Project Title: 
Poultry Industry Research

Project No: 
A-2028

Project Director: 
J. F. Lowry

Sponsor: 
Georgia Department of Agriculture

Agreement Period: 
From 8/1/77 Until 7/31/78

Type Agreement: 
Std. Ind. Res. Agr. dtd. 7/21/77

Amount: 
$230,000

Reports Required: 
Monthly Progress; Final (Annual) Technical

Sponsor Contact Person(s):

Technical Matters

Contractual Matters (thru OCA)

Mr. H. R. Jordan, Jr.
Georgia Department of Agriculture
19 Hunter St., SW
Atlanta, Ga. 30334

Defense Priority Rating:

Assigned to: Technology & Development Laboratory (School/Laboratory)

COPIES TO:

Project Director
Division Chief (EES)
School/Laboratory Director
Dean/Director-EES
Accounting Office
Procurement Office
Security Coordinator (OCA)
Reports Coordinator (OCA)

Library, Technical Reports Section
Office of Computing Services
Director, Physical Plant
EES Information Office
Project File (OCA)
Project Code (GTRI)
Other
GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 8-1-80

Project Title: Poultry Industry Research

Project No: A-2028

Project Director: (See ltr. dtd. 11-28-77)

Sponsor: Georgia Department of Agriculture

Effective Termination Date: 9/30/79

Clearance of Accounting Charges:

Grant/Contract Closeout Actions Remaining:

- Final Invoice and Closing Document
- Final Fiscal Report
- Final Report of Inventions
- Govt. Property Inventory & Related Certificate
- Classified Material Certificate
- Other

Assigned to: TAL/AED

(Copies To:
Project Director
Division Chief (EES)
School/Laboratory Director
Dean/Director—EES
Accounting Office
Procurement Office
Security Coordinator (OCA)
Reports Coordinator (OCA)

Library, Technical Reports Section
EES Information Office
Project File (OCA)
Project Code (GTRI)
Other)
Subject: Monthly Progress Summary
Letter for EES/GIT Research
Project A-2028 for Period
1 August 1977 through 31 August 1977

Attention: Mr. Hubert Jordan

Dear Mr. Jordan:

This summarizes activities on Research Project A-2028 with the following designated tasks:

001 Waste Utilization for the Generation of Methane Gas
002 Energy Conservation in the Poultry Industry
003 Solar Energy Application to the Poultry Industry
004 Mechanization in Poultry Processing
005 Poultry Industry Wastewater Treatment

Project 001

After some unexpected delays in starting the experiment, a result of the breakdown of the transfer pump and an air leak through a sight-gauge on the suction side of the pump, considerable progress has been made.

The first run was started to study the mode of top loading and bottom discharge of the digested sludge. The digester was loaded with 10% by volume v/v chicken manure. After incubating the manure for three weeks at 98°F, the additions of manure were made on a regular basis to maintain the desired residence time of twenty-one days. This run will last for two and a half more weeks.

Based on the results to date, one can say that:

1. Fuel gas with the methane concentration of 60 to 75% was generated.
2. The total amount of gas generated will be reported after the completion of the run. This volume would increase with the increase in volatile solid concentration as planned for the future runs.
3. Samples collected from the top and the bottom of the digester indicated that more vigorous circulation would be desirable for uniform distribution of the nutrients and microorganisms in the system.

4. The sludge samples are being analyzed to study their fertilizing properties.

Project 002

Progress to date in the energy conservation program includes an identification of the areas of concentration for this year's work. Because of the intensive work with the broiler processing plants in previous years, FY78 funds will be directed towards implementation of energy conservation programs in the various other aspects of the poultry industry: growout operations, egg production, egg processing, and rendering plants.

An evaluation of the several magazines and journals relating to the poultry industry have yielded a multitude of energy conservation ideas. All of these plans can save energy but, from the viewpoint of the man in the field, may have some problems which are not readily apparent to the uninitiated. To identify the areas of concern to the industry, field visits have been conducted and specific problems and potential solutions have been discussed. These will continue in order to assure that everyone is aware of the efforts under this year's contract and to make certain that the program is responsive to industry's needs.

One area of interest is in the alternate fuels for growout houses employing a modern wood and/or coal fired system to meet the stringout environmental conditions required by the young birds. A plan to develop a central plant design will be considered in more depth in the following months along with the other concepts.

Project 003

Selection of locations and volunteers for the installation of the extended roof demonstration unit is continuing. This effort has been hampered by the resignation of the Project Director, Ms. Joan Wood. Her position will be filled during the coming month by Mr. John Giles and the effort will resume with the goal of completing the installation prior to the cold weather season.

Project 004

Discussions were held with plant managers and engineers in poultry processing plants to determine their opinions on possible areas of improvement in yield and bird handling in their particular plant layouts and processes. There was general agreement that an accurate assessment of yield losses at various process line stations was necessary before potential yield improvement areas can be isolated.

A technical concept for a yield evaluation system which will involve the automatic weighing and counting of birds before and after a process line station was completed. The system will employ commercially available weighing cells and a computer system for data acquisition, storage and analysis. The basic
computer system has the capability of being programmed for later use in process line automation and control. Shackles will be modified as required for use of the yield evaluation system.

Efforts will continue into the selection of equipment that can be integrated into a reliable yield evaluation system which will not disrupt the normal process line operation.

**Project 005**

Met with management of seven Georgia Poultry processing companies to discuss waste water treatment needs and problems. Toured each of these facilities and noted varying degrees of treatment success associated with different plant situations. Obtained plant data on water consumption and effluent quality for future use. Plants visited were:

- Mar-Jac, Inc., Gainesville
- Tip-Tip Poultry, Marietta
- Wilson Foods, Cumming
- Centra Soya, Athens
- Gold Kist, Inc., Athens
- Marell Poultry, Murrayville
- ConAgra, Dalton

Met with environmental engineers from the Environmental Protection Division of the Georgia Department of Natural Resources and the Environmental Engineering Laboratory of the USDA Russell Research Center. Discussed effluent limitation regulations and recent developments in waste treatment technology.

Made telephone contact with four equipment manufacturers regarding treatment applications to the poultry industry. Started a waste treatment equipment literature file.

Research activity was in the following areas:
- Federal EPA Wastewater Discharge Guidelines
- Georgia EPD Wastewater Discharge Guidelines
- Sources and Components of Poultry Processing Waste
- Identification of Problem Areas for Further Study:
  - Evaluation of waste (particularly feathers) screening methods
  - Compatibility of detergents and cleaning solvents in common use with waste treatment systems
  - Potential for water recycling from poultry waste streams in Georgia (e.g. irrigation).

Respectfully submitted,

James F. Lowry
Program Manager
October 5, 1977

Georgia Department of Agriculture
Agriculture Building
Capitol Square
Atlanta, Georgia 30334

Subject: Monthly Progress Summary
Letter for EES/GIT Research
Project A-2028 for Period
1 September 1977 through
30 September 1977

Attention: Mr. Hubert Jordan

Dear Mr. Jordan:

This summarizes activities on Research Project A-2028 with the following designated tasks:

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Project 001

The first run in the top loading mode has been completed. The concentration of the sludge fed was maintained at 10% v/v, i.e., total solids and the volatile suspended solids were maintained at 2% and .95% respectively. The fermentation was carried out at 98°F.

The amount of gas generated fluctuated between 45 and 55 cubic feet per hour with methane concentration within the range of 55 to 65%. This volume is very near the theoretical design value for operation at this solids loading. If it can be extrapolated linearly, then at 30% loading we will have achieved the design value of 150 cubic feet/hour of the digester.
The digested sludge samples were analyzed to evaluate their fertilizing values which are given below:

<table>
<thead>
<tr>
<th>TOTAL</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>2.13%</td>
<td></td>
</tr>
<tr>
<td>Phosphorous</td>
<td>3.22%</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>0.73%</td>
<td></td>
</tr>
<tr>
<td>Fiber</td>
<td>19.05%</td>
<td></td>
</tr>
</tbody>
</table>

(no trace of heavy metals)

Project 002

Work is progressing in the two main thrusts of the project: Energy alternatives for the grow-out house and the brooder effectiveness evaluation.

A wood-fired forced air furnace is currently in use with gas-fired brooders on a turkey farm in Arkansas, and plans are under way to install a similar system for warm-air brooding in a Georgia chicken grow-out house. We are planning to divide a house in half and utilize the furnace in one half and conventional gas brooders in the other half. The house will be instrumented and data collected on temperature distribution, humidity, air flow, fuel consumption, fuel cost, mortality, feed conversion, and evisceration yield.

In researching reports of gas-fired infra-red brooder performance test, it has been found that, to date, performance has only been measured in terms of air temperature distribution; but the real heating effect is due to the radiant flux density. Plans are underway to build a test stand to measure radiant flux density and IR wavelength for a number of brooders in use in Georgia. We hope to define optimum wavelength, radiant element temperature, fuel consumption rate, and gas-to-heat conversion efficiency for chick brooding.

Project 003

The hillside collector was inspected in order to evaluate its condition before the winter testing period. The upper layer of the polyethylene glazing has hardened and in some areas it has split along the 2 X 2 frame. It is believed that high temperatures (due to absorbed sunlight), in addition to stress at the frame are responsible for this deterioration since the glazing remains pliable except near the frame. The upper layer of polyethylene will be replaced before winter. Aluminum tape or wooden battens (depending on cost comparison) will be stapled over the glazing along each 2 X 2 frame member in an effort to reduce the temperature by reflecting the sunlight.
Three prospective partners for solar retrofit project were called. Prospective locations and additional funds were discussed with John French of Central Soya, Bob Mitchell of Strain and Cagles, and Larry Kohn of Heard and Vernon. All three expressed interest in the project and are presently looking for locations and funds.

Project 004

The selection of components for the yield evaluation system continued. Purchase orders for some of the related electronic data processing equipment and conveyor line hardware were submitted. Construction of a pilot conveyor system which will be used for check-out of the automatic poultry weighing system and for debugging of the data processing equipment was begun at Georgia Tech.

Contacts were made with several poultry processors to explore the possibility of installing a yield evaluation system on their processing line.

Project 005

Started reviewing literature and discussions with equipment designers on feather screening. Inconclusive testing has been done at Texas A & M; more thorough work has been done in Holland, although test reports have not yet been received from Europe. It is generally felt that rotary drum screening (the predominant method in use) is a poor method of feather removal, and technology is available to remedy the situation. Work will continue in this area.

Talked with several sales representatives about new compact biotreatment systems that have recently come on the market. Potential fouling from high oil and grease concentrations in poultry waste water is a concern. Mar-Jac is planning to construct a small test unit.

Talked with representatives of several city/county water and sewer agencies where poultry plants are located. Rates vary widely from area to area. Exploring impact of changes in ways of computing sewage bills to encourage economy and water conservation.

Prepared guidelines and example specifications that can be used by the poultry industry in evaluating and purchasing waste water treatment systems.

Respectfully submitted,

James F. Lowry
Program Manager

R.L. Yaks
Laboratory Director
Attention: Mr. Hubert Jordan

Dear Mr. Jordan:

This summarizes activities on Research Project A-2028 with the following designated tasks:

001 Waste Utilization for the Generation of Methane Gas
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Project 001

The concentration of sludge fed to the digester was increased to 15% v/v. The reason for this gradual increase in feed concentration was to observe:

1. If there was a linear relationship between the available organic solids and the amount of gas produced.
2. Percent decrease in B.O.D. value of feed.
3. Mechanical difficulties involved in handling higher feed concentration.

The total gas produced would be reported more conclusively in the next report.

(continued)
The analysis of the gas being produced is given below:

<table>
<thead>
<tr>
<th>Gas</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>0.57 %</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>29.0 %</td>
</tr>
<tr>
<td>Oxygen</td>
<td>0.369 %</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.15 %</td>
</tr>
<tr>
<td>Methane</td>
<td>69.8 %</td>
</tr>
</tbody>
</table>

The analysis of digested sludge to evaluate its fertilizing property in terms of N, P and K is reported below:

<table>
<thead>
<tr>
<th>Property</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>2.92 % w/w</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>3.50 % w/w</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>0.26 % w/w</td>
</tr>
</tbody>
</table>

The above results indicate that we can produce:

1. Biogas with high methane concentration.
2. The digested sludge with valuable fertilizing properties.

Project 002

The brooder testing program is continuing with the evaluation and selection of infra-red detection instruments. Due to the complexity and sophistication of this equipment, the purchase cost is considerable. Negotiations with a local vendor have resulted in a very reasonable rental contract. The testing equipment is portable, allowing onsite testing for more realistic data.

The alternate fuel demonstration project is having some difficulty in finding a grower interested in allowing the wood fired space heating/brooding furnace to be installed at one house. The preliminary design is complete. The search for a willing grower is continuing and will be complete by early November.

Project 003

A partner for the solar retrofit project has been found. The solar retrofit system will be built on a new 450 foot broiler house on Mr. William Harris' farm, 5 1/2 miles north of Chatsworth, Georgia. Mr. Harris will be growing broilers for Gold Kist Inc. He is also a partner in Cole Concrete Products Inc. of Forest Park, Georgia.

Design of the low cost, adaptable solar retrofit system is continuing. Two different systems are being compared on the basis of initial and life cycle cost, adaptability to existing broiler houses, net energy output, and the degree to which the system can be automatically controlled. One of the two systems being compared uses water as the heat transfer medium; the other uses air. Design details and cost (continued)
analysis of the air system have been completed. During November, after small scale testing of an experimental water distribution system, the design details and cost analysis of the water system will be completed.

During October, some time was spent reviewing literature and talking with poultry growers in order to gain knowledge of broiler house conditions and heating system requirements.

Wilson Foods Inc. agreed to provide for replacement of the polyethylene glazing on the hillside solar collector at Lamar Hicks' Farm. The new Monsanto 602 polyethylene was delivered to Wilson Foods. Samples of reflective tape, provided by 3M Company, will be applied over the polyethylene along several of the 2x2 frame members. Durability of the tape will be evaluated during the coming year. A new sensing element has been ordered for one of the recording thermometers used in the Hillside Collector Project. The recording units have been repaired and recalibrated by Mr. Walter Reagh in the instrumentation and calibration group here at EES.

Project 400

The selection of the electronic components for the first yield evaluation system was completed and the corresponding purchase orders were submitted. A poultry processing plant was chosen for installation of the yield evaluation system and discussions concerning the interfacing of the weighing system with the existing evisceration equipment were held with the plant engineer. Negotiations were begun with poultry equipment suppliers to explore the possibility of a reduced price purchase or a loan of the necessary evisceration and weighing shackles which will be installed on the evisceration conveyor system.

Project 500

Randy Mattison, Project Director, attended a seminar on water recycling and re-use at New York University. It was well attended by representatives of government, industry consultants, and equipment manufacturers. It included some good open discussions of treatment processes, new innovations in the wastewater treatment field, and the latest ideas on water conservation and recycling. One experimental project discussed in particular was the recycling of non-potable water for fluming at a poultry plant in Maryland. This looks promising if USDA receives it well.

Mr. Mattison has also completed an article on Wastewater Treatment Plant Specifications. It has been submitted to Broiler Industry and Poultry Processing and Marketing magazines for possible publication.

While touring a number of poultry processing plants, one plant manager commented that he would not hesitate to increase his water flow to decrease pollutant concentration and avoid sewage surcharge. As a result, a survey of sewage surcharges and water volume costs has been initiated. Cost analysis of this data indicates that increased water flow volume charges are always greater than the saving of surcharge. This information is being used as the basis for
I wrote a journal article to promote water conservation in the industry.

Mr. Mattison attended a conference on water conservation sponsored by the Atlanta Regional Commission and spoke with Georgia Representative John Carlisle about pending water conservation legislation. In addition representatives of several plumbing fitting manufacturers were contacted about new flow restriction/reduction products that may be applicable to the poultry industry.

Respectfully submitted,

Richard H. Wright
Program Manager

R. L. Yohn
Laboratory Director
20 December 1977

Georgia Department of Agriculture
Agriculture Building
Capitol Square
Atlanta, Georgia 30334

Subject: Monthly Progress Summary
Letter for EES/GIT Research
Project A-2028 for Period
1 November 1977 thru 30 November 1977

Attention: Mr. Hubert Jordan

Dear Mr. Jordan:

This summarizes activities on Research Project A-2028 with the following designated tasks:

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Project 001

We have been gathering biogas at the rate of 50 cu. ft./hr. at 10% v/v manure loading, with methane content fluctuating between 68 to 75%.

Digested sludge had a moderate B.O.D. value and this needs to be repeated after collecting several samples.

The protein content of the digested sludge was found to be 19%. This figure can increase with the decrease in retention time of the chicken manure in the digester. Investigations have been started into the effects of higher loading rate on the consistency of the quantity and quality of the biogas.

Calculations for the economic feasibility of a 100,000 gallon digester were carried out. The following conclusions were drawn:

1. The amount of gas that could be produced per day = 3600 cu. ft.
2. Total equivalent heat available per day = $23.4 \times 10^6$ B.T.U.
3. Power potential = 85.52 KW

continued
4. Waste heat potentially recoverable = $11.7 \times 10^6$ B.T.U./day
5. Excess electricity potential per day for any other use = 35.52 KW
6. Excess recovered heat potential for other use = $10.5 \times 10^6$ B.T.U./day
7. Projected capital investment = $145,000
8. Projected value of excess energy = $30,027/\text{year}$
9. Projected operating cost (labor, repair, etc.) = $6,000/\text{year}$
10. Net return of cash = $24,027$
11. Total time to recover capital invested based on extra energy produced = 6 years
12. Projected value of feed product, based on market value of $100/\text{ton}$ for sale of effluent as feed = $37,248/\text{year}$
13. Projected net value of product \[\left((\text{energy} + \text{feed}) - \text{operating cost}\right) = 79,904$
14. Projected capital investment including sludge handling equipment = $165,000$
15. Total time to recover the invested capital based on #13 = 2.06 years

**Project 002**

The alternate fuel program has found a broiler grower interested in working with the EES on the wood fired furnace/warm air brooding project. Mr. George Key, a grower for Strain Poultry, has consented to the use of one of his two houses as the project site. Since the two houses are of identical construction, one will be used as a control house. The houses are side curtain types.

Most of the design phase is complete and the furnace has been ordered. Quote from the contractor who will be supplying and installing the ductwork and the furnace house are awaited. It is anticipated that a decision on this will be made within two weeks.

Rather than having two projects beginning at the same time, the brooder testing program has been scheduled to begin early next year. This will allow full attention to be concentrated on the furnace project and its inevitable start-up problems.

**Project 003**

The comparison of cost, materials, and design of the proposed air and water systems has been completed. The two systems being compared have approximately the same cost of materials. It has been decided to proceed continued
with the water system design since the system operating modes are easily
controlled and because of the smaller storage volume required by water
compared to rocks. Many of the design details and materials and equipment
selections have been completed.

A definite commitment has not been obtained from our prospective
partner, Mr. William Harris. Consequently, we are continuing the search
for additional funds and a building site in case Mr. Harris is not able
to work with us.

Preparations for data collection at the Hillside Collector test site
were made this month. A new flock of birds will be in the test house
early in December.

Project 004

This month's activities have centered around completing the design
details for the first installation of the yield evaluation system. The
mechanical design of the weighing stations was completed and all materials
were ordered and received. The computer which will be used for data ac-
quisition and analysis was received and the writing of the control and
data reduction programs was begun. The shackle hardware which will be
modified for use with the weighing stations was also received and the
required modifications and assembly have started.

Project 005

Project Director Randy Mattison attended the Southeastern Plant
Engineer and Pollution Exposition in Atlanta, and talked with several
equipment manufacturers about poultry waste problems.

Meetings were held with several poultry processors and Ron Thornton
of NASA, to discuss potential applications of aerospace technology to
waste treatment in the poultry industry.

An egg processor in Douglas, Ga., requested assistance through the
Georgia Tech EES Industrial Extension Office. They are facing some severe
problems with their waste water being discharged to the city sewer.
Alternatives to remedy the problem were reviewed with them and several
steps were suggested to improve the situation.
The installation of a new wastewater spray irrigation/zero discharge system was inspected at Crystal Farms' Egg Plant in Chestnut Mountain. This appears to be an ideal system for an egg processing plant; its performance will be followed.

Respectfully submitted,

Richard S. Combes
Assistant Research Engineer
Project Director

RSC/gg
Subject: Monthly Progress Summary  
Letter for EES/GIT Research  
Project A-2028 for Period  
1 December 1977 through  
31 December 1977  

Attention: Mr. Hubert Jordan  

Dear Mr. Jordan:  

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Project 001  

During December, 1977 we were not able to run the digester long enough to be able to report the reliable results. The following factors hindered the operation of the digester.  

1. We were without any supply of raw manure for two weeks.  
2. Some equipment broke down which needed to be either repaired or replaced, i.e.:  
   a. centrifugal pump used for transporting diluted manure and recycling it to the digester broke down. It was sent for repair.  
   b. gas meter stopped functioning and it was necessary to order a new counter unit.  
3. There was a shortage of manpower. Mr. Thomas Buckley, who has been operating the pilot plant on a daily basis, was not well during most of the working days.  

continued
4. December being relatively shorter caused further delay in receiving any part needed urgently.

During the month of January, 1978 we hope to generate a lot of good and reliable results.

Project 002

Major equipment purchases and selection of subcontractors have been the main activity for the wood fired brooding system project. An order for the 350,000 BTU per hour wood fired furnace was sent out to the Lyndale Manufacturing Company. A hydraulic wood splitter was delivered to the grower so he can begin stockpiling wood for the upcoming heating season.

Selection of the subcontractors for the construction of the furnace house and covered storage and the supply and installation of the air distribution system continue. Because of the cost of the duct system, sealed bids must be obtained before the contract is let. Bid evaluation will be completed by the first week of January. Installation of the duct will begin as soon as the poultry are cleared out of the house. The selection of the furnace house subcontractor is also in progress and due to the relatively small amount of money involved, will shortly be completed.

Start up of the system is anticipated for the end of January.

Project 003

During the month of December the upper layer of polyethylene was replaced on the solar collector at Lamar Hick's farm. Earth which had been lost by erosion at the top of the collector was replaced, and weeds which had grown under the lower edge of the collector were removed. These repairs required about twelve hours labor from two persons. After making these repairs, the stagnation air temperature at the top of the collector increased by about 30° F.

The present growout period at Lamar Hick's farm, which began on December 2, is being used to determine the relationship between the energy consumption of the solar heated house and that of the control houses. This data along with similar data recorded in 1976 will make it possible to more accurately evaluate the amount of energy supplied by the solar system during the next growout period.

continued
An experimental method of providing uniform distribution of water flowing down a poultry house roof was tested during December. Fiberglass screening material was glued to the sheet metal roof with evenly spaced spots of silicone adhesive. After several days, water was trickled down the part of the roof where the screening was attached. The screening material effectively spread two flow streams over an entire one foot wide section of the roof. Water streams applied to an untreated section of the roof zigzagged down the roof as singular streams leaving most of the one foot wide test surface unwetted.

Project 004

The machining of parts for the weighing stations was begun and it is anticipated that all hardware construction will be completed by mid-January.

Dale Atkins attended a seminar on computer interfacing at Hewlett-Packard and continued writing the data acquisition programs. All data acquisition electronics have now been received.

Due to the high cost of commercially available electronic equipment for signal conditioning of the weighing station data, it was decided to construct a specialized signal conditioning unit for each weighing station. The unit will simplify interfacing with the computer system and will help to keep project costs within the designated budget.

Project 005

Further study of the egg washing wastewater problem in Douglas, Ga., has resulted in identification of a vapor compression process as a possible solution. Package treatment plants are not expected to do an adequate job, and lagoon-type treatment is not practical in an urban location. Vapor compression will purify the water and highly concentrate the waste. The concentrated waste will be trucked to a farm lagoon system once per week.

Tests of a new type rotary drum wastewater filtration machine were conducted by the manufacturer at Mar-Jac, J.D. Jewell, and Fieldale in Gainesville. It did a good job of removing suspended solids, but energy costs to keep the screen from blinding may be its downfall.

An article titled "Guidelines for Selection of Wastewater Treatment Systems" was written by Project Director Randy Mattison. It should appear in the February issue of Poultry Processing and Marketing. The December 1977 issue of "Poultry Engineering Progress" contained conversion factors
that poultry processors can use to calculate effluent pollutant concentrations in ppm that are allowable for each plant. This should help them in day-to-day monitoring of the waste treatment system performance.

Respectfully submitted.

Richard S. Combes
Assistant Research Engineer
Project Director

RSC/gg
Subject: Monthly Progress Summary
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Project A-2028 for Period
1 January 1978 through
31 January 1978

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Project 001

Serious mechanical problems arose with the operation of the Cumming digester due to the severe weather conditions experienced in January. Corrective action was conducted throughout the month to rectify all process failures. Ninety-five per cent of the problems have been corrected. It is anticipated that the methane digester experiments will be continued within the next few days. It is planned to increase the loading of manure gradually to a level of 20% by volume from its current level of 12-15%. The goal is to produce a minimum of 100 cubic feet of biogas per hour at 20% loading. Further loading to 30% is then planned.

The specific failures included a performance failure of heating tapes due to apparent power failure. The resultant "freezing" of pipes caused bursting of several sections of the piping, particularly at elbows. A sleeve on a plastic valve also cracked due to differential contraction. All pipes and elbows which had failed were replaced and re-insulated to avoid a repetition of these set-backs. The plastic valve assembly is being replaced by a steel unit. Also during this period, the digester re-cycling pump failed. Its motor was removed, rewound, and replaced in
position. A totalizer unit was installed on the gas meter assembly for continuous recording of total gas production, i.e., cumulative gas yields.

Project 002

A change in management of the energy conservation program of the Georgia poultry research took place this month. Carl Brønn resigned from the Engineering Experiment Station, and Randy Mattison, Assistant Research Engineer, assumed the duties of project director. Mr. Mattison is also project director of the Poultry Wastewater Task.

Requests for press releases on the project were received from the Wall Street Journal and Watt Publishing Co. Appropriate information was forwarded.

Wood-Fired Brooding

Contracts were awarded for construction of the furnace concrete pad and enclosure. Work was delayed due to weather. The contract for duct fabrication and installation was also awarded, but installation will not take place until the present flock of broilers are shipped for processing early February. Furnace fabrication has been completed; it is ready to be shipped.

Brooder Testing

Twelve brooder manufacturers have been contacted, and eight have made commitments to lend brooders for testing so far. Delivery of the radiometer has been delayed about three weeks due to a factory inventory problem. Design of the test stand has been completed.

Project 003

After much deliberation, a non-storage solar heating system design using air as the heat transfer fluid has been decided upon for the second generation project. A broiler house to be used for testing the solar heating system has been located. The house is on a farm operated by Mr. William Waddell located west of Villa Rica about 45 miles from Atlanta. Plans for the heating system have been discussed with a prospective contractor.

Data collection at the first generation solar heated broiler house in Cumming continued through the growout period extending from December 2 to January 24. It has been planned to leave the solar heated air outlets closed during this period to better determine the energy consumption
relationship between the solar heated house and its control houses. The air outlets were left open instead of closed during the last six weeks of the growout period as a result of a misunderstanding with the caretaker. Gas consumption in the solar heated house was higher than expected. The concrete pipes connecting the solar collector with the house will be checked for blockage before the next growout period which begins February 10.

Project 004

The fabrication of parts for the two weighing stations was completed. One of the weighing stations was temporarily installed on the evisceration line at Mar-Jac in Gainesville to check for proper hardware operation and attachment to the existing conveyor system. No problems developed and the weighing station was removed so that calibration and interfacing with the data acquisition system could be performed at Georgia Tech.

Components for the electronic signal conditioning units were ordered and assembly of the related circuits was begun.

Project 005

Project Director Randy Mattison visited Bestovall Foods, a fowl processor in Monroe. They have an interesting wastewater situation in that their cooking and canning process is only operated periodically. This problem will be studied further.

National Eggs Products Company in Social Circle was visited to gain a familiarity with egg-breaking wastewater problems.

An article dealing with the importance of water conservation to the poultry industry was co-authored by Tom Ebert of Mar-Jac, Inc., and Randy Mattison. It has been submitted to Poultry Processing and Marketing Magazine for publication.

Project Director Randy Mattison attended a seminar and dinner for Georgia legislature members to provide information on the projects.

Respectfully submitted,

Richard S. Combes
Project Director

RSC/gg
Georgia Department of Agriculture  
Agriculture Building  
Capitol Square  
Atlanta, Georgia  30334  

Subject: Monthly Activities Report  
Project A-2028  
February, 1978  

Attention: Mr. Hubert Jordan  

Dear Mr. Jordan:  

I enjoyed my recent visit with you and Dr. Cobb to discuss the Georgia Tech Poultry research. As you requested I have attached a copy of the plans for the second solar broiler house and a copy of the February "Poultry Engineering Progress" newsletter. The following is a summary of activities for the subject project with the following designated programs:  

001 Waste Utilization for the Generation of Methane Gas  
002 Energy Conservation in the Poultry Industry  
003 Solar Energy Application to the Poultry Industry  
004 Mechanization in Poultry Processing  
005 Poultry Industry Wastewater Treatment  

Project 001  

During the past month, the methane digester was placed back into operation. The digester processing rate has been placed on a schedule of 400 gallons of 12-15% manure every Monday, Wednesday and Friday.  

Because of the length of time the digester could not be fed, due to failure of the recycling pump, it is anticipated that several weeks of operating on this schedule will be required to reach steady state conditions.
It is planned to obtain gas production rates with manure loading of 15%, 20% and 30%.

Several additional mechanical problems have been encountered and resolved this month. The mechanical seal on the Liquid Jet Vacuum pump failed and a replacement was ordered. Until this pump is operational, no volumetric data can be obtained. The pressure relief u-tube inside the digester broke and was replaced with an external u-tube filled with anti-freeze for cold weather protection. The hot water heating circuit which heats the mix tank has been plagued with loss of water which causes the system to turn off. It was determined that the gear pump which also supplies water to the mix tank was defective and it was replaced with a submersible pump. The hot water circulating pump also failed and was replaced.

Project 002

Construction of the wood-fired brooding system is about 80% complete as the furnace house concrete pad was poured, the furnace was delivered and set in place, and the majority of the ductwork was installed. Remaining work includes construction of a shed around the furnace, hook-up of the duct and flue system to the furnace, electrical wiring, and installation of monitoring equipment. A problem in the structural support of the air diffusers was also discovered and re-design initiated.

The brooder efficiency testing project was again set back by further delays from the radiometer vendor. Arrangements have been made to conduct the tests at the University of Georgia Agricultural Experiment Station. Their environmental control rooms will be ideal for reducing background errors.

Background work was initiated in the study of energy conservation and heat recovery potential for egg laying farms, egg processing plants, and poultry by-product rendering plants.

Project 003

Construction drawings for the second generation solar broiler house heating system were completed during February. Materials for construction were ordered. A definite commitment of cooperation was received from Gold Kist, Inc. for the duration of this project at Mr. Waddell's farm. Requests for quotations were sent to prospective contractors and the bid submitted by Ace Contracting Company was accepted. Construction of the solar heating system is expected to begin as soon as the present flock of birds is harvested.

Blockage of house litter was discovered in ten of the twelve concrete air ducts at the first generation solar heating system. The blockage was removed with the aid of one man and a roto rooter from Wilson Foods, Inc. Rats are thought to be the cause of this blockage since the concrete pipe
joints were not sealed at the time of installation, allowing the rats to enter the pipes. Several solutions to this problem are being considered.

Project 004

Assembly of the amplifier and signal conditioning circuits for the weighing stations continued. However, completion of the circuits was delayed due to slow delivery of critical components.

Preparation of computer programs for data acquisition and analyses has now reached a developmental stage where actual signals from the weighing stations are needed for program debugging and calibration. It is anticipated that the necessary electronic circuits will be completed in early March and system checkout can begin.

Project 005

Visits to Georgia Poultry Processing Plants were continued this month to discuss wastewater problems and observe operating treatment. A lagooning system that meets 1983 effluent standards and spray irrigation system that meets 1985 standards were observed.

After meeting with Mr. Harvey Brown, executive director of Georgia Council of Consulting Engineers, work was begun on the compilation of a directory of technical consultants in Georgia. Each firm is being interviewed by telephone to determine professional qualifications, experience in wastewater treatment, experience with the poultry industry, and willingness to accept jobs of the size and scope of a poultry processing plant requiring sewer pre-treatment. When completed, this directory will be circulated to Georgia Poultry processors.

If you have any questions at any time regarding the progress of the research, please contact me.

Sincerely,

Richard S. Combes
Project Director

RSC/dh
Attachment
C.C. Dr. John Cobb
Subject: Monthly Activities Report
Georgia Tech Poultry Research
Project A-2028
March, 1978

Attention: Dr. John Cobb

Dear Dr. Cobb:

Due to the fact that Hubert Jordan has left the Department of Agriculture, I will plan to submit the monthly activities report for Georgia Tech Poultry Research to you, in accordance with Mr. Jordan's instructions. I hope to be able to meet with you in the near future to discuss the proposed Georgia Tech research under the recently passed budget for FY 79.

The following is a summary of activities for the subject project with the following designated programs:

001 Waste Utilization for the Generation of Methane Gas
002 Energy Conservation in the Poultry Industry
003 Solar Energy Application to the Poultry Industry
004 Mechanization in Poultry Processing
005 Poultry Industry Wastewater Treatment

Program 001

Considerable progress has been made since the operational interruptions due to mechanical failure. Fresh raw manure (6% w/w Appxly.) is being added to the digester at a regular interval in the beginning to maintain the retention time of 40 days which, in future, can be reduced gradually. The volume of gas generated has increased during the last three weeks from zero to 42 Cu. Ft./hr. with 44% methane which is expected to improve with time. These are not steady state results.
A typical analysis of a digested sludge gave the following results:

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Mixed Tank</th>
<th>Digestor Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top</td>
<td>Bottom</td>
</tr>
<tr>
<td>Total Solids</td>
<td>5.49% w/w</td>
<td>1.32%</td>
</tr>
<tr>
<td>Fixed Solids</td>
<td>1.88% w/w</td>
<td>0.65%</td>
</tr>
<tr>
<td>Volatile Solids</td>
<td>3.58% w/w</td>
<td>0.67%</td>
</tr>
<tr>
<td>pH</td>
<td>8.24</td>
<td>8.13</td>
</tr>
</tbody>
</table>

Biochemical Oxygen Demand (BOD₅) of raw manure was reduced from 32,500 mg/lit. to 4,150 mg/lit. This was 87.5% reduction with 40 days of retention time and inadequate mixing. The NPK analysis of the digested sludge gave Nitrogen 2.5%, Potassium 0.95% and Phosphorous 4.4%.

Other highlights are described briefly as follows:

1. A vacuum gauge was installed in the line just before the gas meter to monitor the vacuum continuously. It is found to be 30" of H₂O.
2. Built an adapter for the manure truck to be able to discharge the raw manure in the holding tank.
3. Electrical circuits have been modified so that every automatic control valve can also be operated manually.
4. On 3/24/78 there were two muffled explosions inside the digester. These vibrated the digester and the unit monitoring the sludge level inside the fermenter was blown. No serious damage was done and no one was hurt. This halted the operation of digester for a week. At present the monitor is being repaired and every possible cause is being investigated. The probable causes were:
   a. Corrosion of the connection between monitor and the tank resulted into a small air leak since the unit is operated under vacuum (30 inches of water).
   b. As soon as the monitor was activated to measure the sludge level inside the digester, the mobile weight of the monitor hit the top causing the spark which ignited the gas-air mixture.

Routine operation of the digester should resume during the first week of April.

Program 002

Progress is continuing on the wood-fired broiler grow-out system. Construction of the furnace house was completed and purchase orders released for gas meters and electrical hook-up. Air diffuser structural reinforcement
was also installed.

Temperature and humidity recorders were placed in both the test and control houses to obtain background data before experimentation begins. Environmental correlation between the two houses is very close, so the control house should provide a good basis for evaluating the performance of the test system.

Discussions were held with representatives of Heat Bath Manufacturing Co., two of the participating companies in the brooder tests, regarding the efficiency testing program. They are very enthusiastic and have requested that carbon monoxide readings be included in the test plan. Steps are being taken to do this.

The brooder test site has been switched to the Russell Research Laboratories in Athens due to continuing scheduling difficulties. The radiometer delivery date is now April 10. Test stand materials have been procured, and construction is under way.

Program 003

During March, we completed construction of the solar broiler house heating system except for the installation of the fiberglass glazing material and polyethylene air distribution duct. The glazing material and mounting hardware for the polyethylene duct were shipped after the contractor had completed construction of the collector framework. Construction of the heating system will be finished by April 15.

During the construction delay, we installed the differential temperature thermostat in the fan control circuit. We installed thermocouples at various locations around the collector for measuring the heating system performance.

Program 004

The amplifiers for the yield evaluation system at the Mar-Jac poultry plant in Gainesville have been completed but actual installation has been delayed due to the delayed shipments of the load beams from Transducers Inc. in California. As a result of this delay actual installation has been re-scheduled for mid April, at which time the load beams will be mounted on the weighing rails and the hardware will be interfaced with the mini-computer to produce the required information.

Concurrently, however, work was begun at the Mar-Jac plant on the bird hanging evisceration shackles which were modified to interface with the weighing equipment and with the processing line equipment. The shackles have been completed and are ready for installation and trial runs. Equipment debugging and calibration should begin in mid April with actual data collection scheduled for the first part of May.
Program 005

The processing plant production and waste load scenario to be used in system cost analysis has been completed. This data resulted from discussions with processors, information collected on plant operations, and analysis of waste treatment needs for Georgia Poultry Processing plants. Cost analysis will be applied to eight leading commercial waste treatment systems, with additional systems to be analyzed as time permits.

The shearing effect of wastewater pumping on subsequent screening and flocculation processes was discussed with several experts in the field. It is felt that the effect is significant, but quantified data is not available on poultry processing wastewater. This information would be of use in designing new plants, but will not benefit existing operations.

Project Director Randy Mattison attended a Georgia Conservancy seminar to review the progress of the Georgia EPD in the area of wastewater pollution control. It is apparent that effluent standards will be vigorously enforced as they become effective, and processors should not expect or anticipate waivers or extensions for compliance.

If you have any questions on these summaries, please contact me.

Sincerely,

Richard S. Combes
Project Director

RSC/dh
Attachment
POULTRY INDUSTRY ENERGY SURVEY

The Engineering Experiment Station has conducted an energy survey of poultry industry operations for the years 1974 and 1976. This energy data has allowed us to monitor the trends in energy use and energy costs to the industry. We are currently conducting a survey for energy use in the calendar year 1977 under our poultry industry energy research program, and we request your participation by filling out the attached survey and returning it to us in the enclosed envelope form. Any information furnished to Georgia Tech will be considered proprietary. Using the completed forms we will evaluate the energy data for each sector of the industry and make a copy of the computer printout available to all participating facilities. The industry-wide energy data will be summarized in a future issue of Poultry Engineering Progress.

If there are any questions regarding the survey, please contact Randy Mattison or Richard Combes at 404/894-3623.

PUBLIC PARTICIPATION IN ENVIRONMENTAL REGULATIONS

The E.P.A. and the Georgia Environmental Protection Division of the Department of Natural Resources are conducting regional meetings on current and proposed environmental regulations. The nature of the regulations, levels of enforcement, and environmental impacts will be discussed. Participation from the public is sought to identify problems and oversights in the regulations. Copies of the regulations can be found in most college or public libraries in the state, and meeting times and locations will be announced in local newspapers. Further information can be obtained from the Georgia Conservancy, 404-262-1967, or from any office of the Department of Natural Resources.
Attention: Dr. John Cobb

Dear Dr. Cobb:

The following is a summary for the subject project with the following designated programs:

001 Waste Utilization for the Generation of Methane Gas
002 Energy Conservation in the Poultry Industry
003 Solar Energy Application to the Poultry Industry
004 Mechanization in Poultry Processing
005 Poultry Industry Wastewater Treatment

As the summaries indicate, all projects have reached the point where most of the hardware which has been designed is delivered and installed. During the next 3 months, we hope to collect some meaningful data on the wood-fired and the new solar heating systems for broiler houses and on the poultry processing electronic yield evaluation system.

Program 001

The anaerobic digester is being operated under the pressure of 1" to 2" of water head. This has the following advantages over the previous system where the vacuum was used to evacuate the biogas.

1. Air cannot leak into the digester and the process of anaerobic digestion can be maintained. This would also eliminate the possibility of any explosion.
2. Reduction in the cost of equipment since the vacuum system would not be necessary.

3. No amount of energy would be required in operating the gas meter.

At present the system is being loaded with a slurry (6.8% w/w) to maintain the residence time of 42 days. The amount of gas produced is 41 cu. ft. per hour with 63% methane. An interesting observation is made that 60 cu. ft. per hour of gas was produced during the first five hours after loading the digester. This indicated that 10.34% of the total gas was produced during 4% of the time after the loading of fresh manure and the gas production dropped off till the next loading took place. Thus the digester would have to be loaded every day and possibly a continuous loading may even be more desirable, but this would need further investigation.

The digested sludge was sent to Mr. George Black to carry out some feeding trials. The preliminary results were very encouraging. In fact, cows and calves seemed to prefer the feed mixed with digested sludge over the regular feed.

The digested sludge showed the reduction in COD values between 73.4% to 79.8% and that of BOD$_5$ between 81.3% and 84.5%. Results are presented in Table 1.

**Program 002**

This month's activities included the completion of construction on the furnace and ducting system for the wood-fired grow-out. Initial testing was begun with good results. The system will be operated in a "Testing and Tune-up" mode for approximately one month before any attempt is made at brooding chicks.

The data collection forms for the annual survey of energy consumption in the poultry industry have been mailed to all Georgia poultry and egg processors, feed mills, and hatcheries. Returns have been good, and computer compilation of the data will begin next month.

The test stand for the infra-red brooder efficiency study has been assembled. Testing will begin as soon as the radiometer arrives (it is due the first week of May).

The feasibility study on the use of waste heat from egg candling lights to heat the egg washer water sump has been completed. While technically fea-
<table>
<thead>
<tr>
<th></th>
<th>Digester Sample</th>
<th>Raw Slurry Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>from</td>
<td>from Mix Tank</td>
</tr>
<tr>
<td></td>
<td>TOP</td>
<td>BOTTOM</td>
</tr>
<tr>
<td>pH</td>
<td>8.13</td>
<td>8.04</td>
</tr>
<tr>
<td>Alkalinity mg/l. as CaCO₃</td>
<td>13820</td>
<td>13930</td>
</tr>
<tr>
<td>Total solids % w/w</td>
<td>2</td>
<td>3.71</td>
</tr>
<tr>
<td>Fixed solids % w/w</td>
<td>1.02</td>
<td>1.62</td>
</tr>
<tr>
<td>Volatile solids % w/w</td>
<td>0.94</td>
<td>2.13</td>
</tr>
<tr>
<td>BOD₅ mg/litter</td>
<td>3400</td>
<td>4100</td>
</tr>
<tr>
<td>COD</td>
<td>8680</td>
<td>11440</td>
</tr>
<tr>
<td>Reduction in COD %</td>
<td>79.81%</td>
<td>73.4%</td>
</tr>
<tr>
<td>Reduction in BOD₅ %</td>
<td>84.5%</td>
<td>81.3%</td>
</tr>
<tr>
<td>N</td>
<td>-</td>
<td>2.44</td>
</tr>
<tr>
<td>P</td>
<td>-</td>
<td>4.42</td>
</tr>
<tr>
<td>K</td>
<td>-</td>
<td>1.17</td>
</tr>
</tbody>
</table>
sible, the cost is not justifiable at the present time with commercially available heat exchangers of the type needed.

A hatchery and rendering plant in Clarksville were visited to identify opportunities for energy conservation in these areas.

Program 003

Construction of the second generation solar broiler house heating system was essentially completed in April. Gas meters were installed in the solar heated house and control house. Preliminary tests of the heating system will begin with sunny weather in May.

Some of the air ducts at the first generation solar broiler house in Cumming were once again blocked with house litter as a result of rats. We propose to install hardware cloth several inches underground surrounding each of the concrete air ducts to eliminate this problem.

Program 004

The shipment of load beams from Transducers, Inc. which was delayed six weeks was received. The complete yield evaluation system including weighing stations, amplifiers, electronic interfacing and computerized data acquisition system was assembled for checkout. The initial tests pointed out the need for minor modifications to the amplifiers. The necessary modifications were completed and the entire system is now operating properly. Calibration of each weighing station is now under way and should be completed early in May.

The modified shackles have been installed on the evisceration line at Mar-Jac, Inc. in Gainesville and no problems have developed. Installation of the weighing stations at Mar-Jac will begin immediately after calibration is completed. It is anticipated that the system will be completely operational on the Mar-Jac evisceration line by late May.

Program 005

Project Director Randy Mattison attended a meeting of the Waste Water Equipment Manufacturers Association in St. Louis, Mo. There were technical sessions on changes in EPA limitations, cost effectiveness calculations, coagulation of protein and fat using ligninsulfonate recovered from pulp and paper plant waste, and a show of the latest equipment. Several equipment manufacturers were contacted regarding the cost analysis of pretreatment systems for poultry plants on municipal sewer systems.

Compilation of the directory of qualified wastewater treatment engineering consultants is 90% complete. Each consultant is being interviewed by telephone to determine experience, qualifications, and interest in working on
projects in the poultry industry.

If you have any questions regarding these reports, please contact me.

Sincerely,

Richard S. Combes
Program Manager

RSC/dh
A survey of poultry processing mechanization and handling techniques in twelve processing plants in Georgia, Arkansas, and North Carolina has been completed under the sponsorship of the National Science Foundation. The following table lists some of the information collected:

<table>
<thead>
<tr>
<th></th>
<th>Range</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employees</td>
<td>215 to 1700</td>
<td>965</td>
</tr>
<tr>
<td>Labor Turnover (%)</td>
<td>2 to 400</td>
<td>90</td>
</tr>
<tr>
<td>Water Use (gal/bird)</td>
<td>5 to 12</td>
<td>7.5</td>
</tr>
<tr>
<td>Broiler Live Weight (lbs.)</td>
<td>3.65 to 4.25</td>
<td>3.8</td>
</tr>
<tr>
<td>Live Raw Line Speed (birds/min.)</td>
<td>77 to 135</td>
<td>114</td>
</tr>
<tr>
<td>Evisceration Line Speed (birds/min.)</td>
<td>40 to 64</td>
<td>52</td>
</tr>
<tr>
<td>8 Hour Production (birds)</td>
<td>60,000 to 248,000</td>
<td>92,500</td>
</tr>
</tbody>
</table>

Lung guns were in use in nine of the twelve plants, and six of the twelve plants were using automatic drawing equipment.

The final report for this project will contain projections for the future for the poultry processing industry in terms of possible applications of electrical and mechanical labor saving devices. Contact Dale Atkins or Dr. Bob Cassanova at Georgia Tech for further information.
Subject: Monthly Activities Report
Georgia Tech Poultry Research
Project A-2028
May, 1978

Attention: Dr. John Cobb

Dear Dr. Cobb:

The following is a summary of activities during May for the following designated programs:

- 001 Waste Utilization for the Generation of Methane Gas
- 002 Energy Conservation in the Poultry Industry
- 003 Solar Energy Application to the Poultry Industry
- 004 Mechanization in Poultry Processing
- 005 Poultry Industry Wastewater Treatment

**Program 001**

The digester was loaded everyday with 400 gallons of 30% V/V slurry for two weeks to maintain 21 days retention time. The temperature was kept constant at 98°F, to operate the system in the mesophilic range. If all the added volatile solid was destroyed, the theoretical volume of the biogas produced would be 1382.6 cu. ft. It was observed that the total volume of the biogas produced every 24 hours for 21 days retention time was 1152 cu. ft. as compared with 984 cu. ft. for 42 days retention time. This indicated that 83.32% of the theoretical value of the gas volume was produced per day for 21 days retention time as compared with 71.17% for 62 days residence time. Although the total amount of gas produced by a known weight of volatile solids would remain constant, the above figures indicated an
increase in the rate of production of biogas with a decrease in the retention time from 42 to 21 days. The methane content of the biogas fluctuated between 60 to 65%.

Additional samples will be analyzed to establish the effect of decrease in retention time on the B.O.D. and C.O.D. values.

The above results would have an interesting impact on the engineering aspects of the digester design, i.e. smaller digester and less capital investment would be necessary.

The presence of grit in the raw manure interrupted the continuous operation of the system by clogging the pipes and pump. For a second generation of digester it is highly recommended to include the degritting system.

During the month of June, operation of the digester in the thermophilic temperature range will be analyzed.

Program 002

The results of the survey of 1977 Energy Consumption in the poultry industry have been compiled and will be presented in a future issue of "Poultry Engineering Progress."

The laboratory work involved in the brooder radiation tests is now 95% complete. Preliminary analysis shows that significant differences of radiant flux occur with different radiant elements and different burner configurations. Data analysis should be complete within a month.

Planning is under way to hold an open house at the wood-fired grow-out house in Carrollton. The tentative date is July 19.

Program 003

Preliminary testing of the second generation solar broiler house heating system began in May. The first test indicated a collector efficiency of 30% at 4:00 pm solar time under a hazy sky. A temperature rise of 35°F was obtained with an air flow rate of approximately 3700 CFM.

We installed a variable pitch diameter pulley on the fan motor shaft to allow adjustment of the air flow rate through the collector. We also installed a watt-hour meter in the fan circuit to determine the fan power consumption, and we installed a differential pressure manometer in order to monitor the pressure drop in the collector as well as in the air dis-
Distribution system. If necessary, the solar heating system will be used to preheat the house before the next flock of birds arrives in June.

During May at the first generation solar broiler house we dug up the twelve concrete air ducts in the house. Holes were discovered in several pipes and all but a few had loose fitting joints. The holes were covered with hardware cloth and sealed with concrete as were the joints. We feel that these measures will prevent rats from entering and clogging the pipes in the future.

The glazing support frames have been removed from the collector for reglazing and other repairs as necessary. While the frames are off we plan to install thermocouples at various locations in the rock bed in order to determine the temperature profile in the collector.

Program 004

The electronic yield evaluation system has been installed at the Mar-Jac Poultry plant in Gainesville and calibration and accuracy testing is near completion. Data will be collected on bird weights and losses for several weeks in June.

The specially modified evisceration line shackles have been in operation for a month with no apparent problems. The weighing rails have been up for several weeks and are operating satisfactorily.

There have been several problems with noise and drift in the transducer amplifiers. The amplifiers required some modification to insure accuracy and repeatability of the data. As a result of the modifications the amplifier drift is now being subtracted out by the computer software. The noise is being reduced by averaging the signal over ten readings at each weighing.

Program 005

The directory of qualified wastewater treatment consultants in Georgia has been completed, and a copy will be included in the project's final report.

Preliminary design work has been completed by project director Randy Mattison on a catch basin flotation system that will remove fat and grease from carcass washer water before the grease becomes emulsified. Country Pride is planning to install a prototype in their Gainesville plant.

A detailed operating and cost analysis of dissolved air flotation systems has been completed. This type of system has proven particularly
effective as a pre-treatment prior to the discharge of processing wastes to municipal sewers.

If you have any questions regarding these reports, please contact me.

Sincerely,

Richard S. Combes
Project Director

RSC/dh
Attachment
SOLAR HEATING FOR BROILER GROWOUT

Growing commercial broilers requires from 25 to 40 gallons of LP gas per 1000 birds depending upon weather conditions, house construction and management practices. Since current broiler production in Georgia is about 450 million birds per year, 10 to 20 million gallons of LP gas are consumed in growout operations annually. The problem of U.S. dependence on non-renewable energy supplies, imported oil in particular, has become a top priority national issue since the 1973 oil embargo.

The Georgia Poultry Federation and the Georgia Department of Agriculture have responded to our state and national goal of energy independence by funding two solar broiler house heating demonstration projects during the past two years. The first generation solar heating system was installed in May, 1976, at Lamar Hick's farm near Cumming, and construction of the second generation system was completed in April, 1978, at William Waddell's farm near Villa Rica. Mr. Hicks grows poultry for Wilson Foods, Inc. in Cumming and Mr. Waddell grows for Gold Kist, Inc. in Carrollton. The emphasis in both demonstration projects is on development of low cost retrofit solar heating systems. The Cumming system uses a passive solar collector design in which natural convection causes warm air to flow into the house from a 3300 square foot collector mounted on a hillside beside the house. The heating system cost about $6,600 to install and provided approximately 40% of the heating needs for the 300 foot house during the first year of operation. The
Villa Rica system consists mainly of a 3000 square foot roof mounted solar collector and a fan to force warm air through perforated polyethylene air ducts into the house. Installed cost of the system is $6,700. Preliminary tests of the Villa Rica heating system indicate the collector efficiency to be on the order of 30%. We estimate a 40% reduction of LP gas consumption with the Villa Rica system. Additional performance data will be available after continuous testing of both solar heating systems through July, 1979. If you have questions regarding these projects call John Giles at 404/894-3623.
Subject: Monthly Activities Report
Georgia Tech Poultry Research
Project A-2028
June, 1978

Attention: Dr. John Cobb

Dear Dr. Cobb:

The following is a summary of activities during June for the following designated programs:

001 Waste Utilization for the Generation for Methane Gas
002 Energy Conservation in the Poultry Industry
003 Solar Energy Applications to the Poultry Industry
004 Mechanization in Poultry Processing
005 Poultry Industry Wastewater Treatment

Program 001

During the month of June, an attempt was made to raise the operating temperature of the anaerobic digester in Cumming to operate in the thermophilic range. This operational mode will result in thermophilic bacteria producing methane from the raw poultry manure, rather than mesophilic bacteria, which digest the manure at a temperature of 95-98°F. The desired temperature for thermophilic operation was 122°F (50°C). Unfortunately, the digester heating system was unable to raise the temperature of the sludge in the digester past 113°F, which is on the lower end of the thermophilic temperature range. At this temperature, gas production dropped to a value of one third of the gas volume collected while operating the digester at the mesophilic temperature (i.e., 95-98°F). Further analysis is needed to understand these results.
During July, it is planned to operate the digestor in the plug flow mode. This mode entails top loading with material balance compensation and draw off of sludge from the bottom, while operating at mesophilic temperatures. This mode of operation will be evaluated for BOD reduction; changes in nitrogen, phosphorus and potassium values relative to those in the raw manure; the amount of gas produced with no mixing; and finally the economics of this system.

Program 002

The wood-fired furnace on a grow-out farm in Carrollton underwent full scale testing. A duct outlet temperature of 120°F and a room air temperature of 90-95°F was maintained with no difficulty during June. Response time to thermostat demand is very fast. Gas meters were installed on the test and control houses and a new flock of chicks was placed in the houses. No adverse effects of the wood-fired warm air brooding have been noticed in two weeks of operation.

An open house will be held on July 19 from 1 pm to 4 pm to demonstrate the wood-fired brooding system to the public.

The laboratory testing of brooder radiant energy has been completed. All data has been plotted by computer and data analysis is underway.

Program 003

Repair of the first generation solar broiler house heating system continued through June. We cleaned out the air ducts and stripped the glazing support frames of polyethylene and staples. Many of the wooden frame members have rotted at the corner joints. Unusable members will be replaced.

Transmittance of the two year old Monsanto 602 polyethylene glazing was measured with a radiometer. Results of the measurements will be presented in the final report.

The proposed design of a poultry growout house with an integral solar heating system was completed in June. A drawing of the house and heating system will be included in the final report.

Project Director, John Giles, visited a solar heated growout house in June at the University of Arkansas at Fayetteville in order to learn more about current solar poultry house heating projects in other areas of the country.

Program 004

The complete yield evaluation system is now in operation at the Mar-Jac, Inc. poultry plant. Calibration and accuracy testing of the system was completed. As a result of modifications to the amplifiers and computer program, the weight signal noise and drift can now be reduced to acceptable levels. As more weighing stations are added in next year's project, further modifications to the electronics will be made to make the system more compact and portable.

An initial set of data was obtained and indicated that evisceration line yield varied between 73% and 77% for individual birds during a typical day.
Technical assistance was provided to a poultry processor and an egg processor who are in the early stages of designing wastewater treatment systems for plant discharges to municipal sewer systems.

A study of published literature regarding the impact of hexane solubles (grease) on sewage plant operations was conducted. The imposition of grease limitations on poultry plant wastewater discharges is justified, but the level of limitation is sometimes very arbitrary.

Compilation of information and data for the final report has begun.

This summary will be the final monthly activities report for the current research contract. The final report for the research activities for the period August 1, 1977 through August 1, 1978 will be prepared in August.

If you have any question on the reports, please contact me.

Sincerely,

Richard S. Combes, P.E.
Program Manager

RSC:dh
Attachment
The Georgia Tech Engineering Experiment Station has been conducting tests on an experimental methane generating system that is operating on a chicken egg laying farm in Cumming. Poultry manure is fed with water to an anaerobic digestion tank in which the methane is produced. Throughout the past year, operating characteristics, such as tank temperature, manure concentration in the feed slurry, and retention time, have been varied in order to define optimum operating parameters for the system. One significant result is that a long retention time does not assure optimal gas production, as shown in the following table:

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In these tests the digester tank temperature was maintained at 98°F and 60 to 65% of the gas generated was methane. Bigger does not necessarily mean better! Laboratory tests on the digested sludge from the tank bottom show the following properties:

- pH: 8.04
- Alkalinity mg/l as CaCO$_3$: 13930
- Total Solids % w/w: 3.71
- Fixed Solids % w/w: 1.62
- Volatile Solids % w/w: 2.13
- BOD$_5$ mg/l: 4100
- Reduction in BOD$_5$: 81.3%
- COD mg/l: 11,400
FINAL REPORT

PROJECT A-2028

GEORGIA POULTRY INDUSTRY RESEARCH

By
M. Bery
R. Cassanova
R. Combes
J. Giles
R. Mattison
L. Moriarity
D. O'Neil

Prepared for
GEORGIA DEPARTMENT OF AGRICULTURE

December, 1978

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia 30332

1978
Final Report
Project A-2028

GEORGIA POULTRY INDUSTRY RESEARCH

Authors
M. Bery
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Prepared for
Georgia Department of Agriculture
by
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

December, 1978
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Dr. John Cobb, Georgia Department of Agriculture
Mr. Bob Mitchell, ConAgra Poultry
Mr. Dale Morris, Mar-Jac, Inc.
Mr. Charles Hamilton, Mar-Jac, Inc.
Mr. Tom Ebert, Country Pride
Mr. George Key, Strain Poultry
Mr. Gene Butterworth, Strain Poultry
Mr. William Waddell, Gold Kist, Inc.
Mr. Charles Heaton, Gold Kist, Inc.
Mr. Lamar Hicks, Tyson Foods
Mr. Pete Martin, Tyson Foods

and the many other industry personnel who personally participated in the research projects.
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SUMMARY

The Georgia poultry industry currently produces more poultry products (poultry and eggs) than any other state in the nation. In 1973, the Georgia Poultry Federation identified a need for research addressing technical problems in the poultry industry, and was instrumental in securing funding from the Georgia Department of Agriculture for research performed by the Georgia Tech Engineering Experiment Station (EES).

This report covers EES poultry industry research for the period August 1, 1977 to August 1, 1978, addressing the following areas:

- Poultry waste utilization
- Energy conservation in broiler growout operations
- Solar energy applications in broiler growout
- Yield evaluation in poultry processing
- Wastewater treatment in the poultry industry

The research stressed demonstration of innovative engineering concepts applied to technical problems not otherwise addressed by the Georgia industry. The research program resulted in design and construction of a solar heating system for a poultry house; a wood-fueled heating system for a poultry house; and an electronic data acquisition system for evaluating product yield in a poultry processing plant. Engineering evaluations were also made of the energy efficiency of conventional poultry brooders; the effectiveness of various wastewater treatment systems; and the feasibility of generating methane from raw poultry manure in an anaerobic digestor built under previous research contracts.
The poultry industry in Georgia currently ranks as the State's largest agribusiness with respect to gross annual revenues. The average daily industry production is 5,100,000 pounds of chicken and 13,850,000 eggs. This considerable production of poultry products involves thousands of workers and an ever increasing amount of investment and operating capital. The escalating degree of technical sophistication in the component operations in the Georgia poultry industry has made obvious the need for technical research in several areas.

Beginning in 1974, the Georgia Poultry Federation, representing the Georgia industry, was instrumental in securing research funds from the Georgia Department of Agriculture for technical research at the Georgia Tech Engineering Experiment Station. To date, the research program has addressed a number of technical problems in the poultry industry, including:

- Energy conservation and alternate energy sources,
- Waste utilization in caged layer operations,
- Mechanization of operations in poultry processing plants,
- Wastewater treatment, and
- Noise abatement in poultry processing plants.

As a result of research performed under the sponsorship of the Georgia Department of Agriculture and further efforts of the Georgia Poultry Federation, several additional poultry industry research contracts have been awarded to the Georgia Tech Engineering Experiment Station.
federal agencies including National Science Foundation, Department of Energy and National Aeronautics and Space Administration.

This report covers research performed during the period August 1, 1977 to August 1, 1978. The research program addressed the following subjects:

1. **Poultry Waste Utilization** - The program started in 1974 which assessed the potential for generating methane gas from poultry manure was completed this year. The pilot plant on a commercial egg laying farm in Cumming, Georgia was successfully operated during the latter part of the year. The pilot plant involved anaerobic digestion of raw poultry manure to produce methane and a saleable sludge byproduct.

2. **Energy Conservation** - The energy conservation research consisted of several phases:
   - Design, construction and testing of a wood-fueled poultry house heating system,
   - Thermal analysis of conventional gas and electric poultry brooders currently on the market, and
   - Engineering assistance to poultry farmers, processing plants, and egg processing plants with particular energy problems.

3. **Solar Energy Applications** - The solar energy research consisted of design, construction and testing of a full-scale solar heating system on a poultry house in Villa Rica, Georgia. In addition, the poultry house solar heating system already in operation in Cumming, Georgia was monitored and extensively repaired.
4. **Mechanization in Poultry Processing** - A two-station continuous yield evaluation system was designed, installed and operated at a broiler processing plant in Gainesville, Georgia. This system will continuously log the real product yield and allow plant personnel to detect yield losses very quickly.

5. **Poultry Wastewater Treatment** - Regulatory guidelines and limitations were established both for the present and near future for sources of wastewater in the poultry industry. Wastewater treatment methods and equipment were evaluated from the standpoint of treatment effectiveness.

The following sections discuss each of these research projects in detail.
II. POULTRY WASTE UTILIZATION

A. Introduction

The largest single problem resulting from the recent increase in the number of birds reared in confinement units under a single management involves wastes handling and disposal. The odor and fly nuisance of the wastes, the large volumes accumulated yearly, the decline of farm animal and poultry wastes as a competitive fertilizer and the encroachment of urban areas close to poultry production units complicate the problem of manure handling and disposal.

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 poultry wastes are rich in fertilizing constituents, untreated raw wastes spread on fields and allowed to enter the surface waters will accentuate the already serious problem of stream pollution. From the standpoint of public health, esthetics and economics, farm waste should be given a treatment that will stabilize the manure, remove its nuisance characteristics, sustain its fertilizer value and reduce the pollutational properties of the manure to a safe level before final disposal. Since the farm waste has a very high concentration of organic solids and a B.O.D., anaerobic fermentation is the most suitable treatment method applicable to this type of wastes.

The objectives of this project were to:

1. Develop the process of anaerobic digestion to utilize poultry manure profitably by producing biogas as the primary product and stabilized sludge to be evaluated as animal feed supplement or as organic fertilizer as by-product.
This involved studying the effects of loading rate, solid concentration, temperature, pH, operating pressure and mode of operation on the volume of biogas as well as the quality of digester gas in terms of its methane content.

2. Simplify the design of the system so that the farmer can operate and maintain it without any difficulty.

3. Evaluate the suitability of the system for a poultry farm as a method of disposing poultry manure meeting EPA requirements.

4. Conduct a detailed economic feasibility study of the system.

B. Pilot Plant

1. Description & Operation of 10,000 gallon anaerobic digester

Initially the pilot plant was designed and commissioned on a short term basis only. Since its design and operation was to be simplified based on experimental results and experience some future changes were anticipated.

The pilot plant at Cumming consists of a 10,000-gallon anaerobic digester, a 2,000-gallon manure holding tank, a 1,000-gallon tank for mixing, heating and holding the slurry before loading the digester. The plant is fully automated for measuring, loading and controlling the batch size. The system has on-line process monitoring equipment to measure continuously pH, oxidation-reduction potential, temperature and the level of the digester content. It also has an automated gas chromatograph to analyze the biogas continuously.

The major pilot plant equipment are described below.

The manure holding tank (Fig. 1) is a mild steel tank 8' I.D. x 8' height with a cone bottom to an 8" discharge spout. It has a closure mounted at the top to receive manure and its bottom can discharge manure
Figure 1. Manure Holding Tank
on a screw conveyor for carrying manure to a 1,000 gallon batch holding mixed tank.

The mix tank (Fig. 2) is a stainless steel tank with 6' I.D. and 6' height. It is equipped with an agitator operated by a 3H.P. motor mounted at the top. It has a hot water exchanger to preheat the batch to the desired temperature before loading the digester. It is provided with level controllers to simplify the preparation of predetermined batch.

The digester (Fig. 3) is a mild steel vertical cylindrical tank with 10' I.D. and 22.5' height. It has a conical bottom. It is intentionally heated externally using electric heaters in order to monitor energy consumption and is insulated with polyurethane thus allowing us to maintain virtually constant temperature. It is provided with necessary instrumentation mentioned previously to measure various process variables. The centrifugal pump is used to mix the digester content by recycling the slurry.

The overflow water from the layer feeders is collected in a concrete 4' x 6' x 6' septic tank. This water is used as process water to dilute the manure to a predetermined solid concentration. The system flow diagram is shown in Figure 4. The pilot plant has a live control panel (Fig. 5) with a schematic of the system and appropriately placed indicator lights showing the flow of the system continuously.

The digester is very versatile in its operation. It can be operated in four modes of operation, i.e., (WSTR) well stirred tank reactor, plug flow reactor with top loading, plug flow reactor with bottom loading and lastly plug flow reactor with top loading and volume compensation.
Figure 2. Manure Tank and Mix Tank
Figure 3. Anaerobic Digester
Figure 4. Digestor Hydraulic System
Figure 5. Digestor Control Panel
It was of importance to investigate these process modes and to select the one giving best results in terms of volume of biogas and its methane content as well as B.O.D. and C.O.D. values of the digested sludge.

The WSTR mode was more commonly studied. Theoretically it means that there is enough turbulence in the system so as to avoid any temperature, pH and solid concentration gradient in the system. In this mode a predetermined quantity of sludge was discharged from the bottom of the digester and the same volume of freshly prepared slurry was loaded from the top of the digester and then mixing was resumed by recycling the sludge for the period of 24 hours until the next discharging and loading was to be carried out. This mode of operation was energy-intensive.

The plug flow mode with top loading is similar in loading to the WSTR operation but no mixing is carried out. The slurry is digested during the period it moves from the feeding end to the discharge end of the digester. In this mode no energy for mixing the slurry is required. While a process energy-savings (vs. WSTR) is apparent, there is a greater potential for clogging of pipes and pumps. However, rheological studies indicated that resistance to flow decreased with time of digestion.

The intention is to capitalize by the process mode on that attractive flow property.

The plug flow mode with bottom loading is relatively better than the one with top loading since the settled solid particles are pushed upward and the clogging of the pipes and valves can be less frequent.

In the plug flow mode with top loading, with a required volume compensation, the slurry is allowed to settle. The excess of water is
decanted from the top and the digested slurry is discharged from the bottom.

The reasons for considering various plug flow systems as opposed to WSTR are:

1. Since no mixing is desired, this mode is not as energy intensive.

2. More organic waste can be handled in the same size of reactor with the possibility of much higher yield per unit volume of the digester.

3. Lower capital investment per unit volume of the waste handled.

The points against plug flow systems can be summarized as follows:

1. There is no proved linear relationship between the amount of gas produced and the solid concentration of the slurry handled.

2. The throughput rate would be too slow to degrade the waste to produce the proportional quantity of the biogas.

3. The loading rate would have to be slowed down considerably to produce a stabilized sludge with acceptable B.O.D. and C.O.D. values.

4. If not careful, the plug flow mode can lead to some serious clogging problems.

2. Recent system modifications

Some system modifications have been introduced to make pilot plant operation more simple, efficient and relatively trouble free (Figure 6).

a. Initially, the plant was highly automated with a little or no control by the operator. A manual override was added so that if
Figure 6. Digestor Hydraulic System (Modified)
any control valve malfunctions, the process can be operated manually. This also avoids having to go through a series of resetting steps before an operation can be repeated.

b. In the original system a gear pump was used to feed the heat exchanger reservoir as well as the pump water to make a new batch of slurry in the mixed tank. These two, being interrelated, created too many problems in maintaining correct levels of hot water in the holding tank.

In the modified system these two loops were separated. The hot water circulation loop through the heat exchanger was made into a completely closed loop system thus making it totally trouble-free.

The gear pump was eliminated and a small submerged pump was placed in the septic tank. This was used to make a new batch without interfering with the operation of the circulation pump used for recycling the digester content.

c. Initially, the digester was operated under a negative pressure. It has been suggested that by a continuous evacuation of biogas carbon dioxide is not allowed to accumulate in the system thus maintaining a better pH control of the slurry. Our experience indicates that to operate an anaerobic digester under vacuum is undesirable for various reasons. It adds to the capital investment, installation, and maintenance costs. The whole pilot plant has to be leak-proof since any pinhole can lead to the false volume of the biogas produced. Intrusion of atmospheric air into the system can create explosive conditions. Hence, it was decided to eliminate the vacuum system and the system was modified to be operated under a positive pressure. This proved to have the
following advantages. Since the vacuum system was unnecessary the capital cost was reduced. The possibility of any explosion was eliminated. This safer system enables one to monitor the biogas continuously and more accurately. Future units will be operated under a positive pressure which is cheaper, simpler and safer to operate.

C. Experimental Results and Discussion

The research activity was directed on two fronts, i.e., bench top experiments and pilot plant experiments. Although the bench top and other laboratory scale experiments have been described fully in previous reports, the most significant experiments are reviewed in the context of the full-scale experimental studies.

1. Bench Top Experiments

The most important bench top experiments included investigating the need for seeding the chicken manure slurry, and the viscosity measurements to study the changes in the rheological properties of the sludge.

The five gallon fermenters were operated hyperbarically at 3 psig. Four fermenters were run at mesophilic temperature (98°F) and one at thermophilic temperature (140°F). The experiments lasted for 82 days. The results of these experiments are shown in Table 1. The results indicated that the total gas yield per pound of volatile solids for 10% v/v and 40% v/v concentrations compare favorably with the values observed in the literature. The percentage of Methane in the biogas produced averaged 66% and up to 78% has been observed in other experiments. Values of 75% were realized in the large-scale tests for short periods.
Table 1. Gas Yield Per Pound of Volatile Solids in 5 Gallon Reactors

<table>
<thead>
<tr>
<th>Concentration % v/v</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>40(140°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Gas, ft.³</td>
<td>6.60</td>
<td>4.73</td>
<td>10.6</td>
<td>21.1</td>
<td>4.59</td>
</tr>
<tr>
<td>Total Methane, ft.³</td>
<td>4.34</td>
<td>2.08</td>
<td>5.69</td>
<td>12.4</td>
<td>0.742</td>
</tr>
<tr>
<td>% Methane</td>
<td>66</td>
<td>44</td>
<td>53</td>
<td>59</td>
<td>21</td>
</tr>
<tr>
<td>Induction time, days</td>
<td>41</td>
<td>55</td>
<td>48</td>
<td>24</td>
<td>(toxic)</td>
</tr>
<tr>
<td>Maximum Rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>v gas/v reactor/hr.</td>
<td>0.037</td>
<td>0.029</td>
<td>0.058</td>
<td>0.055</td>
<td>0.004</td>
</tr>
<tr>
<td>ft.³/lb vol. solids</td>
<td>10.1</td>
<td>3.60</td>
<td>5.44</td>
<td>8.09</td>
<td>1.76</td>
</tr>
</tbody>
</table>

Table 2. Analysis of Digested Sludge from 5 Gallon Reactor

<table>
<thead>
<tr>
<th></th>
<th>10%</th>
<th>20%</th>
<th>Typical Chicken Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture, %</td>
<td>3.1</td>
<td>15.0</td>
<td></td>
</tr>
<tr>
<td>N, %</td>
<td>1.85</td>
<td>1.59</td>
<td></td>
</tr>
<tr>
<td>N (as protein), %</td>
<td>11.56</td>
<td>9.44</td>
<td>15</td>
</tr>
<tr>
<td>*Digestible Protein (Pepsin), %</td>
<td>2.51</td>
<td>1.00</td>
<td>13</td>
</tr>
<tr>
<td>P₂O₅, %</td>
<td>13.81</td>
<td>8.86</td>
<td>3.0</td>
</tr>
<tr>
<td>K₂O, %</td>
<td>0.77</td>
<td>0.38</td>
<td>0.6</td>
</tr>
<tr>
<td>Crude Fiber, %</td>
<td>15.38</td>
<td>13.24</td>
<td>5</td>
</tr>
</tbody>
</table>
The experiments also indicated that a 40% slurry gave the best overall results. These experiments also proved that seeding the slurry with methanogenic bacteria was not necessary in order to induce the methanogenic process.

The sludge separated from the fermenters loaded with 10% v/v and 20% v/v slurry was analyzed and results are shown in Table 2. The fertilizer value of the digested sludge is comparable with the raw manure.

The analysis of Table 2 was undertaken to provide some information on the basic nutritive value of the poultry waste before and after anaerobic digestion. Relatively little information is available in the literature. It is known that the use of dried poultry manure can lead to toxin formation and the death of cattle unless strict control is applied (Communication with MAOT, Ltd., Tel-Aviv, Israel). Consequently, anaerobic digestion which eliminates pathogenic bacteria is seen to be a useful conversion process to animal feed. Our laboratory tests indicate that one ton of dry effluent would contain about 210 lbs. of crude protein which compares well with the value of 280 lbs. reported by Hamilton-Standard. The digestible protein is, however, much lower than that of dried chicken manure. This is a simple laboratory analysis, however, Hamilton-Standard demonstrated in cattle feed trials that the crude protein in their effluents were as digestible as cottonseed meal (a standard protein supplement). Use of their effluent as an animal feed supplement was estimated to produce an increase in profit of 18% in the cattle fattening operation.

The fluid from the fermenters containing 10, 20, 30 and 40% v/v slurry was decanted. The Figures 7 and 8 show the results for undigested
Figure 7. Viscosity versus Shear Load in Undigested Manure
Viscosity vs. Shear Load

Digested Manure
(5 months)
canc., vol./vol.

Figure 8.  Viscosity versus Shear Load in Digested Manure
and digested manure respectively. A Thomas-Stormer viscometer was used for the measurements. The results indicated that the viscosity of the poultry manure reduced with the degree of digestion. The highest viscosity measured after digestion was 567 centipoise for a 75 gm shear force. This value was less than the infinite viscosities observed at low shears for undigested and suspended slurries for the above concentrations. It was also observed that the rheological properties approach ideal Newtonian behavior during digestion. A relationship between the concentration of the undigested slurry and the viscosity of extrapolated infinite shear force applied to the measurements of the digested sludge samples is shown in Figure 9. It is concluded that the infinite compaction of the sludge into cement does not occur even after several months of compaction time.

Thus, the results of bench top experiments can be summarized as below:

1. A significant decrease in the viscosity of the digested sludge can be expected.
2. The rheological properties of the sludge approaches Newtonian behavior during the extended digestion.
3. Compaction of the digested sludge is limited.

2. Pilot Plant Experiments

The pilot plant operation highlighted many interesting aspects of the anaerobic digestion system which would not have shown up in the bench scale work. Some of the important observations made are described below.

a. Materials Handling and Corrosion

The corrosive nature of the biogas was observed. Digester, pipes,
Viscosity@ Shear Load versus Conc.,%vol./vol.

Correlation Coefficient = 0.9805

Figure 9. Viscosity versus Concentration
gas meter, pumps and instruments used must be selected carefully if the plant is to last longer than five years. The problems created by vacuum system were noticed by hearing muffled explosions. Since the system did not have a process to remove grit from the slurry before feeding it to digester, the increased solid concentration of slurry lead to the build up of grit at the bottom of digester in pump and pipes and caused clogging. In this section some of the successful pilot plant runs are described and results are interpreted for future design modification of the plant and its effects on the economic feasibility of the process.

Most of the runs made initially used the Well Stirred Tank Reactor (WSTR) mode for operating the digester.

b. Hypobaric (Vacuum) Operation

The digester was loaded with 10% v/v slurry maintaining a 42-day retention. The digester content was maintained at mesophilic temperature (98°F). The volume of biogas produced was monitored continuously and the gas samples were analyzed (Table 3). The digested sludge samples were analyzed (Table 4) to evaluate the condition of sludge, its fertilizer value and protein content.

The system was operated under vacuum. The gas analysis indicated that there was an air leak in the system and the measured gas volume was unreliable.

<table>
<thead>
<tr>
<th>Table 3. Analysis of Biogas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of Biogas 20.00 cu ft/hr.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Constituents of Biogas</th>
<th>% Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂</td>
<td>0.00</td>
</tr>
<tr>
<td>CO₂</td>
<td>28.25</td>
</tr>
<tr>
<td>O₂</td>
<td>1.50</td>
</tr>
<tr>
<td>N₂</td>
<td>8.37</td>
</tr>
<tr>
<td>CH₄</td>
<td>61.87</td>
</tr>
</tbody>
</table>
Table 4. Analysis of Digested Sludge

<table>
<thead>
<tr>
<th>Type of Analysis</th>
<th>Digested Sludge</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top discharge</td>
<td>Bottom discharge</td>
</tr>
<tr>
<td>Total Solids</td>
<td>0.44%</td>
<td>2.30%</td>
</tr>
<tr>
<td>Fixed Solids</td>
<td>0.24%</td>
<td>1.33%</td>
</tr>
<tr>
<td>Volatile Solids</td>
<td>0.2%</td>
<td>0.97%</td>
</tr>
<tr>
<td>pH</td>
<td>7.9</td>
<td>7.7</td>
</tr>
<tr>
<td>Alkalinity mgm/lit as CaCO₃</td>
<td>4740</td>
<td>5023.2</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>-</td>
<td>2.31%</td>
</tr>
<tr>
<td>Protein</td>
<td>-</td>
<td>14.4%</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>-</td>
<td>3.22%</td>
</tr>
<tr>
<td>Potassium</td>
<td>-</td>
<td>0.73%</td>
</tr>
<tr>
<td>Fiber</td>
<td>-</td>
<td>19.05%</td>
</tr>
<tr>
<td>Heavy metal</td>
<td>-</td>
<td>No Trace</td>
</tr>
</tbody>
</table>

The analysis of sludge indicated that it was a fertilizer of acceptable quality. The protein content of the sludge was 14.4%.

c. Hypobaric Operation (Vacuum)

In the next run fresh manure with 6% w/w (approximately) total solids was loaded to the digester. The system was maintained under a vacuum of 30" of water and at 98°F. The retention time was 42 days. The volume of gas generated increased to 42 cu ft/hr. G.C. analysis of the biogas (Table 5) indicates that there was a pin-hole in the system, the vacuum was sucking in air thus giving false volume of the biogas, and the anaerobic digester was gradually turning into a partially aerobic system. The samples of raw and digested sludge were analyzed as shown in Table 6.
Table 5. Analysis of Biogas

<table>
<thead>
<tr>
<th>Components</th>
<th>% v/v</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂</td>
<td>0.37</td>
</tr>
<tr>
<td>CO₂</td>
<td>42.17</td>
</tr>
<tr>
<td>O₂</td>
<td>2.08</td>
</tr>
<tr>
<td>N₂</td>
<td>11.19</td>
</tr>
<tr>
<td>CH₄</td>
<td>47.26</td>
</tr>
</tbody>
</table>

Table 6. Analysis of Raw and Digested Sludge

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Mixed Tank</th>
<th>Digester Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw Manure</td>
<td>Top</td>
</tr>
<tr>
<td>% w/w Total solids</td>
<td>5.49</td>
<td>1.32</td>
</tr>
<tr>
<td>% w/w Fixed solids</td>
<td>1.88</td>
<td>0.65</td>
</tr>
<tr>
<td>% w/w Volatile solids</td>
<td>3.58</td>
<td>0.67</td>
</tr>
<tr>
<td>pH</td>
<td>8.24</td>
<td>8.13</td>
</tr>
<tr>
<td>BOD₅ mg/liter</td>
<td>32500</td>
<td></td>
</tr>
<tr>
<td>% Reduction in BOD₅</td>
<td>87.5%</td>
<td></td>
</tr>
<tr>
<td>% Nitrogen</td>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td>% Potassium</td>
<td></td>
<td>0.95</td>
</tr>
<tr>
<td>% Phosphorus</td>
<td></td>
<td>4.4</td>
</tr>
<tr>
<td>% Protein</td>
<td></td>
<td>15.62</td>
</tr>
</tbody>
</table>
As a result of the above observations the vacuum system was eliminated and the future runs were planned by maintaining a positive pressure in the system. The advantages of this system were that air leak into the digester was prevented and the digester could be operated under anaerobic condition. This also prevented the muffled explosions in the past. No energy was consumed in operating the gas meter and the elimination of the vacuum system cut down the initial capital investment.

d. Environmental–Pollutant Control/Hyperbaric Operation

The digester was maintained under a positive pressure of 2" water head. Its content was kept at 98°F. It was loaded with 6.8% w/w slurry maintaining 42 days retention time. A production rate of 41 cu. ft./hr. of biogas with 63% methane was produced. An interesting observation was made that 60 cu. ft. per hour of gas was produced during first five hours after loading the digester. This indicated that 10.34% of the total biogas was produced during initial 4% of the time after loading the fresh manure and that the gas production dropped until next loading took place. These results indicated that digester should be loaded everyday and possibly a continuous loading may even be more desirable. The digested sludge showed the reduction in COD values between 73.4% to 79.8% and that BOD₅ between 81.3% and 84.5%. The results are given in Table 7.

e. Gas Production Rates/Hyperbaric Operation

The next run was made to investigate the above recommendation of loading the digester more frequently. In this run the digester was loaded everyday with 400 gallons of 30% v/v slurry for two weeks to maintain 21 days retention time. The temperature was kept constant at 98°F to operate the system in the mesophilic range. If all the added volatile
solids were destroyed, the theoretical volume of biogas produced would be 1382.6 cu. ft. It was observed that total volume of biogas produced every 24 hours for 21 days retention time was 1152 cu. ft. as compared with 984 cu. ft. for 42 days retention time. This indicated that 83.32% of the theoretical value of the biogas volume was produced per day for 21 days retention time as compared with 71% for 62 days residence time. Although the total amount of gas produced by a known weight of volatile solids would remain constant, the above figures indicated the increase in the rate of production of biogas with the decrease in the retention time from 42 to 21 days. The methane content of the biogas fluctuated between 60 to 65%.

Table 7. Analysis of Sludge

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Digester Sample From</th>
<th>Raw Slurry Sample From Mixed Tank</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top</td>
<td>Bottom</td>
</tr>
<tr>
<td>Alkalinity mg/l. as CaCO₃</td>
<td>8.13</td>
<td>8.04</td>
</tr>
<tr>
<td>Total Solids % w/w</td>
<td>13820</td>
<td>13930</td>
</tr>
<tr>
<td>Fixed Solids % w/w</td>
<td>2</td>
<td>3.71</td>
</tr>
<tr>
<td>Volatile Solids % w/w</td>
<td>0.94</td>
<td>2.13</td>
</tr>
<tr>
<td>BOD₅ mg/lit</td>
<td>3400</td>
<td>4100</td>
</tr>
<tr>
<td>COD</td>
<td>8680</td>
<td>11440</td>
</tr>
<tr>
<td>Reduction in COD</td>
<td>79.81%</td>
<td>73.4%</td>
</tr>
<tr>
<td>Reduction in BOD₅</td>
<td>84.5%</td>
<td>8.13%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td></td>
<td>2.44</td>
</tr>
<tr>
<td>Phosphorus</td>
<td></td>
<td>4.42</td>
</tr>
<tr>
<td>Potassium</td>
<td></td>
<td>1.17</td>
</tr>
<tr>
<td>Protein</td>
<td></td>
<td>15.25</td>
</tr>
</tbody>
</table>
Table 8. BOD and COD Values of Raw and Digested Manure

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Digester Sample From</th>
<th>Raw Slurry Sample From</th>
<th>Mixed Tank</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top</td>
<td>Bottom</td>
<td>Top</td>
</tr>
<tr>
<td>BOD&lt;sub&gt;5&lt;/sub&gt;</td>
<td>4600</td>
<td>12000</td>
<td>28000</td>
</tr>
<tr>
<td>COD</td>
<td>8800</td>
<td>25100</td>
<td>72200</td>
</tr>
<tr>
<td>% Reduction in BOD&lt;sub&gt;5&lt;/sub&gt;</td>
<td>83.57%</td>
<td>57.1%</td>
<td>---</td>
</tr>
<tr>
<td>% Reduction in COD</td>
<td>87.81%</td>
<td>65.23%</td>
<td>---</td>
</tr>
</tbody>
</table>

The reduction in retention time has negative effect on the BOD and COD values of the digester effluents. Table 8 indicates that the reduction in BOD<sub>5</sub> (57.1%) and COD (65.2%) is considerably lower in the case of 21 days retention time as compared with the reduction in BOD<sub>5</sub> of 81.3% and that in COD of 73.4%.

f. Plug Flow Reactor (PFR) Operations

In the next series of experiments a number of attempts were made to operate the digester in a plug flow mode. It appeared that this was unsuitable for the vertical reactor given the equipment which was used. In the case of low solid concentration a rapid separation between liquid and solids was observed whereas in the high solid concentration range clogging of pipes, pumps and digester bottom was observed. Since there was no means of removing grit from the slurry the clogging became a very serious problem. Hence, it is recommended that the plug flow mode is unsuitable for our digester in its current design. But this process mode may be feasible using a horizontal type tubular flow reactor with a very high ratio of length over its diameter. Digested sludge was sent to a farm in Calhoun, Georgia, to evaluate its acceptability to animals as a feed supplement.
A mixture of digested sludge (40% v/v) and corn was kept near the regular feed. The cattle adapted to the effluent-based feed rapidly according to Mr. George Black, owner of the Calhoun farm.

D. Economic Feasibility Study

Anaerobic digestion is an alternate method of treating organic wastes. To make it more attractive and profitable it is essential that the by-products such as biogas, organic fertilizer or animal feed supplement are produced and sold in large quantities.

It was decided to conduct an economic feasibility study of the process, assuming the use of manure of 100,000 birds. The following assumptions are made:

1. The amount of manure produced per bird per day is 0.2 lb.
2. The total solids in the manure is 25%.
3. 75% of the total solids in the poultry manure are volatile solids.
4. 8 cubic feet of biogas is produced for every lb. of volatile solids destroyed.
5. The retention time maintained is 20 days.
6. 90% of the volatile solids are destroyed.
7. A 340-day per year operation

   Total manure produced per day = 20,000 lbs.
   Total solids produced per day = 5,000 lbs.

   Let the total solid concentration of the slurry handled be 8% w/w.

   Total sludge handled per day = \( \frac{5000 \times 100}{8 \times 10} \) = 6,250 gallons.

Sizing:

Two stage anaerobic digestion is considered where in the first stage complex waste is broken down into organic acids and methane is produced in the
second stage. Let the total retention time be 20 days and it is assumed that the residence time in each stage be 10 days. Two digesters of equal size may be considered. Total working volume in each stage is 6,250 gallons. Therefore, two digesters each of total volume 65,000 gallons would be needed.

<table>
<thead>
<tr>
<th>Units</th>
<th>Equipment</th>
<th>Size (gallons)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Digesters</td>
<td>65,000</td>
<td>$30,000</td>
</tr>
<tr>
<td>1</td>
<td>Mixed Tank</td>
<td>7,000</td>
<td>$5,000</td>
</tr>
<tr>
<td>1</td>
<td>Degritting System</td>
<td></td>
<td>$5,000</td>
</tr>
<tr>
<td>1</td>
<td>Sludge Settling Tank</td>
<td>20,000</td>
<td>$10,000</td>
</tr>
<tr>
<td></td>
<td>Electricity generator</td>
<td>64 KW</td>
<td>$30,000</td>
</tr>
<tr>
<td></td>
<td>Panel, Instruments</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heat recovery system</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gas storage, compressor</td>
<td></td>
<td>$15,000</td>
</tr>
<tr>
<td></td>
<td>distribution</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plumbing, pumps, instrumentation</td>
<td></td>
<td>$15,000</td>
</tr>
<tr>
<td></td>
<td>Installation</td>
<td></td>
<td>$20,000</td>
</tr>
</tbody>
</table>

Total $130,000

Total biogas produced per day 27,000 cu ft.
B.T.U. available from biogas at 650 B.T.U./cu. ft. $17.55 \times 10^6$ B.T.U./day
Amount of electricity generated per day 64 KW
Amount of waste heat recovered (i.e., 45% of the total Fig. 10) $0.329 \times 10^6$ B.T.U./hr.
Total amount of electricity consumed in the plant 19 KW
Total amount of waste heat consumed in the plant 82,250 B.T.U./hr.
Excess electricity available 45 KW
Excess waste heat available 246,750 B.T.U./hr.
Value of excess electricity produced (340 working days/year, $0.35 per KW-hrs.) $12,853/yr.
Figure 10. **OVERALL FUEL EFFICIENCY 75%**

- **100% Fuel**
  - **25% Thermal loss**
  - **Generator**
    - **45% Waste heat Recovery**
    - **Heat for Cooling, Heating, Hot water**
  - **30% Electricity**
Propane value of excess waste heat recovered ($5/M B.T.U.) $2,013/yr.

Total value of the excess energy produced $14,865

Total animal feed supplement produced per day 1812 lbs.

Total value of the feed produced at $100/ton $30,804/yr.

Amount saved by not having to dispose the manure at $10 per ton $8,500/yr.

Gross return of capital/year

\[ 14,865 + 30,804 + 8,500 = 54,169 \]

Expenses

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
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</thead>
<tbody>
<tr>
<td>Labor cost, 9 man months/year</td>
<td>$9,000</td>
</tr>
<tr>
<td>Maintenance</td>
<td>$2,000</td>
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<tr>
<td>Depreciation (7%)</td>
<td>$9,100</td>
</tr>
<tr>
<td>Total expenses per year</td>
<td>$20,100</td>
</tr>
</tbody>
</table>

Gross earning per year

\[ 54,169 - 20,100 = 34,069 \]

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
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<tr>
<td>Rate return before taxes</td>
<td>$34,069</td>
</tr>
<tr>
<td></td>
<td>$34069 x 100 / 130,000 = $26.2%</td>
</tr>
<tr>
<td></td>
<td>$130,000 / 34069 = 3.81 years</td>
</tr>
</tbody>
</table>

Summary

1. Total capital invested = $130,000
2. Rate of return before taxes = 26.2%
3. Duration to recover the capital invested = 3.81 years
E. Future Design Recommendations

Anaerobic digestion is a very effective method of treating and disposing organic wastes profitably. A number of complex biochemical and biological reactions take place in the system. Researchers have studied various digesters of different shapes and designs to optimize the process of anaerobic digestion.

In Georgia Tech we have designed and operated a 10,000 gallon fully automated, multimodal type anaerobic digester. We have gained enough experience to recommend the following second generation system to carry out anaerobic digestion of organic wastes and more specifically poultry manure.

1. Cylindrical well stirred tank reactors with floating head or fixed head with flat or conical bottom are optional designs. In the case of the floating head, the digester also acts as a biogas storage tank, holding gas in the head space above the slurry but some of it is exposed to air. The conical bottom has the advantage that the settled particles can be removed more easily. The preferable combination would have to be a WSTR with fixed head and conical bottom.

2. Rectangular shape is less desirable as compared with circular because this may lead to dead pockets and some accumulation of the sludge may be seen around the corners.

3. To make the system energy efficient and better protected from cold weather all the digesters, holding tanks and pipes should be built below the ground, housed, or insulated where costs and climate allow.

4. The material of construction for the digesters and holding tanks should be durable, non-corrosive, and of low-cost. Easily installed systems make rubber or fibrous-reinforced flexible materials attractive.

5. Two stage anaerobic digestion should be considered where during the
first stage volatile acids are produced and methane is generated in the second stage, i.e., two digesters should be built to carry out the above steps separately.

6. A separate sludge settling tank should also be built which would enhance the solid-liquid separation by decanting the water from the top for reuse.

7. The anaerobic digester must be operated under positive pressure rather than under vacuum and the biogas produced can be measured and analyzed continuously.

8. The vertical plug flow reactors are undesirable since in the case of low solid concentration of feed there would be separation of liquid from solid phase whereas in the case of high solid concentration clogging can take place. On the other hand, the higher solid content of the slurry does not produce the proportionate quantity of biogas per unit retention time.

The horizontal tubular flow reactor may have some future but this design needs to be investigated especially for the prevention of solid settling in the digester.

9. In the case of poultry manure an extra pretreatment stage must be included to remove the grit from the slurry before loading the digester.

10. Fully automated systems must be provided with the manual override. The extent of automation and instrumentation desired would be determined by the individual need and the ability to invest the capital.
F. Conclusions

A number of conclusions have been drawn during the course of this project based on the operating experience gained as well as the experimental results.

1. To make the system energy efficient, all or a 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 of the plant.

3. Circular digester with a conical bottom for draining solids 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 slurry.

6. The digestion plant should be semi-automated with manual override with each loop of operating separated. There must not be any loop within a loop.

7. 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 less than four years.

8. By anaerobic digestion of poultry waste an excess amount of clean fuel gas can be produced. The stabilized sludge produced has a good fertilizer value and may also be utilized as a profitable feed supplement.
9. So far it appears that the retention time of up to 20 days can produce a large quantity of biogas and can also reduce B.O.D. and C.O.D. up to 85% as compared with the raw manure.

10. The anaerobic digestion is a most economical biological treatment method for organic waste with high solid content and B.O.D. and C.O.D. values higher than 1,000 mg/lit.

11. The vertical plug flow reactors is generally unsuitable for use in the plug flow mode. The horizontal tubular flow reactor with a very high ratio of length to diameter may be the more practical design.

12. The continuous WSTR and horizontal plug flow reactor configurations appear good designs for future investigation.
III. ENERGY CONSERVATION IN THE POULTRY INDUSTRY

The rising cost and diminishing availability of traditional energy supplies have been a problem of concern for all segments of the economy, and "Energy Conservation" has become an important management policy in maintaining a business's profitability. The poultry industry is no exception to this trend.

Georgia's poultry industry can be broken down into several segments: egg production and processing, broiler hatching and growout, poultry processing and further processing, rendering of waste products, and feed milling. While all of these areas use varying levels of energy, efforts in the FY 78 poultry energy conservation program were concentrated in the area of broiler growout in an attempt to address critical needs and to avoid duplication of energy conservation work for poultry processing plants funded by the U. S. Department of Energy.

Emphasis on broiler growout was justified by the fact that approximately 4,500 growout farms are in operation in Georgia, and most of these farms utilize liquified petroleum gas (LPG) for chick brooding and space heating. There is increasing concern over the continued availability of LPG (since many industries are switching to LPG from natural gas due to the interruptible nature of natural gas service in critical time periods). Also, the price of LPG has been increasing, and most farmers are concerned about diminishing profit margins.

Assistance in energy conservation activities was available to the remaining sectors of the industry on a request basis. Appendix A presents the results of a feasibility study on the proposed recovery of waste heat
from egg candling lights for use in heating egg washer water. The project was deemed not economically feasible at present due to the high cost of the air-to-water heat exchanger.

In addition, an energy consumption survey for the calendar year 1977 was conducted for the various sectors of the poultry industry to augment data collected in a similar survey for 1976. Monthly data was collected for the calendar year 1977 and included usage and cost of electricity, natural gas, propane, and fuel oil. The responses received were coded to prevent release of proprietary information; and the data is presented in Appendix B. Table 9 presents comparative data for both 1976 and 1977. Shown are energy consumption and cost parameters for each sector of the industry. Values for "average" consist of the sum of the responses for each category divided by the number of respondents. "Range" denotes the lowest and highest response in each category. "Median" denotes the 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 are considerably higher or lower than the average.

Except for hatcheries, energy consumption declined between 1976 and 1977 in the poultry industry - 22.7% for poultry processors. The hatcheries show an increase of 17.9%, but only four of the 1977 respondents also participated in the 1976 survey. In most areas energy conservation efforts have proven fruitful.

In order to provide timely dissemination of research activities and data of interest to the poultry industry, publication of a monthly newsletter, Poultry Engineering Progress, was initiated. A copy of each issue
Table 9. Poultry Industry Energy Usage

<table>
<thead>
<tr>
<th></th>
<th>1976</th>
<th>1977</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Range</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td><strong>HATCHERIES (6)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Btu/1000 Birds</td>
<td>365,635</td>
<td>300,353</td>
</tr>
<tr>
<td>$/1000 Birds</td>
<td>1.851</td>
<td>1.714</td>
</tr>
<tr>
<td><strong>EGG PROCESSORS (5)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Btu/1000 Doz Eggs</td>
<td>370,567</td>
<td>71,285</td>
</tr>
<tr>
<td>$/1000 Doz Eggs</td>
<td>2.090</td>
<td>0.861</td>
</tr>
<tr>
<td><strong>FEED MILLS (7)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Btu/Ton</td>
<td>210,029</td>
<td>47,524</td>
</tr>
<tr>
<td>$/Ton</td>
<td>0.743</td>
<td>0.342</td>
</tr>
<tr>
<td><strong>POULTRY PROCESSORS (9)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Btu/1000 Lbs*</td>
<td>1,407,811</td>
<td>783,254</td>
</tr>
<tr>
<td>$/1000 Lbs*</td>
<td>4.657</td>
<td>3.551</td>
</tr>
</tbody>
</table>

* = Processed Weight

Numbers in parenthesis indicate the number of respondents in each category.
can be found in Appendix C.

A. Scope of Broiler Grow-out Energy Conservation

The energy conservation research plan was narrowed down to concentrate on the most critical grow-out process--brooding--in order to provide sufficient depth to produce meaningful results. Figure 11 indicates the relative areas in which energy is consumed in the grow-out operation. It is recognized that: 1) broiler grow-out farmers are experiencing an immediate need to conserve energy; 2) development of a new type of brooding system may be necessary to reduce long-run dependence on limited resource fuels.

As a result, two levels of research, short range and long range, were initiated as part of the FY 78 program. The short range approach dealt with existing brooding systems in common use throughout the industry and provides an indication of the cost effectiveness and energy efficiency of the leading brooder designs. This information should be invaluable to a farmer contemplating replacement of old brooding equipment or the construction of a new house. The long range study was aimed at providing an alternative technology and fuel source to LPG, wood-fired warm-air brooding, for possible future use. Wood is a fairly plentiful and renewable commodity in Georgia, and its use may prove to be both convenient and cost effective to Georgia
B. Short Range: Brooder Testing

Infra-red brooding of poultry came into popularity in the 1950's with the advent of low-cost natural gas and propane. It replaced coal-fired stoves and hot water radiators, and produced higher quality birds with reduced mortality in a cleaner environment. Several studies have been conducted on the fuel consumption of various brooders, and comfort conditions for brooding broiler chicks have been well defined.

Infra-red radiant heat transfer is desirable in poultry brooding because of space ventilation requirements, i.e., the ambient air temperature has very little impact on the radiant heating effect. The radiant flux emitted by the brooder radiating element is given by:

$$W_r = \varepsilon \sigma (T_1^4 - T_2^4) \text{ Watts/cm}^2$$

where $T_1$ = Absolute Temperature of Radiating Element
$T_2$ = Absolute Ambient Temperature
$\varepsilon$ = Total Emission Factor
$\sigma$ = Stefan-Boltzmann Constant

If a given radiating element is heated to a temperature $T$, a maximum level of radiant flux will be emitted at a wave length, $\lambda_m$. This is known as Wien's Displacement Law:

$$\lambda_m T = 2898 \mu^\circ K$$

The wavelength range of infrared radiation is from $0.76\mu$ ($0.76 \times 10^{-6}$ meters) to roughly $1000\mu$, but a useful radiant heating effect will occur only with wavelengths less than about $10\mu$.

It is apparent that brooders of differing design will perform some-
what differently. Tests conducted by McElyea and Hargrave yield some striking differences in fuel consumption and other parameters among different brooders, as shown in Figure 12. Therefore, the objective of this project was to perform a controlled evaluation of brooders of varying design configuration from nine different manufacturers in an effort to identify design characteristics and components that contribute to optimum performance in terms of fuel consumption rate and effective brooding area as a function of brooder height. The effective brooding area, or "chick comfort zone", is considered any area receiving an incident radiant flux from 86 to 250 Btu/hr-ft\(^2\) (0.027 to 0.079 Watts/cm\(^2\)) as concluded by Harwood and Reece.

1. Test Procedure

The radiant flux densities recorded in the tests were measured with a Molelectron PR-200 pyroelectric radiometer with a removable quartz window. The incoming radiation is chopped and calibrated with an internal LED source, and the digital output reads directly in milliwatts per square centimeter. This instrument was originally developed for use in laser research and has a faster and more linear response than the more traditional thermopiles.

The testing was performed by Georgia Tech research personnel in a laboratory at the Russell Research Center of the U.S. Department of Agriculture's Agricultural Research Service. It was felt that a laboratory test under controlled environmental conditions would yield better comparative data on brooder performance than a farm test. Unfortunately, time limitations and limited availability of test equipment precluded a repetition of the test on a farm with birds present.

Each brooder was individually suspended from a specially designed
Figure 12.
MISSOURI STATE BROODER TEST (1972)
FUEL CONSUMPTION

FUEL CONSUMPTION (Gal)
supporting structure at heights of 18, 24, and 30 inches above the radiometer sensing element. At each height, each brooder was allowed to operate until a steady state radiant flux was achieved, whereupon flux measurements were recorded at 15 cm intervals moving radially from the center of the brooder. This was repeated at each height until a "floor map" of radiant flux was generated. In addition, readings at each data point were taken with no filter on the radiometer (a "windowless" condition) and with a quartz filter window. This provides a measure of not only the quantity of incident radiation on a point, but it also provides an indication of the quality of that radiation: the quartz filter transmits radiation in the wavelength range of 0.23μ to 3.5μ with a 0.92 transmission factor. 17

A description of each brooder tested is presented in Table 10 and Figure 13. Selection of the brooders was based on recommendations of poultry men regarding opinions on the best brooders currently on the market, variety in design, and willingness of manufacturers to participate. Manufacturer confidentiality was assured. In addition to five "conventional" gas brooders, two electric units, and one "cold room" brooder were tested. Unit number 7 is not designed or promoted as a poultry brooder, but is used to provide infra-red heating to large high-bay buildings, such as aircraft hangers.
Table 10.
DESCRIPTION OF BROODERS TESTED

1. Single port vertical burner beneath coarse ceramic dish with raised spikes. Burner supported by heavy wire - no bottom disc. Circular hover

2. Single port vertical burner beneath smooth ceramic dish with raised spikes. Burner supported on circular bottom disc. Circular hover

3. Single port vertical burner with venturi mixing nozzle beneath coarse ceramic dish with raised spikes. Burner supported on circular bottom disc. Circular hover


6. Cold room brooder. Six linear multi-port burners, arranged in a hexagonal configuration each beneath a rectangular (3 1/2" x 4") ceramic with spikes. Large hexagonal hover approximately 5 ft across flats.

7. Rectangular heater with porous Schwank element - no open flame 48 in. by 3 in. electric ignition. Polished reflector. Intended for high bay ceiling installation.

8. 60 in. rectangular electric heater with calrod-type element. Polished parabolic reflector. 240v.

9. 48 in. rectangular electric heater with helical filament in quartz tube. 115v.
Figure 13.
Brooder Cross-Section and Conventional Brooder component Dimensions, Inches
2. Results and Discussion

Table 11 lists a summary of the results of the brooder testing and effectiveness. Plots of the experimental data from which the effective brooding areas were derived appear in Appendix D. A relatively high A/F* ratio indicates that a large effective brooding area was generated with a low fuel consumption. The $\frac{\$}{\text{hr-ft}^2}$ ratio can be used to compare the cost effectiveness of the electric brooders with the gas-fired units. The A/F* ratio indicates that the electric devices are efficient in converting input energy to infra-red, but the cost ratio shows that electricity is a more expensive energy source than LPG.

The conventional brooders, numbers 1 through 5, consumed fuel in the range of 0.17 to 0.22 ft$^3$/hr (roughly 25,000 to 33,000 Btu/hr). In most cases, the maximum effective brooder area was produced at a brooder radiant element height of twenty-four inches, meaning that an optimum height exists somewhere between 18 and 30 inches. Therefore, brooder effectiveness can be increased as much as twenty percent ($100 \times \frac{6940-5809}{5809}$ for brooder number 3) simply by operating it at an optimum height. This means that for a given rate of fuel consumption more chicks can be kept comfortable at the optimal brooder height than at other higher or lower heights. It is likely that the optimal height may be slightly different for different types of brooders.

It is interesting to note that brooder number 1 has low A/F* ratio for the 18" height while it is "competitive" for the other heights. This was the only unit tested that produced an incident radiation that exceeded Harwood and Reece's upper limit for chick comfort - it was too hot directly beneath the burner! (see Figure 14). Unit number 1 was the only conven-
Table 11.
RESULTS OF BROODER TESTING

<table>
<thead>
<tr>
<th>No.</th>
<th>F ft³/min</th>
<th>$/hr LPG</th>
<th>F*</th>
<th>18&quot;</th>
<th>24&quot;</th>
<th>30&quot;</th>
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<tbody>
<tr>
<td>1</td>
<td>0.17</td>
<td>0.092</td>
<td>25,700</td>
<td>29.5</td>
<td>2734</td>
<td>106</td>
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<td>2</td>
<td>0.20</td>
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<td>224</td>
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<tr>
<td>3</td>
<td>0.19</td>
<td>0.103</td>
<td>28,730</td>
<td>43</td>
<td>5809</td>
<td>255</td>
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<tr>
<td>4</td>
<td>0.22</td>
<td>0.119</td>
<td>33,260</td>
<td>35</td>
<td>3848</td>
<td>445</td>
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<tr>
<td>5</td>
<td>0.17</td>
<td>0.092</td>
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<td>45</td>
<td>6362</td>
<td>208</td>
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<tr>
<td>6</td>
<td>0.12</td>
<td>0.065</td>
<td>18,140</td>
<td>**</td>
<td>**</td>
<td>**</td>
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<td>7</td>
<td>0.14</td>
<td>0.076</td>
<td>21,170</td>
<td>Rect. 2962</td>
<td>.369</td>
<td>.140</td>
</tr>
<tr>
<td>8</td>
<td>1339 watts</td>
<td>.060</td>
<td>4,570</td>
<td>Rect. 1576</td>
<td>.548</td>
<td>.345</td>
</tr>
<tr>
<td>9</td>
<td>1240 watts</td>
<td>.056</td>
<td>4,230</td>
<td>Rect. 0</td>
<td>**</td>
<td>0</td>
</tr>
</tbody>
</table>

** = Convective
N. A. = Data not applicable
$A = \pi r^2$

$F^{*} = \frac{F(60 \text{ min/hr})(2520 \text{ Btu/ft}^2)}{1000 \text{ watts/\text{kw}-hr}}$

$/\text{hr LPG} = \frac{F(\$0.33/\text{gal})}{(92,000 \text{ Btu/gal})}$

$F^{*} = \frac{F(3.413 \text{ Btu/hr-watt})}{1000 \text{ watts/\text{kw}-hr}}$

$/\text{hr Elect} = \frac{F(\$0.045/\text{kw-hr})}{1000 \text{ watts/\text{kw}-hr}}$

$c/\text{ft}^2 = \frac{($/hr)(100c/$)(144 \text{ in}^2/\text{ft}^2)}{A}$
tional brooder tested that did not have a bottom disc supporting the burner.

The other units had "cool" spots directly under the burner with a typical radius of twelve inches (this corresponds to the familiar doughnut-shape formed by chicks during brooding). Reduction of the bottom disc diameter on brooder number five to an optimal size could increase its effective brooding area by as much as 450 in$^2$ at the twenty-four inch height (see Figure 15).
Another variable is the distance from the radiant element to the bottom disc—an increased distance will increase the element-to-floor configuration factor and decrease the cool spot size.

LPG has a maximum flame temperature of about $3500^\circ F$, but this extreme temperature is only reached at the peak of the flame inner cone (see Figure 16).
Therefore, it is desirable to maintain the flame such that the peak of the inner cone is held just below the bottom of the radiant element. Impingement of the inner cone on the radiant element can result in: 1) reduced temperature of the radiant element, 2) incomplete combustion, and 3) formation of carbon monoxide. Black carbon deposits will generally form on the element when this occurs. Brooder number 3 had an "ideal" flame, while most others had some degree of inner cone impingement on the radiant element. It is also important that a blue flame is produced by the burner - yellowness indicates that the fuel is not being properly mixed with air.

An important difference in brooders is the type of material used as a radiating element. Factors that can influence radiant element performance are dirt, flame quality (i.e. inner cone impingement), surface texture, and type of material. In order to evaluate all of these properties, a separate test would have to be performed using a standardized burner and installation configuration.

It should be noted that the data obtained from unit number four is not in concurrence with field test data supplied by the manufacturer. Since it was the only brooder tested with a stainless steel radiant element, it would be unfair to generalize about the performance of this material with-
out further data.

Brooder number 6 did not emit enough radiant energy to exceed the minimum chick comfort limit, although it was able to easily maintain an adequate brooding temperature beneath its hover by convection heating. This unit is promoted as a "cold room" brooder and has a large hover that literally traps the warm air and combustion products and holds the gases over the chicks. Its effectiveness is minimal at heights above 18 inches, but at the 18 inch height it can effectively brood chicks with a reasonable cost ratio.

Unit number 7 is unique in that it utilizes a narrow rectangular array of "Schwank"-type radiant elements. It is suspected that this unit would excel if mounted at a height greater than 30 inches, although its capability as a brooder in such a situation is not known. It is designed to keep people warm in cold environments. In its present design at the test heights used in this experiment, the polished reflector (or "hover") actually blocked some of the lateral radiation, thus reducing the effective brooder area considerably. With some minor modifications to the radiant element configuration and the reflector/hover design, this unit would have tremendous potential as a chick brooder.

Electric brooder number 8 is designed to operate on 240 volts, single phase. It was discovered during the test that the laboratory line voltage was only 208 volts, but the unit still performed well. Unit 9 operated at 110 volts and did not have the capacity to generate an effective brooding area at 18 inches.

Electric brooding is a viable alternative in areas where gas may be in short supply, although electricity is a relatively expensive energy form in
most areas and is interruptible (the service interruptions usually coming in periods of extremely bad weather - when brooders are needed most).

Unit 9 is probably not appropriate for use as a large scale brooder. It will probably operate effectively at a height less than 18 inches, but the A/F* ratio will be very low, a large number of units would be needed, and the quartz tube is very fragile and subject to breakage (as demonstrated in the laboratory). It is doubtful the tube could withstand the normal abuse inherent in grow-out operations from catching and clean-out crews.

With all of the units tested, it was found that 30% to 60% of the incident radiation was in the short infra-red (0.7μ to 4.0μ) range.

Finally, the brooder pilot fuel consumption is another important element in brooder design. Because most brooders run intermittently, the pilot fuel consumption can be significant. In order to evaluate a potential brooder purchase, a utilization factor should be determined through a winter growout season in the region of the house to be equipped in a house of similar construction. This utilization factor will indicate what percentage of the time the brooder thermostats will be calling for heat - and conversely, how long the brooders will be operating on pilots alone. Ideally, a brooder will have an A/F* ratio that is high (above 0.250) and a pilot cfm that is low (0.1 cfm or less). Table 12 lists the pilot gas consumptions for the nine units tested.

Table 12

<table>
<thead>
<tr>
<th>Unit</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot CFM</td>
<td>0.4</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
<td>0.1</td>
<td>-0.1</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
</tbody>
</table>

1. Electric Spark Ignition
2. Not Gas-Fired
C. Long Range: Wood-Fired Warm Air Brooding

The objective of this aspect of the state energy conservation program was to develop a wood-fired brooding system for poultry growout houses. Young chickens require carefully controlled environmental conditions during the first few weeks of their lives with regard to the temperature and humidity. Conditions outside a relatively narrow range result in poor feed conversion, high mortality rates, and in general, a lower quality flock which is reflected in a high downgrading percentage at the processing plant. In response to the requests of a number of farmers and poultry integrators, a demonstration project was initiated to study and develop wood energy as an alternative to conventional fossil-derived energy sources. Wood energy is not feasible for everyone, but with the quantity of wood waste generated from pulp and paper operations and the quantity of on-farm timberland in Georgia, utilization of renewable wood resources appears attractive.

1. Site Description

The growout house chosen for this project was on a farm operated by Mr. George Key near Carrollton, Georgia. The operation is under contract to Strain Poultry Farms, Inc. The farm has two identical growout houses in close proximity to each other with the same orientation with regard to the sun and prevailing winds. The dimensions of the houses are 325 feet long by 35 feet wide, and a normal flock of chickens will consist of 15,000 to 17,000 broilers per house.

The houses are of the side curtain variety, and are built of wood frame construction with a sheet metal roof. The ceiling is insulated and dropped to a height of about 10 1/2 feet above the house floor. There are five
ventilation fans in each house - two controlled by a timer and three controlled by thermostats. Each house contains twenty Cumberland propane brooders rated at 30,000 Btu/hr per unit. Both houses are set up for half-house brooding. About forty acres of mature timberland are located on the farm.

2. Experiment System Description

Figure 17 indicates the main elements of the wood-fired warm air brooding system, and Figure 18 shows the flow of events in the construction of the system. A separate structure was provided to house the furnace and wood supply, and a concrete pad about six inches thick was required to support the 3100 pound wood furnace. The furnace house is located at the mid-point of the growout house to allow a symmetrical and naturally balanced air distribution system. Exposed ducting from the furnace to the house was insulated and weather proofed to reduce the potential heat losses that could occur during inclement weather conditions. The side curtain was cut appropriately to allow the duct to enter the house. Following the inclined roofline to the ceiling, the duct branches out into two long runs down the length of the house. Flexible eight inch diameter duct downcomers were located at approximately 15 foot intervals to supply warm air to ground level. The air was distributed parallel to the ground by means of slightly oversized concentric ceiling diffusers.

The entire duct system was sized using the static regain method as described in the ASHRAE Handbook of Fundamentals. As partial house brooding is practiced by Strain Poultry Farms, there are times when only one half of the duct system will be utilized. A damper was installed to block off either half of the house if necessary. Both sides of the
Figure 17.
WOOD FIRED WARM AIR BROODING SYSTEM
STRAIN POULTRY FARMS, INC.
GEORGE L. KEY, GROWER

DRAWING IS NOT TO SCALE
Figure 18. Construction of Wood Fired Brooding System
system were sized generously in order to accommodate an increased air flow. This also allowed complete symmetry and natural balancing for ease of installation and operation.

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

The furnace selected for this program was model 1007 designed and built by the Lynndale Manufacturing Co. of Harrison, Arkansas. Appendix E shows a schematic drawing and list of specifications for the furnace. The furnace has a 47 cubic foot fire box and is rated at 350,000 Btu/hr. Combustion of the wood is controlled by a forced draft fan in order to slow the burning process when heat is not required in the chicken house. If the house thermostat does not call for heat, the draft fan does not operate, and the fire simply smolders at a slow rate since it is starved for oxygen. This particular furnace features a secondary combustion chamber into which fresh air is introduced to combust any creosote gases before they reach the exhaust stack.

The brooding air is heated by being blown around the outside of the furnace fire box by a 4140 cfm fan. It is then directed into the duct system for distribution in the chicken house. This blower is also controlled
by the house thermostat; in addition, the blower will not operate if the tem-
perature of the air entering the duct system is not above a setpoint tem-
perature. The initial design called for 100% outdoor air with no return air.

3. Results and Discussion

Construction and installation of the furnace and air distribution system
was completed during the winter of 1977-78, and the first flock of chicks
to be brooded with wood-fired warm air was placed in June of 1978. Prior
to this, temperature and relative humidity data were recorded on a con-
tinuous basis using Rustrak model 225 hygrothermographs. From the charts
shown in Appendix F, it is apparent that the test and control houses
possess 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.

In order to ensure survival of the first group of chicks brooded with
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 the experimental system. Gas meters installed on each
house showed that gas consumption for the test house was roughly 50% of
that for the control house. Now that the experimental system has been success-
fully demonstrated, gas to the test house will be completely shut off.

It will be necessary to monitor the performance of the system through
an entire winter's heating system in order to obtain a good indication of
the wood-fired warm air brooding system effectiveness. Experience thus
far indicates that a 95°F room temperature can easily be maintained during
half-house brooding with the warm-air duct thermostat set at 130°F.
Table 13 lists the costs of the actual test system and a projected commercial installation of similar equipment. It assumes that the farmer already has a chain saw, provides labor at no cost, and has equipment available to transport the wood from the forest to the chicken house. The differences in the two costs listed are primarily due to instrumentation and a difference in ductwork - it is anticipated that a less expensive duct system can be installed in a working non-experimental farm.

Table 13.

**WOOD-FIRED GROW-OUT SYSTEM COSTS**

<table>
<thead>
<tr>
<th>Item</th>
<th>Experimental System</th>
<th>Commercial Farm System (Estimated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log Splitter-Waldrep Chain Saw Co.</td>
<td>$850</td>
<td>$900</td>
</tr>
<tr>
<td>Concrete Pad and Furnace House-L. Rodgers Construction Co.</td>
<td>$825</td>
<td>$1,000</td>
</tr>
<tr>
<td>Furnace - Lynndale Mfg. Co.</td>
<td>2,400</td>
<td>3,300</td>
</tr>
<tr>
<td>Furnace Installation - Carroll Mach. and Fabrication</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Electrical Wiring - Sullivan Electric Co.</td>
<td>150</td>
<td>250</td>
</tr>
<tr>
<td>Ductwork - Ace Contracting</td>
<td>$4,300</td>
<td></td>
</tr>
<tr>
<td>Misc. Electrical Supplies</td>
<td>50</td>
<td>150</td>
</tr>
<tr>
<td>Misc. Mechanical Supplies</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Instrumentation:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temp/MH - Fisher Scientific</td>
<td>720</td>
<td></td>
</tr>
<tr>
<td>Hour Meters - Eagle Signal</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>Gas Meters - Rockwell</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$9,785</td>
<td>$6,250</td>
</tr>
</tbody>
</table>

**D. Conclusions**

Alternatives are being explored for broiler growout farmers who are facing problems in both the cost and supply of traditional energy forms. Opportunities for the optimal utilization of gas-fired brooders have been identified as well as a wood-based technology that could in many cases completely replace fossil-derived fuels in the operation of poultry growout farms.
REFERENCES (Section III)


11. Ibid., pp. 72.


13. La Toison, pp. 4.

14. McElyea and Hargrave.


19. Ibid., p. 164.

IV. SOLAR ENERGY APPLICATION TO THE BROILER FARM HOUSE

Investigation of the use of solar heating for livestock shelters is a recent agricultural research topic. Interest in solar heated poultry houses has come as a result of increasing fuel prices and the desire to reduce our dependence on nonrenewable energy supplies. Current broiler production in Georgia is about 450 million birds per year requiring the equivalent of 10 to 20 million gallons of LP gas annually depending upon weather conditions and management practices. Widespread implementation of solar energy in poultry growout operations requires low cost solar heating system using materials and construction methods appropriate for poultry houses. This project was undertaken in an effort to develop such solar heating systems.

The Georgia Department of Agriculture has responded to our state and national goal of energy independence by funding the two solar broiler house heating systems reported on herein. These two full scale solar broiler house heating systems were designed at the Georgia Tech Engineering Experiment Station (EES) and constructed during the past two and one half years. The first generation solar heating system shown in Figure 19 was installed in May, 1976, on Mr. Lamar Hick's farm near Cumming, Georgia. Construction of the second generation system shown in Figure 20 was completed in April, 1978, at Mr. Billy Waddell's farm near Villa Rica, Georgia. The first generation system uses a passive solar collector design in which natural convection causes warm air to flow into the house from a 3,300 square foot collector mounted on a hillside beside the house. The heating system cost about $6,600 to build and provided approximately 40 percent of the heating
Figure 19. First Generation Solar Heated Broiler House

Figure 20. Second Generation Solar Heated Broiler House
needs for the 300 foot house during the first year of operation. The second
generation system consists mainly of a 2950 square foot roof mounted solar
collector and a fan to force warm air through perforated polyethylene air
ducts into the house.

EES research on solar heating in poultry houses for fiscal year 1978
was divided into four major areas, including I - monitoring the results
of the first generation solar heating system, II - designing and retro-
fitting a broiler house with a roof mounted solar collector, III - de-
signing a broiler house with a solar heating system built as an integral
part of the house, IV - information dissemination to the local farmer.

The research is discussed in detail in the following sections.

A. Monitoring the First Generation System

1. Results

Gas meter readings were recorded before and after each growout period
at the first generation system during the 1977-1978 heating season. The
first test period began December 2, 1977 after the upper layer of polyethy-
lene glazing was replaced. Meter readings for three consecutive growout
periods were recorded with the last one ending June 14, 1978.

Comparison of the gas consumption in the solar house with that of the
two control houses indicated that the solar heating system was not operating
properly after the first growout period which ended January 24, 1978.
Blockage of warm air ducts with house litter caused by rats was discovered
in 10 of the 13 air ducts connecting the collector to the house. The air
ducts were cleaned out using a rotary drain cleaning tool with water to
wash the litter out of the pipes. Gas consumption in the solar house com-
pared to the control house average showed no improvement after the second
growout period from February 9 to April 3, 1978. The air ducts were dis-
covered to be blocked again.

2. Repairs

To correct this problem we dug up each pipe in the house and sealed
all joints and holes. Hardware cloth was placed over the larger openings,
and the joints and holes were filled with concrete. The glazing support
frames were removed from the collector to facilitate cleaning of the air
ducts. Each air duct was cleaned out using 30 feet of 1\frac{1}{4} inch diameter
PVC water pipe attached to a shop vacuum cleaner. The rock bed was cleaned
of house litter and the rocks were redistributed over the bed. In addition,
treated 2 x 6's were installed at the upper edge of the collector to form
an earth retaining wall. Figure 21 shows the rock bed before repainting and
Figure 22 shows the deterioration of some 2 x 2 frame members which have been
in service for two years.

The glazing support frames will be rebuilt with new 2 x 2's where
necessary. After new polyethylene is wrapped around the frames the frames
will be nailed in place, and the heating system will be ready for the 1978-
1979 heating season.

3. Polyethylene Transmittance Testing

Four samples of 6 mil Monsanto 602 polyethylene glazing used on the
first generation system were tested for solar transmittance. A sample of
new polyethylene was compared with samples of which were in service for
different length of time as indicated in Table 14. A PR 200 pyroelectric
radiometer manufactured by Molectron Corporation was used for the tests.
Figure 21. Rock Bed Before Repainting

Figure 22. Deterioration of Frame Members
Table 14. Transmittance of 6 mil Monsanto 602 Polyethylene from First Generation Solar Heating System

<table>
<thead>
<tr>
<th>Sample</th>
<th>Exposure, Months</th>
<th>Transmittance, Percent</th>
<th>Percent of New Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td>0</td>
<td>81</td>
<td>100</td>
</tr>
<tr>
<td>Upper Glazing</td>
<td>6</td>
<td>78</td>
<td>96</td>
</tr>
<tr>
<td>Upper Glazing</td>
<td>19</td>
<td>75</td>
<td>93</td>
</tr>
<tr>
<td>Lower Glazing</td>
<td>25</td>
<td>70</td>
<td>86</td>
</tr>
</tbody>
</table>
Samples of polyethylene were attached to the open slide-in optical window supplied with the instrument. The measurements were made using the sun as the source between 2:00 pm and 3:30 pm on June 14, 1978, with clear sky and steady radiometer output.

Notice that the lowest value of transmittance is from the sample of lower glazing which had the longest exposure to the sun. This sample was covered by the upper glazing during the service period, but the lower glazing is exposed to the relatively high temperature rock bed, adding to its degradation.

The combined transmittance of the double layer of polyethylene decreased by 13 percent from 66 percent when new to 53 percent after 1½ years of service. This reduction of sunlight transmission reduces the effectiveness of the solar collector, but the limiting factor with the use of polyethylene is the physical break down of the upper layer near the frame. The upper glazing was replaced in December, 1977 after 1½ years of service because of cracking along the frame members. The brittleness and subsequent cracking of the polyethylene is believed to be caused by a combination of high temperature near the frame due to absorbed sunlight, stress concentration in the polyethylene near the frame, and exposure to ultraviolet radiation.

4. Future Research

The first generation solar heating system will be operated for its third heating season during the winter of 1978-1979. We will monitor the system with a 24 point strip chart recorder which will continuously record temperatures at selected locations around the collector. We feel that the problem of blockage in the air ducts has been solved and that the system
will operate as designed during the coming winter.

B. Design and Construction of the Second Generation System

During fiscal year 1978 our greatest effort in solar broiler house research was the design and construction of a roof mounted solar collector for broiler house heating. The originally proposed design of an extended roof collector was abandoned for the following reasons: side curtain ventilation would have been restricted; the design did not incorporate recirculation between the collector and storage bed; and roof angles commonly found in growout houses are inappropriate for the roof extension.

1. Design

Design of the retrofit solar heating system began with a comparison of a trickle type water collector and an air-type collector. The water system was attractive because of the ease of fluid control and smaller storage volume as compared to an air system with rock bed storage. Costs of the two systems we compared were about the same. The possibility of leaks and freezing in a water system are serious drawbacks. In addition, the use of water involves reduced heat transfer effectiveness since heat must be transferred to the house air through a water-to-air heat exchanger. An air system design was decided upon after considerable deliberation.

The final design evolved from our efforts to retain the inherent simplicity and low cost construction common to broiler growout houses. Figure 23 is a diagram of the system. In this solar heating system, air flows between fiberglass reinforced plastic glazing and the black insulated absorber surface. The glazing is spaced 3½ inches above the absorber surface by 2 x 4's. Outside air enters each end of the collector, flows to the duct in the center
Figure 23
SECOND GENERATION SOLAR
BROILER HOUSE

GEORGIA TECH
ENG. EXP. STATION
through a tube axial fan in the house with final distribution in the house via two 100 foot long, 18 inch diameter perforated polyethylene ducts shown in Figure 24. The collector measures 156' x 19' for an area of about 2950 square feet. The growout house is a 250' x 40' pole supported structure. Construction drawing of the system is in Appendix G.

The collector was sized by matching solar radiation input with estimated heat load of the house. It was assumed, based on experience, that 200 Btu/ft$^2$ day could be obtained from this type of low cost solar collector under winter conditions. The estimated heat load was 2,250 Btu/bird obtained from average gas consumption over a two year period in the control houses for the first generation solar broiler house. Since the house capacity at the site of the second generation solar broiler house is about 12,000 birds and heat is needed for approximately 30 days of a typical 52 day growout period, the energy needed to supply 100 percent of the heating load is about 900,000 Btu/day. To supply 60 percent of the heat with solar, 540,000 Btu/day must come from the solar collector. Dividing the solar heat load of 540,000 Btu/day yields an area of 2,700 ft$^2$. Total area of the completed collector is 2,950 ft$^2$. It must be kept in mind that there will be an excess of solar energy during the day and no solar energy at night since the system does not have heat storage capacity. This means that the amount of heat from the solar collector will be considerably less than 60 percent of the total annual heating load. During the 1978-1979 heating season, the solar heating system will be closely monitored to determine the amount of heat supplied by solar energy.
Figure 24. Air Distribution System For Second Generation Solar Broiler House
2. **Construction**

The site selected for construction of the heating system is a farm owned by Mr. Billy Waddell located about 5 miles west of Villa Rica, Georgia. Mr. Waddell grows broilers for Gold Kist, Inc. of Carrollton, Georgia. There are three growout houses on the farm, two of which were built at the same time and are of nearly identical construction and orientation. The solar heating system was built on one of these houses and the other was selected as a control.

Construction of the heating system was done according to the plan in Appendix G by Ace Contracting Company of Atlanta. Total cost of construction was $7,260 as indicated in Table 15. Since black faced thermax sheathing is now available for the same price as foil faced sheathing, the $580 for painting the sheathing can be substracted from the cost of the heating system. With this subtraction the installed cost of a duplicate system would be about $6,700 or about $2.30 per square foot of collector area.

Some difficulties were encountered during construction. It was somewhat difficult making the 2 x 4's conform to the shape of the roof since the roof was not entirely flat. Shorter lengths of 2 x 4's might be used to allow for this in the future. Some warpage of the 2 x 4's and the 2 x ½ wooden battens over the glazing occurred after construction of the collector was complete. This warpage is believed to be due to the high temperature in the collector. A solution to this problem would be to use metal 2 x 4's rather than wood. The increased cost would likely be offset by a longer useful collector life.

3. **Instrumentation and Controls**

An Esterline Angus 24 point strip chart recorder was installed in the
Table 15. Construction Cost Breakdown for
Second Generation Solar Heating System

<table>
<thead>
<tr>
<th>ITEM</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>85 4' X 10' Rolls 0.060&quot; Kalwall Sun-Lite Premium II</td>
</tr>
<tr>
<td>2.</td>
<td>100 4' X 8' Sheets 1&quot; Foil Faced Thermax Sheathing</td>
</tr>
<tr>
<td>3.</td>
<td>18&quot; Belt Driven Tubeaxial Fan</td>
</tr>
<tr>
<td>4.</td>
<td>2 18&quot; Diameter 100' Polyethylene Ducts</td>
</tr>
<tr>
<td>5.</td>
<td>Adjustable Differential Temperture Thermostat and Relay</td>
</tr>
<tr>
<td>6.</td>
<td>Room Temperature Thermostat</td>
</tr>
<tr>
<td>7.</td>
<td>Wiring</td>
</tr>
<tr>
<td>8.</td>
<td>Construction (includes lumber and duct work)</td>
</tr>
<tr>
<td>9.</td>
<td>Painting Thermax Sheathing</td>
</tr>
<tr>
<td></td>
<td>Total</td>
</tr>
</tbody>
</table>
solar heated house to record temperatures at selected points on the collector and in the house. In addition, the recorder will monitor solar radiation and relative humidity inside and outside the solar and control houses. Gas meters were installed in both the solar and control houses and a watthour meter was installed in the solar heating system fan circuit to determine the amount of electrical energy required to operate the heating system. An inclined tube manometer was installed with pressure taps on both sides of the fan to measure the pressure increase across the fan. The instrumentation set up is shown in Figure 25. Air flow rates will be determined by traversing the ducts with a pitot tube attached to a velometer.

Control of the solar heating system is accomplished automatically with a differential temperature thermostat wired in series with a house air temperature thermostat. With these controls, the farmer can set the house temperature thermostat at the desired temperature and the system will operate automatically. For example, if the differential temperature thermostat senses that the collector temperature is 10°F or more above the house temperature and the house air temperature thermostat is "calling" for heat, the solar heating system fan will turn on and warm air will be supplied to the house. If the temperature in the collector is less than 10°F above the house temperature (such as at night), the solar heating system will not operate even if the house air thermostat is "calling" for heat. Conventional gas brooders will be in place as usual with the same thermostat settings as the control house brooders.

4. Testing

Heating has not been necessary since construction of the solar heating
Figure 25. Monitoring Instruments For Second Generation Solar Broiler House
system was completed, but some preliminary tests and observations have been made. The first test on May 29, 1978, indicated a collector efficiency of 30% at 4:00 pm solar time under a hazy sky. A temperature rise of 35 F was obtained with an air flow rate of approximately 3700 cfm. On a sunny day in June the absorber surface temperature reached 250 F. The roof temperature underneath the collector was 145 F compared to the roof temperature of 160 F ten feet away from the collector. This difference was due to the collector insulation. Summer temperature in the solar heated house should be lower than normal due to the reduced roof temperature. Gas meters in each house showed that without solar heat the gas consumption in the control house was within 4 percent of that in the solar heated house for the period from March 24, 1978 to May 12, 1978. This indicates that the control house will provide an accurate means of comparison for determination of the heating contribution due to solar during the 1978-1979 heating season.

C. Design of Integral Solar Heating System

In addition to the research described to this point, a broiler house with an integral solar heating system was designed during fiscal year 1978. A drawing of the house and heating system is in Appendix H. This heating system is similar in design to the second generation retrofit solar heating system, but there are some important variations in the design.

The integral design uses the sheet metal roofing as the absorber plate with air flow under the sheet metal. This design provides a stagnant air space between the absorber plate and the glazing to reduce heat loss from the upper surface of the collector. The back of the collector is ½ inch plywood insulated with 3½ inches of fiberglass which is better insulation and
lower in cost than the Thermax sheathing used in the second generation system.

Improvements in the integral solar heating system design are likely since the performance of the second generation solar heating system has not been tested under winter conditions.

D. Dissemination

An important part of practical research is dissemination of the results to potential users. The fifth issue of Poultry Engineering Process, included in Appendix C, was devoted to a description of the first and second generation solar heated broiler houses. The newsletter features a different aspect of poultry research each month and is sent to appropriate poultry industry persons.

In an effort to show poultry farmers and poultry industry personnel the results of our research, we held an open house at the solar and wood heated growout houses on July 19, 1978. A number of poultry farmers visited the second generation solar broiler house on the 19th and for several days afterward. We answered questions and received comments during the open house and by mail and phone afterward. The enthusiasm shown by poultry farmers for alternative means of heating growout houses is encouraging.
A. Introduction

A large part of the challenge in controlling and increasing yield in poultry processing plants is the application of quality controls at critical points on the processing line. At the present time supervision of line operations is carried out visually and quantitative assessment of production is made only on total throughput for the whole plant. Continuous quantitative measurement of bird weights is not made due to a lack of a simple and cost effective method which is compatible with existing conveyor systems and processing line speeds.

In more recent years, various processing functions have become more mechanized. Even though machines are able to replace or reduce manual labor at many work stations, the amount of product downgrading and rejection may increase due to the machines' inability to automatically adjust for bird size. Hence, labor costs may be reduced with increased automation but saleable yield may decrease. The greater use of machines in poultry processing has brought about the need to continuously evaluate yield at various processing line locations so that machines can be "fine tuned" for optimum yield and any maladjustments can be detected immediately.

The mechanization project for FY 77-78 has been aimed at two major tasks:

(1) develop a versatile and economically feasible hardware concept which can be utilized for evaluating yield on the evisceration line, and

(2) generate a sufficient quantity of data to demonstrate the operation and potential uses of the system.
The mechanical hardware which will be utilized on the overhead conveyor system must be compatible with existing machinery and be rugged enough to withstand the daily clean-up operation. The electronics must also be extremely rugged and be versatile enough to accommodate the individual requirements of poultry plants and to permit a thorough analysis of acquired data.

B. Yield Evaluation System Concept

A system concept was developed to satisfy the above mentioned requirements and, where feasible, to utilize commercially available components. The heart of the system is a Hewlett-Packard 9825 desktop calculator which can store up to 32,000 entries and can be programmed to acquire and analyze data from a number of weighing stations. By using a programmable calculator for which data acquisition and analysis programs can be written, the size and complexity of the system can be increased at any time. This concept has not been used before in poultry weighing systems. Commercially available weighing and drop-off systems use hard-wired components and modules which limit the utility of these systems.

The following sections describe in detail the various systems and components which have been developed and discuss the initial group of data collected from the system installed at the Mar-Jac, Incorporated processing plant.

C. Description of Hardware and Software

The overall organization and operation of the yield evaluation system installed at the Mar-Jac plant in Gainesville can probably best be understood by referring to Figure 26, which shows the various system components and the relationships among them. At the left hand side of the diagram
Figure 26. Overall System Organization
the location of the two weighing stations are shown. The first station is located before the eviceration line, while the second station is located after the line, thus enabling yield values to be determined by comparing bird weights at Station 1 and Station 2. The bird weights are converted into low level electrical signals at the weighing stations, and clue signals are then fed over about 100 feet of shielded instrumentation cable to a two channel amplifier and signal conditioning unit. In addition to amplifying the signals by a factor of about 4000, the amplifier and signal conditioning unit also filters the signal to attenuate any frequency components greater than 30 hz. This low pass filtering is done to reduce the efforts of both induced 60 hz electrical noise and mechanical vibrations present at the weighing stations. From the amplifier and signal conditioning unit the signals are then fed into an HP6940B Multiprogrammer unit in which the analog electrical signals are converted into 12 bit digital signals for use by the HP9825A calculator. Under control of the calculator these digital values representing bird weight are then stored on a cassette tape cartridge for later analysis.

A more detailed picture of the system hardware is shown in Figure 27, The heart of each weighting station consists of two strain gauge load cells powered by a common 10 volt zener diode voltage supply. The sensitivity of the load cells is such that a one pound force applied to either cell will change the bridge output by 400 micro volts. Shielded instrumentation cable is used between the load cells and amplifier to alternate the effects of the strong 60 hz electrical fields present in the plant. The bridge output voltages are fed into two stages of AD521K integrated circuit instrumentation amplifiers. The first stage provides a gain of 833, while the record stage serves as a combination of summing point, 30 hz low pass filter network.
Figure 27. Amplifier and Load Cell Circuitry For One Weigh Station
and amplifier with a gain of 5. The output voltage is then a signal obtained by adding the two load cell voltages, amplifying them by a factor of about 4000, and filtering to remove any frequency components greater than 30 hz.

As mentioned earlier, the overall operation of the system is under control of the HP9825A calculator. A simplified block diagram of the system software is shown in Figure 28. After reading the time of day and date from real time clock module, the calculator goes into a scanning mode in which station one is constantly interrogated to determine if a bird is on the weighing pan. When a bird is detected (indicated by a positive voltage readout) the calculator goes into a wait state for 200 msec, after which ten readings are taken at 12 msec intervals. The 200 msec wait is to allow the voltage reading to stabilize and ten readings are taken to obtain a good average value for the weight. The calculator then returns to a scanning mode in which it is now looking for a bird to clear the weight pan. When this occurs (indicated by the voltage going negative), the calculator pauses for 200 msec and then ten "zero" readings are taken and averaged. The difference between these two averaged readings is calculated and the result after being multiplied by an appropriate conversion factor is stored in the calculator memory as the sum of the bird weight and shackle weight. By taking a "zero" reading with each bird reading, errors due to both long term and short term drift are eliminated. After reading 130 birds at station one, the calculator enters a state in which station two is now scanned. Upon reading 130 birds at station two the calculator records the station one and station two data along with the data and time of day on a cassette
Figure 28. System Software
data cartridge. This set of data constitutes a data file. After recording the data the calculator then returns to scanning station one and the process is repeated as often as desired. Assuming a 15 minute cycle time and eight hours of operation daily, 32 files containing over 8000 readings, representing one day of production can be recorded as a single cassette cartridge completely automatically.

In addition to controlling the operation of the yield evaluation system, the calculator is also used to reduce and analyze the resulting data. After subtracting the shackle weight and eliminating any obviously bad data (birds less than two pounds or more than five pounds) the average bird weight and standard deviation are calculated and printed for station one and station two. The average yield percentage is then calculated and printed, as well as maximum and minimum bird weights and the weight distribution. Figure 29 shows a sample print out for one data file.

D. Summary of Data Collection and Analyses

Large amounts of data have not yet been collected and analyzed, but some preliminary results have been obtained that are quite encouraging. For sets of data have been collected so far with each data set consisting of the weights of about 115 birds taken both prior to and after evisceration. Although the individual bird weights varied between two and four pounds, the average weights and average yields were remarkably uniform, with the results indicating that the lighter birds may be providing slightly higher yields. This conclusion is highly tentative though, and much more data needs to be collected and analyzed to support any firm conclusions. These results are presented in Table 16.
<table>
<thead>
<tr>
<th>Station</th>
<th>Average Weight</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.83</td>
<td>0.31</td>
</tr>
<tr>
<td>2</td>
<td>2.23</td>
<td>0.31</td>
</tr>
</tbody>
</table>

**Difference:** 0.60

**Yield Pct:** 78.94

**Max Weight:** 3.88

**Min Weight:** 2.13

**Total Readings:** 130.00

**Good Readings:** 112.00

**Lost Readings:** 18.00

**St 1 Under:** 10.00

**St 1 Over:** 0.00

**St 2 Under:** 6.00

**St 2 Over:** 0.00

Figure 29. Sample Data Analysis Printout
Table 16.
Yield Evaluation Results

<table>
<thead>
<tr>
<th>File Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Bird Weight - Station 1</td>
<td>2.83 lbs</td>
<td>2.83 lbs</td>
<td>2.90 lbs</td>
<td>2.89 lbs</td>
</tr>
<tr>
<td>Average Percent Yield</td>
<td>78.9%</td>
<td>78.6%</td>
<td>78.1%</td>
<td>78.2%</td>
</tr>
</tbody>
</table>

Composite histograms of the preliminary data are shown in Figure 30. As might be expected, the weight distributions are approximately Gaussian.

During the proposed project effort for FY 78-79, three more weighing stations will be added to the Mar-Jac, Inc. evisceration line to obtain more comprehensive data on the locations and amounts of yield losses.
Figure 30. Composite Histograms of Preliminary Data
VI. POULTRY WASTEWATER TREATMENT

Increased concern over environmental quality and the need for water resource management planning has had an impact on all industries that use water in a production process. Poultry and egg processors have been particularly vulnerable to environmental regulation due to strict U.S.D.A. sanitation and potable water requirements for product washing, scalding, chilling, and plant clean-up, resulting in significant wastewater discharges.

There are basically two alternatives available for the discharge of wastewater: environmental discharge to a natural body of water or discharge to a sewage treatment system. Generally, the type discharge is mandated by plant location: a plant located in a rural setting may not have access to a municipal sewer; or a plant in an urban setting may not have enough land available to install an acceptable treatment system to allow an environmental discharge.

A. Waste Characterization

The nature of wastewater resulting from poultry processing has been thoroughly studied. Table 17 lists the contributions to the wastewater maximum daily pollutant loads from each step involved in processing poultry. The

<table>
<thead>
<tr>
<th>Process Step</th>
<th>Water Flow Gal./Bird</th>
<th>BOD (PPM)</th>
<th>#/Day</th>
<th>Suspended Solids (PPM)</th>
<th>#/Day</th>
<th>Oil &amp; Grease (PPM)</th>
<th>#/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scalding</td>
<td>0.25</td>
<td>900</td>
<td>187</td>
<td>600</td>
<td>125</td>
<td>350</td>
<td>73</td>
</tr>
<tr>
<td>Carcass Washer</td>
<td>0.35</td>
<td>100</td>
<td>29</td>
<td>80</td>
<td>23</td>
<td>150</td>
<td>44</td>
</tr>
<tr>
<td>Evisceration</td>
<td>3.20</td>
<td>230</td>
<td>611</td>
<td>300</td>
<td>797</td>
<td>180</td>
<td>478</td>
</tr>
<tr>
<td>Chiller</td>
<td>0.50</td>
<td>440</td>
<td>183</td>
<td>250</td>
<td>104</td>
<td>800</td>
<td>332</td>
</tr>
<tr>
<td>Giblet Chiller</td>
<td>0.10</td>
<td>2397</td>
<td>199</td>
<td>976</td>
<td>81</td>
<td>132</td>
<td>11</td>
</tr>
<tr>
<td>Misc. &amp; Clean-up</td>
<td>2.60</td>
<td>-</td>
<td>50</td>
<td>-</td>
<td>40</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>7.00</td>
<td>-</td>
<td>1259</td>
<td>-</td>
<td>1170</td>
<td>-</td>
<td>938</td>
</tr>
<tr>
<td>Daily Maximum</td>
<td>-</td>
<td>1510</td>
<td>-</td>
<td>1403</td>
<td>-</td>
<td>1125</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 17.
BROILER PROCESSING PLANT WASTE LOAD —TYPICAL MAXIMA

91
information presented is a composite of data from the United States Environmental Protection Agency (EPA)\textsuperscript{1} and several Georgia poultry processors, and it represents a broiler processing plant of "average" size: 100,000 birds per day processed on a single eight hour shift using 700,000 gallons of water. The figures presented are maximums because these are the values used to design waste treatment systems. The average daily pollutant loads would be about fifty per cent of the maximums. It is apparent that the evisceration step in poultry processing is the largest contributor to the plant waste load.

Pollutant loading of wastewater from egg grading and breaking plants is widely variable in nature, depending on the type and quality of eggs processed, the types of products produced, and management's concern and awareness in the areas of water consumption and inedible product recovery. It is generally accepted that from one to six per cent of the eggs entering an egg processing plant are broken by the time they exit the egg washer.\textsuperscript{2} Since egg graders and breakers use only a small amount of water each day (as compared to other industries), wastewater pollutant concentrations are very high - as shown in Table 18 for an egg grading plant.

Table 18.

TYPICAL WASTE LOAD AT AN EGG GRADING PLANT

<table>
<thead>
<tr>
<th>Water Flow</th>
<th>BOD</th>
<th>Suspended Solids</th>
<th>Oil &amp; Grease</th>
</tr>
</thead>
<tbody>
<tr>
<td>13,320 gal/day</td>
<td>2450 ppm</td>
<td>700 ppm</td>
<td>210 ppm</td>
</tr>
</tbody>
</table>
B. State and Federal Regulation

The E.P.A. and the Environmental Protection Division of the Georgia Department of Natural Resources impact the poultry industry in several ways.

First, and most prominent, are the federal E.P.A. effluent limitations effective in 1977 - the "Best Practicable Control Technology Currently Achievable" (B.A.T.E.A.)\(^3\). Pollutant concentration limits in wastewater discharges to the environment have been identified for poultry processors, processors who perform further processing (meaning cooking of product), and processors with on-site rendering plants. Table 19 indicates a procedure for calculation of effluent limits in each case.\(^4\)

Figures 31 and 32 illustrate the relationships among live weight killed, water use, and allowed pollutant concentration. These limitations are stringent. For example, a broiler processor that slaughters 100,000 birds per day averaging 3.8 pounds live weight per bird and discharging 700,000 gallons of water per day to a stream could not exceed the following average

![Figure 31.](image)
Table 19.
E.P.A. LIMITATION CONVERSIONS FOR POULTRY PLANT DAILY FLOWS

<table>
<thead>
<tr>
<th></th>
<th>Processing</th>
<th>Processing and on-site rendering</th>
<th>Processing + Further Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1977</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPM BOD₅</td>
<td>(.055) (LWK) (MGPD)</td>
<td>.055+(.018) (RM) (LWK) (MGPD)</td>
<td>.055+(.036) (FP) (LWK) (MGPD)</td>
</tr>
<tr>
<td>PPM SS</td>
<td>(.074) (LWK) (MGPD)</td>
<td>.074+(.020) (RM) (LWK) (MGPD)</td>
<td>.074+(.042) (FP) (LWK) (MGPD)</td>
</tr>
<tr>
<td>PPM Oil &amp; Grease</td>
<td>(.024) (LWK) (MGPD)</td>
<td>.024+(.012) (RM) (LWK) (MGPD)</td>
<td>.024+(.012) (FP) (LWK) (MGPD)</td>
</tr>
<tr>
<td><strong>1983</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPM BOD₅</td>
<td>(.036) (LWK) (MGPD)</td>
<td>.036+(.008) (RM) (LWK) (MGPD)</td>
<td>.036+(.018) (FP) (LWK) (MGPD)</td>
</tr>
<tr>
<td>PPM SS</td>
<td>(.041) (LWK) (MGPD)</td>
<td>.041+(.012) (RM) (LWK) (MGPD)</td>
<td>.041+(.022) (FP) (LWK) (MGPD)</td>
</tr>
<tr>
<td>PPM Oil &amp; Grease</td>
<td>(.024) (LWK) (MGPD)</td>
<td>.024+(.006) (RM) (LWK) (MGPD)</td>
<td>.024+(.012) (FP) (LWK) (MGPD)</td>
</tr>
</tbody>
</table>

LWK - Bird Slaughter Rate ("Live Weight Killed") in thousands of pounds per day

MGPD - Water Flow Rate in millions of gallons per day

RM - Amount of material rendered in thousands of pounds per day

FP - Amount of Further Processed product in thousands of pounds per day (Note: This is for operations containing a cooking step - not cut-up only operations.)
Figure 32. EPA Effluent Limitations for BOD$_5$ and Suspended Solids
pollutant concentrations after 1983:

\[
\begin{align*}
\text{BOD}_5 &= 20 \text{ ppm} \\
\text{Suspended Solids} &= 22 \text{ ppm} \\
\text{Oil & Grease} &= 13 \text{ ppm}
\end{align*}
\]

Another impact of E.P.A. regulation is indirect. Effluent limitations have been established for many other industries and for municipal sewage and waste treatment plants, and as a result, the municipal treatment plants - many of which receive untreated wastewater from poultry and egg processors - have been forced to improve their respective waste treatment capabilities to yield an effluent compatible with the federal regulations applicable to them. Since improvement in effluent quality is accompanied by additional capital equipment and operating costs, federal guidelines have been established for "Equitable Recovery of Industrial Waste Treatment Costs". Some of the purposes of these guidelines are:

1. "...imposing the cost of waste treatment directly upon the source of pollution."

2. "...(to) encourage the use of user charges based upon volume, loading, and character of wastes."

In general, any sewer system receiving federal assistance to build or expand treatment facilities is expected to impose the industrial user charges, and many sewer systems are beginning to establish limits for pollutant concentrations based on twenty-four hour composite sampling of industrial plant effluent. The following is an example of maximum pollutant levels allowed for discharging to one sewage treatment plant in Georgia:

\[
\begin{align*}
\text{BOD} &= 250 \text{ ppm} \\
\text{Suspended Solids} &= 250 \text{ ppm} \\
\text{Oil & Grease} &= 100 \text{ ppm}
\end{align*}
\]
Above these levels, a surcharge is implemented based on total pounds per day of each pollutant. High levels of oil and grease usually present the sewer systems with the most problems because it can coat biological surfaces and inhibit aeration in trickling filters.  

The Georgia Department of Natural Resources is the agency that performs the issuance of permits, field work, and stream monitoring to enforce the E.P.A. regulations in Georgia. In addition, the state has imposed some other regulations aimed at environmental quality. While the E.P.A. has concerned itself with the quality of individual plant effluents, the state regulations deal primarily with the quality of the receiving body of water. In other words, at any point in a stream in Georgia, that stream must contain a minimum level of dissolved oxygen and must not contain any toxic, corrosive, acidic, caustic, or bacterial substances in amounts harmful to human or animal health. Table 20 lists some of these specific requirements. This means that a plant discharging water to an already "dirty" stream will be required to meet more stringent wastewater requirements than a plant discharging to a "clean" stream (which still must comply with the federal E.P.A. limitations). Furthermore, a plant that has been in compliance with the regulations could conceivably suddenly become in violation if a new wastewater source begins operating upstream of the plant.

C. Waste Load Reduction

The best form of wastewater treatment is to prevent waste material from coming in contact with the water. While this strategy is not 100% practical, a lot can be done to reduce the amount of waste matter before it becomes emulsified in the waste stream.

In many egg processing plants, broken eggs are allowed to accumulate
<table>
<thead>
<tr>
<th>Steam Type</th>
<th>pH Range</th>
<th>Dissolved Oxygen (mg/l)</th>
<th>Fecal Coliform (per 100 ml)</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Wild River</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II. Scenic River</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III. Urban Stream</td>
<td>6.0 - 8.5</td>
<td>≥ 3.0 at any time</td>
<td>2000 (geometric mean - 4 samples during 30 days)</td>
<td>5000 Max.</td>
</tr>
<tr>
<td>(must be aesthetically compatible to adjacent areas)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV. Trout Streams</td>
<td>6.0 - 8.5</td>
<td>6.0 daily ave.</td>
<td>1000 (geometric mean - 4 samples during 30 days)</td>
<td>4000 Max.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 5.0 at all times</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V. Warm Water Fish Streams</td>
<td>6.0 - 8.5</td>
<td>5.0 daily ave.</td>
<td>1000 (geometric mean - 4 samples during 30 days)</td>
<td>4000 Max.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 4.0 at all times</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI. Industrial navigation, and agricultural use</td>
<td>6.0 - 8.5</td>
<td>≥ 3.0 at all times</td>
<td>≥ 5000 (geometric mean - 4 samples during 30 days)</td>
<td>≥ 90°F; Receiving water ΔT ≤ 5°F (estuarine ΔT ≤ 1.5°F)</td>
</tr>
<tr>
<td>VII. Recreational Use</td>
<td>6.0 - 8.5</td>
<td>Depends on Fish Designation</td>
<td>≤ 100 (geometric mean) coastal</td>
<td>≤ 900°F; receiving water ΔT ≤ 5°F (estuarine ΔT ≤ 1.5°F)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>≤ 200 (geometric mean) - other</td>
<td></td>
</tr>
</tbody>
</table>
on the plant floor to be periodically washed down the drain. Installation of catch pans beneath critical points, such as where the eggs are transferred from flats to the washer conveyor, could not only reduce the effort required for clean-up, but could also make possible recovery of the previously lost eggs for inedible rendering.

Efficient blood recovery procedures are the most effective steps in the reduction of waste loads in poultry processing plants, since chicken blood has a BOD of about 92,000 mg/l.10 By scraping the blood from the blood tunnel walls and floor with a squeegee before clean-up, most of the blood can be recovered for rendering, making it a revenue producing product rather than a wastewater liability. Also, installation of blood drip troughs from de-feathering to hock cutting and from hock cutting to oil sac cutting from which blood may be collected have proven to be beneficial investments.

If evisceration wastes can be disposed with only minimal contact with water, pollutant loads can be reduced considerably. This can be done with dry offal or vacuum transfer systems. The usefulness of this type of system, however, is severely diminished if a large amount of water is allowed to enter the vacuum system.

Fat and grease are easiest to recover from wastewater if the pollutants are not allowed to become emulsified. Emulsification, or breakdown into tiny particles mixed with water, occurs quickly in a turbulent pipe or in a pump. Large quantities of renderable fat and grease can be recovered simply by placing a grease trap beneath the final carcass washer and the chiller overflow.
At one time it was thought that the answer to pollution was simply dilution. Unfortunately, this approach just masks the real problem, and the E.P.A. regulations are set up such that dilution will decrease the allowable pollutant concentrations. In sewage, dilution may successfully avert a sewage surcharge, but volume charges for the necessary water may exceed the surcharge cost.

Conservation of water makes sense for many reasons. First, at any given time it is a finite resource. Purification plants and well pumps can provide at most only a fixed quantity of water, given that water tables are not receding or a severe drought is not occurring. Secondly, water has a cost - it is an expense to any production operation, whether a bill is received from the local waterworks or the company accountants amortize drilling costs and record electricity bills for pumping. Thirdly, according to laboratory analysis of poultry processing wastes by Dr. Franklin E. Woodard of the University of Maine, "... a smaller daily discharge of BOD after treatment would result if the water volume could be reduced, even though the concentration of BOD in the incoming waste stream would be...increased." Finally good water conservation practices can significantly reduce capital expenditure requirements for potable water storage, piping, and waste treatment equipment due to the reduction in water volume. The following are some water conservation suggestions applicable to the poultry industry:

1) Shut off unused water during breaks in production
2) Establish a regular preventive maintenance procedure to repair leaks in valves and fittings.
3) Install pressure regulators in water lines to prevent excessive flow.
4) Use demand-type handwash valves and low flow spray nozzles along the evisceration trough (except where U.S.D.A. requires otherwise).

5) Provide an intermittently timed flush of the evisceration trough.

6) Install a dry offal/vacuum transport system.

7) Meter ice added to the chiller and credit the volume toward the chiller overflow requirement.

8) Re-use the chiller overflow water as make-up for the scalder overflow.

9) Use high pressure/low flow spray nozzles in the bird carcass washer.

10) Use high pressure/low flow nozzles on clean-up hoses. There should be a shut-off valve at the point of water discharge.

11) Consider the use of carbon dioxide for packaging instead of ice.

12) Record water usage daily and investigate unusual fluctuations.

13) Generate an employee awareness of the cost of water and wastewater treatment and why it is important to conserve water.

The cost of water in a typical Georgia community in 1978 was 28¢ per 1,000 gallons supplied plus 48¢ per 1,000 gallons discharged to the sewer. In some districts only water supply is metered, so sewage charges are based on a percentage of the water bill. Surcharges for highly polluted wastewater would be in addition to the basic bill. Therefore, our "typical" plant using 700,000 gallons of water per day would expect to pay $196 per day for water supply and $336 per for the sewer (assuming no surcharges are applicable). Note that the example plant is fairly water conservation conscious - using only seven gallons per bird.

E. Available Waste Treatment Processes

Most poultry and egg processing plants that have an environmental dis-
charge of wastewater have already made significant strides in the area of pollution control due to enforcement of the 1977 effluent limitation standards by the state of Georgia. Many of these plants have had the foresight to install waste treatment capability compatible with the upcoming 1983 standards. One poultry processor and one egg processor have installed zero discharge spray irrigation systems in the past year.

Because of the time lag in municipal sewer systems' applications for federal grants to upgrade facilities and completion of construction, many processors using sewers for wastewater discharges have not yet been fully impacted by environmental legislation. These plants will very soon require considerable efforts in the form of pre-treatment. Unless the plant has an engineering staff with experience in poultry and egg processing waste treatment design and time available to work on the project, it would probably prove profitable to retain a consultant. Appendix I lists Georgia consultants who are known to have sufficient capabilities, experience, and interest to work in the field. The "by-guess-and-by-golly" design approach can prove disastrous both in terms of money spent and lost time.

1. Physical Chemical Processes

of the most successful and widely used forms of pre-treatment is dissolved air flotation (DAF). After pressurizing a screened influent flow with air such that the water is 80% to 90% saturated, the flow is depressurized in a large tank designed to provide a peak flow retention time of three to five minutes. A surface chemistry reaction take place between the small rising air bubbles and colloidal particles suspended in the wastewater - the particles "cling" to the air bubbles and float to the surface of the tank. Addition of chemicals called flocculents can cause the waste
particles to group together to form large particles in which the dissolved air becomes entrained, causing the particles to float to the surface. The floating material is then skimmed from the tank and collected for rendering (assuming any flocculation chemicals used are acceptable to the renderer - many of the candidate chemicals are not suitable for inclusion in animal feeds). The skimmings will normally be of 8% to 10% solid content, but collection in a "float-thicken" tank can increase the solids content to 15% to 20%.

Presently, DAF equipment costs range from $30,000 to $90,000 for the typical poultry processing plant with the installed cost in the area $60,000 to $120,000 including equipment, foundation, piping and electrical controls. Circular and rectangular tanks are available. There are three basic types of systems: full pressurization, partial pressurization, and recycle pressurization, as shown in Figure 33. Recycle pressurization offers the greatest flexibility because a portion of the system effluent is returned to the influent stream via a pressurization tank. This means that the influent stream does not need to be pressurized; pressurizing the influent and subsequent passage through an expansion valve into the flotation tank has a tendency to break down or shear flocs formed with chemical treatment, thereby diminishing some of the effectiveness of the chemicals. Obviously, full and partial pressurization indicate that all or part of the influent stream is pressurized. As 20% to 30% of the recycle pressurization flotation tank influent is recycled water, a slightly larger flotation tank (and slightly higher capital cost) is required for this flexibility.

In installing a DAF system, as with practically all waste treatment systems, it is highly desirable to utilize gravity flow as much as possible to minimize
Figure 33. Dissolved Air Flotation Processes
pumping cost. This not only produces considerable savings of capital and operating costs, but assists in waste treatment efficiency. Every time a wastewater flow is agitated or pumped, a "shearing effect" takes place that tends to reduce the size of suspended particles in the fluid. In general, the smaller the particles, the more difficult it is to remove those particles from the fluid. Also, in the case of organic particles, decreased particle size presents an increased surface area for bacterial activity - causing possible increases in both suspended solids and BOD. Therefore, an ideal situation would be to locate a processing plant on a hillside such that the wastewater can flow downward by gravity to the offal screens from the plant, and downward to the various treatment systems to finally be discharged at the bottom of the hill.

Another treatment alternative that can be considered for use upstream of a DAF or other type system is a coagulation tank. The primary purpose of the tank would be to remove settlable solids from the flow. In addition, it could be used to collect and remove large floating fat or grease particles that could possibly clog DAF air eductor orifices. Finally, a coagulation basin (with or without chemical addition) can be used as a flow equalization tank. A peak flow rate retention time of 30 to 60 minutes is desirable.

A process differing slightly from DAF is presently being promoted heavily in the waste treatment field. It is called induced or dispersed air flotation. This process has been widely used in mineral benefication for many years and has the increased flexibility over DAF of producing a controllable variable bubble size in order to float specific contaminants. Comparative full scale operating data on poultry processing waste still is not available, however, so the cost effectiveness of the system in relation to DAF still is not known.
A treatment system that is fairly new to poultry applications is electro-coagulation. In this process, a direct current at less than 15 volts is passed through the wastewater. This causes a flocculation of negatively charged particles due to the attraction of cations. Microbubbles of hydrogen and oxygen formed by electrolysis rise to the surface of the tank entrained in the flocs. An operating cost of about 16¢/1000 gallons is claimed with this system at a Georgia poultry processing plant with resulting BOD and suspended solids of 100 ppm and oil/grease of 20 ppm.

2. Biological Processes

A biological waste treatment system that has been successfully applied to treating poultry wastewater is "activated sludge", and there are several forms of activated sludge systems available as "package plants". A conventional activated sludge plant consists of an aerated tank followed by a sedimentation tank. Generally 5% to 10% of the sedimentation sludge is recycled to the aeration tank for bacterial "seeding" of the influent. In general, a hydraulic retention time (HRT) of 0.15 to 0.33 days is necessary (HRT = tank volume in gal./flow rate in GPM), and a solids retention time (SRT) of three to six days is usually required (SRT = tank volume/volume of sludge removed per day).

Some of the various forms of activated sludge are conventional activated sludge, extended aeration, and contact stabilization. Extended aeration is an inexpensive, small installation using 100% underflow recycle; power and operating costs are relatively high. With contact stabilization, or "bio-absorption," influent organics are absorbed by sludge. The process uses a short (20 to 40 minute) retention followed by 1 1/2 to 5 hours of clarifi-
cation, and soluble organics are difficult to remove from the waste system.

In some applications, package plants will operate effectively at reasonable cost, but there are a few drawbacks to consider before purchasing such a system. Biological systems operate best in a steady state mode - constant loading rate of a fairly homogeneous influent in an unchanging environment. Most systems can operate effectively for a processing plant working a five day week on single shifts. However, a shutdown of more than two or three days may cause the bacteria to become endogenous and die; and re-starting such a system may be slow and difficult. Biological systems of this type generally require a more skilled operator than a DAF system in order to maintain the system and to produce a consistent effluent.

The use of a system of ponds is probably the most cost effective and reliable method of complete waste treatment available. The difficulty is that a considerable land area is required - aeration ponds are typically fairly shallow and provide a retention time of about twenty days. A carefully designed land application system is probably the optimum form of wastewater disposal, but it is not without problems. These systems must be located in fairly remote areas due to the possibility of wind transport of an undesirable virus in aerosols. Also, water run-off can be a serious problem during a period of freezing weather or unusually heavy and prolonged rainfall.

The use of "rotating biological contactors" (RBC) is one means of utilizing the effectiveness of a lagoon in a relatively small land area. In this type system, large diameter thin discs that are placed close together form a large surface area to which a biological film can become attached. The discs are slowly roated (at 2 to 8 RPM) in a shallow wastewater pond such that 30% to 50% of the surface area is submerged at any one time. The
pond is channelled such that the wastewater must flow past or through at least one set of contactor discs. Capital, operating, and maintenance costs are significant items that must be evaluated with other treatment alternatives before selecting an RBC system.

After determining what type of waste treatment process will be most appropriate in a particular application, there are several parameters to consider in evaluating the various models of equipment available. Obvious items will be capital cost, energy cost, and operating and maintenance cost. Some good figures to calculate for comparison of systems are: \(^{17}\)

\[
\begin{align*}
\text{$/1000 gal. capacity} \\
\text{$/lb. BOD removal per day} \\
\text{Lb BOD removed/HP-HR}
\end{align*}
\]

F. Conclusion

Due to the successes of several poultry and egg processors in dealing with environmental responsibilities, it is apparent that compliance with federal, state, and local regulation is a reasonable expectation, although achievement of compliance may require considerable effort for some firms. Activities that will assist in the improvement of wastewater characteristics are water conservation, waste load reduction through process improvements, and upgrading of wastewater treatment facilities.
REFERENCES (Section VI)


6. Ibid. P.2


APPENDIX A

Candling Light Heat Recovery
CANDLING LIGHT HEAT RECOVERY

Background

Recovery of energy lost in the form of heat from egg candling lamps has been studied at the Crystal Farms Egg Processing Plant in Chestnut Mountain, Georgia. The objective of this study was to evaluate use of this waste heat for pre-heating or heating of the water in the egg washer adjacent to the candling lamps.

Conclusions

The recovery of candling lamp heat will not be cost-effective for either pre-heating of waste water or heating to maintain wash water temperature. The payback period for equipment required for either of these uses would exceed ten years.

Through a separate study, however, a need for hot air to dry plastic egg flats has been identified and preliminary indications are that the candling lamp waste heat may be utilized for this purpose in a cost-effective manner.

Discussions

The egg washer and the inspection station are consecutive elements of the egg processing line. At the inspection station, high-wattage, incandescent "candling" lamps are used to allow inspection of the interior and shell of the eggs.

The egg washer includes a 150 gallon water tank and a pump, piping, sprinkler, and scrubbing system designed for 90 gallons per minute recirculation rate. The tank is dumped and refilled once every four hours, and the water
in the tank is heated by means of a hot water coil in the bottom of the tank. This hot water is supplied by a remote, natural gas fired water heater.

The water from the heater is supplied at approximately 180°F with a controller at the tank turning the pump on and off to maintain the desired wash water temperature. The wash water is maintained at as high a temperature as possible without inflicting thermal shock damage to the eggs. This temperature through experience, is controlled at 110°F in the summer and 100°F in the winter.

The candling lamps are cooled by forced air convection with the hot air being carried away through a 5 inch diameter, uninsulated, sheet metal duct. This duct extends to the roof, however, a pair of dampers and an outlet near the floor allow this hot air to be used for supplemental space heating during the winter.

The air blower is rated at 800 ft³/min, however, our measurements indicate that actual flow is only 545 ft³/min at 175°F. The low recorded flow rate may be due to a measurement error caused by possible leakage at the dampers or may be accurate and be due to the flow restriction imposed by the duct work.

In evaluating energy recovery from the hot air to maintain the wash water temperature, the following assumptions were made:

(1) Air flow is 545 ft³/min. at 175°F.
(2) The system would be utilized approximately 30 weeks per year when the hot air is not needed for space heating.
(3) Water temperature is maintained at 110°F
(4) Fifty percent of the total available energy is recovered.
(5) The system is used eight hours per day for 5½ days per week.

The energy recovered per year is then computed as follows:

\[ Q = \dot{m}_\text{air} c_p \Delta T \tau \eta = \left(545 \text{ ft}^3/\text{min}\right) \left(0.0625 \text{ lbm/ft}^3\right) \left(60 \text{ min/hr}\right) \left(0.24 \text{ Btu/lbm}^\circ\text{F}\right) \left(175 \circ\text{F} - 110 \circ\text{F}\right) \left(8 \text{ hr/day}\right) \left(5.5 \text{ days/week}\right) \left(30 \text{ weeks/year}\right) \left(50\%\right) \]

\[ Q = 21.0 \times 10^6 \text{ Btu/year} \]

Even if future natural gas cost is inflated to $2.00 per million Btu, only $42 per year is saved.

A heat exchanger core suitable for recovering this heat and fabricated of conventional materials has been quoted at $400. This design is without consideration of special material requirements due to chlorine and phosphoric
APPENDIX B

1977 Georgia Poultry Industry Energy Survey Data
### 1977 Yearly Energy Information

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1977 Energy Survey - Egg Processors
1977 Yearly Energy Information

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<th>BTU/1000 DOZ EGGS</th>
<th>$/1000 DOZ EGGS</th>
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1977 Energy Survey - Poultry Hatcheries
## 1977 Yearly Energy Information

<table>
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<tr>
<th>CODE #</th>
<th>ELEC. USE (KWH)</th>
<th>ELEC. COST ($)</th>
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<th>COST ($)</th>
<th>BTU/1000 BIRDS</th>
<th>$/1000 BIRDS</th>
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### 1977 Industry Sample Energy Information

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<th>ELEC. USE (KWH)</th>
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<th>NAT. GAS COST ($)</th>
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<th>FUEL OIL (GAL)</th>
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</thead>
<tbody>
<tr>
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<th>PROP. (BTU)</th>
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### 1977 GROSS INDUSTRY SAMPLE INFORMATION

<table>
<thead>
<tr>
<th>ENERGY USE (BTU)</th>
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### 1977 AVERAGE INDUSTRY SAMPLE INFORMATION

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1977 Energy Survey - Poultry Feed Mills
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1977 YEARLY ENERGY INFORMATION

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<th>FUEL OIL (BTU)</th>
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<th>COST ($)</th>
<th>BTU/TON</th>
<th>$/TON</th>
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1977 GROSS INDUSTRY SAMPLE INFORMATION

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### 1977 Industry Sample Energy Information

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<th>ELEC. USE (KWH)</th>
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<th>FUEL OIL COST ($)</th>
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<th>PROP. (BTU)</th>
<th>FUEL OIL (BTU)</th>
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### 1977 Average Industry Sample Information

<table>
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<table>
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This issue of Poultry Engineering Progress is the first in a series of regular newsletters printed as a service to the Georgia poultry industry. The newsletter will have several functions; 1) keeping you informed about the ongoing poultry related projects at Georgia Tech, and 2) providing a ready reference to new ideas and methods in wastewater treatment, mechanization, solar applications and energy conservation. The monthly newsletter will also tell you who to call for specific information concerning these topics. Additionally, the engineering reports will contain a mini-evaluation of the economic feasibility of each idea.

By providing an informal report keeping you up to date on our activities, we hope to encourage your active participation in the poultry work at Tech.

Once a year EES conducts an energy survey of the Georgia poultry industry in order to monitor the progress made by the industry in reducing energy consumption. From the progress report we can see what changes in consumption patterns have occurred and then determine trends which help us plan our programs for the future. The 1976 energy survey will provide the baseline by which the future energy conservation programs will be compared. The tables below summarize the results of the 1976 survey. The data are presented in the common "energy unit per 1000 birds" or "per 1000 dozen eggs" basis.

<table>
<thead>
<tr>
<th></th>
<th>Propane gals.</th>
<th>Natural Gas therms</th>
<th>Fuel Oil gals.</th>
<th>Elc. kwh</th>
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<td>Broiler growout</td>
<td>40.</td>
<td>5.</td>
<td>135.</td>
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<tr>
<td>Broiler processing</td>
<td>0.25</td>
<td>18.5</td>
<td>6.9</td>
<td>300.</td>
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<tr>
<td>Hatcheries</td>
<td>0.62</td>
<td>1.</td>
<td>56.</td>
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<tr>
<td>Feed mills</td>
<td>4.8</td>
<td>0.7</td>
<td>86.2</td>
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<tr>
<td>By-product rendering</td>
<td>14.</td>
<td>8.9</td>
<td>22.6</td>
<td></td>
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<tr>
<td>Feed delivery</td>
<td>3.3</td>
<td></td>
<td>599.8</td>
<td></td>
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<tr>
<td>Commercial Egg</td>
<td>0.49</td>
<td>0.94</td>
<td>0.64</td>
<td>40.7</td>
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</table>

**SUMPTION SURVEY**
note that these figures do not include transportation.

Studies performed by a Delmarva group indicate that the gasoline consumption rate for deliveries and service to the hatcheries to the processing plant is 6.62 gallons/birds. These results represent a yearly average and probably be substantially higher during the winter months.

Energy cost breakdown for the broiler industry sector, including transportation, is given in the following table:

<table>
<thead>
<tr>
<th></th>
<th>$/1000 Birds</th>
<th>Percent of Total Cost</th>
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</thead>
<tbody>
<tr>
<td>Mills</td>
<td>1.85</td>
<td>4.3</td>
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<tr>
<td>Growout</td>
<td>0.74</td>
<td>1.7</td>
</tr>
<tr>
<td>Processing</td>
<td>23.73</td>
<td>55.3</td>
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<tr>
<td>Plants rendering</td>
<td>12.82</td>
<td>30.0</td>
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<tr>
<td></td>
<td>3.74</td>
<td>8.7</td>
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<tr>
<td></td>
<td>$42.88</td>
<td>100%</td>
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</table>

Information about the survey and the energy situation obtained from Rich Combes or Carl Brønn, EES.
Since most laboratories report the results of wastewater effluent analysis in terms of parts per million (ppm), or milligrams per liter (mg/l), it will be convenient for poultry processors to quickly calculate what concentrations are allowable according to the EPA limitations for each particular production situation in order to monitor the performance of a waste treatment system. The table on the back of this page can be used to make the conversions if the following figures are known:

- LWK - Bird Slaughter Rate ("Live Weight Killed") in thousands of pounds per day
- MGPD - Water Flow Rate in millions of gallons per day
- RM - Amount of material rendered in thousands of pounds per day
- FP - Amount of Further Processed product in thousands of pounds per day (Note: This is for processed containing a cooking step - not cut-up only operations.)

The Technology and Development Laboratory of the Georgia Tech Engineering Experiment Station is currently doing a study of poultry and egg wastewater treatment in conjunction with the Georgia Poultry Federation. Anyone with questions or particular wastewater problems should feel free to call Randy Mattison at Georgia Tech regarding the program. The telephone number is (404) 894-3623.
<table>
<thead>
<tr>
<th></th>
<th>Processing</th>
<th>Processing and on-site Rendering</th>
<th>Processing + Further Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1977</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPM BOD$_5$</td>
<td>0.055 (LWK) / (MGPD)</td>
<td>0.055 + 0.018 (RM) (LWK) / (LWK)(MGPD)</td>
<td>0.055 + 0.036 (FP) (LWK) / (LWK)(MGPD)</td>
</tr>
<tr>
<td>PPM SS</td>
<td>0.074 (LWK) / (MGPD)</td>
<td>0.074 + 0.020 (RM) (LWK) / (LWK)(MGPD)</td>
<td>0.074 + 0.042 (FP) (LWK) / (LWK)(MGPD)</td>
</tr>
<tr>
<td>PPM Oil &amp; Grease</td>
<td>0.024 (LWK) / (MGPD)</td>
<td>0.024 + 0.012 (RM) (LWK) / (LWK)(MGPD)</td>
<td>0.024 + 0.012 (FP) (LWK) / (LWK)(MGPD)</td>
</tr>
<tr>
<td><strong>1983</strong></td>
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<tr>
<td>PPM BOD$_5$</td>
<td>0.036 (LWK) / (MGPD)</td>
<td>0.036 + 0.008 (RM) (LWK) / (LWK)(MGPD)</td>
<td>0.036 + 0.018 (FP) (LWK) / (LWK)(MGPD)</td>
</tr>
<tr>
<td>PPM SS</td>
<td>0.041 (LWK) / (MGPD)</td>
<td>0.041 + 0.012 (RM) (LWK) / (LWK)(MGPD)</td>
<td>0.041 + 0.022 (FP) (LWK) / (LWK)(MGPD)</td>
</tr>
</tbody>
</table>
Currently, the Technology and Development Laboratory is conducting a survey to determine the present status of poultry process handling and mechanization. For example plants in the southeast area are being surveyed as to the types of electrical and mechanical equipment, the number of personnel doing particular jobs, water usage and line speeds. The report will contain some of these comparative statistics showing the different methods used in various plants. The plants will remain anonymous. Possible projections for the future in terms of electrical and mechanical labor saving devices will also be outlined in this report which is sponsored by the National Science Foundation.

In addition to the NSF project, a state sponsored project is being conducted to determine yield losses throughout the plant. The first Yield Evaluation System will be installed in Mar-Jac Company in Gainesville in March. Initially, the birds will be weighed prior to and just after evisceration. Once sufficient data is collected, the weighing stations will be moved closer together to obtain additional information about bird count, yield loss, and the number of birds removed from the line at a particular spot. The system will consist of waterproof electronic weight sensors which will transmit the data to a minicomputer which will be housed in a control room. The minicomputer program can be modified to reflect the desired information. As soon as sufficient data is generated, and if time and money allow, it is hoped that the equipment will be moved to a second, less automated, plant where additional data will be collected for further mechanization studies. For further information please contact Dale Atkins or Dr. Bob Cassanova at Georgia Tech. The telephone number is (404) 894-3623.
The Engineering Experiment Station has conducted an energy survey of poultry industry operations for the years 1974 and 1976. This energy data has allowed us to monitor the trends in energy use and energy costs to the industry. We are currently conducting a survey for energy use in the calendar year 1977 under our poultry industry energy research program, and we request your participation by filling out the attached survey and returning it to us in the enclosed envelope form. Any information furnished to Georgia Tech will be considered proprietary. Using the completed forms we will evaluate the energy data for each sector of the industry and make a copy of the computer printout available to all participating facilities. The industry-wide energy data will be summarized in a future issue of Poultry Engineering Progress.

If there are any questions regarding the survey, please contact Randy Mattison or Richard Combes at 404/894-3623.

The E.P.A. and the Georgia Environmental Protection Division of the Department of Natural Resources are conducting regional meetings on current and proposed environmental regulations. The nature of the regulations, levels of enforcement, and environmental impacts will be discussed. Participation from the public is sought to identify problems and oversights in the regulations. Copies of the regulations can be found in most college or public libraries in the state, and meeting times and locations will be announced in local newspapers. Further information can be obtained from the Georgia Conservancy, 404-262-1967, or from any office of the Department of Natural Resources.
A survey of poultry processing mechanization and handling techniques in twelve processing plants in Georgia, Arkansas, and North Carolina has been completed under the sponsorship of the National Science Foundation. The following table lists some of the information collected:

<table>
<thead>
<tr>
<th></th>
<th>Range</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employees</td>
<td>215 to 1700</td>
<td>365</td>
</tr>
<tr>
<td>Labor Turnover (%)</td>
<td>2 to 400</td>
<td>50</td>
</tr>
<tr>
<td>Water Use (gal/bird)</td>
<td>5 to 12</td>
<td>7.5</td>
</tr>
<tr>
<td>Broiler Live Weight (lbs.)</td>
<td>3.65 to 4.25</td>
<td>3.8</td>
</tr>
<tr>
<td>Live Hang Line Speed (birds/min.)</td>
<td>77 to 135</td>
<td>114</td>
</tr>
<tr>
<td>Evisceration Line Speed (birds/min.)</td>
<td>40 to 64</td>
<td>52</td>
</tr>
<tr>
<td>8 Hour Production (birds)</td>
<td>60,000 to 248,000</td>
<td>92,500</td>
</tr>
</tbody>
</table>

Lung guns were in use in nine of the twelve plants, and six of the twelve plants were using automatic drawing equipment. The final report for this project will contain projections for the future for the poultry processing industry in terms of possible applications of electrical and mechanical labor saving devices. Contact Dale Atkins or Dr. Bob Cassanova at Georgia Tech for further information.
SOLAR HEATING FOR BROILER GROWOUT

Growing commercial broilers requires from 25 to 40 gallons of LP gas per 1000 birds depending upon weather conditions, house construction and management practices. Since current broiler production in Georgia is about 450 million birds per year, 10 to 20 million gallons of LP gas are consumed in growout operations annually. The problem of U.S. dependence on non-renewable energy supplies, imported oil in particular, has become a top priority national issue since the 1973 oil embargo.

The Georgia Poultry Federation and the Georgia Department of Agriculture have responded to our state and national goal of energy independence by funding two solar broiler house heating demonstration projects during the past two years. The first generation solar heating system was installed in May, 1976, at Lamar Hick's farm near Cumming, and construction of the second generation system was completed in April, 1978, at William Waddell's farm near Villa Rica. Mr. Hicks grows poultry for Wilson Foods, Inc. in Cumming and Mr. Waddell grows for Gold Kist, Inc. in Carrollton. The emphasis in both demonstration projects is on development of low cost retrofit solar heating systems. The Cumming system uses a passive solar collector design in which natural convection causes warm air to flow into the house from a 3300 square foot collector mounted on a hillside beside the house. The heating system cost about $6,600 to install and provided approximately 40% of the heating needs for the 300 foot house during the first year of operation. The
Villa Rica system consists mainly of a 3000 square foot roof mounted solar collector and a fan to force warm air through perforated polyethylene air ducts into the house. Installed cost of the system is $6,700. Preliminary tests of the Villa Rica heating system indicate the collector efficiency to be on the order of 30%. We estimate a 40% reduction of LP gas consumption with the Villa Rica system. Additional performance data will be available after continuous testing of both solar heating systems through July, 1979. If you have questions regarding these projects call John Giles at 404/894-3623.
The Georgia Tech Engineering Experiment Station has been conducting tests on an experimental methane generating system that is operating on a chicken egg laying farm in Cumming. Poultry manure is fed with water to an anaerobic digestion tank in which the methane is produced. Throughout the past year, operating characteristics, such as tank temperature, manure concentration in the feed slurry, and retention time, have been varied in order to define optimum operating parameters for the system. One significant result is that a long retention time does not assure optimal gas production, as shown in the following table:

<table>
<thead>
<tr>
<th>Retention, Days</th>
<th>Gas Produced, Ft³/Day</th>
<th>Theoretical Maximum, Ft³/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>1152</td>
<td>1383</td>
</tr>
<tr>
<td>42</td>
<td>984</td>
<td>1383</td>
</tr>
</tbody>
</table>

In these tests the digester tank temperature was maintained at 98°F and 60 to 65% of the gas generated was methane. Bigger does not necessarily mean better! Laboratory tests on the digested sludge from the tank bottom show the following properties:

- pH: 8.04
- Alkalinity mg/l as CaCO₃: 13930
- Total Solids % w/w: 3.71
- Fixed Solids % w/w: 1.62
- Volatile Solids % w/w: 2.13
- BOD₅ mg/l: 4100
- Reduction in BOD₅: 81.3%
- COD mg/l: 11,400
Reduction in COD 73.4%
Nitrogen 2.44%
Phosphorus 4.42%
Potassium 1.17%

Cattle feed trials have been conducted with the digested sludge, and the preliminary results are very encouraging. To obtain further information on this research program, contact Dr. M. Bery at Georgia Tech, 404-894-3632.
APPENDIX D

Brooder Test Data Plots
UNIT #1 @ 30", UNFILTERED

UNIT #1 @ 30" WITH QUARTZ FILTER

RADIATION (mW/cm²)

FLOOR DISTANCE FROM BROODER CENTERPOINT (INCHES)
UNIT #3 @ 18”, UNFILTERED

UNIT #3 @ 18” WITH QUARTZ FILTER
UNIT #4 @ 18'', UNFILTERED

UNIT #4 @ 18'' WITH QUARTZ FILTER

FLOOR DISTANCE FROM BROODER CENTERPOINT (INCHES)

RADIATION (W/sq ft)

FLOOR DISTANCE FROM BROODER CENTERPOINT (INCHES)

RADIATION (W/sq ft)
UNIT #4 @ 24", UNFILTERED

UNIT #4 @ 24" WITH QUARTZ FILTER

FLOOR DISTANCE FROM BROODER CENTERPOINT (INCHES)

RADIATION (mW/cm²)
UNIT #5 @ 18" UNFILTERED

UNIT #5 @ 18" WITH QUARTZ FILTER

RADIATION (mW/cm²)

FLOOR DISTANCE FROM BROODER CENTERPOINT (INCHES)
UNIT #5 @ 30", UNFILTERED

UNIT #5 @ 30" WITH QUARTZ FILTER
UNIT #6 @ 18" BENEATH ELEMENT, UNFILTERED

UNIT #6 @ 18" BENEATH ELEMENT, WITH QUARTZ FILTER

FLOOR DISTANCE FROM BROODER CENTERPOINT (INCHES)

RADIATION (μW/cm²)
UNIT #6 @ 24" BETWEEN ELEMENTS, UNFILTERED

UNIT #6 @ 24" BETWEEN ELEMENTS, WITH QUARTZ FILTER

FLOOR DISTANCE FROM BROODER CENTERPOINT (INCHES)

RADIATION (mW/cm²)

FLOOR DISTANCE FROM BROODER CENTERPOINT (INCHES)

RADIATION (mW/cm²)
UNIT #7 @ 30" LONGITUDINAL, UNFILTERED

UNIT #7 @ 30" LONGITUDINAL, WITH QUARTZ FILTER

FLOOR DISTANCE FROM BROODER CENTERPOINT (INCHES)

FLOOR DISTANCE FROM BROODER CENTERPOINT (INCHES)

RADIATION (mW/cm²)
UNIT #8 @ 24" LONGITUDINAL, UNFILTERED

UNIT #8 @ 24" LONGITUDINAL, WITH QUARTZ FILTER

FLOOR DISTANCE FROM BROODER CENTERPOINT (INCHES)

RADIATION (mW/cm²)
UNIT #8 @ 24" TRANSVERSE, UNFILTERED

UNIT #8 @ 24" TRANSVERSE, WITH QUARTZ FILTER

FLOOR DISTANCE FROM BROODER CENTERPOINT (INCHES)

RADIATION (mW/cm²)

FLOOR DISTANCE FROM BROODER CENTERPOINT (INCHES)

RADIATION (mW/cm²)
UNIT #8 @ 30" LONGITUDINAL, UNFILTERED

UNIT #8 @ 30" LONGITUDINAL, WITH QUARTZ FILTER

FLOOR DISTANCE FROM BROODER CENTERPOINT
(INCHES)
UNIT #9 @ 18" TRANSVERSE, UNFILTERED

UNIT #9 @ 18" TRANSVERSE, WITH QUARTZ FILTER

FLOOR DISTANCE FROM BROODER CENTERPOINT (INCHES)

RADIATION (mW/cm²)
APPENDIX E

Wood Furnace Specifications
Applications:

- Residential: Basement, garage, workshop, or a building 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. Three 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:

<table>
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<th>Model</th>
<th>810</th>
<th>910</th>
<th>1007</th>
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<tr>
<td>BTU Output</td>
<td>125,000</td>
<td>200,000</td>
<td>350,000</td>
</tr>
<tr>
<td>Firebox (cu. ft.)</td>
<td>15</td>
<td>18</td>
<td>47</td>
</tr>
<tr>
<td>Shipping Wt. (3 pc, shipping)</td>
<td>1200 lbs.</td>
<td>1300 lbs.</td>
<td>3100 lbs.</td>
</tr>
<tr>
<td>Unassembled Width</td>
<td>31&quot;</td>
<td>34&quot;</td>
<td>44&quot;</td>
</tr>
<tr>
<td>Assembled Width</td>
<td>34&quot;</td>
<td>39&quot;</td>
<td>46&quot;</td>
</tr>
<tr>
<td>Length</td>
<td>68&quot;</td>
<td>73&quot;</td>
<td>96&quot;</td>
</tr>
<tr>
<td>Height</td>
<td>51&quot;</td>
<td>51&quot;</td>
<td>64&quot;</td>
</tr>
<tr>
<td>Firebox Metal Thickness</td>
<td>10 ga.</td>
<td>10 ga.</td>
<td>7 ga.</td>
</tr>
<tr>
<td>Flue Size</td>
<td>7&quot;</td>
<td>7&quot;</td>
<td>9&quot;</td>
</tr>
<tr>
<td>Blower CFM</td>
<td>1600</td>
<td>2000</td>
<td>4140</td>
</tr>
<tr>
<td>Motor</td>
<td>1/3 HP 115V</td>
<td>1/2 HP 115V</td>
<td>1 HP 115V</td>
</tr>
</tbody>
</table>
APPENDIX F

Poultry House Control Qualification Test Data
POULTRY HOUSE CONTROL QUALIFICATION TEST
GEORGE KEY POULTRY FARM
CARROLLTON, GA.

Control House 3/16/78

Test House 3/17/78

Temperature °F Relative Humidity %

Temperature °F Relative Humidity %
APPENDIX G

Construction Drawing - Solar Heating System
APPENDIX H

Integral Solar Heating System
NOTE INSTALL LOUVERED AIR INLET IN END WALL

MIGLE BRACKETS

WING NUTS IN END CAES:

8" GOLLAR EXTENDS INTO ATTIC SPACE FITTED WITH DAMPER

16 TUBES Malay FAN

8" STRAIGHTENER

ELEVATION SCALE 1/16

SECTION A-A SCALE 1/16

IN THE ATTIC SPACE, FITTED WITH DAMPER

PLAN SCALE 1/16

INTEGRAL SOLAR HEATING SYSTEM

A-10-16 SCALE: AS NOTED

BROILER HOUSE WITH INTEGRAL SOLAR HEATING SYSTEM

DREW BY: J. LEVINSKY
APPROVED BY: J. M. B.
DATE: 10-1-16

GALVANIZED STEEL ROOFING

EAVES

CALKED EDGE

PANELS

AIR FLOW SPACE

POLYETHYLENE DUCT

FIBERGLASS INSULATION

KALMILL FIBERGLASS SHUTTERING

2 1/2 BATTON" EYE

2 MIL POLYETHYLENE

10 LAYERS POLYETHYLENE DUCT COVERING 10.20 MILL GE EQUIVALENT

PLATE

ENGINEERING EXPERIMENT STATION
GEORGIA TECH, ATLANTA

FRAME: A-10-16

NOTED
APPENDIX I

Georgia Wastewater Engineering Consultants
QUALIFIED GEORGIA WASTEWATER
CONSULTING ENGINEERS INTERESTED IN
POULTRY PROJECTS*

Firm is known to have
done previous design
work for poultry plants

Anderson Nichols & Co., Inc.
Suite 514
151 Ellis Street NE
Atlanta 30303
(404) 581-0806

Black, Crow & Eidsness, Inc of Georgia
Suite 1640, Peachtree Summit
401 W. Peachtree Street NE
Atlanta 30308
(404) 588-1990

Chester Engineers, Inc.
5 Dunwoody Park
Atlanta, Georgia 30341
(404) 394-8620

Dames & Moore
Suite 200
455 East Paces Ferry Road NE
Atlanta 30305
(404) 262-2915

Drake & Funsten
Suite 618
1430 W. Peachtree Street NW
Atlanta 30309
(404) 892-1771

Driggers & Associates
P.O. Box 1892
Albany 31702
(912) 432-0569

*Based on telephone interviews.
Firm is known to have done previous design work for poultry plants

Engineering-Science, Inc.
57 Executive Park South, N.E.
Atlanta, Georgia 30329
(404) 325-0770

Engineering Service Associates, Inc.
P.O. Box 158
Griffin 30224
(404) 228-8511
(404) 688-3096 (Atlanta)

Environmental Research & Technology, Inc.
Suite 110
296 Interstate North NW
Atlanta 30309
(404) 955-3121

Environmental Science & Engineering
Suite 1800
230 Peachtree Street NW
Atlanta 30303
(404) 688-5029

Guillebeau, Britt & Waldrop, Inc.
4277-D Memorial Drive
Decatur 30032
(404) 294-6540

Harrington, George & Dunn
Suite 448
148 International Boulevard
Atlanta 30303
(404) 588-1898

John J. Harte Associates, Inc.
3290 Cumberland Club Drive NW
Atlanta 30339
(404) 434-0697
The firm is known to have done previous design work for poultry plants.

Hartrampf/Powell, Inc.
Suite 127
180 Allen Road NE
Atlanta 30328
(404) 252-2063

Hays, James and Associates, Inc.
186 Jackson Street SE
Lawrenceville 30245
(404) 963-7123

Harry Hendon and Associates, Inc.
571 Armour Circle NE
Atlanta 30324
(404) 876-4302

Hensley - Schmidt, Inc.
2840 Professional Parkway
Atlanta 30339
(404) 952-8861

Hussey, Gay and Bell, Inc.
P.O. Box 14247
Savannah 31405
(912) 354-4626

Jordan, Jones and Goulding, Inc.
Suite 200
2000 Clearview Avenue NE
Atlanta 30340
(404) 455-8555

Keck and Wood, Inc.
3722 Pleasantdale Road
Atlanta 30340
(404) 939-1334
Firm is known to have done previous design work for poultry plants

Kun-Young Chin and Associates
109 East Adair Street
Valdosta 31601
(912) 244-4002

Law Engineering Testing Co.
2749 Delk Road S.E.
Marietta, Georgia 30062
(404) 952-9005

Lockwood Greene Engineers, Inc.
1776 Peachtree Road NW
Atlanta 30309
(404) 873-3261

Marbury Engineering Co.
2330 Whispering Pines Road
Albany 31707
(912) 435-6133

McCrary Engineering Corp.
Suite 125
6075 Roswell Road
Atlanta 30328
(404) 255-9544

Douglas C. McCurry, Consulting Engineer
Suite 36
1000 Circle 75 Parkway
Atlanta 30339
(404) 955-1990

Parsons, Brinckerhoff, Quade & Douglas, Inc.
134 Peachtree Street
Atlanta 30303
(404) 688-6445
Firm is known to have done previous design work for poultry plants

Patchen Mingledorff Associates, Inc.
3355 Northeast Expressway NE
Atlanta 30341
(404) 451-7545

Polytech Inc.
Suite 560
148 International Boulevard
Atlanta 30303

Robert and Company Associates
96 Poplar Street NW
Atlanta 30303
(404) 577-4000

Robert P. Grey, Inc.
200 Grey Creek Drive
Athens, Georgia 30601
(404) 549-6988

Ross Saarinen, Bolton & Wilder, Inc.
Suite 290
1945 The Exchange, NW
Atlanta 30339
(404) 952-8643

Rosser White Hobbs Davidson McClellan Kelly, Inc.
P.O. Box 54680 122 West Bay Street
Atlanta 30308 Or Savannah 31401
(404) 688-5200 (912) 232-1146

Stanley Consultants, Inc.
Suite 200
2600 Century Parkway NE
Atlanta 30345
(404) 325-5858
Firm is known to have done previous design work for poultry plants

The T.E. Stivers Organization, Inc.
P.O. Box 1008
Decatur 30031
(404) 378-1392

Sweitzer & Peoples, Inc.
Suite 180
6425 Powers Ferry Road
Atlanta 30039
(404) 955-2034

W. L. Thompson Consulting Engineers
1730 Connally Drive
East Point 30344
(404) 761-4351

Tribble & Richardson, Inc.
P.O. Box 7005
116 Pierce Avenue
Macon 31204
(912) 742-7395

Welker & Associates, Inc.
Box 397
Marietta 30061
(404) 422-1902

Roy F. Weston, Inc.
Suite C
4329 Memorial Drive
Decatur 30032
(404) 294-7575

Wiedeman and Singleton
1787 Peachtree Road NE
Atlanta 30309
(404) 876-5862

Williams, Sweitzer and Barnum, Inc.
P.O. Box 1751 Or 1372 Peachtree Street NE
Rome 30161 Atlanta 30309
(404) 234-0552 (404) 892-7246
(404) 688-3283 (Atlanta)
A STUDY OF POULTRY PROCESSING PLANT NOISE CHARACTERISTICS AND POTENTIAL NOISE CONTROL TECHNIQUES

Prepared by
J. C. Wyvill
A. D. Jape
L. J. Moriarty
R. D. Atkins
R. A. Cassanova, Project Director

Prepared for
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio
Research Grant No. NSG 3228

and
Georgia Department of Agriculture
Atlanta, Georgia
Research Project A-2028-006
ERRATA SHEET

For

A STUDY OF POULTRY PROCESSING PLANT NOISE
CHARACTERISTICS AND POTENTIAL NOISE CONTROL TECHNIQUES

1. On page 17 the equation should read:

\[ \alpha_{SAB} = \frac{4}{5} \left[ \frac{1}{\text{antilog} \left( \frac{L_p - L_w}{10} \right) - Q_8} \right] \]

2. On page 20, the equation should read:

\[ \alpha_{SAB} = \frac{.161 V}{T_5} \]

3. On page 20, in Table 7, the value of \( \alpha_{SAB} \) for the Central Soya plant should be .068

4. On page 20, the note at the bottom of the page should also contain the following comment:

"The constant (.161) was obtained from the following calculation:

\[ \left[ \frac{4 \times 60}{4.34 (343.5)} \right] \]

The factor of 4 in this calculation represents the initial energy absorption of room surfaces in a diffuse reverberant field. Since non-diffuse conditions existed at Central Soya the factor of 4 was reduced to 2 (see page 17) and this constant similarly was halved on calculations for that plant."

5. On page 28, the note at the bottom of the page should read:

"Reference 2, page 228. Note that due to the non-diffuse conditions at the Central Soya plant, a factor of 2 rather than 4 was used for it (see page 17)."

6. On page 9, the equation should read:

\[ \bar{L}_p = 10 \log \left[ \sum Si (\text{antilog} \left( \frac{L_o}{10} \right)) \right] \]
A STUDY OF POULTRY PROCESSING PLANT NOISE CHARACTERISTICS
AND POTENTIAL NOISE CONTROL TECHNIQUES

Final Report

for

Research Grant No. NSG 3228
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio

and

Research Project A-2028-006
Georgia Department of Agriculture
Atlanta, Georgia

Prepared by

J. C. Wyvill
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L. J. Moriarty
R. D. Atkins

R. A. Cassanova, Project Director

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia 30332
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ACKNOWLEDGMENT

While this effort reflects the concerns of an industry, its completion depended on
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whom this study might never have occurred.
PERSPECTIVE

Poultry processing noise is a problem for which ready solutions are difficult. Efforts by plant personnel to quiet noise sources have met with little success and noise levels remain high, often exceeding shift duration exposure limits established by OSHA.

Much of the problem can be traced to the recent transition of the industry to mechanization. Since World War II, the production of poultry meat products has grown rapidly from the small family-type operation to large volume processing plants. The processing functions in the 1940's and early 1950's were primarily manual, with only a few machines being used to reduce physical exertion or to improve production efficiency. As the demand for poultry products grew and competition forced the development of more efficient, labor-saving methods, various manual operations were replaced by mechanical devices.

In spite of the improvements which have taken place, poultry processing remains labor intensive, with large numbers of people now being exposed to high noise levels. Requirements of the Poultry Products Inspection Act of 1959 increase the difficulty of controlling noise by requiring rigid cleanability standards for all surfaces in the plant, which preclude the use of many sound-absorbing and vibration-dampening materials. So frustrated has the industry become that in a 1976 meeting sponsored by the National Science Foundation, excessive noise in poultry processing plants was identified by industry representatives as a major problem for which workable solutions do not exist.

Under the joint sponsorship of the National Aeronautics and Space Administration and the Georgia Department of Agriculture, this study was conducted to evaluate the extent, cause, and potential solution to this noise problem.
THE GENERAL ENVIRONMENT

Introduction

In order to characterize the environment in a typical poultry processing plant, noise contours were developed for two representative plants: Central Soya of Athens, Inc., Athens, Georgia, and Tip Top Poultry, Inc., Marietta, Georgia. Contour information was restricted to the evisceration area of both plants because nearly 60 percent of all process employees are stationed in this area during a normal work shift.

Both plant evisceration areas were composed of tile walls, sheet metal ceilings, and concrete floors. Processing was performed in an assembly-line fashion in which the birds travel through the area on overhead shackles while personnel remain at fixed stations. Processing machinery was present throughout the area. Plant personnel worked in 8-hour shifts with 1/2 hour for lunch.

Data Acquisition

The measurement procedure used to gather contour data on the general environment consisted of taking readings in a grid pattern laid out for the evisceration area. Unfortunately, the congestion of machinery and personnel sometimes prevented readings from being taken in certain areas of the plant. Figures 1 and 2 show the placement of microphones for measurements in the two plants.

To speed record taking, three microphones were attached, three feet apart, to an aluminum bar mounted on a tripod (see Figure 3). This allowed three measurements to be taken at one time. All measurements were tape recorded to allow level and frequency analysis in the laboratory. Additional readings, using a hand-held sound level meter, were taken in inaccessible areas. A complete list of the equipment used and the general arrangement of equipment for data gathering and analysis are presented in Appendix A.

Noise Contour Development

All observed noise levels were recorded, by grid position, on a plot of each plant. These levels were A-weighted and time-averaged over a two-minute interval. On each plot, lines of constant noise level were then drawn. The resulting contours are presented in Figures 4 and 5. Appendix B provides time histories and frequency analysis of selected data points observed throughout each plant.
FIG. 1 LOCATION OF MEASUREMENT POINTS IN CENTRAL SOYA PLANT
FIG. 2 LOCATION OF MEASUREMENT POINTS IN TIP TOP PLANT
FIG. 3 MEASUREMENT EQUIPMENT SET-UP
FIG. 4 NOISE CONTOURS FOR CENTRAL SOYA PLANT
FIG. 5  NOISE CONTOURS FOR TIP TOP PLANT
The Noise Environment

The noise contours display specific information about the noise environment. For instance, in the plot for the Central Soya plant (Figure 4) there are only three areas of the plant where the noise contours converge. Within these areas the apparent sources of noise are the lung guns, a component of the chiller, a circulating fan, and a source from the picking area. Because there are two hock cutters immediately on the other side of the wall in the picking area which are exposed to the evisceration area through conveyor portals in the wall, it is probable that they are contributing substantially to the noise coming from the picking area.

The contours also provide information on the type of noise fields throughout the plant. Since the surfaces of the plant were composed of hard materials, it is probable that a reverberant noise field exists throughout much of the plant. Since this plant is irregular in shape, having one dimension many times that of another, it is expected that the reverberant noise field will not be uniform in level, but rather will decay in level with increasing distance from those sources contributing to it.* The noise field observed in Figure 4 does exhibit a continual but gradual decrease in levels well below the free field rate of 6 dB/doubling distance with increasing distance from the primary noise source areas. Consequently, it is probable that much of the noise field being observed is predominantly reverberant.

The noise contours for the Tip Top plant (Figure 5) indicate six areas of the plant where the noise contours converge. Within these areas, the apparent sources of noise are the lung guns, a component of the chiller, an air jet on the spray wash station, the hock cutter, the gizzard peelers, and an exhaust fan. Furthermore, this plant also appears to have much of its noise field dominated by reverberant noise, as evidenced by those areas of uniform level throughout much of the plant. Because this plant is more symmetrical than the other, a uniform reverberant field should be expected.

In comparing the two plants, only three identified sources are similar: the lung guns, chiller component, and hock cutter. Both plants also appear to have much of their noise field dominated by reverberant noise. Because the frequency spectra observed throughout both plants were extremely similar (see Appendix B), it would appear that both plants have a similar reverberant noise environment as defined by major contributing sources and absorption characteristics.

*Reference 1, page 4-13.
REVERBERATION EVALUATION

Introduction

Since the noise environment observed in both plants was thought to be substantially influenced by reverberation, a series of tests were performed to quantify the reverberant environment within each plant.

Direct/Reverberant Field Test

The first method used to evaluate reverberation entailed introducing a source of known response characteristics into each plant and observing the resultant noise field. Since any observed noise field is a combination of direct and reflected noise levels and the direct noise field of the source was known, the reverberant noise field was subsequently determined.

Qualifying the Source. The source selected for use in the direct/reverberant field tests was a 12-inch paper speaker, which received a white noise input signal boosted at maximum gain though a 30-watt amplifier. To observe the speaker's output response, it was placed in an anechoic chamber on the Georgia Tech campus. Figure 6 displays the measured directivity characteristics observed for one plane of the speaker's response. The frequency response data were obtained through octave band filtering of the measured broadband response characteristics.

To complete the characterization of the speaker's response, the sound power output related to each response curve was calculated. Since each response pattern was symmetrical about the perpendicular axis to the speaker, it was assumed that the three dimensional response pattern would essentially bear the same characteristics observed in Figure 6 in any plane rotated about this perpendicular axis. Using coordinates for the midpoint of 10 equilateral triangles forming the surface of a hemisphere around the front of the source, the average sound pressure level over the hemisphere was calculated, using the following formula:

\[ L_p = 10 \log \left( \frac{L_{pi}}{2 \pi r^2} \frac{Si}{\text{Antilog} \frac{10}{10}} \right) \]

Where

- \( L_p \) = space averaged sound pressure level
- \( Si \) = surface area of \( i^{th} \) segment

*Reference 2, page 152.
Fig. 6  Speaker Directivity Pattern *

* Observed at a radius of 1.83 meters from center of speaker.
L_{pi} = \text{sound pressure level at the midpoint of } i^{th} \text{ segment}
\quad r = \text{radius of hemisphere (meters)}

Table 1 presents the ten values of L_{pi} used in the calculation. Si was 2.1 square meters for each triangle and r = 1.83 meters.

<table>
<thead>
<tr>
<th>Point (i)</th>
<th>250 Hz</th>
<th>500 Hz</th>
<th>1000 Hz</th>
<th>2000 Hz</th>
<th>4000 Hz</th>
<th>Broadband</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>71.8</td>
<td>77.8</td>
<td>78.0</td>
<td>74.8</td>
<td>76.0</td>
<td>83.0</td>
</tr>
<tr>
<td>2</td>
<td>75.0</td>
<td>81.0</td>
<td>81.2</td>
<td>76.5</td>
<td>82.3</td>
<td>87.6</td>
</tr>
<tr>
<td>3</td>
<td>71.8</td>
<td>77.8</td>
<td>78.0</td>
<td>74.8</td>
<td>76.0</td>
<td>83.0</td>
</tr>
<tr>
<td>4</td>
<td>71.8</td>
<td>77.8</td>
<td>78.0</td>
<td>74.8</td>
<td>76.0</td>
<td>83.0</td>
</tr>
<tr>
<td>5</td>
<td>75.0</td>
<td>81.0</td>
<td>81.2</td>
<td>76.5</td>
<td>82.3</td>
<td>87.6</td>
</tr>
<tr>
<td>6</td>
<td>72.2</td>
<td>77.8</td>
<td>77.4</td>
<td>73.4</td>
<td>75.0</td>
<td>82.8</td>
</tr>
<tr>
<td>7</td>
<td>72.2</td>
<td>77.8</td>
<td>77.4</td>
<td>73.4</td>
<td>75.0</td>
<td>82.8</td>
</tr>
<tr>
<td>8</td>
<td>75.5</td>
<td>81.0</td>
<td>81.2</td>
<td>76.2</td>
<td>82.6</td>
<td>87.6</td>
</tr>
<tr>
<td>9</td>
<td>72.2</td>
<td>77.8</td>
<td>77.4</td>
<td>73.4</td>
<td>75.0</td>
<td>82.8</td>
</tr>
<tr>
<td>10</td>
<td>78.6</td>
<td>83.0</td>
<td>85.7</td>
<td>91.7</td>
<td>96.0</td>
<td>98.2</td>
</tr>
</tbody>
</table>

The sound power level was then determined using the following formula:

\[ L_w = L_p + 20 \log r + 10 \log 2 \pi \]

where

\[ L_w = \text{sound power level} \]
\[ L_p = \text{space averaged sound pressure level} \]
\[ r = \text{radius of hemisphere (meters)} \]

Table 2 contains the calculated values of sound power output for the speaker.

*Reference 2, page 155.
Table 2
SOUND POWER LEVELS CALCULATED FOR TEST SPEAKER

<table>
<thead>
<tr>
<th>Octave Band</th>
<th>Lw (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>87.50</td>
</tr>
<tr>
<td>500</td>
<td>92.99</td>
</tr>
<tr>
<td>1000</td>
<td>93.78</td>
</tr>
<tr>
<td>2000</td>
<td>95.72</td>
</tr>
<tr>
<td>4000</td>
<td>99.99</td>
</tr>
<tr>
<td>broadband</td>
<td>103.03</td>
</tr>
</tbody>
</table>

The Field Test. The source was then taken to each plant and positioned as shown in Figures 7 and 8. The speaker was placed on the floor of the plant facing the ceiling for both tests. With the source powered, measurements were taken at one-foot intervals on either side of the speaker in a single plane. Additional spot readings outside that plane were taken at several locations near the source to establish the level variation for the entire area surrounding the speaker (see Figures 7 and 8 for the location of all measurement points).

Figures 9 and 10 display the broadband levels observed in the measurement plane for each plant. It should be noted that an accident occurred during the Tip Top plant testing in which the speaker was sprayed with water prior to the measurements on the right hand side of the speaker. This appears to have reduced the response output of the speaker to some extent. Appendix C contains the results of octave band filtering of each of the measured values.

Since the measurement points intersected the directivity pattern of the speaker, the direct field levels were determined based on the following calculations:

\[ L_p = L_{pe} - 20 \log \frac{r}{r_0} \]

Where

- \( L_p \) = direct field sound pressure level for the measurement point
- \( L_{pe} \) = sound pressure level obtained from the speaker directivity pattern for the angle corresponding to the measurement point.
- \( r \) = distance from speaker to measurement point (meters)
FIG. 7 LOCATION OF MEASUREMENT POINTS FOR DIRECT-REVERBERANT TEST
CENTRAL SOYA PLANT

NOTE: SMALL PRINT INDICATES NOISE LEVEL (dB.)
FIG. 8 LOCATION OF MEASUREMENT POINTS FOR DIRECT-REVERBERANT TEST TIP TOP PLANT
Fig. 9  Direct/Reverberant Noise Fields for Test Speaker

CENTRAL SOYA PLANT
Fig. 10  Direct/Reverberant Noise Fields for Test Speaker
TIP TOP PLANT

Legend
Measured Level
Reverberant Level
Direct Level
\( r_0 \) = distance from speaker at which \( L_p \) was measured (meters)

From these figures, it is apparent that the overall level observed at distances beyond a few feet from the source are substantially influenced by the reverberant noise field. However, the reverberant field in the Central Soya plant does not appear to be uniform in level to the left of the speaker, but rather decays at a rate of approximately 3dB/doubling of distance from the source. This phenomenon has been observed by others for rooms in which one dimension is more than five times that of another.* For the Central Soya plant, the room length of 51.2 meters is nearly ten times the ceiling height of 5.5 meters. This is not true of the Tip Top plant where the largest dimension is roughly four times that of the smallest.

**Defining the Reverberant Environment**

The information obtained from the direct/reverberant field test was used to calculate the average surface absorption coefficient for each plant, using the following equation:

\[
\alpha_{SAB} = \frac{4}{5} \left[ \text{antilog} \frac{L_p - L_w - Q_e}{10} - 4 \pi r \right]
\]

Where

- \( \alpha_{SAB} \) = average sabine surface absorption coefficient
- \( S \) = surface area of the room (meters\(^2\))
- \( L_p \) = measured sound pressure level (dB)
- \( L_w \) = calculated source sound power level (dB)
- \( Q_e \) = directivity factor of the source
- \( r \) = distance of measurement point from the source (meters)

In order to make this calculation, the sound pressure level measured at a distance of nine feet was used for the Tip Top plant. For the Central Soya plant, since the reverberant noise field was not uniform in level, the nine foot reading was attenuated at a rate of 3 dB/doubling of distance from the source to the picking room wall, and the resulting reverberant field levels were space averaged. The corresponding direct field contribution for the equation at this equivalent distance from the source was estimated to be small and was therefore neglected in the calculation for this plant. Table 3 presents the \( L_p \) values used in the calculation of surface absorption coefficient for each plant.

*Reference 1, page 4-13.

**Reference 2, page 228. Note that the factor of 4 was derived for diffuse conditions. Since non-diffuse conditions were observed in the Central Soya Plant, a factor of 2 was used for it.
Table 3
MEASURED SOUND PRESSURE LEVELS (dB)

<table>
<thead>
<tr>
<th>Octave Band</th>
<th>Central Soya Plant&lt;sup&gt;a/&lt;/sup&gt;</th>
<th>Tip Top Plant&lt;sup&gt;b/&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 Hz</td>
<td>72.9</td>
<td>80.7</td>
</tr>
<tr>
<td>500 Hz</td>
<td>73.9</td>
<td>82.0</td>
</tr>
<tr>
<td>1000 Hz</td>
<td>76.9</td>
<td>84.8</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>77.9</td>
<td>85.0</td>
</tr>
<tr>
<td>4000 Hz</td>
<td>76.9</td>
<td>85.8</td>
</tr>
<tr>
<td>Broadband</td>
<td>83.9</td>
<td>91.1</td>
</tr>
</tbody>
</table>

<sup>a/</sup> Space averaged level for reverberant field.

<sup>b/</sup> Measured at nine feet from the source.

Since the equation called for a measure of the directivity of the speaker to determine the direct field contribution, the following procedure was used to calculate this value. The sound pressure level at the measurement point which would be provided by a nondirectional source was calculated using the total sound power output of the source. This sound pressure level was then compared to the sound pressure level actually provided by the direct sound field at the measurement point. The ratio of the actual direct level to that level which would have been provided by a nondirectional source defined the directivity factor (Qe).* Table 4 presents calculated values for the Tip Top plant measurement point where the direct field entered into the calculation.

Table 4
SOURCE DIRECTIVITY FACTORS FOR TIP TOP MEASUREMENT POINT USED TO CALCULATE SURFACE ABSORPTION COEFFICIENTS

<table>
<thead>
<tr>
<th>Octave Band</th>
<th>Qe</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 Hz</td>
<td>.879</td>
</tr>
<tr>
<td>500 Hz</td>
<td>.767</td>
</tr>
<tr>
<td>1000 Hz</td>
<td>.611</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>.225</td>
</tr>
<tr>
<td>4000 Hz</td>
<td>.383</td>
</tr>
<tr>
<td>Broadband</td>
<td>.315</td>
</tr>
</tbody>
</table>

*Reference 2, page 159.
The final input to the calculation was the total surface area of the test room. For the Central Soya plant the test area was defined as the total evisceration area. However, for the Tip Top plant, the wall in the middle of the evisceration area provided an effective barrier for containing sound and, therefore, was used to define one wall of the test area. The total surface area of the Central Soya plant test area was calculated to be 1834 square meters and that for the Tip Top plant test area was calculated to be 627 square meters.

Using these inputs, the average surface absorption coefficient for each plant was calculated and is presented in Table 5.

### Table 5

ESTIMATED SURFACE ABSORPTION COEFFICIENTS[^1]

<table>
<thead>
<tr>
<th>Octave Band</th>
<th>SAB</th>
<th>Octave Band</th>
<th>SAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 Hz</td>
<td>.031</td>
<td>250 Hz</td>
<td>.032</td>
</tr>
<tr>
<td>500 Hz</td>
<td>.088</td>
<td>500 Hz</td>
<td>.089</td>
</tr>
<tr>
<td>1000 Hz</td>
<td>.053</td>
<td>1000 Hz</td>
<td>.053</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>.066</td>
<td>2000 Hz</td>
<td>.077</td>
</tr>
<tr>
<td>4000 Hz</td>
<td>.222</td>
<td>4000 Hz</td>
<td>.187</td>
</tr>
<tr>
<td>Broadband</td>
<td>.089</td>
<td>Broadband</td>
<td>.104</td>
</tr>
</tbody>
</table>

[^1]: Values include any contribution from atmospheric absorption as well.

It should be noted that there were some energy losses during testing attributable to openings in some of the surface boundaries defining the test areas. Furthermore, no allowance was made in the calculations for nonsurface absorption such as by air, a factor which had approximately a 15% impact on the surface absorption coefficient calculated for the 4000 Hz octave band. However, it is believed that the coefficients in Table 5 reasonably approximate the absorptive qualities of the test rooms.

#### Reverberant Field Decay Test

The second test used to confirm the values obtained from the direct/reverberant test consisted of exciting each plant with noise, then terminating the source of the noise and measuring the time needed for the noise level in the room to decay 60 decibels.
This decay time provided yet another measure of the average absorption coefficient for surfaces in the test area, through the following equation:

\[
\alpha_{SAB} = \frac{16IV}{TS}
\]

Where

\[
\alpha_{SAB} = \text{Average sabine absorption coefficient}
\]

\[S = \text{Total room surface area (meters}^2)\]

\[V = \text{Total room volume (meters}^3)\]

\[T = \text{Reverberation decay time (seconds)}\]

Each plant was excited with noise from a 22 caliber, blank pistol for the test. This source provided sufficient sound power to thoroughly excite the test area but unfortunately provided only broadband comparative values. It was positioned at the location of the speaker in Figures 7 and 8 and was pointed toward the ceiling. Measurements were taken nine feet from the source. Figures 11 and 12 show the time history of the measured decay rate of the sound field in each plant following the pistol shot. The full 60 dB reverberant decay time was determined from these figures, using straight line extrapolation. These values were then inserted into the above equation, using the room statistics for each test area given in Table 6.

<table>
<thead>
<tr>
<th>Table 6</th>
<th>ROOM STATISTICS FOR REVERBERANT FIELD DECAY TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Soya Plant</td>
<td>Tip Top Plant</td>
</tr>
<tr>
<td>[V = 3110 \text{ m}^3]</td>
<td>[V = 847 \text{ m}^3]</td>
</tr>
<tr>
<td>[S = 1834 \text{ m}^2]</td>
<td>[S = 627 \text{ m}^2]</td>
</tr>
</tbody>
</table>

With these inputs, the average broadband surface absorption coefficient for each plant was calculated and is presented in Table 7.

<table>
<thead>
<tr>
<th>Table 7</th>
<th>ESTIMATED BROADBAND SURFACE ABSORPTION COEFFICIENT USING PISTOL SHOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Soya Plant</td>
<td>[\alpha_{SAB} = .136]</td>
</tr>
<tr>
<td>Tip Top Plant</td>
<td>[\alpha_{SAB} = .093]</td>
</tr>
</tbody>
</table>

*This calculation also produced values which include any contribution from atmosphere absorption. Source: Reference 2, page 238.*
Fig. 11  Time History of Reverberant Noise Field Decay

CENTRAL SOYA PLANT
Fig. 12  Time History of Reverberant Noise Field Decay
TIP TOP PLANT
The values in Table 7 are reasonably close to the broadband values shown in Table 5, thereby confirming these values. Due to the non-diffuse conditions existing in the Central Soya Plant, the decay curve for it seems to exhibit some non-linearity which was not accounted for in the straight-line extrapolation. This may explain part of the difference between the absorption coefficient determined for it by this method and that determined by the direct/reverberant field method.
SOURCE EVALUATION

Introduction

Observations made earlier of the general environment indicated only a few major sources were distinguishable above the general din. In order to complete an assessment of the poultry noise problem, a study of these noise sources was performed.

Sound Power Estimates

Using the information contained in the contours of Figures 4 and 5, an estimate was made of the A-weighted sound power output of all distinguishable noise sources. The technique used involved observing that contour line which was within 2 to 6 feet of the apparent acoustical center of the source, calculating the area encircled by the contour line, determining the radius of a circle with an equivalent area to that enclosed by the contour, and assuming a symmetrical hemispherical contour in the vertical plane. These inputs were then applied to the following equation:

\[ L_w = L_{pH} + 20 \log r + 10 \log 2 \pi^* \]

Where

- \( L_w \) = estimated A weighted sound power output
- \( L_{pH} \) = A-weighted sound pressure level of the observed contour line
- \( r \) = radius of circle with equivalent area to that encircled by the contour line.

The selection of 2 to 6 feet was made because contour lines closer than 2 feet typically will be in the near field of the source, while those farther than 6 feet typically will reflect significant reverberant noise field contributions. Unfortunately, certain contour lines within these distance limits were still unduly influenced by contributions from either the reverberant environment or another nearby source. Consequently, any source whose contour pattern appeared to be significantly influenced by activities other than from the direct noise field of that source was listed as having a sound power output which was not determinable from the contour data.

Applying the information contained in the contour plots, the values in Table 8 were developed.

*Reference 2, page 155.
Table 8
ESTIMATED SOUND POWER OUTPUTS OF MAJOR SOURCES

<table>
<thead>
<tr>
<th>Central Soya Plant</th>
<th>Tip Top Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung Guns</td>
<td>Lung Guns</td>
</tr>
<tr>
<td>108.2dBA</td>
<td>102.7dBA</td>
</tr>
<tr>
<td>Chillers</td>
<td>Chillers</td>
</tr>
<tr>
<td>not determinable</td>
<td>not determinable</td>
</tr>
<tr>
<td>Fan</td>
<td>Exhaust Fan</td>
</tr>
<tr>
<td>94.7dBA</td>
<td>not determinable</td>
</tr>
<tr>
<td>Hock Cutters</td>
<td>Hock Cutters</td>
</tr>
<tr>
<td>103.9dBA</td>
<td>100.2dBA</td>
</tr>
<tr>
<td></td>
<td>Drying Air</td>
</tr>
<tr>
<td></td>
<td>94.7dBA</td>
</tr>
<tr>
<td></td>
<td>Gizzard Peeler</td>
</tr>
<tr>
<td></td>
<td>not determinable</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>Total</strong></td>
</tr>
<tr>
<td>109.7dBA</td>
<td>107.05dBA</td>
</tr>
</tbody>
</table>

From these estimates, it appears that the top three noise sources in both plants are the lung guns, a chiller component, and hock cutters. The data in the Central Soya plant, however, need qualifying. The chiller component was positioned so that the lung guns masked much of its observable contribution. However, it is apparent in Figure 4 that a large contribution is coming from the chiller area as noted by the presence of a local increase in sound pressure level in the area immediately between the lung guns and the gizzard peelers. Since the gizzard peelers are apparently not producing that intense a signal, only an item on the chillers appears capable of being the second source. Also the hock cutters in the Central Soya plant were positioned in the picking room such that the combination of their outputs and the reverberant field associated with the pickers could have resulted in observed sound pressure levels more intense than those associated with the direct field of just the hock cutters. These two points are made so that the reader can apply caution when liberally interpreting the benefits of source sound power reduction in the Central Soya plant.

Source Contribution Assessment

As a means of evaluating the contribution of all sources to a locally observed sound pressure level in the noise contour of Figures 4 and 5, a microphone was located at point 6B, channel 2, in the Central Soya plant (see Figure 1) and point 53, channel 2, in the Tip Top plant (see Figure 2). With all sources turned off in each plant, individual sources were turned on and off one at a time. Figure 13 presents the A-weighted sound pressure levels observed for each source tested in each plant. Appendix D provides frequency contribution information about each source in addition to a comparison of the combined frequency spectra of all sources tested to that observed at
Fig. 13  Source Contribution A-Weighted Sound Pressure Level at a Single Point in Each Plant

HOCK CUTTER
CHILLERS
VENT CUTTERS
GIZZARD MACHINE
SPRAY WASHER
CIRCULATING FANS
SHACKLE LINES
PICKERS
VACUUM PUMP
NECK CUTTERS
AIR BLAST DRYER
SHACKLE LINE FOOT REMOVER
WASTE VACUUM
EXHAUST FANS
HANGING CONVEYOR

Sound Pressure Level (dBA)

= TIP TOP POULTRY (pt. 53, ch 2)
= CENTRAL SOYA POULTRY (pt. 68, ch 2)
that point in each plant under normal operating conditions. It should be noted at this
time that a few major sources were not operated in each plant because of difficulties
encountered at the time of testing.

These findings provide information which must be interpreted cautiously. For
instance, the measurement point was close to some sources and far away from others
implying care be taken in comparing source levels. Also, many of the sources were
operated under conditions not typical to normal usage, such as the chillers, which were
operated without ice or water, and the neck cutter, which lacked animal fat from the
chickens to prevent an uncharacteristic whine.

This analysis, however, does provide some insight into the hurdles which can arise
from keying reduction efforts on only one source, by displaying how the contributions of
other sources can become significant even though they are currently masked during
normal conditions.
THE PROBLEM IDENTIFIED

Using the data from the previous sections, an analysis was performed to determine if essentially all of the noise levels currently observed in each plant were directly and indirectly the result of only the few "major" sources identified. Since the direct effects were observable in the contour plot, only the indirect effects or the contribution of these sources to the reverberant field needed analysis. To perform the analysis, the following equation was used:

\[ L_{pr} = L_w + 10 \log \left( \frac{4}{S \alpha_{SAB}} \right) \]

Where
- \( L_{pr} \) = sound pressure level of the reverberant field
- \( L_w \) = sound power output of major noise sources
- \( S \) = surface area of evisceration area
- \( \alpha_{SAB} \) = average broadband surface absorption coefficient

In this calculation, the values of \( \alpha_{SAB} \) utilized were those for broadband noise from Table 5. Using the surface area values contained in Table 9, the calculations were performed.

<table>
<thead>
<tr>
<th>Table 9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SURFACE AREAS ESTIMATED FOR TOTAL EVISCERATION AREA IN EACH PLANT</strong></td>
</tr>
<tr>
<td>Central Soya Plant</td>
</tr>
<tr>
<td>1834 m²</td>
</tr>
</tbody>
</table>

The calculations yielded the following results:

Central Soya Plant
- \( L_{pr} = 90.6 \) dBA

Tip Top Plant
- \( L_{pr} = 90.7 \) dBA

These values were reasonably close to the A-weighted sound pressure levels observed in the reverberant field of each plant per Figures 4 and 5:

*Reference 2, page 228. Note that due to non-diffuse conditions, a factor of 2 rather than 4 was used (see page 17).
Central Soya Plant
Lpr = 90.4dBA (space averaged)

Tip Top Plant
Lpr = Between 90 and 91dBA

Therefore, it appears that the reverberant noise field in these plants is currently powered by only those few "major" noise sources identified in the contour plots.

As a result of these findings, it now becomes evident why there have been many failures in reducing overall plant noise levels. Since most efforts are focused on source quieting, only those efforts which are focused on a major source will be successful in significantly reducing noise levels, and even then the success will depend on the presence or absence of other intense noise sources. Clearly, therefore, a plant must know its major noise sources if source quieting is to be successful. On the other hand, increasing surface absorption in the plant will almost assuredly reduce noise levels in much of the plant through its impact on the reverberant noise field. But, even this solution will be limited in its overall effect by the nature of each plant's reverberant noise field and the distribution and total sound power output of sources throughout the plant.
POTENTIAL SOLUTIONS

In discussing potential solutions to the poultry processing noise problem, it should be stressed that each plant will have differing circumstances which impact their ability to effectively implement certain changes. Nonetheless, these solutions appear practical on the whole for the industry.

Source Solutions

There has been activity in the area of noise reductions at the source. Some actions have deliberately focused on noise reduction, others on productivity improvement. Here is an overview of possible solutions to reducing noise from sources in a poultry processing plant.

Lung gun noise is currently being alleviated in many plants with the use of drawing machines which also pull out lungs. Drawing machines are being widely used in broiler plants which process a relatively uniform bird size. Unfortunately, plants which process hens or a wide range of bird sizes cannot use the existing drawing machines. For these plants, there have also been studies* to baffle or shield noise from the body cavity during the lung gun operation. However, these baffled lung guns have not been used extensively because the baffles are difficult to keep clean and obstruct the view of the operator.

Efforts to quiet hock cutters have been restricted largely to isolating the machine from personnel. There are several designs of hock cutter available, but none are particularly quiet.

Chiller noise can typically be alleviated through vibration dampening. Impact noise from ice drop-off stations is often observable on ice slush chillers. This noise can be reduced through dampening of metallic surfaces in the ice delivery system, as well as by reducing the ice load through energy conservation efforts to jacket the chiller trough. Refrigerated chillers can further eliminate the need for ice altogether.

Lastly, the importance of regular and proper machinery maintenance cannot be overemphasized as a means of controlling source noise. Worn bearings, misaligned drive shafts, and improperly lubricated fittings can all turn a normally quiet machine into an unusually loud machine.

*References 4 and 5.
Room Acoustic Solutions

There has also been activity in the area of increasing the absorptive qualities of a plant.

For the most part, panels made of absorbant material, such as fiberglass or foam, have been developed.* These panels have been covered with plastic films to meet USDA requirements for use in food plants. But difficulties have occurred in the plastic film withstanding the harsh elements of most plants. Perhaps the single biggest problem is shearing of the plastic cover which renders the panel unacceptable for continued use by USDA requirements.

If a design could be developed which utilized a screen to protect the plastic film while remaining transparent to noise or if a cover could be designed of a film tough enough to withstand cleaning and other routine operations, then absorbing panels would clearly help in reducing the transmission of sound in the reverberant noise field.

*References 4 and 5.
CONCLUSION

In general, the poultry processing noise problem is the result of loud sources and reflective surfaces. Within the evisceration area, where nearly 60% of all processing personnel are stationed, it can be concluded that only a few major sources (lung guns, a chiller component, and hock cutters) are responsible for essentially all direct and reverberant sound pressure levels currently observed during normal operations. Consequently, any efforts to reduce the noise problem must first address the sound power output of these sources and/or the absorptive qualities of the room.

Reducing the sound power of major sources can be accomplished either by redesign or source isolation. Studies of redesign have been performed on many items.* The lung guns in particular have had several redesigns proposed. The thrust of these designs has been to shield the sound originating in the body cavity from the suction process. However, these baffled lung guns have not been used extensively because the baffles are difficult to keep clean and obstruct the view of the operator.

Isolation of a source has also been performed on such items as pickers and in some instances hock cutters. However, as was shown in the Central Soya plant, not all isolation mediums have been totally effective.

For either source quieting or isolation to work, the technique will need to be simple and inexpensive and not substantially change the manner in which processing is currently done. Yet, for every decibel of total sound power reduction achieved, a corresponding decibel reduction in observed sound pressure level will be noticed, perhaps not uniformly, but on a space average throughout the plant. The key words here, however, are total sound power reduction. It must be remembered that other sources, which are currently unidentifiable, will begin to contribute significantly to total sound power as the levels of the current major sources are reduced. This implies that a compounding problem exists as lower and lower sound pressure levels are sought.

Increasing the absorptive qualities of the plant is also an area where some studies have been performed.** However, difficulties have arisen with both cost and durability. Still, there is optimism that a design exists which will meet all criteria. Treatment of only the ceiling areas of the two plants studied could help reduce overall sound pressure

*Reference 3.
**Reference 4 and 5.
levels approximately 5dB on average. The ceiling of the Central Soya plant contains approximately 35% of the total surface area and of the Tip Top plant contains approximately 30% of the total surface area.

However, room absorption is also limited in the total sound pressure level reduction achievable. This is because as reverberant levels decline, direct field levels from more obscure sources will begin to control local sound pressure levels. By reducing the intensity of the reverberant field, however, the potential for the current problem of the exposure by processing personnel being controlled by one or two noise sources will be reduced, which will provide both long-lasting and far-reaching benefits.
REFERENCES

5. Clean and Quiet Baffles and Panels, Owens Corning Fiberglass, Publication 1-SD-9224, 1979
EQUIPMENT USED FOR DATA ACQUISITION & ANALYSIS

Microphones: B+K Precision condenser-type acoustic transducers were used for all sound pressure level measurements.

<table>
<thead>
<tr>
<th>Channel</th>
<th>Cartridge Type</th>
<th>Serial No.</th>
<th>Preamp. Type</th>
<th>Serial No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4165</td>
<td>775332</td>
<td>2619</td>
<td>748130</td>
</tr>
<tr>
<td>2</td>
<td>4165</td>
<td>750790</td>
<td>2619</td>
<td>748145</td>
</tr>
<tr>
<td>3</td>
<td>4165</td>
<td>708529</td>
<td>2619</td>
<td>748110</td>
</tr>
<tr>
<td>4</td>
<td>4165</td>
<td>732743</td>
<td>2619</td>
<td>748132</td>
</tr>
</tbody>
</table>

Power Supply to Pre-Amplifier: Two type 2807 B+K twin channel power supplies.

Tape Recorder: Hewlett-Packard type 3964A Instrumentation Tape Recorder.

Power Source for Field Use: All microphones and tape recorders were operated from a TRIPP-LITE 400-watt inverter that was powered from a 12-volt automobile battery. The use of the inverter was necessary to make the data-gathering equipment more portable and to reduce the problems encountered with voltage fluctuations and power line noise that were present in some of the plants where we acquired data.

Sound Source: The source for the reverberation time was a .22 caliber blank pistol.

The source for the direct field/reverberent field comparison was a B+K type 4205 white noise generator connected to a Bogen 30-watt power amplifier. The power amplifier drove a 12-inch paper loudspeaker that was mounted in an 18-inch square wooden box.

Analyzer: All time records and spectra were computed on a Hewlett-Packard type 5420A digital signal analyzer. The results were plotted with a Hewlett-Packard type 8972 four-color graphics plotter.

RMS Averages: All root-mean-square averages were determined with a fluke type 8010 digital multimeter.

A-Weighting: B+K Type 2203 Precision sound level meter was used to A-weight all readings. This meter was also used to take auxiliary readings in the plants.
Figure 1A
DATA ANALYSIS CONFIGURATION
A-3
Figure 2A
DATA RECORDING CONFIGURATION
Appendix B

GENERAL PLANT ENVIRONMENT DATA
GENERAL PLANT ENVIRONMENT DATA

The figures in this appendix show frequency spectra and time histories of selected measurement points observed in both plants during normal operations. While not exhaustive, these points provide an example of the frequency characteristics observed throughout the noise field. The plant name and measurement position for each graph are noted in the upper right-hand corner. These values correspond to those coordinates listed in Figures 1-B and 2-B. Both Linear and A-weighted readings are presented for each point selected.

Warning: The frequency data are presented in both a linear and logarithmic fashion. Since the analyzer used was only capable of performing constant bandwidth analysis the logarithmic presentation is merely a distorted presentation of the constant bandwidth analysis. It is presented here only for those readers who are more familiar with viewing constant percentage bandwidth outputs.

Again, it must be stressed that the logarithmic presentations are not the result of constant percentage bandwidth analysis, but merely a distorted presentation of constant bandwidth analysis.
FIG. 13 LOCATION OF MEASUREMENT POINTS IN CENTRAL SOYA
Noise Contour

Data

FREQUENCY SPECTRA CENTRAL SOYA PLANT
Figure 3B

Central Soya Contour Data
Position 6 Row A
Channel 2
SPL 94.77 dB Linear
Central Soya Contour Data
Position 6 Row A
Channel 2
SPL 94.77 dB Linear

Figure 4B
Central Soya Contour Data
Position 6 Row A
Channel 2
SPL 93.3 dB (A)

Figure 5B
Central Soya Contour Data
Position 6 Row A
Channel 2
SPL 93.3 dB (A)

Figure 6B
Central Soya Contour Data  
Position 6 Row B  
Channel 2  
SPL 96.8 dB Linear  

Figure 7B
Central Soya Contour Data
Position 6 Row B
Channel 2
SPL 96.8 dB Linear

Figure 8B
Central Soya Contour Data
Position 6 Row B
Channel 2
SPL 95.7 dB (A)

Figure 9B
Central Soya Contour Data
Position 6 Row B
Channel 2
SPL 95.7 dB (A)

Figure 10B
Central Soya Contour Data
Position 6 Row B
Channel 2
SPL 96.8 dB Linear

Figure 11B
Central Soya Contour Data
Position 7 Row B
Channel 4
SPL 96.56 dB Linear

Figure 12B
Central Soya Contour Data
Position 7 Row B
Channel 4
SPL 96.56 dB Linear

Figure 13B
Figure 14B
Central Soya Contour Data
Position 7 Row B
Channel 4
SPL 95.1 dB (A)

Figure 15B
Central Soya Contour Data
Position 7 Row D
Channel 4
SPL 96.09 dB Linear

Figure 16B
Central Soya Contour Data
Position 7 Row D
Channel 4
SPL 96.09 dB Linear

Figure 17B
Figure 18B

Central Soya Contour Data
Position 7 Row D
Channel 4
SPL 94.8 dB (A)
Central Soya Contour Data
Position 7 Row D
Channel 4
SPL 94.8 dB (A)

Figure 19B
Central Soya Contour Data
Position 12 Row B
Channel 3
SPL 89.8 dB Linear

Figure 20B
Central Soya Contour Data
Position 12 Row B
Channel 3
SPL 89.8 dB Linear

Figure 21B
Central Soya Contour Data
Position 12 Row B
Channel 3
SPL 88 dB (A)

Figure 22B
Figure 23B

Central Soya Contour Data
Position 12 Row B
Channel 3
SPL 88 dB (A)
Central Soya Contour Data
Position 15  Row B
Channel 4
SPL 92.51 dB Linear

Figure 24B
Central Soya Contour Data
Position 15 Row 4
Channel 4
SPL 92.51 dB Linear

Figure 25B
Figure 26B

Central Soya Contour Data
Position 15 Row B
Channel 4
SPL 91.1 dB (A)
Central Soya Contour Data
Position 15 Row B
Channel 4
SPL 91.1 dB (A)

Figure 27B
Central Soya Contour Data
Position 18 Row E
Channel 3
SPL 93.92 dB Linear

Figure 28B
Central Soya Contour Data
Position 18 Row E
Channel 3
SPL 93.92 dB Linear

Figure 29B
Central Soya Contour Data  
Position 18 Row E  
Channel 3  
SPL 92.4 dB (A)  

Figure 30B
Noise Contour
Data

TIME AVERAGES
CENTRAL SOYA PLANT
Central Soya Contour Data
Time Average (RMS)
Position 6 Row A
Channel 2
SPL 94.77 dB Linear

Figure 31B
Central Soya Contour Data
Time Average (RMS)
Position 6 Row A
Channel 2
SPL 93.30 dB (A)

Figure 32B
Central Soya Contour Data
Time Average (RMS)
Position 7 Row B
Channel 4
SPL 96.56 dB Linear

Figure 33B
Central Soya Contour Data
Time Average (RMS)
Position 7 Row B
Channel 4
SPL 95.10 dB (A)

Figure 34B
Central Soya Contour Data
Time Average (RMS)
Position 7 Row D
Channel 4
SPL 96.09 dB Linear

Figure 35B
Central Soya Contour Data
Time Average (RMS)
Position 7 Row D
Channel 4
SPL 94.80 dB (A)

Figure 36B
Central Soya Contour Data
Time Average (RMS)
Position 12 Row B
Channel 3
SPL 89.80 dB Linear

Figure 37B
Central Soya Contour Data
Time Average (RMS)
Position 12 Row B
Channel 3
SPL 88.00 dB (A)

Figure 38B
Figure 39B

Central Soya Contour Data
Time Average (RMS)
Position 15  Row B
Channel 4
SPL 92.51 dB  Linear
Central Soya Contour Data
Time Average (RMS)
Position 15 Row B
Channel 4
SPL 91.10 dB (A)

Figure 40B
Central Soya Contour Data
Time Average (RMS)
Position 18 Row E
Channel 3
SPL 93.92 dB Linear

Figure 41B
Central Soya Contour Data
Time Average (RMS)
Position 18 Row E
Channel 3
SPL 92.40 dB (A)

Figure 42B
Figure 43B
Figure 44B
Figure 45B
Figure 46B

TIP TOP CONTOUR DATA
Position 8 Channel 3
SPL 94.7 DBA
Figure 48B
Figure 49B
Figure 50B
Figure 51B
Figure 53B
Figure 548
TIP TOP CONTOUR DATA
Position 23 Channel 2
SPL 90.37 dBA

Figure 55B
Figure 56B
Figure 57B
Figure 59B
TIP TOP CONTOUR DATA
Position 40 Channel 4
SPL 87.0 dBA

Figure 60B
Figure 61B
Figure 62B
Figure 63B
TIP TOP CONTOUR DATA
Position 53 Channel 3
SPL 92.1 dB Linear

Figure 65B
Figure 67B
Figure 68B
A SPEC 1
92.000

TIP TOP CONTOUR DATA
Position 68 Channel 2
SPL 92.7 dB Linear

Figure 70B
Figure 71B
Figure 73B

TIP TOP CONTOUR DATA
Position 71 Channel 2
SPL 93.0 dB Linear
TIP TOP CONTOUR DATA
Position 71 Channel 2
SPL 90.7 dBA

Figure 75B
Figure 76B

TIP TOP CONTOUR DATA
Position 71  Channel 2
SPL 90.7  dBA
TIP TOP CONTOUR DATA
Position 74  Channel 2
SPL 96.1 dB Linear

Figure 77B
Figure 78B
Figure 80B
Figure 82B
Figure 83B
Figure 84B
Appendix C

OCTAVE BAND ANALYSIS OF DIRECT/REVERBERANT FIELD TEST
OCTAVE BAND ANALYSIS OF DIRECT/REVERBERANT FIELD TEST

The broadband test data gathered in each plant during the direct/reverberant noise field test were octave band analyzed to provide an assessment of the frequency characteristics of the direct and reverberant sound fields associated with the output of the test speaker. The findings are presented in this appendix. They indicate that the reverberant sound field becomes dominant at a distance of only a few feet from the source at all frequency intervals studied.
Fig. 1C Direct/Reverberant Noise Fields for Test Speaker
TIP TOP PLANT
Fig. 2C  Direct/Reverberant Noise Fields for Test Speaker

TIP TOP PLANT
Fig. 3C Direct/Reverberant Noise Fields for Test Speaker
TIP TOP PLANT
Fig. 4C Direct/Reverberant Noise Fields for Test Speaker

TIP TOP PLANT
Fig. 5C Direct/Reverberant Noise Fields for Test Speaker
TIP TOP PLANT
Fig. 6C  Direct/Reverberant Noise Fields for Test Speaker
CENTRAL SOYA PLANT
Fig. 7C Direct/Reverberant Noise Fields for Test Speaker
CENTRAL SOYA PLANT
Fig. 8C  Direct/Reverberant Noise Fields for Test Speaker
CENTRAL SOYA PLANT

1000 Hz Octave Band Noise
Fig. 9C  Direct/Reverberant Noise Fields for Test Speaker
CENTRAL SOYA PLANT
Fig. 10C Direct/Reverberant Noise Fields for Test Speaker

CENTRAL SOYA PLANT
Appendix D

AN ANALYSIS OF INDIVIDUAL SOURCE CONTRIBUTION CHARACTERISTICS
AN ANALYSIS OF SOURCE FREQUENCY CHARACTERISTICS

The data gathered to evaluate the contribution of various sources to the observed sound pressure level at a point in each plant were also analyzed for frequency content. This was done to distinguish qualities about the sources which might be useful in any subsequent source abatement efforts. Unfortunately, as mentioned in the text, the data must be reviewed very carefully since the measurements were taken with some of the sources operating under conditions which were other than typical.

Regarding the Central Soya plant sources, the circulating fans are very close to being a major source in this area of the plant. While they are not always operated, when they are they could still go essentially undetected under normal operations because of their nearness to the lung guns. The spray wash station, on the other hand, shows level peaks which reach significant proportions and appear to contribute significantly to a 350Hz peak in the operating data taken at this point. The detected source of these peaks is a series of restrictor valves in the water system, valves which are commonly used throughout the industry. The neck cutter plot is not believed to be characteristic of this device because the blade rubbed on a bare plastic shield without the typical presence of animal fat from the birds to lubricate this contact. And as mentioned in the text, the chillers lacked water and ice, of which the water is probably an attenuator and the ice (through the dump cycle) a source. Figure 11D shows a comparison of the observed levels of the combined sources versus the observed level during normal operations. With the exception of the peaks in the upper frequency range caused by the neck cutter, the two spectra are reasonably similar in shape. The frequency shift of the 350Hz peak on the red plot is believed to be attributable to a higher than normal water line pressure during the individual source testing.

Regarding the Tip Top plant sources, the fans, at least in this area of the plant, are very quiet. But both the hock cutter and the chillers are intense sources which unfortunately during this test are suspected of producing noise levels not typical of those observed under normal operating conditions. Figure 22D seems to bear this out. When a comparison is made between the observed level of the combined sources versus the observed level during normal operations, the former is higher. This is probably again because the chillers were operated without water or ice and because the hock cutter was operated without birds. In addition to level differences, the two spectra also exhibit substantial differences in shape at several points, which further raise questions regarding the representativeness of the source signatures observed from these two machines.
Fig. 1D - A-Weighted Source Contribution Analysis: Circulating Fans
CENTRAL SOYA PLANT (pt. 6B, ch.2)
Fig. 2D - A-Weighted Source Contribution Analysis: Chillers
CENTRAL SOYA PLANT (pt. 6B, ch.2)
Fig. 3D - A-Weighted Source Contribution Analysis: Gizzard Machine
CENTRAL SOYA PLANT (pt. 6B, ch.2)
Fig. 40 - A-Weighted Source Contribution Analysis: Spray Washer
CENTRAL SOYA PLANT (pt. 6B, ch.2)
Fig. 5D - A-Weighted Source Contribution Analysis: Shackle Lines
CENTRAL SOYA PLANT (pt. 6B, ch. 2)
Fig 6D - A-Weighted Source Contribution Analysis: Vacuum Pump
CENTRAL SOYA PLANT (pt. 6B, ch.2)
Fig. 7D - A-Weighted Source Contribution Analysis: Neck Cutters
CENTRAL SOYA PLANT (pt. 6B, ch.2)
Fig. 8D - A-Weighted Source Contribution Analysis: Pickers
CENTRAL SOYA PLANT (pt. 6B, ch.2)
Fig. 9D - A-Weighted Source Contribution Analysis: Waste Vacuum
CENTRAL SOYA PLANT (pt. 6B, ch.2)
Fig. 10D - A-Weighted Source Contribution Analysis: Exhaust Fans
CENTRAL SOYA PLANT (pt. 6B, ch.2)
Fig. 11D - A-Weighted Comparison of Combined Individual Sources vs Actual Operating Conditions
CENTRAL SOYA PLANT (pt.6B, ch.2)
Fig. 12D - A-Weighted Source Contribution Analysis: Hock Cutter
TIP TOP PLANT (pt. 53, ch.2)
Fig. 13D - A-Weighted Source Contribution Analysis: Chillers
TIP TOP PLANT (pt. 53, ch.2)
Fig. 14D - A-Weighted Source Contribution Analysis: Vent Cutters
TIP TOP PLANT (pt. 53, ch.2)
Fig. 15D - A-Weighted Source Contribution Analysis: Pickers
TIP TOP PLANT (pt. 53, ch.2)
Fig. 16D - A-Weighted Source Contribution Analysis: Gizzard Machine
TIP TOP PLANT (pt. 53, ch.2)
Fig. 17D - A-Weighted Source Contribution Analysis: Circulating Fans
TIP TOP PLANT (pt. 53, ch.2)
Fig. 18D - A-Weighted Source Contribution Analysis: Shackle Lines
TIP TOP PLANT (pt. 53, ch. 2)
Fig. 19D - A-Weighted Source Contribution Analysis: Air Blast Dryer
TIP TOP PLANT (pt. 53, ch. 2)
Fig. 20D - A-Weighted Source Contribution Analysis: Shackle Line Foot Remover
TIP TOP PLANT (pt. 53, ch.2)
Fig. 21D - A-Weighted Source Contribution Analysis: Hanging Conveyor
TIP TOP PLANT (pt. 53, ch.2)
Fig. 22D - A-Weighted Comparison of Combined Individual Sources vs Actual Operating Conditions
TIP TOP PLANT (pt. 53, ch.2)