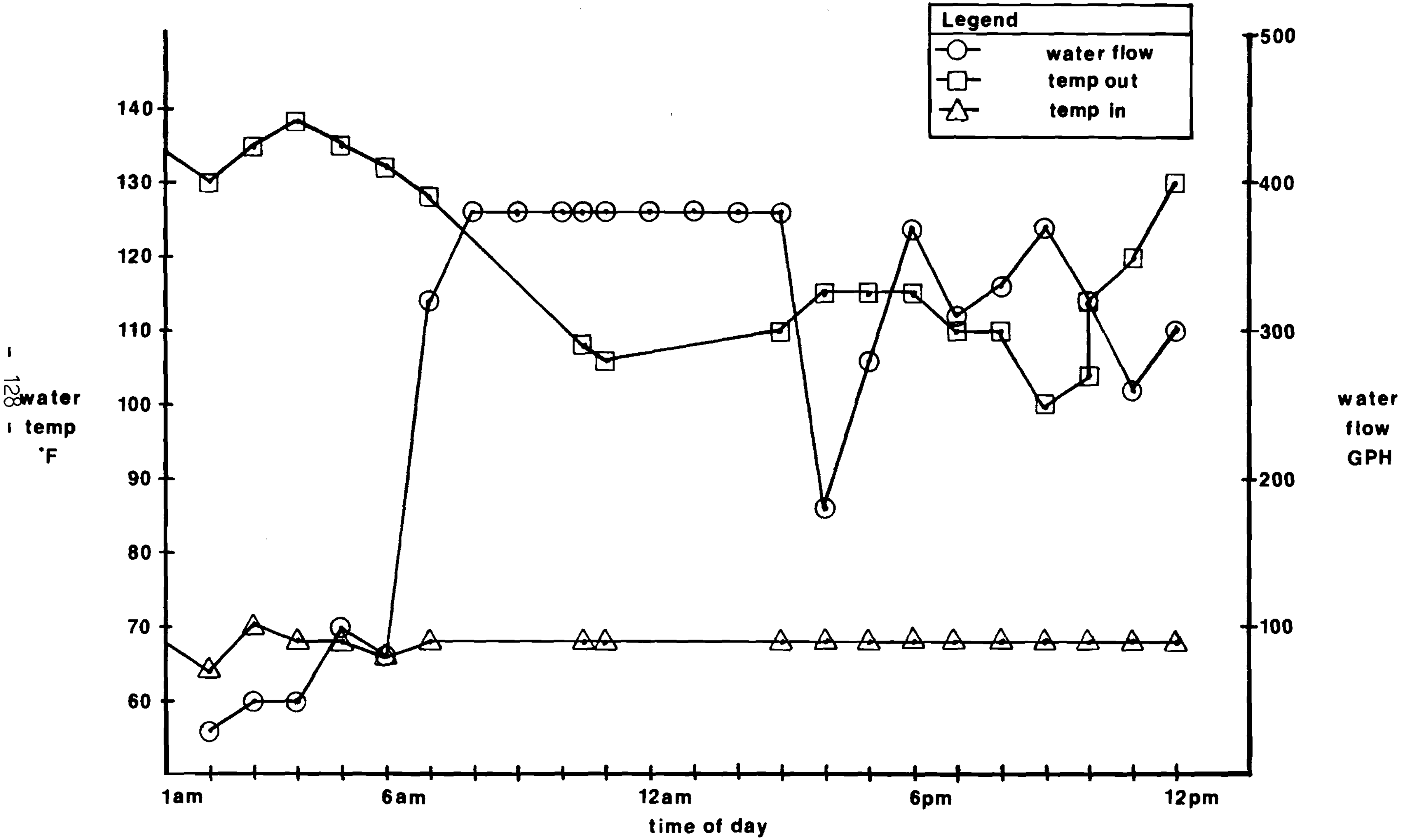
HEAT RECOVERY SYSTEM INSTALLATION
AT CRYSTAL FARMS, INC.

F. SYSTEM PERFORMANCE

The heat recovery system became operational in December 1979. During the first few months of operation, occasional leaks in the refrigerant and water piping required unit outages for repairs. Cold winter weather hampered repair efforts but after repairs were complete, operation resumed. The refrigeration unit itself ran intermittantly due to the lower ambient temperatures which reduced the demand for indoor cooling.

As higher outdoor temperatures in the Spring months increased the cooling load, operation became continuous. At this point, the unit experienced shutdowns due to high head pressures. The problem occurred on weekends when water flow ceased and refrigerant condensing duty was transferred to the existing fan-coil unit. The extra pressure drop caused by uncondensed gas flowing through the heat exchangers was identified as the culprit. Adding a constant differential pressure by pass valve in the hot gas line to divert refrigerant flow around the heat exchangers eliminated the problem. System operation has been constant and satisfactory since the modification.

One primary goal of the research was to determine actual energy recovery rates yielded by the system. Such a determination is made possible on a heat exchanger by an energy balance calculated from data on the flow rate and temperature rise of the fluid being heated. To accomplish this, thermometers were installed on the system water lines together with an integrating water meter. Data gathered from the instrumentation was used to calculate heat recovery rates and to produce system performance curves, a typical example of which is shown in Figure 7.7.



HEAT RECOVERY SYSTEMS PERFORMANCE

FIGURE 7.7

Analysis of the performance data yielded several observations worthy of comment. From Figure 7.6, a direct relationship between flowrate and system outlet temperature is evident, i.e., higher flow causes lower temperature. This is to be expected with any heat exchanger where energy input (in this case-hot refrigerant flow) remains constant. The water flow and temperature fluctuations are also seen to correspond with the plant operating shifts. Since production ceases overnight, the system storage tanks heat up to maximum temperature. When water flow demand resumes beginning with the day shift, temperature initially decreases then varies around a lower temperature according to daily water usage rates.

The quantity of energy transferred by a heat exchanger is governed by the following equation:

$$Q = MCp\,(Tout - Tin)$$

where:

Q=Heat recovery rate, Btu/hr

M=Water flow rate, lb/hr

Cp=Specific heat (water= 1 Btu/lb-°F)

Tout=Outlet temperature, °F

Tin=Inlet temperature, °F

Using this equation and the raw data, heat recovery rates ranging from 114,676 Btu/hr to 135,798 Btu/hr were calculated. The average based upon our operational data was 123,647 btu/hr.

G. ECONOMIC ANALYSIS

In the private, free enterprise sector of the national economy, the acceptability of any investment alternative such as a heat recovery system is largely dependant upon its economic attractiveness. Although several methods exist for analyzing investments one of the more popular schemes involves determining the payback period, i.e., the length of time required for the monetary savings generated to equal the investment.

The following analysis is based upon data actually observed during our research efforts:

Average hourly energy savings: Q=123,647 Btu/hr

Heating boiler efficiency: E=75% (measured)

Gas conversion: C1=100,000 Btu/Therm C2=100 cu. ft./Therm (1000 Btu/cu. ft.)

Current plant gas cost: ¢=22.73 ¢/Therm

Plant operating schedule: 16 hrs/day, 240 days/yr

The yearly gas savings is,:

$$S=\frac{(Q\times 16 \text{ hrs/day} \times 240 \text{ days/year})}{(E \times C1)}= 6330.7 \text{ Therms/yr}$$

In terms of cubic feet, S equates to 633,072 cu ft/yr

The yearly cost savings, \$, is:

$$\$ = \frac{(6330.7 \text{ Therms/yr}) \times (¢)}{100}= 1,438.97 \text{ \$/yr}$$

Thus, the simple payback period (not including tax credits ssince equipment was purchased with state funds) was calculated as follows:

Actual installed cost	$4,021.00
Annual energy savings	$1438.97
Less:	
Maintenance cost	est. $100.00
Net Savings	$1338.97

Simple payback period:

$4,021.00/$1,338.97= 3.0 years

H. CONCLUSION

Recovering waste energy from refrigeration units is an economically viable, technically simple means of conserving energy. The energy costs saved by a properly designed and installed heat recovery system can be significant. Investment in such equipment is particulary attractive during lean market times when egg processing profits are squeezed by operating costs.

There are several factors to be considered in assessing the feasibility of installing heat recovery equipment. Since processing plants differ in size and output, each potential installation should be evaluated with proper attention given to the relationship between waste energy availability and plant requirements for hot water.

Our conclusion, based upon the research effort now concluded, is that heat recovery from egg cooler refrigeration units should be considered by Georgia egg processors as a means of reducing their consumption of fossil fuels.

VIII. HATCHERY HEAT RECOVERY

by
Bill Nolte

A. Introduction

Poultry hatcheries provide a unique opportunity for energy savings in that the setting portion of the hatchery operation produces approximately 100° air and 75% relative humidity year-round. This air cannot be recycled because the eggs are living organisms that contaminate the air with carbon dioxide, viruses, and other pollutants characteristic of life.

Under the sponsorship of the Georgia Department of Agriculture, Georgia Tech designed a heat recovery system for hatcheries. Among those interested in the project was the Wayne Poultry Company. Their hatchery, located in Clermont, Georgia, was selected as a site of the demonstration as it was felt this hatchery represented a typical Georgia plant.

B. Site Description

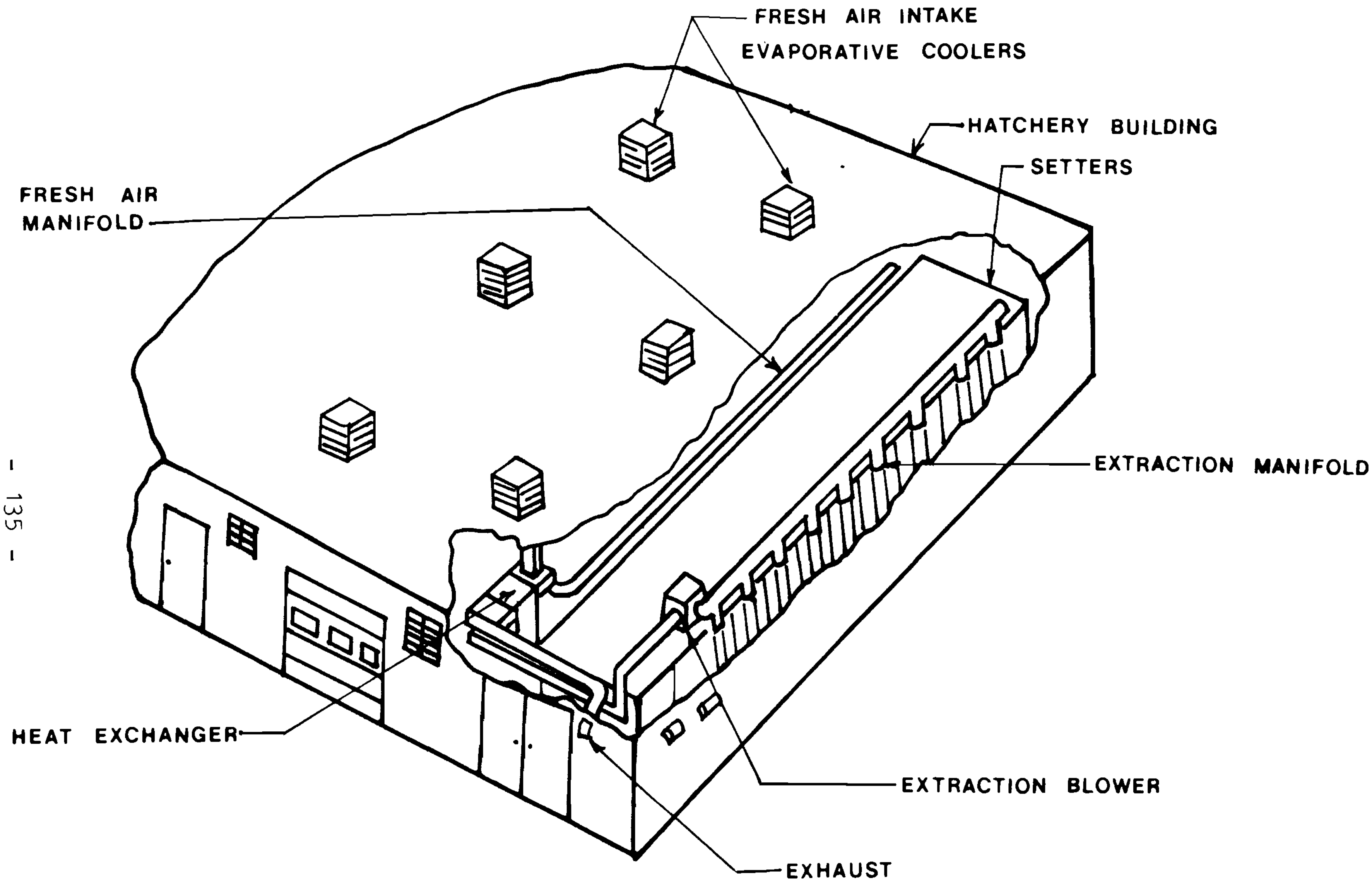
The hatchery is situated in a rural setting on the outskirts of Clermont, Georgia, which is located 12 miles north of Gainesville, Georgia on Hwy 11. In the room housing the setters, there are 12 Model 99 Chickmaster setters along one wall and 8 Model 66 Chickmaster setters along the opposite wall. Adjacent to the room housing the setters is the hatcher room. Here the eggs are allowed to actually hatch and from there the chicks are taken to the processing room where they are debeaked, innoculated, and boxed for shipment. From the processing room they are then taken to the loading dock and placed in waiting trucks to be transported to the growout houses.

C. System Description

For the purposes of the demonstration, it was decided to use only the Model 99 setters, all of which are located along the easterly wall of the building. Of these 12 units, 2 are already piped to the exterior of the building. The system was then designed to handle the remaining 10 setter units with a reserve capacity built in to accommodate installation of up to 10 additional setters. Each 99 setter has an air flow of 200 cu ft per minute through the unit (with the 10 totalling 2,000 cu ft per minute exhaust air).

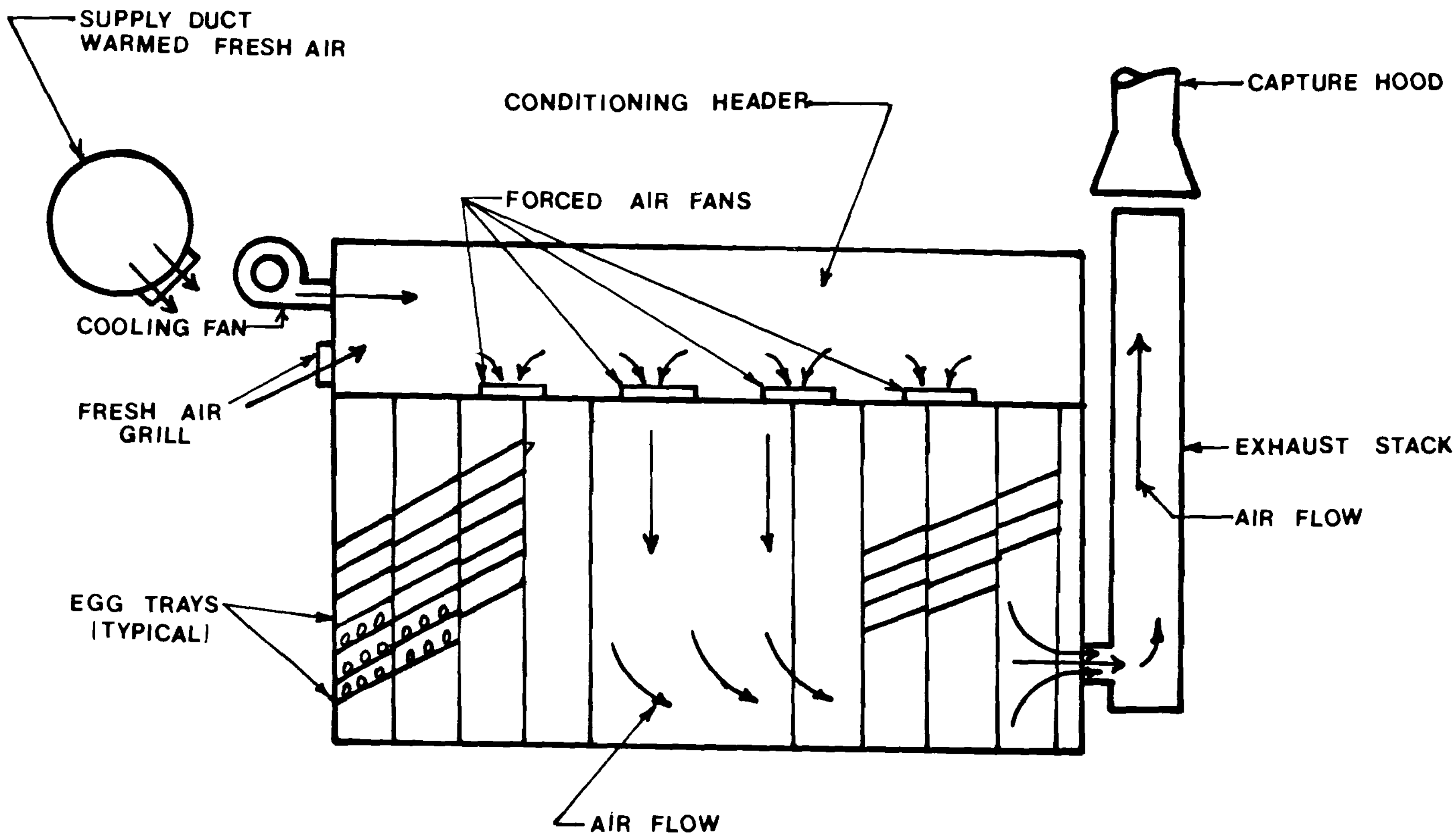
To reclaim the heat from this exhaust air, a Z-Duct air-to-air heat exhanger, Model 75M4A6 was selected. This unit is designed to operate up to 5,000 cu ft per minute, with a nominal rating of 4,000 cu ft per minute. The duct system, consisting of fresh air supply and contaminated air extraction, was designed using the ASHRAE Handbook of Fundamentals and the Manual for Recommended Practice of Industrial Ventilation published by The Committee on Industrial Ventilation. Figure 8.1 shows the component layout of the system as it is installed in the hatchery.

With reference to Figure 8.2, space air from the setter room is drawn through a grill opening in the front of the setter into the header section where the air is then con-



HATCHERY HEAT RECOVERY SYSTEM

FIGURE 8.1



EGG SETTER CROSS SECTION

FIGURE 8.2

ditioned by heating/cooling/humidifying as necessary. To properly set the eggs, the air is maintained at 99.5°F plus or minus 1/4 of 1°. The moisture content of the air is maintained between wet bulb temperatures of 85° and 95°F. After the air has been conditioned, it is forced by 4 fans, located in the bottom of the header section, through the egg trays. After passing through the egg trays to the bottom of the unit, it then moves toward the rear and exits through an exterior exhaust stack.

From the setter exhaust stack, the contaminated air is drawn into the extraction system. The extraction system is simply a duct with multiple hooded intakes designed to capture the setter exhaust. To do this, the extraction system maintains a constant suction. To prevent the system from influencing the performance of the setter units, there is a physical separation of approximately 1 to 3 inches between the setter exhaust air stack and the capture hood of the extraction system. From the capture hood, the exhaust air moves into the manifold portion of the extraction system and then to the centrifugal blower, which is a Lockwood Model 146S. From the blower, the exhaust air moves to the heat exchanger.

The heat exchanger contains an aluminum membrane that is folded so as to provide a long path of travel as well as separating the exhaust air from the fresh air supply. In this unit, the warm exhaust air gives up its heat to the cold incoming fresh air. After the exhaust has finished its travel through the heat exchanger, it passes to the outside of the building.

Fresh air is brought in through rooftop mounted evaporative coolers. In the summertime the air from these coolers simply bypasses the heat exchanger and goes directly into the space air of the setter room since there is no need for further heating. In the wintertime, however, the water supply to the evaporative coolers is disconnected and the pads of the evaporative cooler are used to filter the incoming fresh air. The fresh air is then directed into the heat exchanger where it picks up heat by contact with the aluminum membrane. From the heat exchanger, the warmed air passes into the supply duct. This duct runs in front of the setter units for their total length. Periodically, there are outlets from which fresh air is supplied to the setter room. The outlet is so positioned to direct the fresh air toward the entrance grill of the setter unit.

D. Results and Discussions

At the end of the fiscal year 1980, the heat recovery system was operational but still required final system balancing and the installation of data collection instrumentation. An economic analysis appears in Table 8.1. This shows that over the 20 year life expectancy of the system, the amortized annual cost (at 10%) is $825.79 per year. Based on climatic data for Cornelia, Georgia, which is approximately 10 miles from Clermont and the closest weather data collection station, there are 3,497 degree days of heating per year. As the fresh air is supplied to the setter units between 70° to 80°F, air at temperatures below this must be heated in some manner. Currently this is done by ceiling suspended, lp gas-fired, space heating units. To provide the 18 million Btu's that each setter unit requires each year, these space heaters must burn approximately 2,000 gallons of propane. At 65¢ per gallon, this represents a cost of $1,300 per year. At the amortized cost of $825.79 per year, this leaves an actual savings of $474.21 per year (utilizing 10 setters).

Item	November 1980 $
1) Heat Exchanger t=0	$ 2,525
2) Duct System and Condensate Drain t=0	$ 3,030
3) Labor - Installation t=0	$ 1,473
	$ 7,028

Amortized Annual Cost @ 10% for 20 yrs. is:

(7,028) (.1175) = $ 825.79

Legend	
t=0	20 year life
t=0,5,10,15	replace every 5 years
t=0,1,2,...,18,19	replace every year

ECONOMIC ANALYSIS OF HATCHERY HEAT RECOVERY SYSTEM

TABLE 8.1

actual savings would be realized since the only additional cost to be amortized would be that of the extra duct system and its installation cost.

E. Conclusion

As the cost of lp gas continues its upward price climb, the savings shown by this heat recovery system will be even greater in the future. It is virtually a painless way to make money since the system requires practically no maintenance other than periodic cleaning. It is anticipated that the data collected in the 1980-81 heating season will bear this out.

IX. ENERGY CONSERVATION IN THE POULTRY INDUSTRY

by
Bill Nolte

A. Energy Consumption Survey

The energy consumption survey that was begun in 1976 was continued for this year. As in previous years, monthly data was collected for the calendar year 1979. Information received included the usage and cost of electricity, natural gas, propane, and fuel oil. Tables 9.1, 9.2, 9.3, and 9.4 show respectively the energy survey results for broiler processors, egg processors, hatcheries, and feed mills. Tables 9.5, 9.6, 9.7, and 9.8 show the energy consumption and cost parameters for each section of the industry for the years 1976, 1977, and 1978, respectively. Values for the average consist of the sum of the responses for each category divided by the number of respondents. Range denotes the highest and lowest response in each category. Median denotes response value for which 50% of the responses are higher and 50% are lower. When the median is significantly different from the average, it generally means that one or more of the responses was considerably higher or lower than the average.

B. Poultry Engineering Progress

As an adjunct to the energy conservation effort, publication of a monthly newsletter, Poultry Engineering Progress, was begun in 1976. Surveys have been made to determine reader preference with regard to format, subject matter, length, etc., and these suggestions have been incorporated into the current newsletter.

ENERGY SURVEY RESULTS: GEORGIA BROILER PROCESSORS

CODE NUMBER		1976	1977	1978	1979	%Change Over 1977	%Change Over 1978
10001	Btu/1000 lbs	1,708,841	836,154	722,012	519,777	- 13.65	- 28
	$/1000 lbs	$4.371	$3.965	$4.836	$19.27	+ 10.62	+ 339.3
10002	Btu/1000 lbs	——	830,852	835,689	——	+ 0.58	——
	$/1000 lbs	——	$2.882	$3.846	——	+ 33.45	——
10003	Btu/1000 lbs	867,856	806,073	755,034	1,096,885	- 3.85	+ 45.27
	$/1000 lbs	$3.568	$3.674	$3.761	$ 3.91	+ 2.37	+ 3.96
10004	Btu/1000 lbs	1,284,920	698,725	707,297	1,074,026	+ 1.27	+ 51.85
	$/1000 lbs	$4.739	$3.133	$2.473	$ 4.83	- 21.07	+ 95.31
10005	Btu/1000 lbs	——	——	——	——	——	——
	$/1000 lbs	——	——	——	——	——	——
10006	Btu/1000 lbs	——	——	——	——	——	——
	$/1000 lbs	——	——	——	——	——	——
10007	Btu/1000 lbs	1,126,037	906,490	839,071	781,692	- 7.44	- 6.84
	$/1000 lbs	$4.415	$3.539	$3.618	$ 3.77	+ 2.24	+ 4.20
10008	Btu/1000 lbs	——	——	——	——	——	——
	$/1000 lbs	——	——	——	——	——	——
10009	Btu/1000 lbs	——	——	——	——	——	——
	$/1000 lbs	——	——	——	——	——	——
10010	Btu/1000 lbs	——	——	——	——	——	——
	$/1000 lbs	——	——	——	——	——	——
10011	Btu/1000 lbs	783,254	——	816,867	419,199	——	- 48.68
	$/1000 lbs	$3.51	——	$3.827	$ 3.13	——	- 18.21
10012	Btu/1000 lbs	——	——	709,476	——	——	——
	$/1000 lbs	——	——	$3.249	——	——	——
10013	Btu/1000 lbs	1,312,161	——	1,028,117	905,872	——	- 11.89
	$/1000 lbs	$5.750	——	$5.194	$ 5.86	——	+ 12.82
10014	Btu/1000 lb	1,278,445	——	1,085,032	721,909	——	- 33.47
	$/1000 lbs	$4.149	——	$4.358	$3.20	——	- 26.57
10015	Btu/1000 lb	——	——	878,100	——	——	——
	$/1000 lbs	——	——	$4.48	——	——	——
10016	Btu/1000 lb	——	——	——	721,180	——	——
	$/1000 lbs	——	——	——	$8.28	——	——
10017	Btu/1000 lb	——	——	——	——	——	——
	$/1000 lbs	——	——	——	——	——	——
AVERAGE	Btu/1000 lb	1,407,211	952,864	834,639	693,393	- 12.4	- 16.92
	$/1000 lbs	$4.657	$3.97	$3.87	$6.53	- 2.52	+ 68.73

TABLE 9.1

TABLE 9.2

ENERGY SURVEY RESULTS: GEORGIA EGG PROCESSORS

CODE NUMBER		1976	1977	% CHANGE OVER 1976	1978	% CHANGE OVER 1977
20001	BTU / 1000 doz	———	———	———	458,860	———
	$ / 1000 doz	———	———	———	$4.773	———
20002	BTU / 1000 doz	237,924	248,340	+4.38	266,939	+7.49
	$ / 1000 doz	$1.637	$2.002	+22.30	$2.328	+16.28
20003*	BTU / 1000 doz	71,285	75,104	+5.36	111,443	+48.38
	$ / 1000 doz	$0.861	$0.961	+11.61	$1.539	+60.15
20004	BTU / 1000 doz	672,652	401,019	-40.38	459,005	+14.46
	$ / 1000 doz	$4.141	$3.680	-11.13	$4.055	+10.19
20005	BTU / 1000 doz	317,888	267,746	-15.77	277,766	+3.74
	$ / 1000 doz	$1.115	$1.128	+1.17	$1.339	+18.71
AVERAGE	BTU / 1000 doz	370,567	278,022	-24.97	359,639	+29.36
	$ / 1000 doz	$2.090	$2.014	-3.64	$2.989	+48.41

*Electricity Only

TABLE 9.3

ENERGY SURVEY RESULTS: GEORGIA HATCHERIES

CODE NUMBER		1976	1977	1978	1979	% Change Over 1977	% Change Over 1978
30001	Btu/1000Brds	338,876	281,835	319,076	—	+ 13.21	—
	$/1000 Brds	$1.812	$1.867	$2.010	—	+ 7.66	—
30002	Btu/1000Brds	—	246,979	202,161	—	- 18.15	—
	$/1000 Brds	—	$1.243	$1.112	—	- 10.54	—
30003	Btu/1000Brds	—	198,803	257,736	—	+ 29.64	—
	$/1000 Brds	—	$1.3500	$1.700	—	+ 25.93	—
30004	Btu/1000Brds	—	—	488,921	—	—	—
	$/1000 Brds	—	—	$2.104	—	—	—
30005	Btu/1000Brds	—	—	408,311	—	—	—
	$/1000 Brds	—	—	$2.474	—	—	—
30006	Btu/1000Brds	—	—	373,527	—	—	—
	$/1000 Brds	—	—	$3.407	—	—	—
30007	Btu/1000Brds	—	—	385,581	—	—	—
	$/1000 Brds	—	—	$2.522	—	—	—
30008	Btu/1000Brds	—	—	236,662	—	—	—
	$/1000 Brds	—	—	$3.756	—	—	—
30009	Btu/1000Brds	—	—	—	320,832	—	—
	$/1000 Brds	—	—	—		—	—
AVERAGE	Btu/1000Brds	338,876	235,985	351,845	320,832	+ 49.10	- 9.66
	$/1000 Brds	$1.812	$1.487	$2.142	$1.89	+ 44.05	-13.3

TABLE 9.4

ENERGY SURVEY RESULTS: GEORGIA FEED MILLS

CODE NUMBER		1976	1977	1978	1979	% Change Over 1977	% Change Over 1978
40001	Btu/tons	—	—	351,891	—	—	—
	$/tons	—	—	$1.393	—	—	—
40002	Btu/tons	—	—	335,926	458,448	—	+ 36.5
	$/tons	—	—	$1.567	$2.215	—	+ 41.35
40003	Btu/tons	—	—	26,946	—	—	—
	$/tons	—	—	$.228	—	—	—
40004	Btu/tons	—	—	144,676	—	—	—
	$/tons	—	—	$.618	—	—	—
40005	Btu/tons	222,071	—	212,238	218,864	—	+ 3.12
	$/tons	$.649	—	$.913	$1.1	—	+ 20.48
40006	Btu/tons	132,820	—	208,191	171,229	—	- 17.25
	$/tons	$.640	—	$1.124	$1.1	—	- 2.14
40007	Btu/tons	—	—	10,791	—	—	—
	$/tons	—	—	$.211	—	—	—
40008	Btu/tons	—	—	28,301	—	—	—
	$/tons	—	—	$.491	—	—	—
AVERAGE	Btu/tons	—	—	186,676	282,847	—	+ 51.52
	$/tons	—	—	$.853	$1.47	—	+ 72.33

1976

HATCHERIES (6)	Average	Range		Median
		Low	High	
Btu/1000 Birds	365,635	300,353	485,169	338,876
$/1000 Birds	1.851	1.714	2.670	1.812
EGG PROCESSORS (5)				
Btu/1000 Doz Eggs	370,567	71,285	672,652	246,797
$/1000 Doz Eggs	2.090	0.861	4.141	1.637
FEED MILLS (7)				
Btu/Ton	210,029	47,524	253,188	211,124
$/Ton	0.743	0.342	1.116	0.691
POULTRY PROCESSORS (9)				
Btu/1000 Lbs*	1,407,811	783,254	2,032,285	1,278,445
$/1000 Lbs*	4.657	3.551	5.750	4.413

* = Processed Weight

Numbers in parenthesis indicate the number of respondents in each category.

ENERGY SURVEY SUMMARY

TABLE 9.5

1977

HATCHERIES (9)	Average	Range		Median
		Low	High	
Btu/1000 Birds	431,216	141,540	724,787	286,911
$/1000 Birds	1.274	0.974	2.676	1.445
EGG PROCESSORS (6)				
Btu/1000 Doz Eggs	278,092	75,104	401,019	258,043
$/1000 Doz Eggs	2.014	0.961	3.680	2.040
FEED MILLS (5)				
Btu/Ton	190,834	135,502	247,988	183,427
$/Ton	0.759	0.639	1.033	0.853
POULTRY PROCESSORS (8)				
Btu/1000 Lbs*	1,063,084	789,189	2,829,383	845,234
$/1000 Lbs*	4.288	2.882	11.384	3.607

* = Processed Weight

ENERGY SURVEY SUMMARY

TABLE 9.6

1978

HATCHERIES (8)	AVERAGE	RANGE		MEDIAN
		LOW	HIGH	
BTU/1000 Birds	351,845	202,161	488,921	346,302
$/1000 Birds	$2.142	$1.112	$3.756	$2.289
EGG PROCESSORS (5)				
BTU/1000 Doz Eggs	359,039	111,443	485,860	277,766
$/1000 Doz Eggs	$2.989	$1.339	$4.773	$2.328
FEED MILLS (8)				
BTU/Ton	186,676	10,781	351,891	176,434
$/Ton	$ .853	$ .211	$1.567	$ .766
POULTRY PROCESSORS (10)				
BTU/1000 Lbs*	834,639	707,297	1,085,032	826,278
$/1000 Lbs*	$3.870	$2.473	$5.194	$3.837

* Processed Weight

Numbers in parenthesis indicate the number of respondents in each category.

ENERGY SURVEY SUMMARY

TABLE 9.7

1979

HATCHERIES (2)	AVERAGE	RANGE LOW	RANGE HIGH	MEDIAN
Btu/1,000 Birds	320,832	---	----	---
$/1,000 Birds	$1.89	---	----	---
EGG PROCESSORS (0)				
Btu/1,000 Doz. Eggs	---	---	----	---
$/1,000 Doz. Eggs	---	---	----	---
FEED MILLS (3)				
Btu/Ton	282,848	171,230	458,448	218,865
$/Ton	$1.48	$1.08	$2.22	$1.13
POULTRY PROCESSORS (9)				
Btu/1,000 lbs*	693,393	419,199	1,096,885	721,545
$/1,000 lbs*	6.53	3.13	19.27	4.37

*Processed Weight
Numbers in parenthesis indicate the number of respondents in each category.

ENERGY SURVEY SUMMARY

TABLE 9.8

The intent of Poultry Engineering Progress is to keep the industry apprised of the various energy conservation projects being conducted by Georgia Tech. Throughout the year, the results of each project are updated as new data becomes available. It is hoped this method will keep the industry immediately aware of any energy saving opportunities. A representative copy of the Poultry Engineering Progress can be found in Figure 9.1.

poultry
engineering
progress

a newsletter of the technology/development lab
georgia tech engineering experiment station
atlanta, georgia 30332 (404) 894-3623

l. 5 no. 4

LAR
OULTRY
HOUSE

An open house was held on Saturday, April 5, at the site of the Villa Rica solar heated broiler house demonstration project. Work has recently been completed on modifications to this solar energy air heater. The changes included installation of a new steel absorber surface, cleaning of the collector glazing, installation of a new control system, and improvements in the data collection system. A filter is now being added to reduce the fouling of the collector by dust carried in by outside air.

AR
IDUSTRIAL
PROCESSES

The Georgia Tech Engineering Experiment Station has begun a program to inform Georgia industrial plants about the possibilities of using solar energy to power industrial processes. The six month program, sponsored by the Southern Solar Energy Center in Atlanta, involves visits to twenty textile and food processing plants including several poultry and egg processing plants. During these visits, Tech researchers will present information on current solar technology and the economics of solar energy for industrial process heat. They will also survey the plants for possible applications of solar energy and receive input from plant personnel on their attitudes towards solar energy and any existing barriers to the implementation of solar industrial process heat. Later, Georgia Tech will select six industrial plants for case studies. Engineers will design solar systems for processes in each of these six plants, then report back to management with their findings. In doing so, the research team will accumulate information on the factors which would lead industires to implement solar plans.

For more information, contact Wiley Holcome, 404-894-3623.

FIGURE 9.1

APPENDIX A

DATA ACQUISITION SYSTEM

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Operation of the Data Acquisition System

The path of a signal through the data acquisition system is shown in Figure 1. A signal, say from a thermocouple, goes into the Esterline Angus recorder where it is recorded on paper. This same input signal is transmitted to the sample/hold circuit where it is held until the datalogger reads it. The datalogger reads the analog signal, converts it to a digital signal and then records it on a cassette tape.

Esterline Angus 24 Channel Recorder

The Esterline Angus 24 channel recorder is capable of recording two types of signals. Range A records DC voltage signals from 0 to 100 mv. Range B records type T thermocouple signals from 0 to 300°F.

To get the signal out of the recorder and into the sample/hold circuit, a retransmitting potentiometer was installed in place of the original potentionmeter. This new potentiometer does not affect the operation of the recorder at all. It only allows the same input signal to be transmitted to another device which in our case is the sample/hold circuit.

Sample/Hold Circuit

The sample/hold circuit reads the signal from the Esterline Angus recorder and holds it until the datalogger is ready to read it. The purpose for having the sample/hold circuit is to alleviate any problems with synchronizing the cycle rates of the Esterline Angus and the datalogger. Both of the instruments can cycle at various rates; however, trying to synchronize these rates appeared to be more difficult than using the sample/hold circuits.

Measurement of the droop, which is the voltage drop or rise over a certain time period, showed it to equal about -3.8 mv per minute. This is higher than the specifications which say the droop should not exceed ± 2.4 mv per minute. (The droop may be either positive or negative.) A -3.8 mv per minute droop translates to a temperature drop of about 1°F in five minutes.

The sample and hold circuit has the capacity of sampling and holding information for 24 channels. However, only 12 IC's have been bought so only 12 channels can be used. To use the other 12 channels, 12 more IC's must be bought and plugged into the two remaining circuit boards.

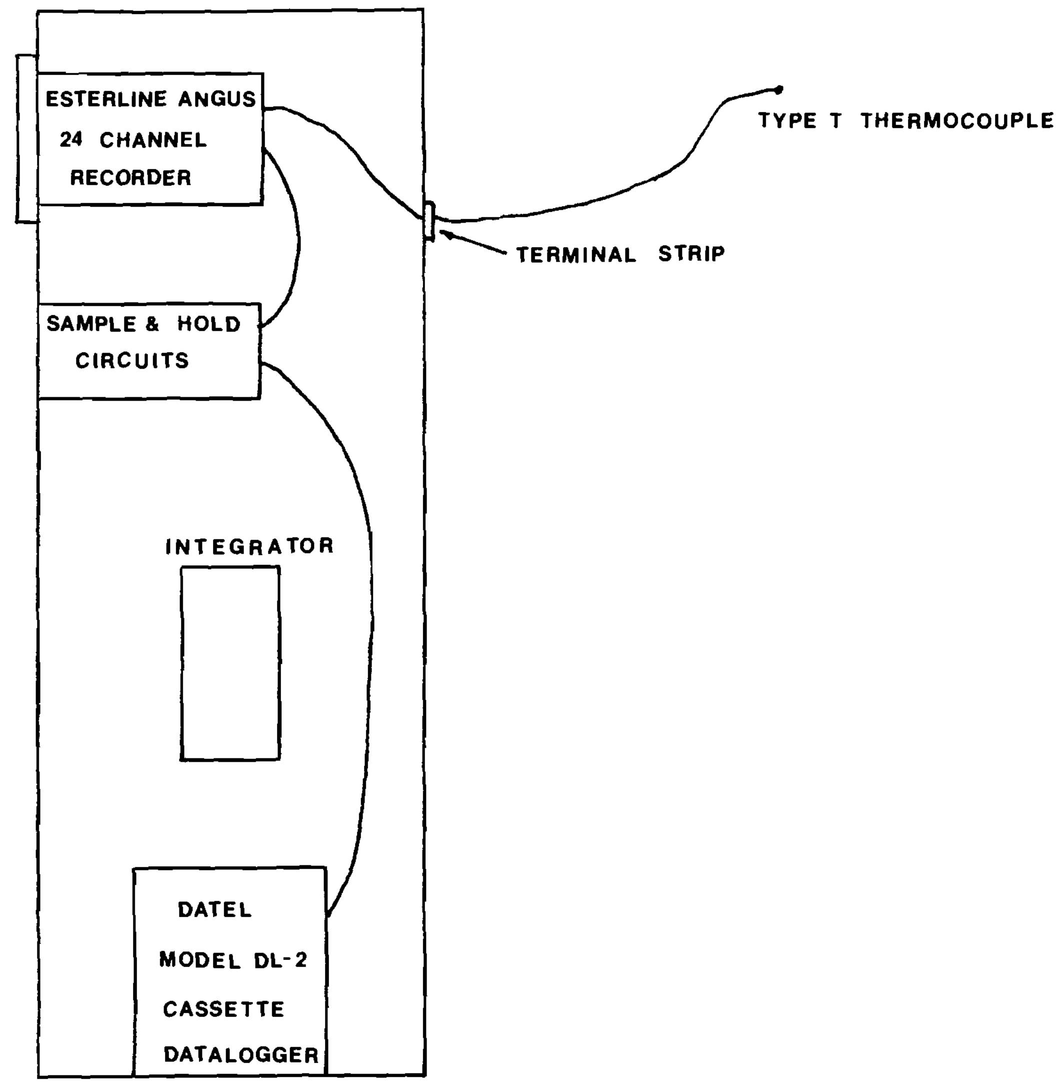


FIGURE 1 — DATA ACQUISITION SYSTEM

DATEL Model DL-2 Cassette Datalogger

The DATEL datalogger can record 64 channels of information. Thirty-two of these channels are high level channels capable of recording signals in the range of -5 v to +5 v. The remaining thirty-two channels are low level channels capable of recording signals in the range of -5 mv to +5 mv.

Presently, only the first 24 of the 32 high level channels are being used. The remaining 8 high level channels (channels 25-32) can not be easily used. To use these channels, the military plug for jack J-13 would have to be disassembled so that channels 25-32 could be "wired in." Only 24 channels were used because the Esterline Angus recorder has only 24 channels.

None of the 32 low level channels will be used for monitoring the solar collector at Villa Rica. Consequently, the military plugs for these channels have not been wired up. If further monitoring requires the use of these 32 channels, then the datalogger manual should be consulted for proper installation to prevent a voltage overload.

Possibility of Erroneous Data

The possibility of recording erroneous data exists when the datalogger reocrds a channel at the same instant when the channel switches from the hold mode to the sample mode. This is because the slide wire will be moving from the value of the previous channel to the value of the present channel. If the datalogger records while the slide wire is moving, it will give an erroneous value.

A lock out switch could have been used to avoid this problem. However, this problem was thought to be insignificant so a lock out switch was not installed.

Wiring Code for Cables Linking, the Esterline Angus Recorder, the Sample/Hold Circuit and the Datalogger

A single cable links the Esterline Angus 24 channel recorder to the sample and hold circuit. At the recorder, the wires in the cable are connected to the gang switch. At the sample/hold circuit the wires are connected to a fifty pin connector which plugs into the back of the sample/hold circuit. Only Pins 1-12, 14, 26-37, and 39 are used.

Two cables link the sample/hold circuit to the Datalogger. At the sample/hold circuit, both cables are attached to a single fifty pin connector which plugs into the back of the circuit. Cable 1 carries channels 1-16 and uses pins 1-12 and 26-29. Similiarly, Cable 2 carries channels 17-24 and uses Pins 30-37. Pins 14 and 39 are used as the ground.

At the Datalogger a military plug is attached to each of the cables. Cable 1 uses plug type PT06E-22-36PWSR and mates with Jack J-12 in the datalogger. Similiarly, Cable 2 uses plug type PT07S-22-36SX and mates with Jack J-13 in the datalogger.

WIRING CODE

Wiring Code

Fifty Pin Plug on Cable from Esterline Angus to Sample/Hold Circuit

CHANNEL	PIN	COLOR CODE
1	1	Yellow/Orange
2	2	Green
3	3	Yellow/Red
4	4	Yellow/Green
5	5	Blue
6	6	Orange
7	7	White/Blue
8	8	Violet
9	9	Brown
10	10	White
11	11	White/Brown
12	12	Yellow
13	26	White/Gray
14	27	Red
15	28	Yellow/Brown
16	29	Gray
17	30	Yellow/Black
[illegible]	[illegible]	[illegible]
19	32	White/Green
20	33	White/Violet
21	34	White/Orange
22	35	Yellow/Blue
23	36	White/Yellow
24	37	White/Red
Ground	14,39	Black

Fifty Pin Plug on Cables from Sample/Hold to Datalogger

CHANNEL	PIN	COLOR CODE
1	1	Violet
2	2	Brown
3	3	Red
4	4	Orange
5	5	Blue
6	6	White/Orange
7	7	Gray
8	8	White/Brown
9	9	White/Red/Black
10	10	Yellow
11	11	White/Black
12	12	White
13	26	Green
14	27	White/Red
15	28	White/Blue
16	29	White/Gray
17	30	White/Yellow
18	31	White/Green
19	32	White/Violet
20	33	White/Black/Green
21	34	White/Black/Yellow
22	35	White/Black/Blue
23	36	White/Black/Orange
24	37	White/Black/Brown
Ground	14,39	Black

Military Plug on Cable 1 from Sample/Hold to Datalogger
(For Jack J-12)

CHANNEL	PIN	COLOR CODE
1 high	C	Violet
1 low	D	Black
2 high	E	Brown
2 low	F	Black
3 high	n	Red
3 low	k	Black
4 high	W	Orange
4 low	X	Black
5 high	Y	Blue
5 low	G	Black
6 high	S	White/Orange
6 low	f	Black
7 high	a	Gray
7 low	J	Black
8 high	B	White/Brown
8 low	V	Black
9 high	h	White/Red/Black
9 low	j	Black
10 high	Z	Yellow
10 low	H	Black
11 high	m	White/Black
11 low	l	Black
12 high	b	White
12 low	K	Black
13 high	A	Green
13 low	T	Black

Military Plug on Cable 1 from Sample/Hold to Datalogger
(continued)

CHANNEL	PIN	COLOR CODE
14 high	M	White/Red
14 low	L	Black
15 high	R	White/Blue
15 low	e	Black
16 high	U	White/Gray
16 low	g	Black

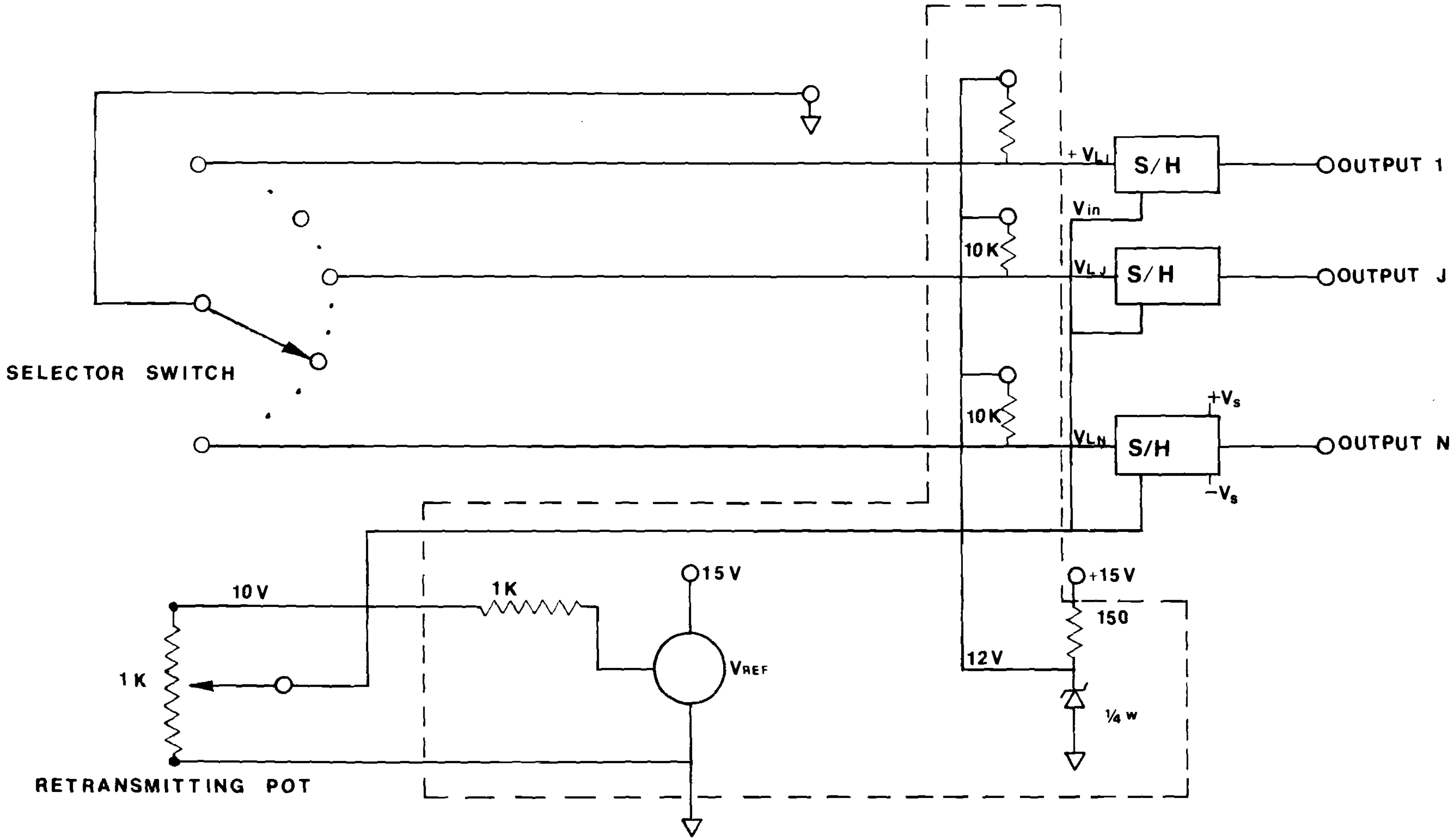
NOTE: ALL GROUNDS ARE JUMPERED INSIDE THE PLUG.

Military Plug on Cable 2 from Sample/Hold to Datalogger
(For Jack J-13)

CHANNEL	PIN	COLOR CODE
17 high	C	White/Yellow
17 low	D	Black
18 high	E	White/Green
18 low	F	Black
19 high	n	White/Violet
19 low	k	Black
20 high	a	White/Black/Green
20 low	J	Black
21 high	W	White/Black/Yellow
21 low	X	Black
22 high	m	White/Black/Blue
22 low	l	Black
23 high	S	White/Black/Orange
23 low	f	Black
24 high	Y	White/Black/Brown
24 low	G	Black

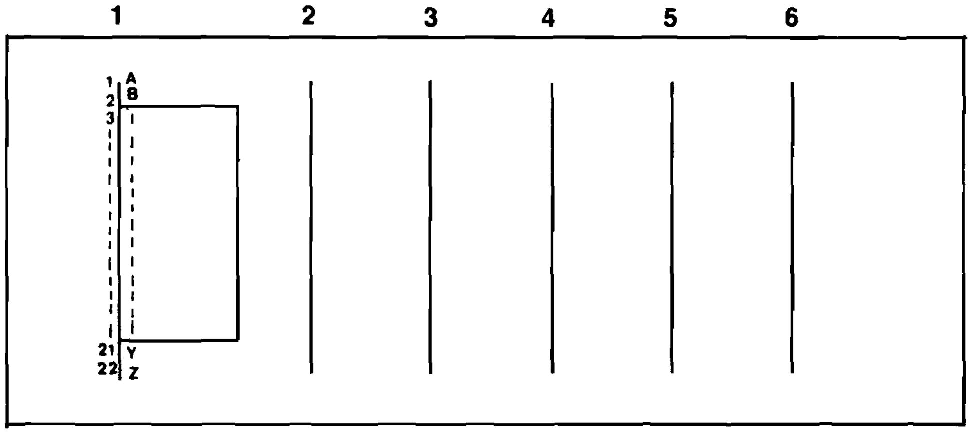
NOTE: ALL GROUNDS ARE JUMPERED INSIDE THE PLUG.

MULTIPOINT RECORDER TO DATALOGGER INTERFACE



MULTIPOINT RECORDER TO DATA LOGGER INTERFACE

SAMPLE/HOLD CARD POSITION DIAGRAM



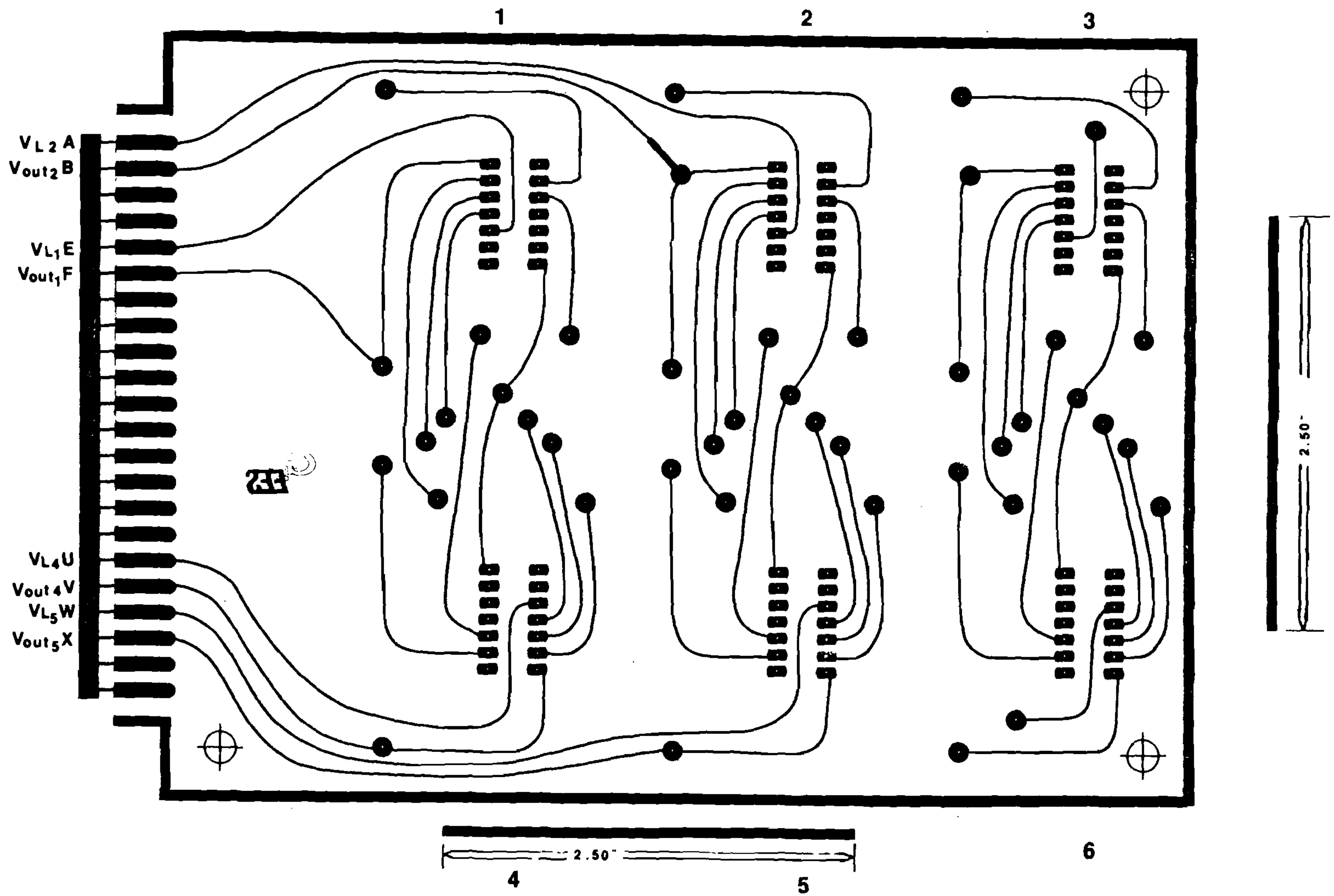
FRONT VIEW

BOARD	DESCRIPTION
1	POWER SUPPLY
2	PULLUP 10.00 V
3	CH 1-6
4	CH 7-12
5	CH 13-18
6	CH 19-24

SAMPLE / HOLD CARD POSITION DIAGRAM

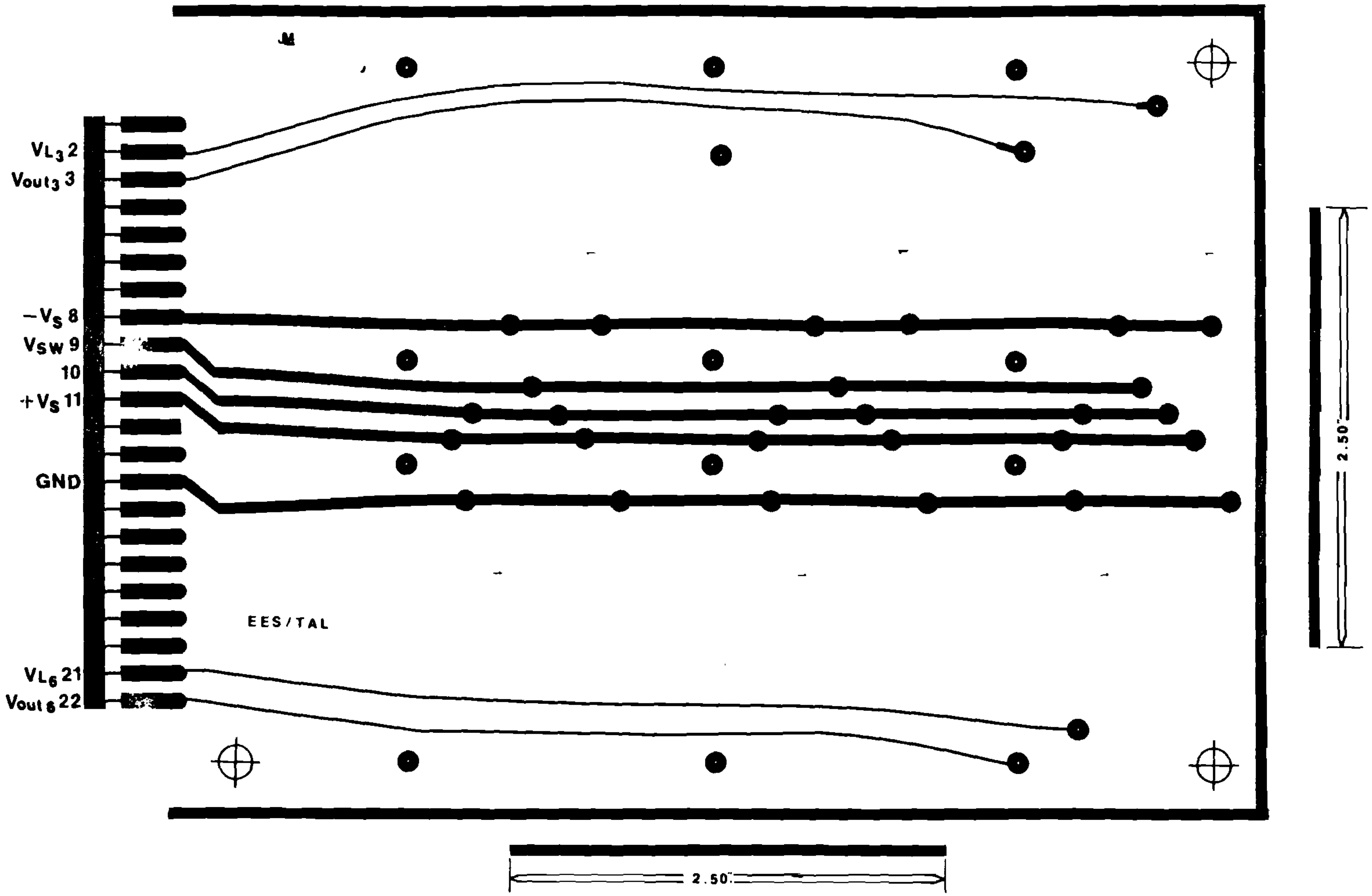
DIAGRAMS FOR BOARDS

3,4,5, & 6

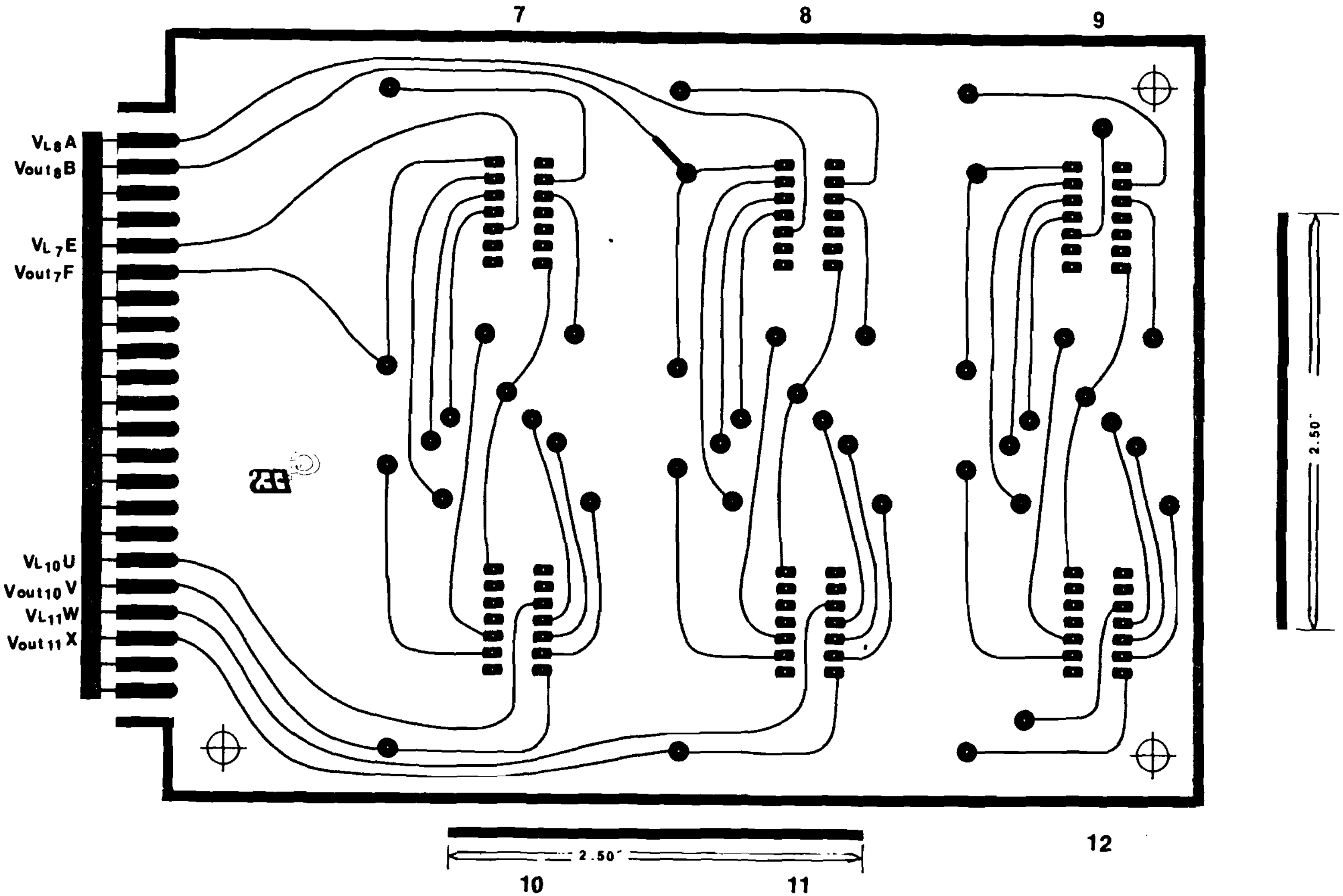


BOARD 3

CHANNELS 1 to 6

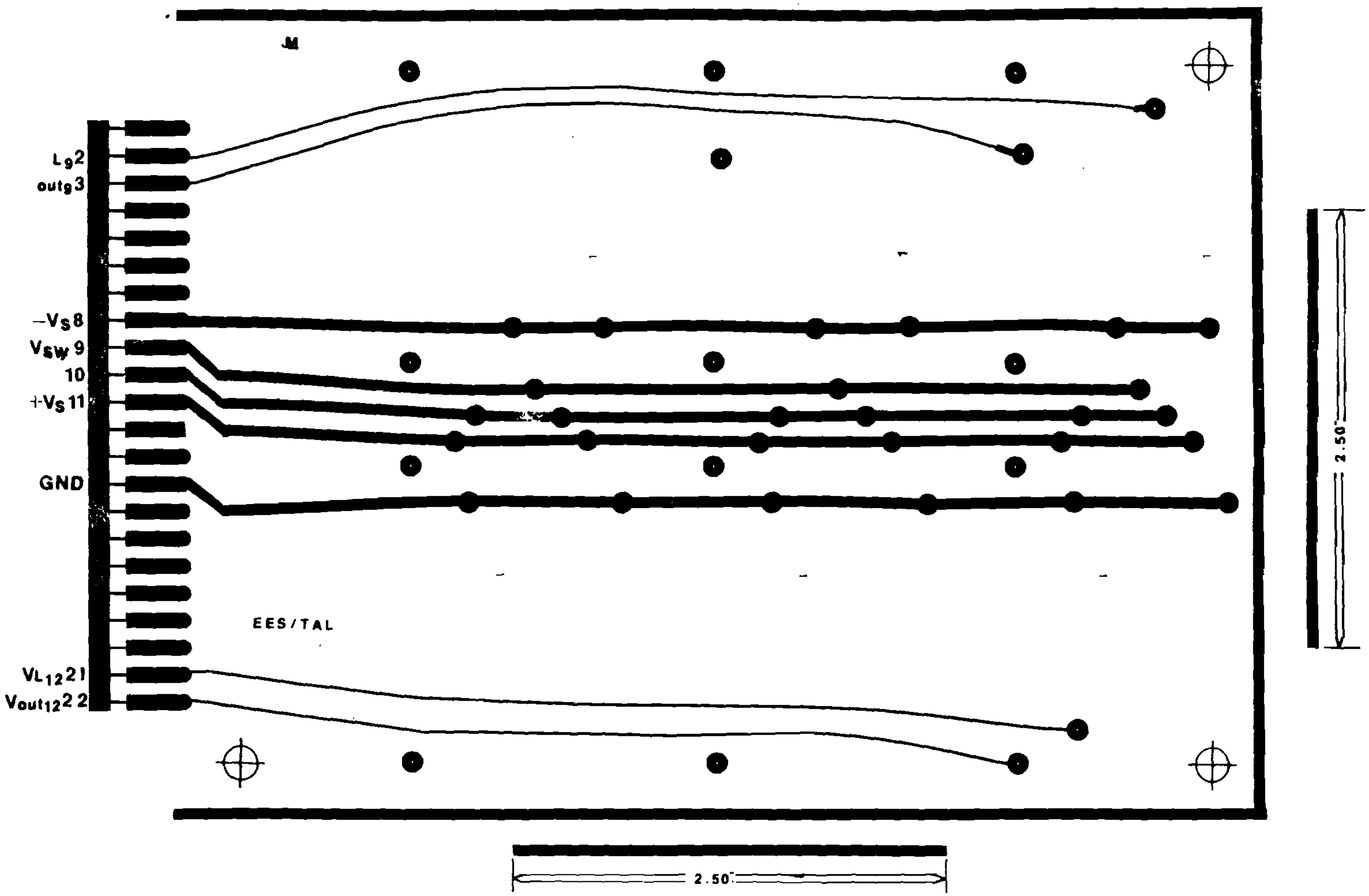

VL3 2
Vout3 3
−VS 8
VSW 9
10
+VS 11
GND
VL6 21
Vout6 22
EES/TAL
2.50"
2.50"

BOARD 3



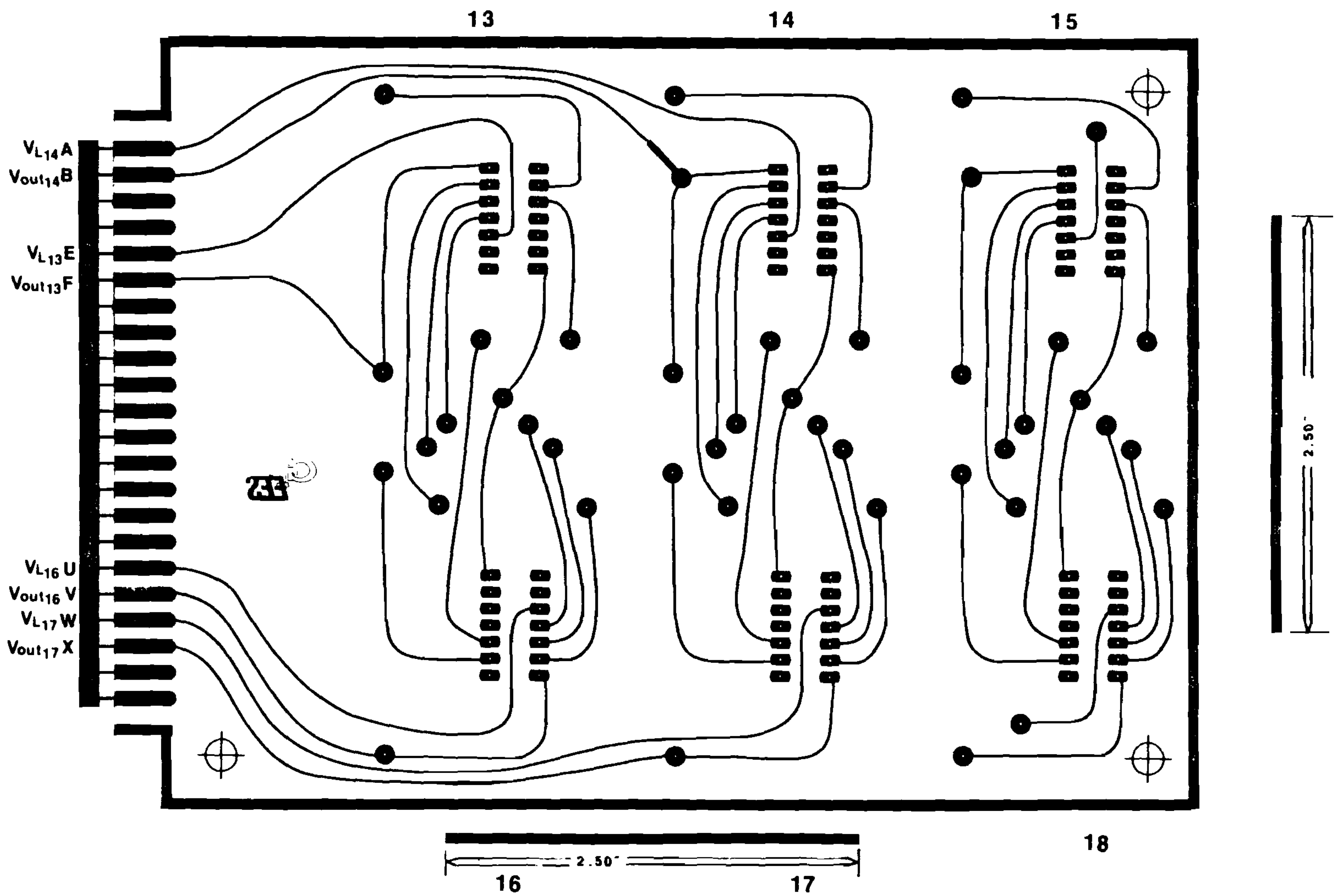
BOARD 4

CHANNELS 7 to 12



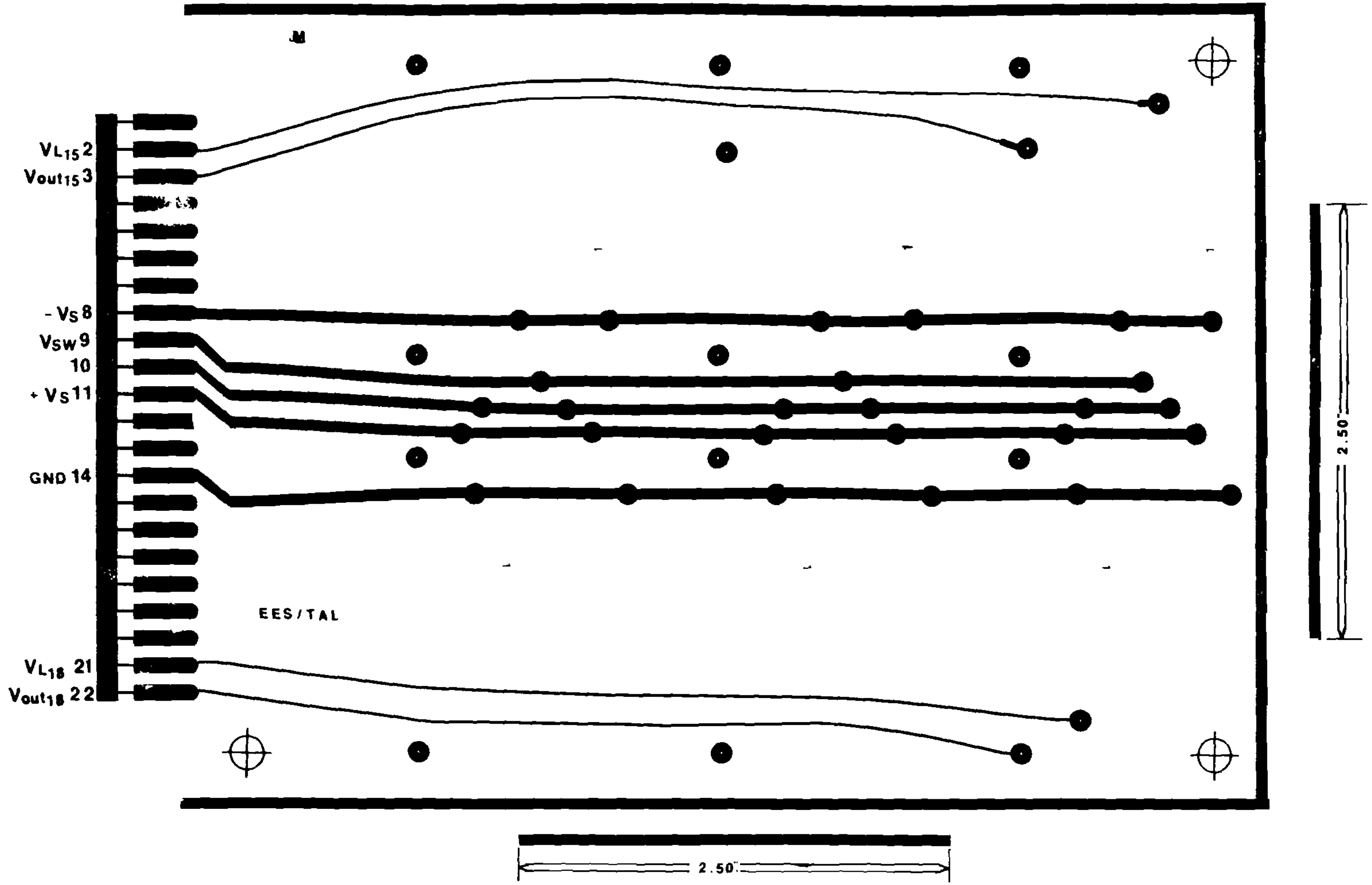
Lg2
outg3
-Vs8
Vsw 9
10
+Vs11
GND
VL12 21
Vout12 22
EES/TAL
2.50
2.50

BOARD 4

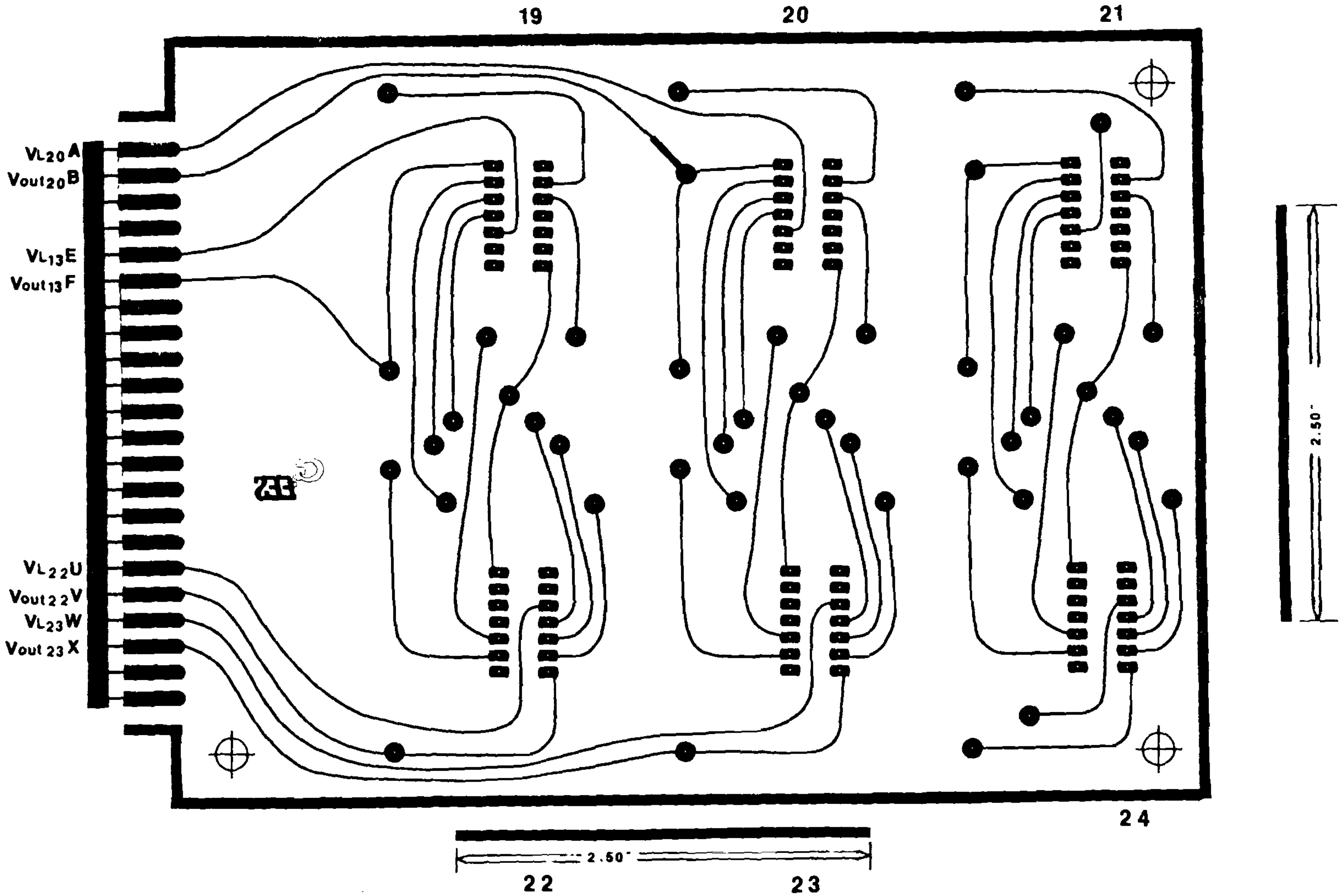


BOARD 5

CHANNELS 13 to 18

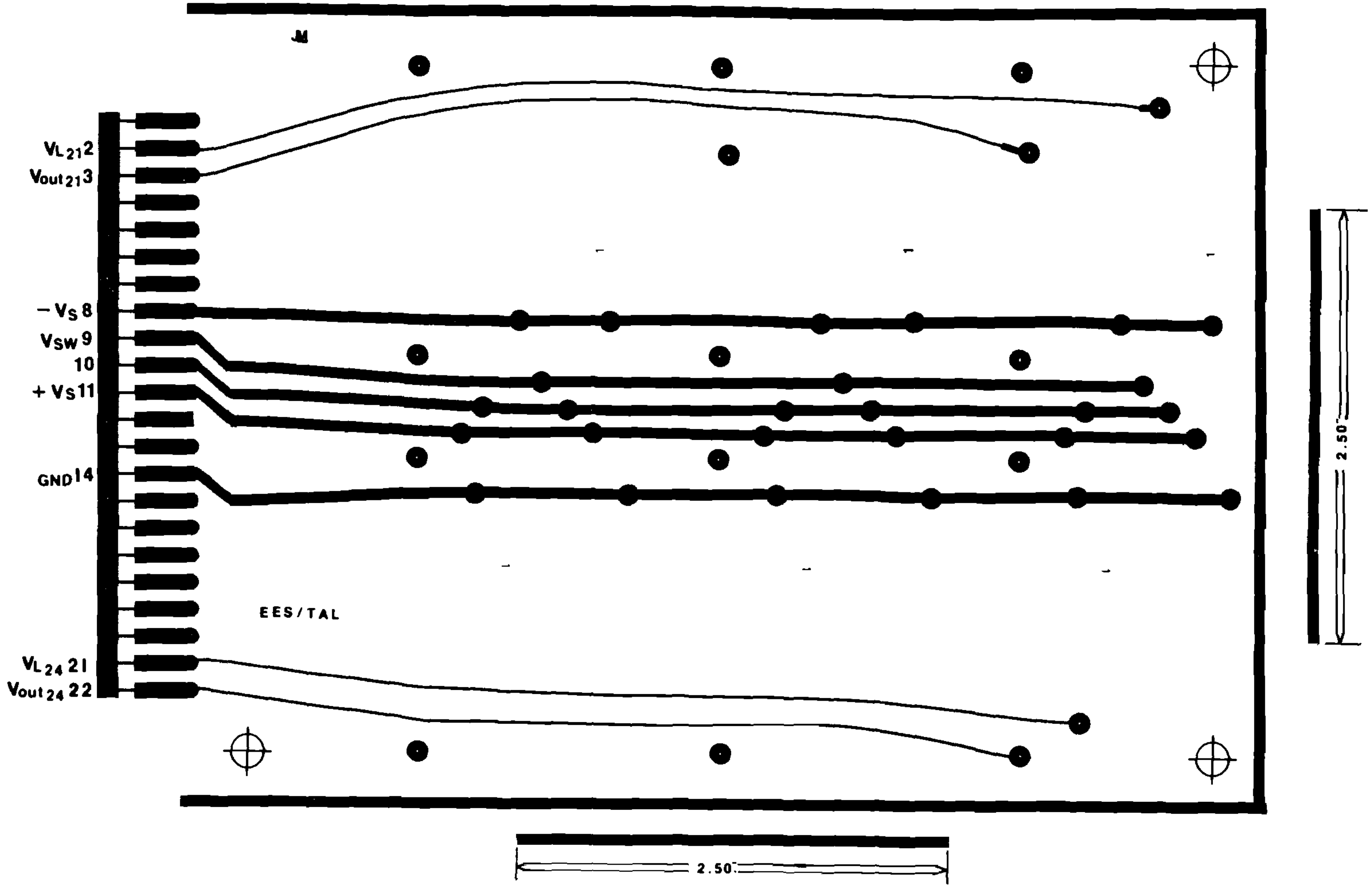

VL15 2
Vout15 3
- Vs 8
Vsw 9
10
+ Vs 11
GND 14
EES/TAL
VL18 21
Vout18 22
2.50"
2.50"

BOARD 5



BOARD 6

CHANNELS 19 to 24


VL21 2
Vout21 3
− VS 8
VSW 9
10
+ VS 11
GND 14
VL24 21
Vout24 22
EES/TAL
2.50"
2.50"

BOARD 6

CASSETTE CAPACITY

APPENDIX 5

CASSETTE CAPACITY

Number of Scans per Cassette as a function of Number of Channels per Scan. The graph shows the number of scans that a 300' tape cassette can accumulate as a function of the number of channels per scan. The number of channels is plotted from one (1) to (64).

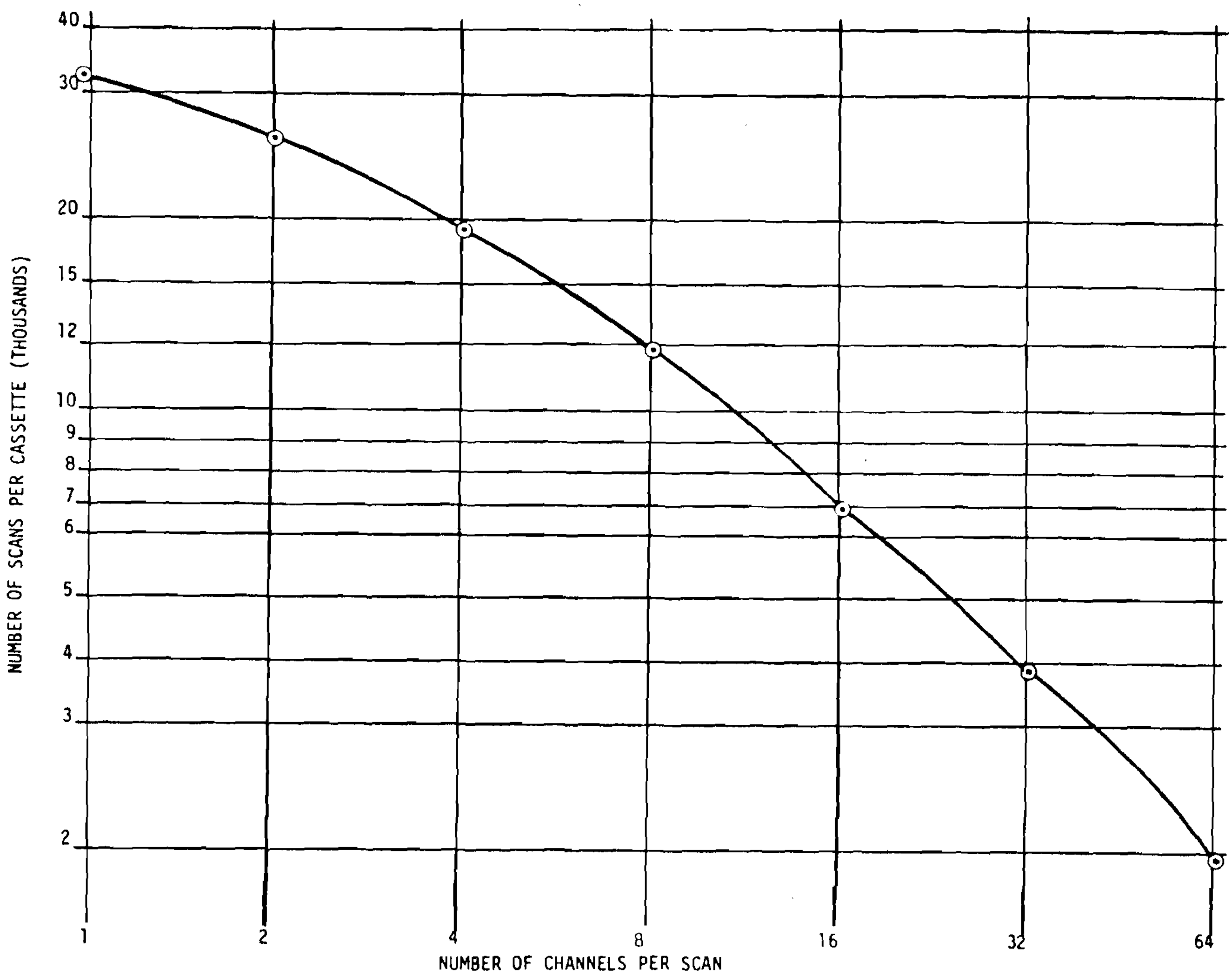


FIGURE 5-1 CASSETTE CAPACITY

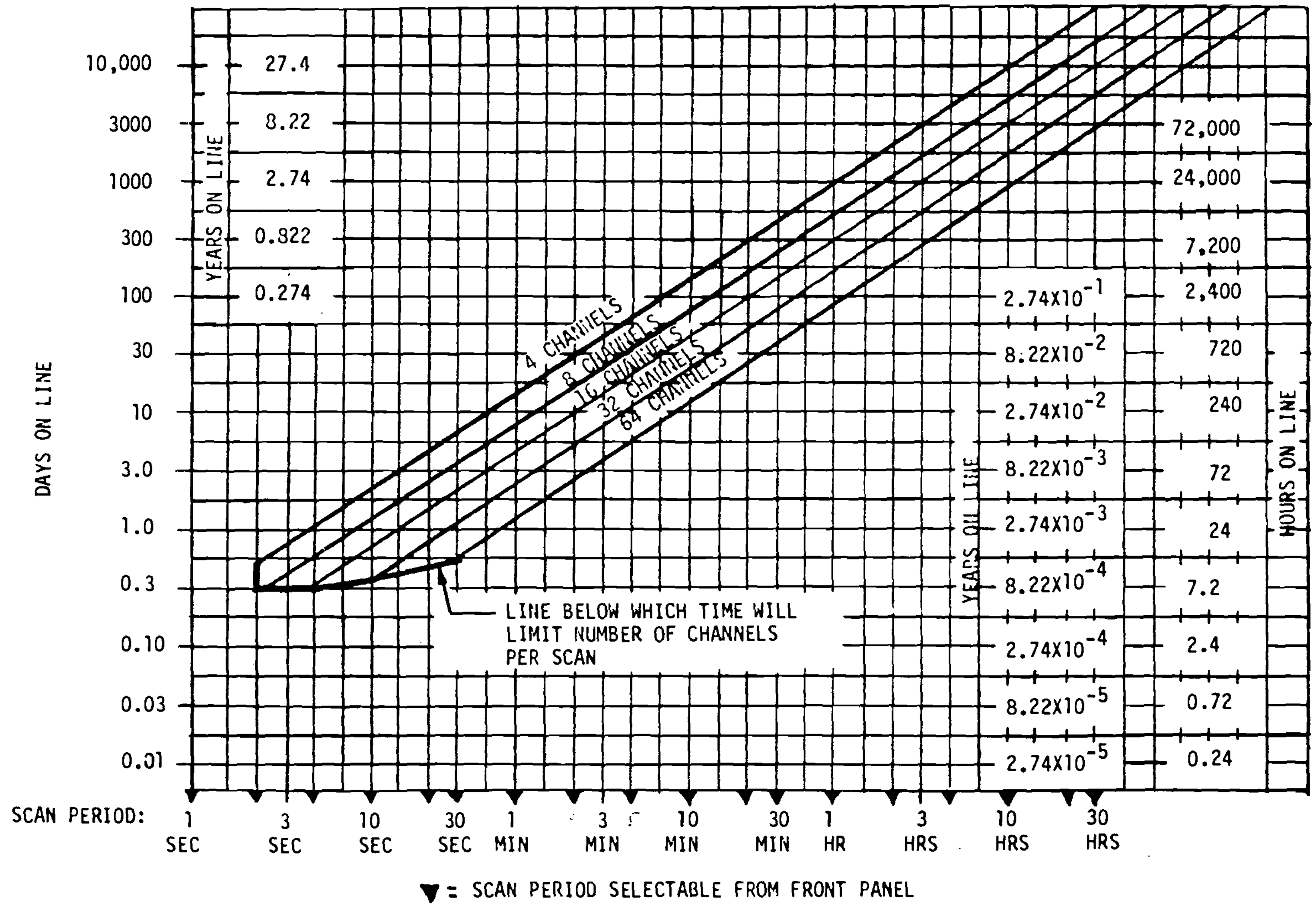


FIGURE 5-2 TAPE CASSETTE CAPACITY (TIME REQUIRED TO FILL A 300' CASSETTE)

ML2AMH1508

TABLE 5-1
SCAN NUMERICAL RELATIONS

CHANNELS/SCAN	TIME/SCAN (Sec)	STEPS/SCAN	SCANS/CASSETTE
1	0.72	72	30,750
2	0.89	89	24,880
3	1.06	106	20,880
4	1.23	123	18,000
5	1.40	140	15,800
10	2.25	225	9,840
15	3.10	310	7,140
20	3.95	395	5,600
25	4.80	480	4,615
30	5.65	565	3,920
35	6.50	650	3.410
40	7.35	735	3,015
45	8.20	820	2,700
50	9.05	905	2,450
55	9.90	990	2,236
60	10.75	1075	2,060
64	11.43	1143	1,937

APPENDIX B

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

22 February 1980

GEORGIA POULTRY FARMER ALTERNATIVE ENERGY SURVEY

The Georgia Tech Engineering Experiment Station is presently involved in helping the Georgia poultry farmer reduce their energy costs by using alternative energy sources. Two projects we are currently evaluating are the use of wood energy and solar energy for heating poultry growout houses.

The enclosed survey is to help us determine how many Georgia poultry farmers have the potential for using other alternative energy sources to reduce their energy usage. To do this we would appreciate you answering all the questions on the survey as completely as possible and then return the survey in the enclosed envelope. Also, all the information will remain confidential.

Thank you for your cooperation.

Enclosures (2) Survey and Self-Addressed Stamped Envelope

ALTERNATIVE ENERGY SURVEY

Location of farm: ______________________ County ______________

Hydroelectric Potential

1. How many streams are on your farm? __________
2. Give average width of stream(s) in feet? ______ ______ ______
3. Give average depth of stream(s) in feet? ______ ______ ______
4. How long are these streams dry in the summer? __________(months)
5. How many times do these streams flood during the year? ________
6. How fast does the water flow? ______(feet per minute)

   [Place a float that sinks well down in the water (such as a capped half full bottle or can) in the center of the stream and measure the distance in feet the float travels in one minute.]
7. Does your farm have an existing dam? ________
8. What is the height of the dam? __________(feet)
9. What is the area of the pond behind the dam? __________(acres)
10. What is the distance from the dam to where the electricity could be used (as in growout houses, layer houses, etc.)? __________(feet)
11. How much electricity is required by these houses? ______ $(\frac{\text{kilowatt-hours}}{\text{month}})$

Biomass Potential

1. What type of poultry operation do you have (growout houses, layer houses, etc.)? ________
2. How many growout houses, layer houses, etc. do you have? ________
3. Give the number of birds in each house? _____ _____ _____ _____ _____
4. What type of litter do you use (pine shavings, pine sawdust, etc.)? _____

   ______________________________.
5. How do you normally dispose of the house litter or manure? __________

   ____.
6. How many acres of timberland do you have that you would be willing to use as fuel in a wood furnace? ____________
7. What type of trees are they? ______________________________.
8. What crops do you grow and how many acres of each? ________

   Crop: ______ ______ ______ ______ ______

   Acres: ______ ______ ______ ______ ______

Georgia Institute of Technology
ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA 30332

24 June 1980

Thank you for your participation in our alternative energy survey. We mailed out 907 survey forms and received 149 replies. Forty-six farmers indicated that they have streams which might be utilized for small hydroelectric power production. Sixty-eight farmers indicated that they own timber which could be used for fuel. The survey indicated that many poultry farmers are interested in alternative energy sources such as methane production, hydroelectric power, and solar energy.

As you requested, I have enclosed some information about alternative energy and about agricultural engineering research at Georgia Tech. Thank you for your cooperation.

Sincerelv.

Wiley Holcombe
Research Engineer
Technology Applications Laboratory
404/894-3623

WDH:dm

Enclosures

APPENDIX C

AGRICULTURAL ENERGY MANAGEMENT TIPS

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LIVESTOCK SHELTER DESIGN

A. Orientation

When determining the location for a livestock shelter several factors should be considered. Remember a building in the wrong location is a 20 year mistake. The building should be situated with its length in a east-west direction. This will provide a minimum exposed area during the afternoon and evening hours thus preventing an excessive heat buildup on summer afternoons. A natural windbreak such as trees should be provided on the north and west sides of the building. During the winter months this will provide protection from the cold northwesterly winds.

Another factor to consider is the amount of roof overhang. The proper relationship between the wall height of the building and the amount of roof overhang can provide shade on the interior of the building during the summer months yet during the winter allow the warm rays of the sun to enter. Figure 1.1 shows this relationship.

Where possible locate the shelter on land with a 2-6% slope and open to prevailing summer winds. Never build in a hole-particularly a shelter in which livestock is constantly contained. Such an area can act as a heat sink and cause the local temperature to be higher than that of the surrounding country-side. An example of this is a large city in which the temperature down-town will normally be 3-5° higher than the temperature in the suburbs.

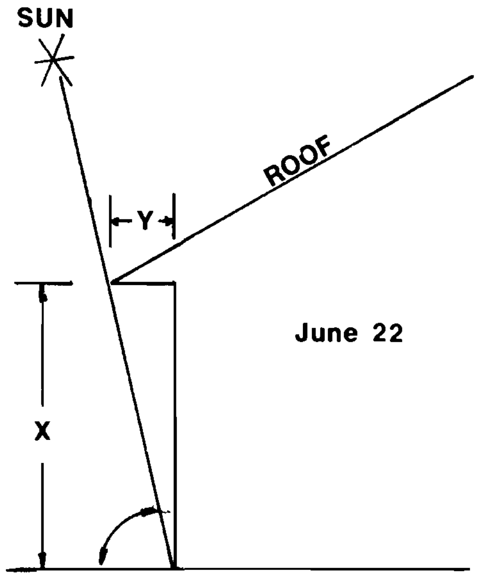
B. Insulation

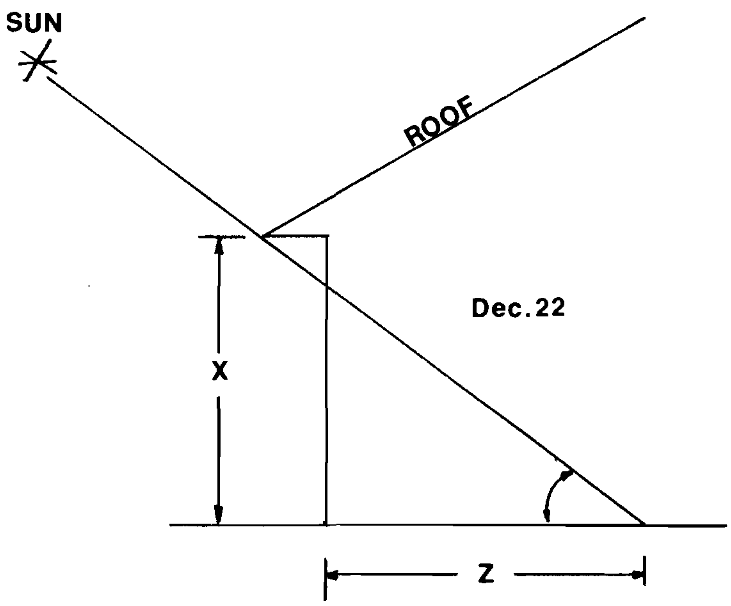
Any material that reduces the rate in which heat is transfered from one area to another is called insulation. All building materials have some insulating value but the term "insulation" is generally used for those products designed for this single service. There are several functions of insulation. First, it helps to conserve heat during cold weather. By conserving heat from the livestock, desirable housing conditions may be maintained without excessive supplemental heating.

Secondly, insulation helps control "sweating". "Sweating" occurs whenever the temperature of the inside wall is as low or lower than the dewpoint temperature of the air inside the room. The dewpoint temperature is the temperature at which water begins to condense from the air. Thus, "sweating" is

FIG 1.1 - SOLAR ALTITUDES IN GEORGIA

LOCATION	LATITUDE	JUNE ALT.	Y	DEC. ALT.	Z
No. Ga.	35°	78°	0.21x	31°	1.45x
Atlanta	34°	79°	0.19x	32°	1.41x
Mid Ga.	33°	79.5°	0.19x	32.5°	1.38x
So. Ga.	31°	81°	0.16x	35°	1.27x





X = wall height
Y = horizontal length of roof overhang
Z = horizontal distance sunlight will penetrate building

TABLE 1.1 RESISTANCE VALUES OF INSULATION

From ASHRAE, Handbook of fundamentals, 1977

Values do not include surface conditions

	Thick.	Resistance R per in. thick 1/k	Resistance R thick. listed 1/C
Insulation			
1. Blanket or batt insulation			
Glass wool, mineral wool, or fiber glass		3.50 Approx, read label	
2. Loose fill insulation			
Glass or mineral wool, 5#/cu ft		3.00 to 3.30	
Vermiculite (expanded)		2.27	
Shavings or sawdust		2.22	
Milled paper or wood pulp		3.70	
3. Rigid insulation			
Expanded polystyrene,			
extruded 2.2#/cu ft		5.00	
molded, 1#/cu ft		3.57	
Expanded rubber (rigid)		4.55	
Glass fiber		4.00	
Building materials - general			
Maple, oak, and similar hardwoods		0.91	
Fir, pine, and similar softwoods		1.25	
Fiber board insulating sheathing	25/32"		2.06
Plywood	3/8"	1.25	0.47
	1/2"		0.62
Bevel lapped wood siding	1/2"x8"		0.81
Drop siding	1"x8"		0.79
Asbestos-cement board		0.25	
Gypsum or plaster board	1/2"		0.45
Asphalt shingles			0.44
Wood shingles			0.94
Masonry			
Sand and gravel concrete block	8"		1.11
	12"		1.28
Lightweight concrete block	8"		2.00
	12"		2.27
Lightweight concrete block, cores filled with vermiculite	8"		5.03
	12"		5.82
Face brick		0.11	
Concrete cast in place		0.08	

prevented when the temperature of the interior walls of a building is above the dewpoint temperature of the inside air.

Thirdly, during the summer, insulation reduces the heat gain to the building. Reduction of the temperature inside the building can be a life and death matter for confined, temperature-sensitive, livestock such as poultry.

The types of insulations fall generally into three catagories-loose fill, blanket or batt and rigid insulation. Loose fill insulation is packaged in bags and is typically glass or mineral wool, vermiculite or cellulose. Loose fill insulation may be poured or blown into place and is particularly adapted for use in the ceilings of existing buildings. Blanket or batt insulation is typically glass wool, mineral wool or fiberglass with a binder so that it may be formed into sheets. Quite often it is also attached to a vapor barrier made of kraft paper or aluminum foil. Rigid insulations are typically beadboard, styrofoam or expanded polyurethane. Generally only polyurethanes will have a vapor barrier attached to them. All of the rigid insulations come in sheets of varying thickness, widths and lengths.

The amount of insulation needed depends on the use of the building, the orientation of the building and the climate. Since doubling the insulation will only conserve half of the remaining heat loss, there is an economically optimum thickness of insulation and this thickness varies with each situation. A method of estimating the amount of insulation that is economically practical is shown in the example below. Insulating values of typical building material are shown in Table 1.1.

Last but not least is the vapor barrier. The vapor barrier is necessary to prevent moisture from reducing the effectiveness of the insulation. To be effective it must be free of damage and must be sealed at all joints so as to form a continuous sheet. The vapor barrier is always placed on the warm side of the building. In the case of a heated livestock shelter this would be the side nearest the animals or birds. Typical vapor barriers are polyethylene sheet, aluminum foil and treated kraft paper.

Example

Assume we have an LP gas heated brooder house, 36'x 300', with an insulated ceiling whose R value is 4. To determine the amount of money that could be saved by increasing the R value to 12 use the formula,

$$Q = \frac{\Delta T \times A}{R}, \text{ where:}$$

Q = Btu per hour saved

ΔT = the difference between inside and outside temperatures

A = insulated area

R = Resistance value of the insulation

If we assume an average winter day with an outside temperature of 40°F and an inside temperature of 70°F, then:

$$Q = \frac{30 \times 36 \times 300}{4} - \frac{30 \times 36 \times 300}{12}$$

Q = 54,000 Btu per hour

If this average temperature occurs 90 days a year, then:

Q = 54,000 x 24 x 90

Q = 116,640,000 Btu per year

LP gas has approximately 91,000 Btu's per gallon, so:

$$\frac{111{,}640{,}000}{91{,}000} = 1282 \text{ gallons LP gas per year}$$

If LP costs 50¢ per gallon, the dollar value is $641 per year.

C. Ventilation

Although specific ventilation requirements vary according to the type of animal or bird to be housed,all livestock shelters must be able to provide good quality air throughout the year. If the building has not yet been built,special attention should be paid to its design and orientation. Optimum use of such natural factors as shade and prevailing winds can greatly reduce the ventilation bill.

When forced ventilation is necessary fans should be selected on the basis of optimum efficiency for your installation. In selecting a fan look at those that bear the AMCA seal. This means that the fans have been tested in a similar manner and that you're comparing apples and apples and not apples and oranges. Next check the CFM per watt ratings at the pressure you intend to use the fan as well as at either 1/10th or 1/8th of an inch of water. Also the ratings should be with whatever accessory equipment you intend to use installed. The addition of shutters and safety guards can very rapidly reduce the air moving capability of the fan.

For existing buildings good maintenance is the key to saving energy. Shutters, fan blades, motors and air inlets should be kept free of dust and dirt. On air inlets with bird screens installed dust accumulation dramatically reduces the free area. This forces the fan to work harder to move the same amount of air. On fan blades,dirt accumulation causes turbulence that forces the blade to be less efficient in moving air. On shutters,dust works its way between the hinge pen and hinge bearing causing additional friction. This makes the blades of the shutter more difficult to move, thereby placing extra load on the fan motor. A dust accumulation on the motor acts as an insulating blanket and forces the motor to run at higher temperatures. This additional heat decreases the insulation life and ultimately causes the motor to burn out.

Once a fan assembly is clean make sure that all moving parts are properly lubricated. Use a dry film lubricant or graphite on shutters as oil will tend to collect dirt and dust causing the shutters to stick.

Periodically check belts for proper tightness. Rubber V-belts gradually stretch with use and a motor that's burning rubber is not turning the fan. You must be careful, however, not to overtighten the belts as this will place an excessive load on the bearings. The belt is properly tightened when there is approximately ¼ inch of play at the midpoint of the belt.

D. High Efficiency Motors

With electricity becoming more and more expensive, its important to know just how efficiently your motors use electricity. Here are four things to consider in evaluating your motors' efficiency.

Efficiency Rating

A motor's efficiency rating shows how well it converts electrical energy into mechanical energy. The larger the rating, the more efficiently the motor uses energy.

Power Factor

Motor line current consists of two components: real and reactive. The real current produces power and does the work. The reactive current creates the magnetic field in the motor. The ratio of this real current to total current is a motor's power factor.

For a given efficiency, a higher power factor means that the motor requires less total current. The resulting lower line current means that less energy is wasted in all feeder circuits serving the motor. Consequently, utilities need less generating equipment and smaller transmission lines to distribute electricity.

Motor Load Variation

Variation of motor load has only a slight impact on efficiency but greatly affects power factor. As shown in Figure 1.2, efficiency is relatively stable from 50 to 125% of full load. But power factor drops off severely as the motor is underloaded.

Voltage Variation

Power factor is more sensitive to line voltage variations than efficiency. Within a 10% variation from rated voltage, efficiency typically varies by only about 1% at rated horsepower. Power factor, however, varies greatly -- as much as 15% for the same voltage variations. In underloaded conditions the effect is even greater. (See Figures 1.3 and 1.4)[1]

What This Means To You

Always replace a motor with one of the same horsepower rating -- unless a service bulletin has been issued by the equipment manufacturer specifying a different horsepower.

Compare the input wattage at full load. High efficiency motors are generally more expensive than standard motors. In many cases this will only be a 10% to 15% premium and the energy savings will quickly payback the additional cost.

Operate motor at full load whenever possible.

Check line voltage at motor and correct as necessary. Additionally, on three phase motors, check for voltage imbalance.

1. Gould, Inc., Electric Motor Division, Bullentin 3306.

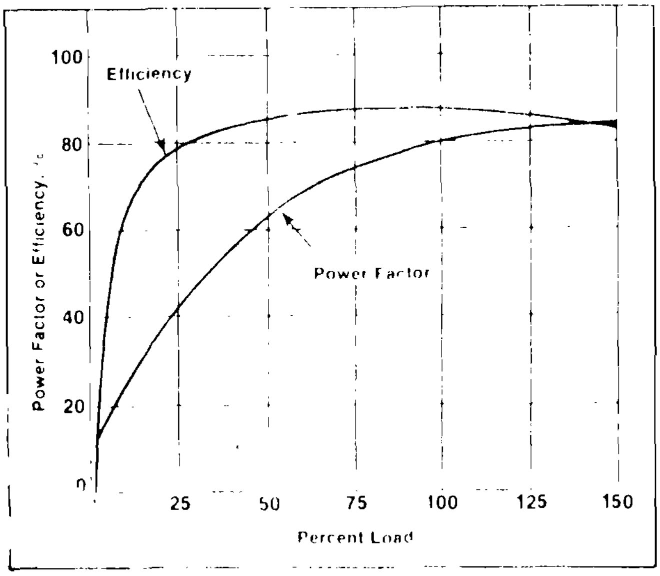


Fig 1.2 Efficiency and Power Factor

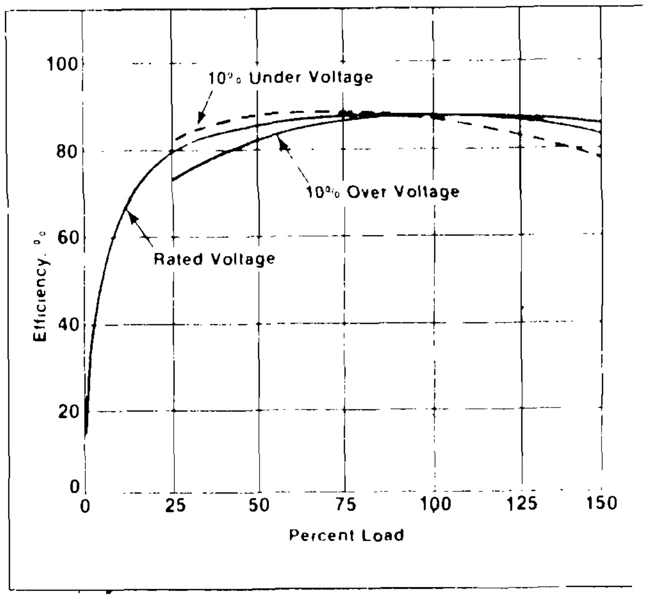


Fig 1.3 Efficiency Sensitivity

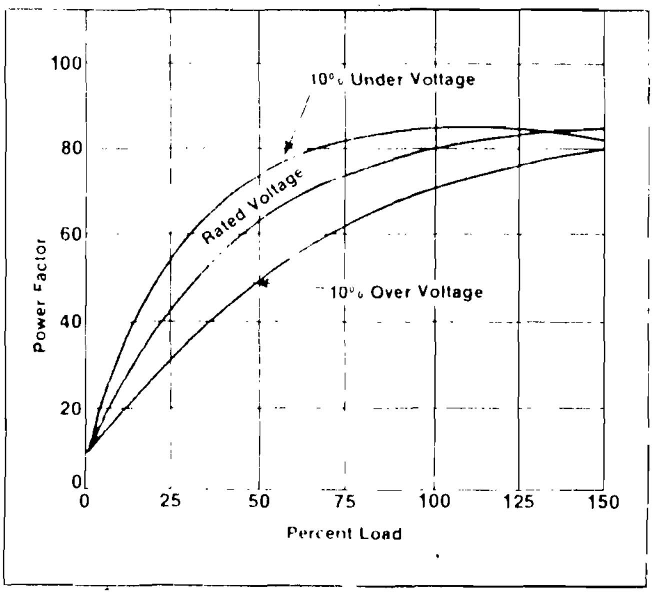


Fig 1.4 Power Factor Sensitivity

E. Lighting

Although lighting does not account for a large portion of your energy bill, proper management can reduce costs to a minimum without restricting usage.

Lamp bulbs and reflectors should be kept clean. Dust and dirt can absorb up to 50% of the light emitted. Bare bulbs should have reflectors installed--inexpensive ones can be made from aluminum pie pans for incandescent bulbs and aluminum roof valley material for fluorescent bulbs.

Avoid dark colors -- they absorb light whereas light colors reflect it. Where possible use one large bulb rather than several small ones -- large bulbs are more energy efficient. For flood and yard night lights consider mercury vapor, metal halide or high pressure sodium lamps. The initial cost is higher than incandescent or flourescent, but the efficiency is greater -- See Table 1.2 (Note: A lumen is a measure of the amount of light a bulb puts out).

Skylights or translucent panels in the roof represent another means of reducing lighting requirements. When properly sized and located, artifical light is required only on the most overcast days.

TABLE 1.2 LAMP DATA

Type of Lamp	Watts	Average Lamp Life	Average Lumen Output
Incandescent	25 40 60 75 100 150	1,000 1,000 1,000 1,000 1,000 1,000	250 450 840 1,150 1,700 2,700
Flourescent	15 20 40	20,000 20,000 20,000	660 1,000 3,200
High Pressure Sodium	70 100 150 250 400 1,000	20,000 20,000 24,000 24,000 24,000 24,000	5,200 8,600 14,000 23,000 45,000 120,000
Mercury Vapor	250 400 1,000	24,000 24,000 24,000	11,000 20,000 48,000
Metal Halide	175 400 1,000	7,500 15,000 10,000	11,000 27,000 82,000

WOOD HEATED SHELTERS

Wood as a fuel is particularly attractive in states, such as Georgia, that are heavily forested and have a highly developed forest products industry. Logging operations leave tops, limbs, etc. - as well as trees that are not commercially useful in that area. Most of Georgia has a surplus of this so-called "scrub" wood - and it is available at a delivered price of $25 to $30 per standard cord (128 cu ft.).

Any space heating situation that uses warm air, hot water or steam can be adapted to a wood-fired furnace. There are a number of manufacturers - domestic and foreign - that can supply off the shelf units ranging in sophistication from a "pot-bellied" stove to a forced - air, central system type furnace to a wood-fired steam boiler. Automatic stoking units for wood-fired furnaces are not as widely available and, generally, are of foreign manufacture.

EES/Georgia Tech has designed and installed a wood-fired, warm air, brooding system in a poultry grow-out house on a farm near Carrollton, Georgia that has been operational since October 1978. There are two identical broiler growout house located on the farm. Each house is 40' x 325' with a nominal capacity of 15,000 birds. They are equipped with automatic side curtains, plus each has 3½" of fiberglass insulation with a tri-ply vapor barrier installed in the ceiling. The temperature is controlled by 5 exhaust fans - 1 on a thermostat and 4 on timers. The houses are physically located on a flat area, approximately 100' apart and in an east - west orientation.

The southern-most house is used as a control and has 20 conventional LP gas brooders with a heating capability of 30,000 Btu/hr each. Although the other house also has the same quantity and size brooders installed, they are used only as a back-up system with the primary heat source being a 350,000 Btu/hr, wood-fired furnace. The furnace is located in a small building - which also contains the wood supply - adjacent to and at the center point of the chicken house. Warm air from the furnace is distributed through a conventional heating duct system. Attached at equal intervals to the main duct are 20 eight inch diameter supply ducts that bring the warm air to 24" above the floor where it is then exhausted through 18" diameter circular diffusers. The air moves uniformly throughout the house and is returned to the furnace-along with the proper amount of make-up air which has entered through the side curtains by means of a return air duct.

During the ten months of operation the system has performed very impressively. It has proved reliable and capable of providing 100% of the heating needs. In one instance it maintained the house at 40° with an outside temperature of 15° with side curtains fully lowered. An automatic device had dropped the curtains after a short power outage and the condition was not discovered until some four hours after the occurrence.

Mortality, feed conversion, yield and down-grading have been about the same for each house although the statistics favor the wood-burner somewhat. The really significant difference was, of course, in the propane used. The wood-burning house used 750 gallons all of which was due to the brooder pilot lights which were left on as a precaution until the reliability of the wood system was proved. The control house, however, has used 3750 gallons. At a cost of 42.7 cents/gal this is an expense of $1600.00.

One of the assumptions made for this demonstration was that the wood for fuel and the labor to process it was available at not cost. On this basis the wood-burning house has a cost advantage of some $1300 per year. With a first cost installation estimated at $9350.00 and an inflation rate of 7% per annum payback is approximately six years. When expenses for both the LP gas system and the wood-fired system are considered on a 20 year life cycle, the annual cost amortized at 7% is $1950/year for the wood-fired system and $3400/year for the LP gas system OR a $1450 per year savings by using a wood-fired heating system. If the wood had been purchased at a price of $27.50/ standard cord and with a usage rate of 29 cords per year, the wood system would have still shown a savings of $652.50 per year.

The net heat from a cord of wood burned in a 60% efficient furnace is equal to the net heat of 140 gallons of propane burned in a 75% efficient heating unit. As the price of propane rises, the economics of conversion to a wood-fired heating system became more and more practical.

Solar Collectors For Agriculture

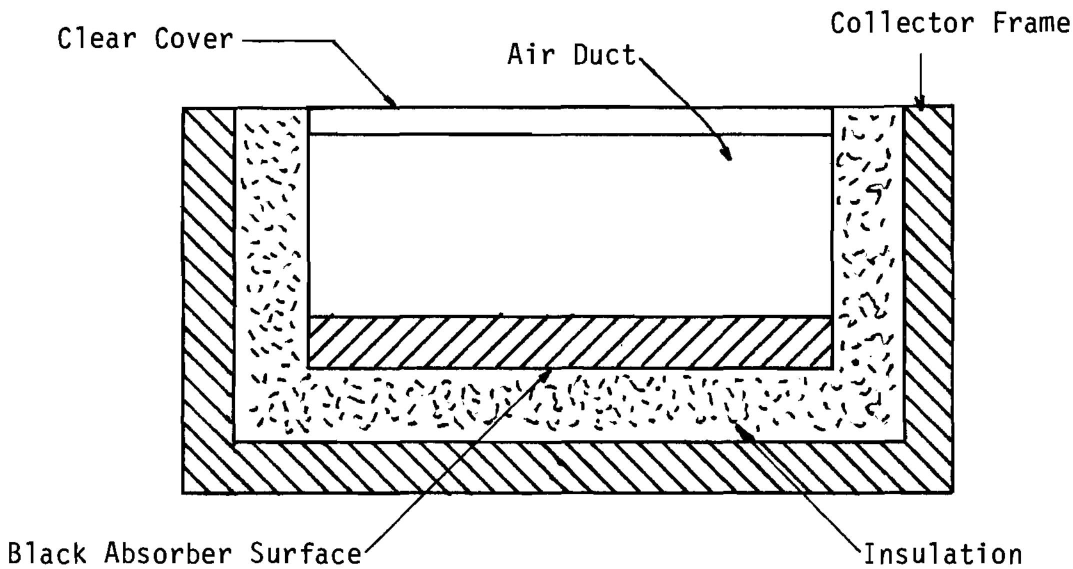
Basically, three types of solar collectors exist for capturing the sun's energy and changing it into useful heat. The three types of collector are: flat plate, evacuated tube, and concentrating collectors. Typically, flat plate collectors are used to supply heat at temperatures between 60°F and 160°F whereas evacuated tube and concentrating collectors are usually used to supply heat at even higher temperatures. For most agricultural applications such as heating animal shelters and crop drying, the temperatures supplied by a flat plate collector will be sufficient.

Flat Plate Collectors

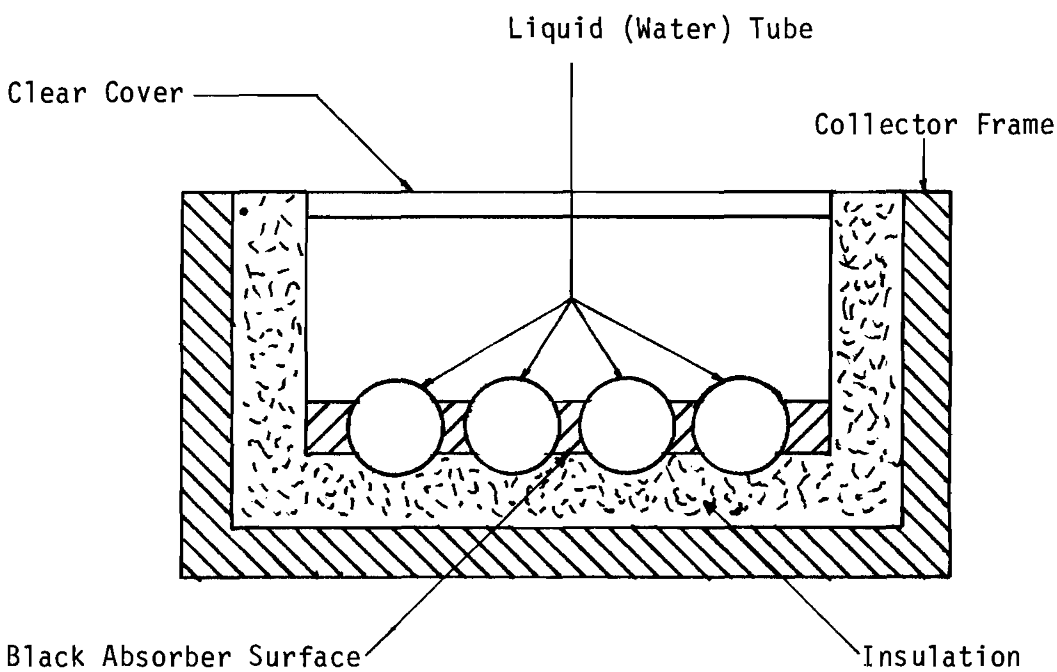
A typical flat plate collector consists of a black absorber surface inside an insulated box with one or more glass or plastic covers over it. The black absorber surface is usually made from a metal such as copper, aluminum or steel. Radiation from the sun strikes the absorber surface which raises its temperature (just like a metal roof which gets hot on a sunny day). To keep the hot absorber surface from losing heat to the outside air, a clear glass or plastic cover is placed over it. This clear cover provides a "greenhouse effect" by trapping the sun's energy inside the collector.

The collected heat from the absorber surface is then transferred to air, water or another heat transfer fluid and used directly for heating the animal shelters or crop drying. Also, the heat can be stored in a rock-bed or a water tank for use at night or during cloudy times. Figure 3.1 the construction of two flat plate collectors, one for heating air and the other for heating a liquid such as water.

A measure of performance for flat plate collectors is the collector efficiency. The efficiency is defined as the ratio of useful heat from the collector to the amount of solar radiation that strikes the absorber surface. Typically, flat plate efficiencies vary between 10% to 70%. Generally, the lower efficiencies occur during the winter and the higher efficiencies occur during the summer.



(a) Air Heating Collector



(b) Liquid Heating Collector

FIGURE 3.1 Flat Plate Solar Collectors

Potential For Solar Energy in Georgia

To determine how much energy savings solar collectors can provide, the amount of solar radiation that reaches the ground must be known. Table 3.1 shows the average daily solar radiation for each month that reaches a surface on the ground with an area of 1 square foot. Also this surface should be pointed directly south and titled at an angle of 20°. The amount of radiation that reaches a surface during different times of the year depends on this tilt angle. A tilt angle of 20° was chosen because this is close to the roof angle of many animal shelters and the roof is usually a suitable place for mounting the collectors.

Table 3.1

Solar radiation for Atlanta, Georgia and Griffin, Georgia on a south facing surface, tilted at an angle of 20°

	Jan	Feb	Mar	Apr	May	June
Atlanta	1136*	1334	1638	1806	1816	1366
Griffin	1193*	1448	1669	2039	1947	1414

* Solar Radiation Units are $\frac{\text{Btu}}{\text{day}}\ \text{ft}^2$

	July	Aug	Sept	Oct	Nov	Dec
Atlanta	1602*	1955	1743	1594	1307	1030
Griffin	1652*	2019	1783	1670	1418	1075

Sizing A Flat Plate Collector

The following example will show how to estimate the size of a flat plate collector without energy storage to heat an animal shelter during the daytime. Suppose that the shelter needs 400,000 Btu's per "day". (Note: Since this system has no storage, "day" refers to daytime hours and not to 24 hours.) 400,000 Btu's per day equals about 6 gallons of LP gas or 600 cubic feet of natural gas when using a conventional gas heater with an efficiency of 70%. Use the radiation data for November in Atlanta as the design data.

Also assume that the flat plate collector efficiency is 20%. Therefore the square feet of collector needed is given by the following formula:

$$\text{Area } (ft^2) = \frac{\text{Heating Load } (\frac{Btu}{day})}{[\text{ Solar Radiation } (\frac{Btu}{day\ ft^2}) \text{ X Collector Efficiency } (\frac{\%}{100})\ ]}$$

$$\text{Area } (ft^2) = \frac{400{,}000\ \frac{Btu}{day}}{1307\ (\frac{Btu}{day\ ft^2})\ X\ (\frac{20}{100})} \cong 1530\ ft^2$$

Chosing A Design Month

In chosing the design month for sizing the collector, the seasonal usage of the collector must be considered. For a solar heated animal shelter, the collector will only be used during the winter. Since this collector is used only part of the year, storage will probably be uneconomical. Therefore, for a solar heated animal shelter assume no storage is used and consequently heat is supplied by the collector only when the sun is shining.

If December or January were chosen as the design month, then the amount of radiation that reaches the ground would be a minimum (see Table 3.1). Also, the outside air temperature will be a minimum which means the heating load for the house will be a maximum. Consequently, a collector sized by these design conditions will be oversized for conditions during months such as November and February when the radiation and outside air temperature are higher than in December and January.

Under current economic conditions, the most cost effective plan is to size the flat plate collectors to be in use 100% of the time during the heating season. This means that November, February, or March, depending on the location, should be used as the design month for sizing the collector. During the months of December and January when the solar collectors are unable to supply all of the daytime heat, the additional heat can be provided by a conventional gas heating system.

Solar Energy At Georgia Tech

The Georgia Tech Engineering Experiment Station funded by the Georgia Department of Agriculture, is currently operating solar heating systems on two poultry growout houses. Both systems utilize low-cost solar air heaters.

One solar heating system located near Cumming, Georgia, incorporates a rockbed collector/storage unit in a passive design (See Figure 3.2). The rockbed is located on a 30° slope below the growout house. The rockbed is approximately six inches deep and has been painted black. Two layers of ultraviolet treated, green house glazing are used for the collector glazing. There is a continuous air inlet at the bottom of the collector and thirteen underground outlet ducts spaced evenly along at the top of the collector. Inlet air rises through the collector as it is heated and flows through the outlet ducts to the house.

A number of problems have been experienced with this system. Low cost materials were used to build this system for approximately two dollars per square foot. These low cost materials have resulted in fairly high maintenance requirements. Rotting has been a problem with some of the wooden frame members. Sections of the specially treated polyethlene are frequently torn loose by the wind. The initial polyethylene lasted two years. Several of the underground ducts have been clogged by rats building nests in them. Also, even though temperatures as high as 150°F are generated in the collector, relatively little heat is transfered to the growout house, possibly because of the small amount of outlet duct area. Modifications are planned to improve the system performance.

A second solar heating system was built on a chicken growout house near Villa Rica, Georgia. This system consists of a rooftop mounted forced air collector with no storage (see Figure 3.3). A black foilfaced insulation board is used for the collector absorber surface. A single layer of Kalwall fiberglass sheet is used for the collector glazing. Outside air is pulled from each end of the collector along five parallel channels to a central plenum by a

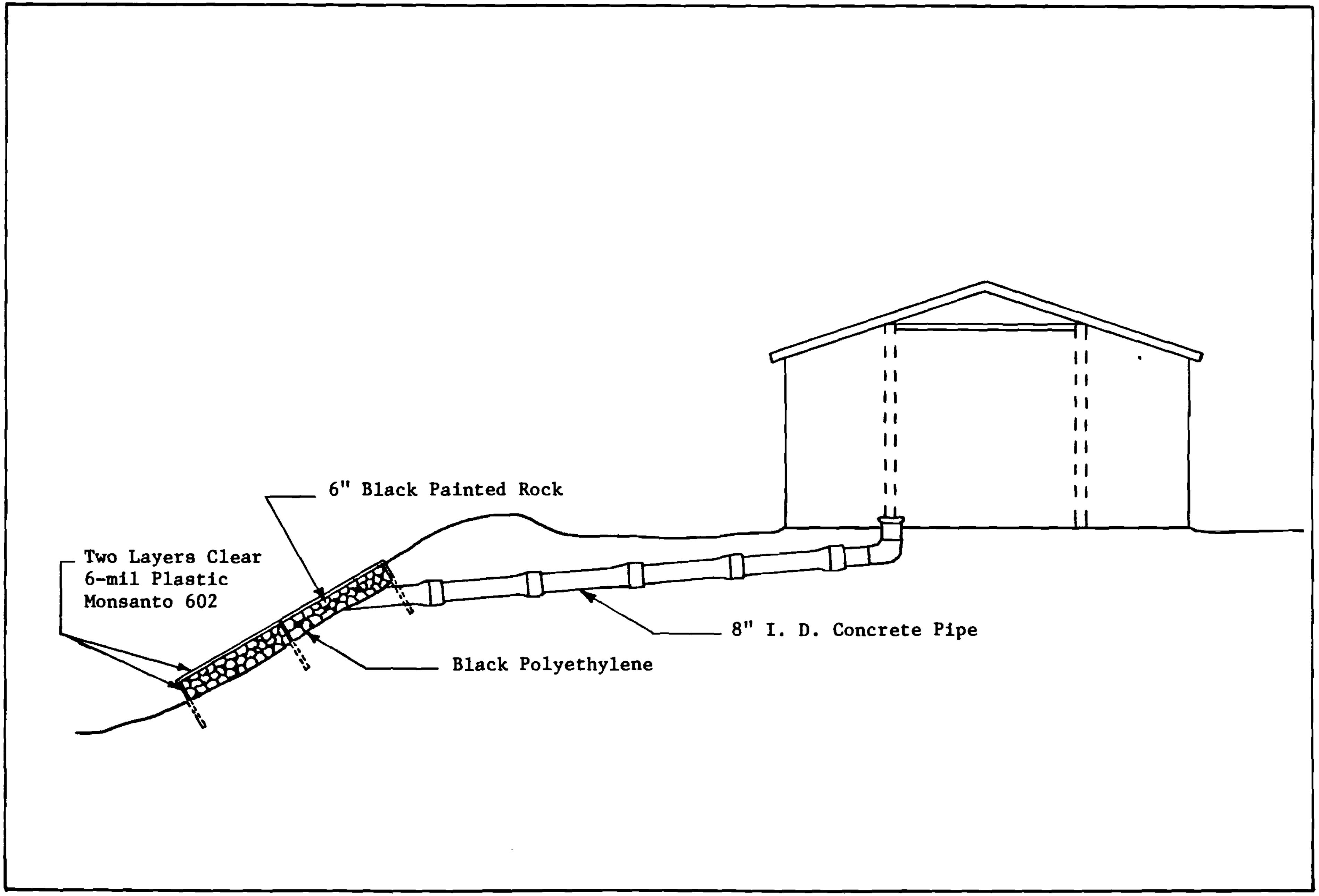


FIGURE 3.2 **Solar Heated Broiler Growout House**

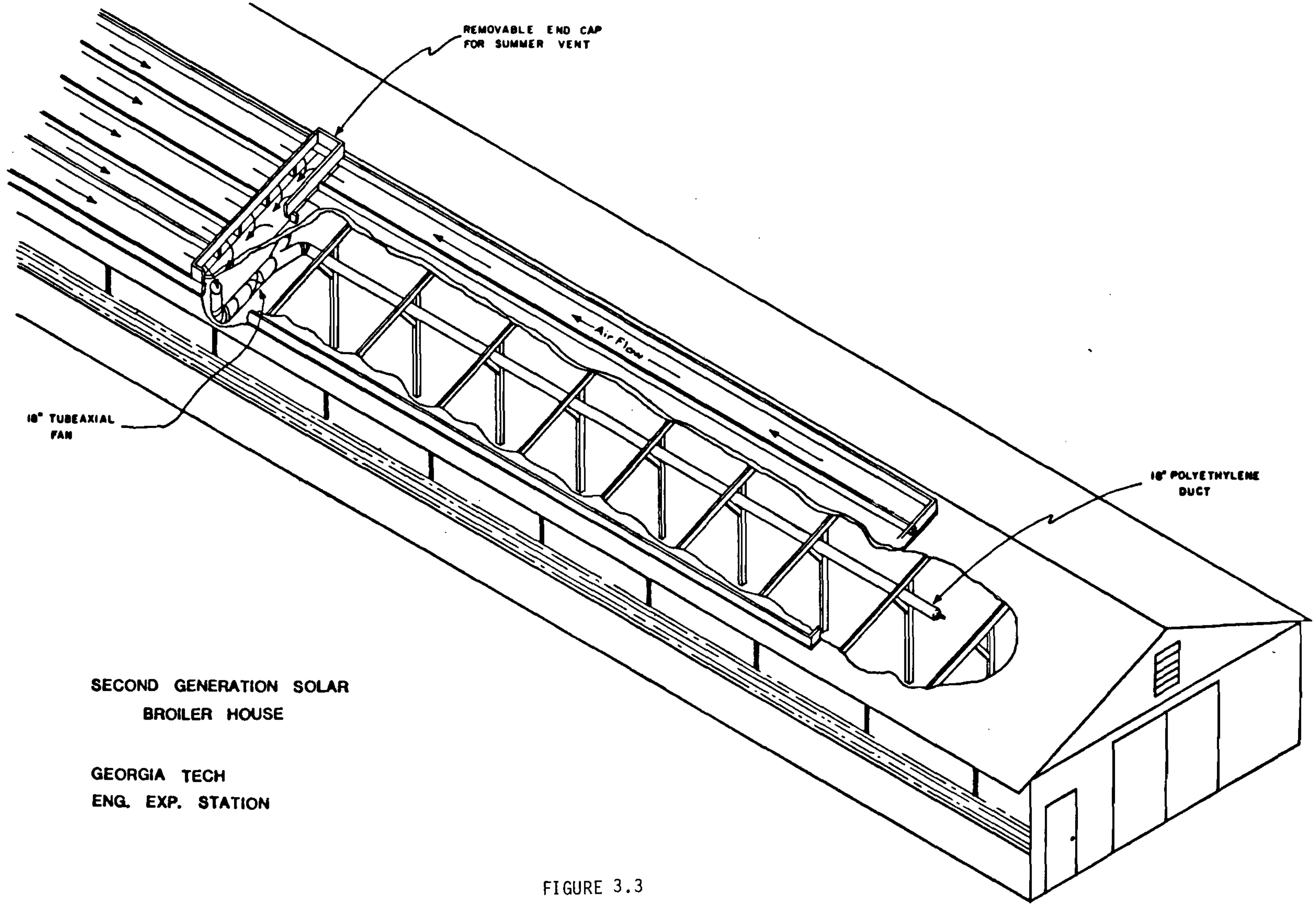

REMOVABLE END CAP
FOR SUMMER VENT
Air Flow
18" TUBEAXIAL
FAN
18" POLYETHYLENE
DUCT
SECOND GENERATION SOLAR
BROILER HOUSE
GEORGIA TECH
ENG. EXP. STATION

FIGURE 3.3

duct fan located in the house. Hot air is distributed through the house by polyethylene ducts that run the length of the house. The system was built for about $2.45 per square foot.

This collector has been performing at a 20 to 25% efficiency. Last winter, the growout house with the solar heating system used approximately 5% less fuel than an identical, non-solar house located on the same farm. Changes are being made in the controls to improve system performance.

Further Information on Solar Energy

The federal government has created an agency to provide general information and answer any questions you may have about solar energy. If you want to be on their mailing list or have any questions you can write to them directly at:

National Solar Heating and Cooling Information Center
P.O. Box 1607
Rockville, Md. 20850

Also you can call them toll free at 1-(800) 523-2929.

ANAEROBIC DIGESTION

Even before the current energy crisis became so apparent, there was a growing waste disposal problem in the livestock industry. This developed over a period of years from the concentration of poultry, swine and cattle industries into extremely intensive operations, the decline of farm animal wastes as a competitive fertilizer, and by an increased awareness of the environmental impact of such concentrated animal wastes. As the various regulatory agencies began to crack down on the odor, stream pollution runoff and health problems created by disposal methods, the livestock industry was forced to look at new ways to handle its wastes.

Manure cannot be left to accumulate within or in the vicinity of farm buildings. It is a health hazard, a breeding ground for the common fly, a source of objectionable odors and public nuisance. Although livestock wastes are rich in fertilizing constituents, untreated raw wastes spread on fields and allowed to enter the surface waters will accentuate the public health, esthetics and economics. Farm wastes should be given a treatment that will stablize the manure, remove its nuisance characteristics, sustain its fertilizer value and reduce the pollutional properties of the manure to a safe level before final disposal. Since the farm waste has a very high concentration of organic solids, anaerobic (an-a-ro-bik) fermentation or digestion is the most suitable treatment method applicable to this type of waste. Anaerobic digestion can help the farmer accomplish these goals of manure disposal as well as providing him with some interesting "dollar-wise" side benefits.

Anaerobic digestion is a valuable process for:

(1) disposing of an undesirable waste
(2) removing odor and health problems
(3) enhancing the value of the waste solids as a feed supplement or fertilizer
(4) generating a usable fuel (methane)

The process of anaerobic digestion is carried out by a wide variety of bacteria. However, the microrganisms responsible for the decomposition of the organic matter are commonly divided into two groups. The first group ferments complex organic compounds to simple organic acids, the most common of which are acetic and propionic acid. This group of organisms consists of both anaerobic and aerobic (oxygen needing) bacteria, collectively called the acid formers.

The second group converts the organic acids formed by the first group th methane gas and carbon dioxide. The bacteria responsible for this conversion are strict anaerobes (survive without oxygen) and are called the methane formers. The most important bacteria of this group are the ones that degrade acetic acid and propionic acid. They have a very slow growth rate; and, as a result, their metabolism is considered rate limitating in the anaerobic process. It is this second step that actual waste stablization is accomplished by the conversion of the organic acids into methane and carbon dioxide.

The simplified diagram below protrays the relationship between the two bacterial stages in digestion of organic matter. Both major groups of bacteria must cooperate to perform the overall gasification of organic matter. The first stage creates food (organic acids) for the second stage where these organic acids are consumed, preventing excess acid accumulation. In addition to producing food for the methane bacteria, acid-formers also reduce the environment to one of strict anaerobiosis by using up the oxygen compounds.

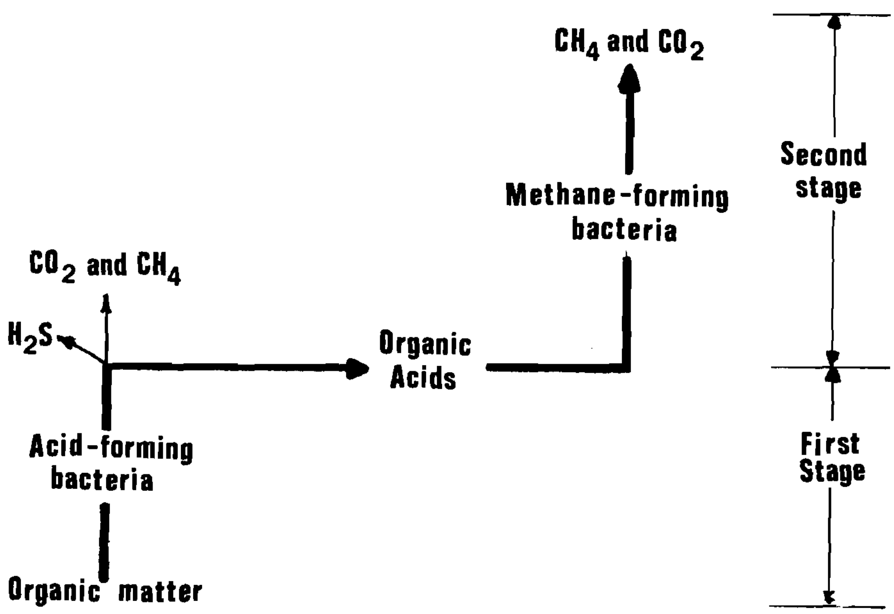
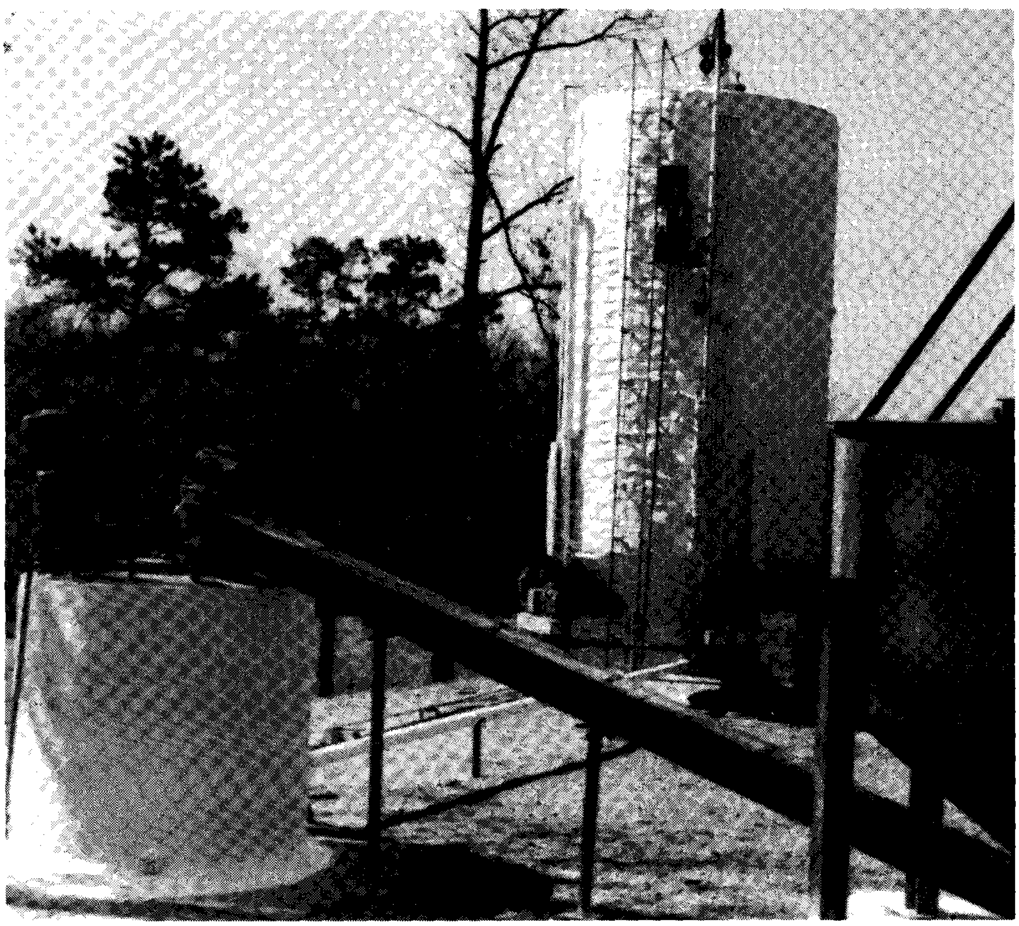


FIGURE 4.1 Bacterial Fermentation

Georgia Tech studies developed a system using this anaerobic digestion process to produce methane and carbon dioxide as a gas by-product along with useful and harmless solid and liquid effluents. The "biogas" product may be used directly as a fuel or converted to pipeline quality to supplement natural gas supplies.

Initial work proved the feasibility of producing fuel from poultry manures which may, in the case of a poultry processing plant, be used to heat the operation and also provide an enriched solid animal feedstock. Georgia Tech has tested a 10,000 gallon anaerobic digester located at a poultry breeder operation near Cumming, Georgia (photo below). The system consists of a holding tank, a mix tank and a digester, all fully instrumented. Capabilities of pressure variation, temperature variation and hydrogen injection were added for test purposes. The major capital equipment items are available for further development research in waste utilization, and many scale-up problems that confront other research organizations have been solved.



The anaerobic digester was designed intentionally to be as versatile as possible in terms of chemical reactor design. No one has, as yet, determined what reactor process mode is optimal for the anaerobic digestion of animal or poultry wastes. Georgia Tech's digester has operated in ten different process configurations. Not only is the unit one of the largest of its kind, but it is also probably the most versatile yet designed.

In the conventional digester (Figure 4.2) the manure is normally heated by by means of coils located within the tank or by a heat exchanger. Operationally a raw manure slurry (water added for better pumping purposes) is added in the zone where the manure is actively digesting and the gas is being released. As gas rises to the surface it lifts manure particles and other materials, such as,grease, oils, and fats, ultimately giving rise to the formation of a scum layer. As a result of digestion, the manure becomes more mineralized and it thickens due to gravity. In turn this leads to the formation of a supernatant (liquid) layer above the digesting manure (sludge). Due to the stratification and the lack of mixing, the volume of a conventional digester is not more than 50% utilized.

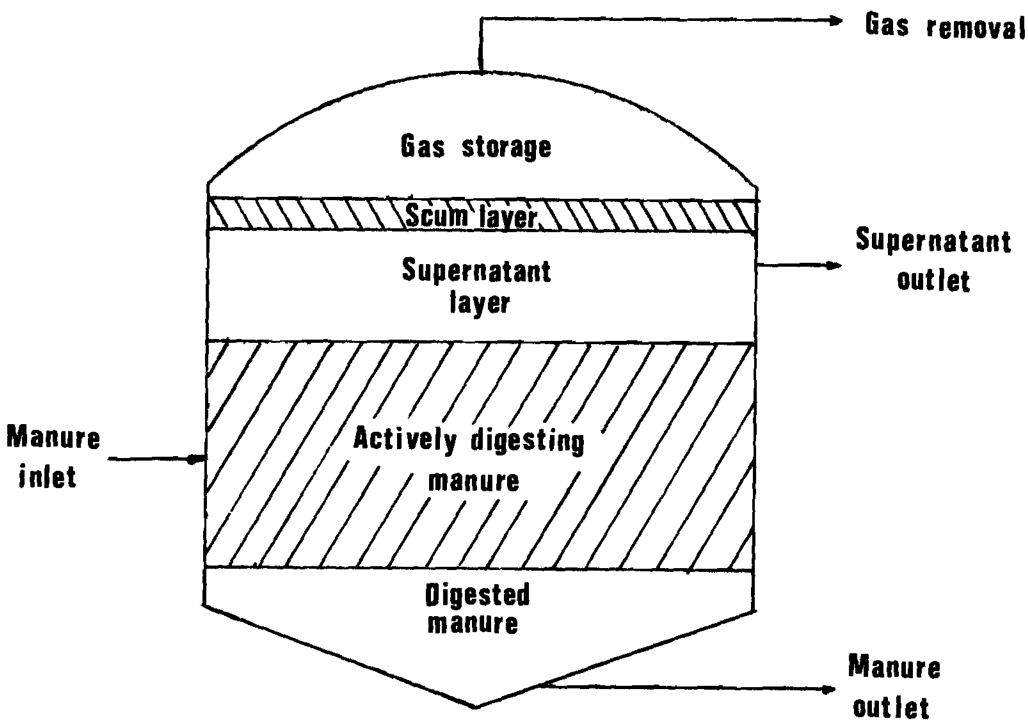


FIGURE 4.2 Conventional Single Stage Digester

Recognizing these limitations, newer design concepts for anaerobic digestion are looking at a two-stage process. In the two-stage process (Figure 4.3) the first tank is used for digestion. It is heated and is equipped with mixing facilities. The second tank is used for storage and concentration of digested manure (sludge) and for formation of a relatively clean supernatant (liquid). Tanks may have fixed roofs or floating covers. Any or all of the floating covers may be of the gasometer type. Alternatively, gas may be stored in a separate gas holder or compressed and stored under pressure. Tanks are usually circular and the bottom should slope to the manure drawoff in the center, with a minimum slope of 1 vertical to 4 horizontal. Some general conditions for manure digestion are as follows: 1) general range of operation 85° - 100°F, 2) general pH limits 6.7 - 7.4, 3) gas composition of approximately 65% methane and 35% carbon dioxide.

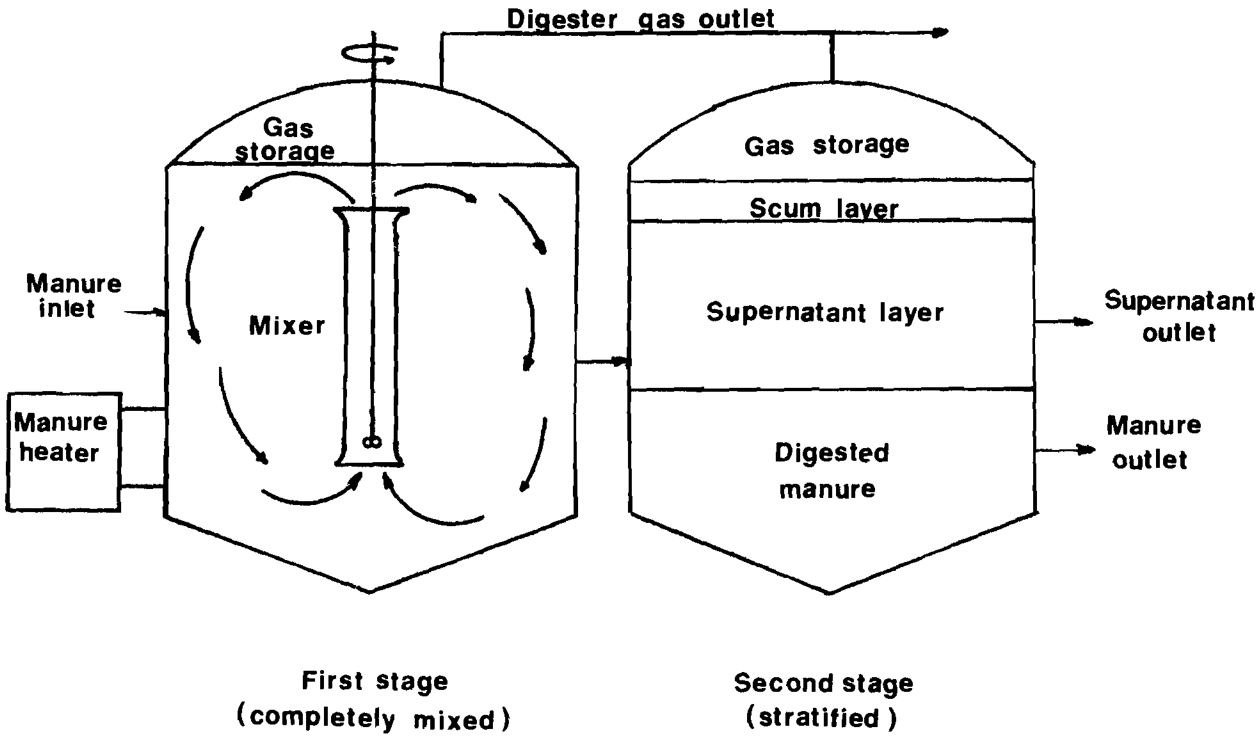


FIGURE 4.3 Two Stage Digester

A number of conclusions have been drawn during the course of the Georgia Tech project based on the operating experience gained as well as the experimental results. A partial list follows:

1. To make the system energy efficient, all or part of the system (digester, tanks and pipes) must be installed below the ground and/or suitably insulated depending on climate.

2. Due to the corrosive nature of the biogas the material of construction must be selected very carefully. Digester and tanks must be made of durable, non-corrosive materials of construction for longer life.

3. A circular digester with a conical bottom for draining solids in preferable.

4. The system should be designed with the provision for back flushing and cleaning it periodically.

5. The plant must have a stage to remove grit from the manure slurry.

6. The anaerobic digestion of poultry manure appears to be an economically feasible process. The rate of return of capital invested could be 26% and the duration to recover capital is estimated to be approximately four (4) years.

7. By anaerobic digestion of poultry waste an excess amount of clean fuel gas can be produced. The stablized manure (sludge) produced has a good fertilizer value and may be utilized as a profitable feed supplement for cattle or hogs.

8. Anaerobic digestion which eliminates pathogenic bacteria is seen to be a useful conversion process to animal feed. Laboratory tests indicate that one ton of dry digested manure (sludge) would contain 250 lbs of crude protein which is as digestible as cottonseed meal (a standard protein supplement). Sludge as an animal feed supplement was estimated to produce an increase in profit of 18% in the cattle fattening operation.

9. Retention times of 20-30 days can produce a large quantity of biogas and economically stablize raw manure by reducing B.O.D. and C.O.D. by as much as 85%.

So through intensive research efforts by Georgia Tech the livestock industry now has an option for disposing of its massive amounts of wastes without damage to the environment and with an alternate energy source as a result.

HINTS ON THE DEVELOPMENT OF SMALL WATER POWERS

This pamphlet has been prepared for those who contemplate the construction of small water power plants on small streams for the purpose of generating electric current for general home use, and it is intended to convey certain information in order that the subject may be grasped by those unacquainted with the general rules and requirements for such developments.

It is generally understood by all that a flowing stream may be made to produce power, but it is not generally understood what information is required by the manufacturer of water power equipment in order that proper advice and recommendations may be given. Therefore we are outlining below the rules and requirements that must be observed when asking for information pertaining to the development of water power. We will add that the subject matter of this pamphlet applies principally to the smaller developments, but, at the same time, the same rules may be applied to the larger developments to a certain extent.

FALL OR HEAD

In order to produce power from a flowing stream there must be a "fall" in the stream. This "fall" is almost always augmented, or increased by the construction of a dam. A dam in the stream is necessary in order to raise the water to a maximum level to create a head, and to divert the water from the stream to the turbine, or water wheel. This head that is created is the vertical distance from the surface of the water at the dam down to the surface of the water in the stream below the dam and at a point where the turbine will be located.

As the useful power that may be produced from any waterpower is the direct product of the "head" and the weight of the water, which weighs 62.34 lbs. per cubic foot, it follows that the "head" available and the amount of water flowing in the stream in cubic feet per minute are absolute factors when it is desired to compute the amount of power that may be developed.

It will be understood that the term "fall" means the natural fall or drop in the course of a stream, and that the term "head" defines the vertical drop resulting from the construction of a dam in the stream.

HOW TO DETERMINE THE "HEAD"

When selecting the dam site it is well to remember that the higher the dam is built the more the "head" will be, and the greater the "head" the more power a given amount of water will produce; and the smaller will be the turbine. Therefore, it is well to exercise care in the selection of the dam site so that the highest possible head may be realized. However, consideration must be given to the cost and possible damage to your neighbor's property. Usually the topography of the ground will suggest the logical location for the dam, although there are other determining factors to be taken into consideration, such as character of foundation, property lines, pond area, etc. Space does not permit a more detailed treatment of these subjects. We will say, however, that it may be well to have an engineer or surveyor run out "contour lines" upstream from the dam site representing proposed water levels back of the dam. In this manner the flooded area may be determined before the dam is built, and serious complications avoided if such there may be.

After the height, or elevation, of the water back of the dam has been established, levels may be run downstream with an engineer's level or transit to determine the "fall" or "head" that may be secured below the dam site within a reasonable distance. It follows that the TOTAL HEAD that may be secured is that which is created by the dam plus the "fall or head" that may be secured below the dam. This TOTAL HEAD is represented by the VERTICAL DISTANCE from the surface of the water back of the dam down to the surface of the water below the dam and at the point where the turbine may be located.

If the developed "head" is low; that is, from a few feet up to ten to fifteen feet, the turbine is usually located right at, or very close to the dam, the water being conveyed to the turbine through an open flume or penstock. But, in some cases, where the head is not any greater than mentioned above, the turbine may be quite small and for that reason alone it might be more economical to convey the water to the turbine through a steel pipe line.

In some cases, regardless of the head secured, it is desirable to place the turbine some little distance below the dam to secure additional head due to the fall of the stream below the dam. In such cases a pipe line, or an open flume or open ditch may be used to convey the water to the turbine. However, there are cases where an open tail race may be excavated from the stream to the powerhouse to secure at least part of the fall below the dam; this being less expensive than the above mentioned pipe line or ditch.

MEASUREMENT OF WATER FLOWING IN THE STREAM

The second absolute factor that determines the amount of power that may be developed is the quantity of water available for power purposes flowing in the stream. Quantity of water for power purposes should be expressed in "cubic feet per minute" (C.F.M.).

There are two well known methods of measuring streams; one by the weir method and the other by the float method. Both methods are fully described and illustrated on a leaflet attached to this pamphlet.

There are cases where it is obvious that the water supply is more than adequate for the power to be developed but in most cases it is highly important that the water be carefully measured.

It will generally be found that the flow of water in any stream will vary greatly with the season of the year and this should be taken into consideration when measurements are taken.

The minimum flow of a stream, in most cases, has a duration of several weeks during the dry season, and this flow, when taken into consideration, represents the amount of water that can be developed continuously, or 100% of the time outside of that period of time the stream may be in flood stage.

As the flow of the stream increases, the amount of power that may be developed increases, although it is true that as the flow increases the actual head on the turbine is decreased somewhat on account of a greater quantity of water being discharged into the tail race which raises the level of the water therein.

As the flow increases beyond the normal, or average stage the head is reduced still further. However, periods of high water and low head are of comparatively short duration and while this condition must be contended with, it should not be allowed to stand in the way of the development of the water power.

It is obvious that a stream should be measured at various times of the year in order that complete data on the flow be established. Daily measurements are ideal and may be made conveniently, especially if the weir method of measuring is used.

It is also obvious that any measurement taken during flood period would be of little value except that such measurements may be used to estimate the size of the flood or waste gate in the dam. It should be noted here that if the stream is subject to floods, provision must be made in the dam to allow the excess water to escape; thereby preventing damage to the dam and powerhouse structure.

EFFECT OF PONDAGE

When a dam is built in a stream there is created back of the dam a pond that is really a storage reservoir that may be used to very good advantage to conserve the supply of water during times when the turbine is consuming less water than is flowing in the stream, and to supply water over and above that flowing in the stream when it is needed. If the pond is of sufficient area the above feature is of much benefit during times when the stream is at minimum flow.

In further explanation it may be stated that the load on any plan is seldom, if ever, fixed as it may and will vary with the needs of the power consumer. For example: Let us assume that the maximum capacity of the turbine is 600 cubic feet of water per minute, and that the load on the turbine at the moment requires all of this water to develop the power required by the load. Assume also, that the flow of water in the stream at the same time is only 300 cubic feet per minute. It will be seen that the turbine will consume the 300 cubic feet of water flowing in the stream plus 300 cubic feet more per minute which will be drawn from the pond. Now assume that in a short time the load changes to the extent that the turbine only requires 100 cubic feet of water per minute. Inasmuch as there are 300 cubic feet of water flowing in the stream and the turbine only requires 100 cubic feet of it, the difference, or 200 cubic feet of water per minute, will be stored in the pond to replace that which was drawn out.

A great many water-power feed and flour mills depend a great deal on pondage as they operate during the day, drawing on the pond for excess water not supplied by the normal flow of the stream. At night they shut down and the flow of the stream refills the pond which allows them to start the next morning with a full pond.

From the above we believe it will be seen how important and necessary the pond is to the successful operation of a water power plant during times when the normal flow of the stream is not great enough to supply the maximum capacity of the turbine installed. In other words one may take advantage of the existence of a pond and install a larger turbine than he could otherwise, and, thereby, be able to carry a greater momentary, or peak load for short times.

Therefore, the area of the pond created by the dam should be given along with the information regarding the head and the quantity of water. The area of the pond may be given approximately and in terms of acres.

ESTIMATING THE POWER REQUIRED

As this pamphlet is principally for those who desire to install water power equipment to drive generators for furnishing electric current for home and farm use, we will confine our remarks to that type of load.

It may be your wish to furnish electricity to only a small cottage, a group of cottages, a group of farm buildings, or perhaps, to a private estate including all the buildings thereon. But, whatever it is, there are certain items of information we should have to be able to advise you regarding the amount of power required to accomplish the results you desire.

A list of the total number of electrical outlets in all of the buildings should be made, and this list should include only the outlets for electric lights.

Then, in addition, list all of the electrical appliances that may be used, including heaters, flat irons, radios, television sets, electrical ranges, milking machines, cream separators, etc. With such a list at hand we can then estimate the approximate peak load that would have to be carried by the turbine and helps us to decide on the proper size of turbine and accessory equipment.

TYPES OF ELECTRIC GENERATORS

There are two types of electric generators that may be used, and we are referring to their electrical characteristics in this instance. One type generates Alternating Current and the other type generates Direct Current. The type to be selected depends on a number of factors which must be given consideration. Alternating Current may be transmitted much greater distances than Direct Current without undue loss and with smaller wires. Therefore, the distance from the power plant to the place where the current will be used is a very important factor and should be stated in your inquiry.

The size of the generator is another factor, but that is determined when the power of the turbine is determined, and, therefore, this will be taken into account when the recommendations are made.

The type of equipment to be operated by the electrical current is, also, a factor, and it is well to remember in this connection that any electrical apparatus having heating elements, such as light bulbs and heaters, may be operated by either Alternating or Direct Current. On the other hand, any apparatus operated by electric motors must be equipped with either Alternating Current motors or Direct Current motors as it is substantially true that it is impossible to have a motor that will operate on both A.C. and D.C. current.

If your buildings are already furnished with Alternating Current equipment it is a very deciding factor in the selection of the generator, irrespective of the distance the current must be transmitted. But, if this apparatus is yet to be purchased, consideration may be given to the selection of a Direct Current generator and equipment to suit. Direct Current generators are generally less expensive than the A.C. type, and, if wound in a certain specific manner for constant voltage, expensive governing equipment for the turbine equipment may be omitted.

For additional information on this subject please write to any of the principal electrical manufacturers, or confer with your local electrician.

Courtesy: The James Leffel & Co. Springfield, Ohio

Different Methods With Instructions For Measuring Water

Measuring Flow of Water by Weir Method

After deciding upon suitable location for the new power plant, the following preliminary measurements must be obtained:

FIRST, obtain in feet the head of water This is the vertical distance from the surface of water above dam down to the tail water surface below dam at the place where turbines will be located.

SECOND, obtain minute cubic feet of water. Several methods may be used, the easiest and most commonly used methods are as follows:

If the stream is large, select place where water flows slowly for some distance between parallel banks and where the bottom of stream is fairly even. Then carefully space and measure the cross sectional area of water in square feet. Then place a float that sinks well down into the water in the center of stream and accurately measure the distance in feet the float travels in one minute. Then multiply this distance by the cross sectional square feet area, and eighty-three per cent of this result will be approximately the minute cubic feet of water flowing in the stream. Or,

If the stream is small the water can be measured by weir. (See the above illustration.) Select first a suitable location in stream where water flows slowly, then place a board with notch in same, forming a weir dam; the down stream edge of weir notch beveled almost to a sharp edge; the width B must be about six times the greatest depth of water flowing over weir. The bottom edge of weir not less than one foot above the surface of water below the down-stream side of weir. Then drive a stake up stream several feet above weir. The top of stake must be exactly level with bottom edge of weir. When all water is flowing over weir, measure the depth C over top of stake, then read above weir table which gives the minute cubic feet of water 1 inch wide flowing over weir. Example: Assume width B of weir as 70 inches, depth C as 12½ inches. Look down the first column in weir table to 12 inches, then horizontally to column under ½ inch. The minute cubic feet flowing over weir 1 inch wide, 12½ inches deep will be 17.78 multiplied by 70 inches, the result is 1244.60 minute cubic feet flowing over weir.

The horsepower of the minute cubic feet of water thus obtained for any head up to 50 feet given in power tables, pages 10 to 13, inclusive.

If water is measured by miner's inch method, give us the number of miner's inches of water per minute, together with the head of water. We then will advise the horsepower that can be developed by our turbines.

Send us full measurements and particulars regarding proposed new turbine installment. We will reply promptly with full information.

Table Giving Minute Cubic Feet of Water 1 Inch Wide Flowing Over Weir

Inches Depth C Over Steke		⅛ Inch	¼ Inch	⅜ Inch	½ Inch	⅝ Inch	¾ Inch	⅞ Inch
1 Inch	.40	.47	.55	.65	.74	.83	.93	1.03
2 "	1.14	1.24	1.36	1.47	1.59	1.71	1.83	1.96
3 "	2.09	2.23	2.36	2.50	2.63	2.78	2.92	3.07
4 "	3.22	3.37	3.52	3.68	3.83	3.99	4.16	4.32
5 "	4.50	4.67	4.84	5.01	5.18	5.36	5.54	5.72
6 "	5.90	6.09	6.28	6.47	6.65	6.85	7.05	7.25
7 "	7.44	7.64	7.84	8 05	8.25	8.45	8.66	8.86
8 "	9.10	9.31	9.52	9.74	9.96	10.18	10.40	10 62
9 "	10.86	11.08	11.31	11.54	11.77	12.00	12.23	12 47
10 "	12.71	12.95	13.19	13.43	13.67	13.93	14.16	14 42
11 "	14.67	14.92	15.18	15 43	15.67	15.96	16.20	16 46
12 "	16.73	16.99	17.26	17 52	17.78	18.05	18.32	18 58
13 "	18.87	19.14	19.42	19.69	19 97	20 24	20.52	20 80
14 "	21.09	21.37	21.65	21.94	22.22	22.51	22.79	23 08
15 "	23.38	23.67	23.97	24.26	24 56	24.86	25.16	25 46
16 "	25.76	26.06	26.36	26 66	26.97	27.27	27 58	27.89
17 "	28.20	28.51	28.82	29.14	29.45	29 76	30.08	30.39
18 "	30.70	31.02	31.34	31.66	31 98	32.31	32 63	32 96
19 "	33.29	33.61	33.94	34.27	34.60	34.94	35.27	35 60
20 "	35.94	36.27	36.60	36.94	37.28	37.62	37.96	38 31
21 "	38.65	39.00	39.34	39.69	40.04	40.39	40 73	41 09
22 "	41.43	41.78	42.13	42.49	42 84	43.20	43 56	43 92
23 "	44.28	44.64	45.00	45.38	45 71	46 08	46.43	46.81
24 "	47.18	47.55	47.91	48 28	48 65	49 02	49 39	49 76