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THE ENERGY RESOURCE ALTERNATIVES COMPETITION

Progress Report
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MASTER

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The Energy Resource Alternatives competition was conducted as agreed upon by SCORE, Inc. and the U. S. Energy Research and Development Administration.

Mark L. Radtke, the principal investigator, devoted 100% of his time to the program throughout the current period.

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ABSTRACT

This progress report describes the objectives and results of the intercollegiate Energy Resource Alternatives competition. The one year program concluded in August, 1975 with a final testing program of forty student-built alternative energy projects at the Sandia Laboratories in Albuquerque, New Mexico. The goal of the competition was to design and build prototype hardware which could provide space heating and cooling, hot water, and electricity at a level appropriate to the needs of homes, farms, and light industry. The hardware projects were powered by such non-conventional energy sources as solar energy, wind, biologically-produced gas, coal, and ocean waves. The competition rules emphasized design innovation, economic feasibility, practicality, and marketability.

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HISTORY OF THE ENERGY RESOURCE ALTERNATIVES COMPETITION

The Energy Resource Alternatives competition was the third program sponsored and conducted by SCORE (Student Competitions on Relevant Engineering). SCORE's previous competitions were the 1971-1972 Urban Vehicle Design Competition and the 1973-1974 Students Against Fires competition.

In June 1974, SCORE selected the College of Engineering of the University of Wisconsin to host a SCORE student coordinating committee to organize the Energy Resource Alternatives (ERA) competition. Three engineering undergraduates were chosen as co-chairmen of the committee under the faculty guidance of professor of Mechanical Engineering.

The ERA competition was officially announced in July 1974. The remainder of the summer was spent defining the scope and objectives of the competition and drafting the "ERA Rules and Guidelines". An ERA Advisory Board was also established to assist SCORE with these activities (see the appendix for a list of the Advisory Board members). The first Advisory Board meeting was held on September 9, 1974 at the National Science Foundation in Washington, D.C.. In retrospect, most of the recommendations offered at this meeting were later realized (see appendix).

The "ERA Rules and Guidelines" (contained in the appendix) were published and mailed in August. Teams began to enter the competition in September by submitting an entry form or project design proposal. SCORE's early team recruitment effort consisted primarily of letters to Deans of Engineering and posters describing the competition. It was evident in early October, with the ERA Symposium I rapidly approaching, that a relatively small number of schools were aware of the competition. In response, the Coordinating Committee launched a nationwide telephone campaign to spark awareness of the competition.

The first issue of a semi-regular newsletter was also sent out in early October to all teams that had entered and anyone else who had expressed an interest in the competition.

Twenty-five schools were represented at the ERA Symposium I held October 18-20 at the University of Texas at Arlington. Speakers from the Southwestern Research Institute, National Science Foundation, Electric Power Research Institute, Institute of Gas Technology, and University of Wisconsin spoke on the state-of-the-art of wind turbines, solar collectors, energy storage systems, coal technology, and methane production (see symposium schedule in appendix). SCORE personnel also gave presentations outlining the goals of the competition. Team member participants pointed out during discussions that the design specifications stated in the rules were incomplete and that the output goals were relatively large in magnitude.

In November, new design specifications were drawn up based on the energy demands of an average home in mid continental U.S.A.. Twenty-four input data was given for an average day in both summer and winter. A demand curve for each of the desired outputs was also given for both a summer and winter day (see appendix). Scaling of projects was acceptable and expected by team entries. The main reasons for this were that the projects had to be transportable to the final testing site and the teams' financial resources were limited. Teams were not penalized for scaled down projects.

A new team recruitment drive was also started in November. The new mailing list consisted of over 5,000 names from the American Society for Engineering Education files of academic department heads. Fliers and leaflets were mailed for distribution at the classroom level. A promotional film on alternative energy sources was obtained and lent to schools free of charge.

Team design proposal evaluations started in early December. The Design Proposal Evaluation Board evaluated the proposals on their feasibility, technical content, and professional quality. Based on these evaluations, a "seed money" grant was recommended for each team ranging from zero to two thousand dollars.

During the competition, two additional rounds of grants were issued. Design proposal quality continued to be the basis for evaluating new entries and progress reports for established teams. Special funding requests were considered as they arrived.

In January 1975, the Coordinating Committee settled on an organizational structure that it remained with for the rest of the competition. Two divisions were formed to handle each of the two large areas of work expected in the upcoming months. A Technical staff took the responsibilities for reviewing new proposals and team progress reports, and for developing the testing criteria that would be essential for comparitive project evaluation at the final test event. The Communications staff had the responsibility of handling all correspondence from the committee and to manage logistics for the ERA office, Symposium II, and the final test event.

During January, the Communications staff waged a second telephone campaign. Two hundred and fifty engineering schools were contacted and ten more teams were added to the forty earlier entries.

To obtain additional project performance data, the Technical staff decided to use home site testing as a major evaluation method. The original specifications required preliminary testing results, while a more formal evaluation proceedure was specified in the Revised Specifications. The relative value of home site data was not specified until much later.

Twenty-five teams sent representatives to the ERA Symposium II held at the University of Wisconsin-Madison on March 21-23, 1975. This symposium was built around work shop sessions which allowed team members to discuss construction and materiel problems. Business meetings were held to discuss further ways SCORE could help teams raise funds and other related competition problems. In addition, field trips allowed participants to visit a number of alternative energy pilot projects in the area. The Technical staff introduced the testing and scoring proceedures they had developed by that time. Team feedback and a valuable exchange of information developed at the symposium (see appendix for symposium schedule and summary of the proceedings).

The selection of the final test event site was accomplished in May. A SCORE selection committee visited three locations which had requested consideration. The Sandia Laboratories in Albuquerque, New Mexico was chosen and work was immediately begun on logistic arrangements and testing equipment specifications for the final testing. SCORE personnel made several trips to Albuquerque over the next three months to work directly with their Sandia counterparts.

In early June, the Home Site Testing materials were sent to the teams. The material included a general homesite testing document which explained the objectives of the proceedure as a means for teams to evaluate their own projects in terms of the ERA competition criteria, prior to final testing, so that modifications could be made to optimize performance at the final test event. It was also intended to provide the Coordinating Committee with vital information on the physical specifications of the projects which were due to appear at final testing so that proper planning could be made. It also allowed the teams a longer time, up to a month, for testing and evaluation in an indepth manner not possible at the final test site because of large numbers of projects and small amounts (3-5 days) of time. The Home Site Testing data could also be used for evaluation of projects lost or destroyed in transit to the final test event, or if severe weather conditions prevented actual testing there. In addition, all component (solar collector, wind turbine, decay chamber, etc.) evaluations would be based on Home Site data, with only output testing to be done at the final test site.

The general Home Site Testing document also included definitions of entry categories, additional specifications which had developed in relation to the specific testing site (Sandia Labs), project performance data sheets, standard output values, and the storage evaluation.

Also in the home site materials were documents for evaluating solar, wind, and methane-producing equipment (components) as well as system output performance evaluations (space heating and cooling, domestic hot water, and electricity). These documents were developed by the ERA Technical staff in consultation with faculty members, government agencies, and the ERA Advisory Board. Their development took about five months. The general document and one of the specific documents (solar collector) is contained in the appendix.

After the Home Site Testing documents were mailed, emphasis shifted to the scoring system development. This scheme, using the testing criteria just developed, emphasized performance, safety, versatility, marketing, and innovation. More details are available in the evaluation and results section of this report.

The general scoring criteria established the areas of expertise required for the judging panels. By mid-June, a twenty member judging panel had been formed to aid with the team evaluation at the final test event (see appendix for list of judges). Schedules, judging forms, and judge preorientation information were developed.

By the first of August, the team final reports be-an pouring into the ERA headquarters. Initial evaluation of the reports proceeded as they arrived.

Teams began arriving in Albuquerque for the final test event on the 8th of August. Project set up, equipment checking, and initial testing hookup continued up to Monday, August 11th. Over three hundred participants representing forty teams from thirty three universities were present. The participants, judges, SCORE staff members, and guests were housed in the Visiting Officers' Quarters of Kirtland Air Force Base.

The final test event officially commenced with a kick-off barbeque on Monday night (see appendix for complete final test event schedule). Testing and evaluation began the following morning. Highlights of the final testing week included two thunderstorms, technical seminars and tours at Sandia Labs, Kirtland Air Force Base, and Los Alamos Labs, field trips to local points of interest, and the daily lunch of four hundred and fifty hamburgers served from the back of a pick-up truck.

Saturday morning was an open house for the press and general public. While television cameras ground away on the test field, the Technical staff was grinding the test data into an overall and category team ranking. The results were announced that evening at the Awards Banquet. The keynote speaker, Dr. R. Buckminster Fuller, presented the awards to the happy but exhausted students.

TECHNICAL OBJECTIVES

The main objective of the Energy Resource Alternatives competition was to demonstrate the feasibility of alternative energy sources as solutions to home-scale energy problems in the design, construction, and operation of alternative energy systems. Such feasibility would be indicated by efficiencies comparable to or better than conventional systems, viable production economics, and a realistic potential for widespread use.

Each of the three phases of the competition (design, hardware construction, and testing) addressed itself to additional , more specialized objectives. In the design phase, students were expected to integrate source capture elements, storage and conversion, and output capability as well as develop control capability for sensing and responding to output requirements-- at least on paper. This was complemented by the educational benefits of a symposium held at that time.

Teams were given output graphs meeting home-sized, time varying, real world demands. At this stage, students were also expected to identify the importance of contacting and working with professional people in other fields, notably economics, materials, life sciences, and consumer affairs. Teams were also exposed to the intricacies of proposal writing and fund raising in order to move into the subsequent hardware construction phase.

The hardware construction phase had the objective of giving students the opportunity to obtain actual hardware experience while still in college. Hardware construction also clarified neccessary tradeoffs between optimum design and real world material or process constraints. The nature of the work was to be maintained at the experimental level, not duplicating commercially available hardware or currently utilized processes. Teams were to attempt to be organized and professional by setting time tables, maintaining high fabrication standards, and keeping up with developments in the competition. It was also intended that teams learn to identify and use their resources of time, materials and finance, and to make industrial contacts for advice and support. Finally, during the construction phase, teams were to do developmental testing and investigate and correct the failures of their projects at that time.

The last stage of the competition, testing, had as its objective for the teams to understand and correct their systems' operation through the collection of data. Another major objective of this phase of the competition was the development by the Coordinating Committee of suitable performance testing procedures, since very little currently existed to evaluate energy systems of this nature. The homesite testing process was built upon for use at the final test event.

HARDWARE SUMMARY

This chapter identifies each major component group (i.e. windmills, storage, etc.) and discusses the materials, construction information, and problems as reported by the teams in their final reports.

Twenty-six teams incorporated solar collectors into their projects and some teams worked with more than one type of collector. About fifteen entries developed flat plate collectors. The glazing consisted of either glass, Tedlar, or combinations of the two. Most teams sealed the collector panels to prevent moisture problems and one even purged the collector space with nitrogen. Aluminum, copper, and steel were common materials used for the absorbers while one team employed direct fluid absorption and another used a composite material.

Most teams reported difficulty with soldering tubing to absorber plate undersurfaces especially when different metals were employed. Teams constructing the collector casings with wood reported that for mass production molded plastic or sheet metal should be used. Wood casings are cheap material-wise, but require a lot of hand labor (which was free and plentiful for most teams).

Several teams reported that flat black paints proved as effective as a selective coating, and the cost difference was significant, while other teams utilized selective coatings on the absorber surfaces. Fiberglass, styrofoam, and foam insulation were used liberally for collector insulation.

Five projects contain flat collectors that consist of arrays of small concentrating troughs. Polished aluminum, anodized aluminum, and aluminum foil formed the reflective surfaces for these flat concentrators. Painted pipe connected serially between each trough produced the high outlet temperatures desired by these teams.

Four teams built parabolic cylindrical collectors with tracking mechanisms. Three of the teams used electric motors and one team used a hydraulic piston for the tracking system. Several teams applied glazing on top of the concentrators to decrease losses while two teams employed evacuated glass tubes directly around the target tubes. Fiberglass and wood comprised the backing structure for the concentrating collectors. One team used a large array of mirrors and focused them all to a point with a mechanical tracking mechanism.

A couple of teams reported difficulty achieving the desired reflector geometries during construction resulting in less than optimal focusing.

Four teams built Savonius windmills. In all cases the windmills were staged machines with each stage having two or three blades. The blades were generally made of sheet metal.

Two teams worked on Darrieus wind machines. One team built high strength Troposkien style blades and another team developed a straight blade design and blade pitching.

Eight teams constructed horizontal wind machines, five of which were the upwind design and three of which were downwind. All the upwind machines used tail vanes except one team that used an electric control and motor to position the blades into the wind. Honeycomb wood, styrofoam, aluminum, and plastic were common blade materials.

One team used a vertical axis sailwing design with return of the dacron blades parallel to the wind. Another team developed big fiberglass cones after the anemometer design.

In general, windmill teams concentrated on blade weight reduction, pitching mechanisms, and construction simplification. About half of the teams had some type of tower structure. Generally, the towers were of a portable design. Many teams modified generator windings and field voltage supplies to adapt the electric machines for the windmills. Some good ideas were developed as the team attempted to optimize the power produced at different wind speeds.

Two teams developed hardware to burn coal cleanly, efficiently, and automatically in a small application. Each team developed a different feed system and a different cleaning design. Both teams had tremendously high output capability compared to other projects and this caused some testing problems with respect to loading equipment.

Three projects developed anaerobic decay chambers. Two teams installed their full sized digesters on local dairy farms with the objective of using the gas. In both cases, the design centered around the consumer who had to operate and maintain the digester.

One team developed a wave trap concept that would capture potential energy of the waves and store it as a water column. Two other teams developed no formal alternative input device but rather placed their emphasis on a special conversion application. In both cases, an alternative energy input was simulated using conventional sources.

Twenty-five teams utilized water for storage in some fashion. A majority of these heated water up to 95°C (200°F). One team developed a chilled water storage for an airconditioning system. One other team used a high pressure, high temperature water storage.

Nine teams used direct electrical storage in lead-acid batteries. Four teams designed storage systems utilizing the heat of fusion. Two of these teams worked with paraffin wax, one team used stearic acid and another chose a salt mixture. A team working with paraffin reported that they did not have much problem with supercooling due to the low melting point.

Three teams built floating gas storage tanks for methane gas, one team developed a flywheel storage, and several teams had projects that required no formal storage, as for the coal teams.

Twenty-four teams produced domestic hot water with a heat exchanger in a storage tank. All other teams had a hot water storage tank which water could be drawn from. One team emphasized industrial grade hot water using a heat pump.

Seventeen teams developed the space heating requirement. Most teams designed a forced air heating system and only a few built the natural convection heaters.

Electricity was generated by sixteen teams. A large percentage of these teams produced alternating current at 110 volts. The other teams produced pulsed DC and straight DC at a variety of voltages. Several teams reported that most household appliances could be run on unfiltered, pulsed DC.

Four teams built hardware to air-condition a house. Two of these teams utilized an absorption airconditioning design, one team modified a dessicant evaporative cooling unit, and the fourth team used modified turbochargers to drive a Ranking air cycle. All of these teams designed with the idea of being able to change some connections to provide space heating capability also.

Several other teams produced outputs desirable for the home but which were not one of the principle outputs desired by the competition. Two teams provided some cooking ability directly, while two others produced gas which could be burned for cooking.

Most teams developed some automatic control capability. In general, these circuits consisted of differential amplifiers which sensed when temperature differentials reached certain set points. These circuits were generally used to a activate pumps and solenoid valves. A few projects with multiple input, storage, and output capability used a more sophisticated control system to allocate energy.

INPUTS

Number of teams	Solar	Wind	Methane	Coal	Wave	Team Numbers
6	X	X				35, 44, 47, 54, 56, 59
20	X					24, 26, 30, 32, 33, 36, 37, 39, 42, 43, 45, 46, 48, 53, 55*, 62, 65, 66, 67, 68
9		X				20, 23, 25, 27, 29, 31, 40, 41, 58
4			X			22, 50*, 60, 63
2				X		34, 57
1					X	28
total 42	26	15	4	2	1	

*simulated

STORAGE

Number of teams	Water	Batteries	Heat of Fusion	Other	Team Numbers
1	X	X	X		35
2	X	X			54, 56
22	X				24, 26, 30, 31, 33, 36, 37, 39, 42, 43, 44, 45, 46, 53, 55, 58, 59, 62, 65, 66, 67, 68
6		X			20, 23, 25, 27, 29, 50
3			X		32, 47, 48
8				X	22, 28, 34, 40, 41, 57, 60, 63
total 42					

OUTPUTS

Number of teams	Domestic Hot Water	Space Heating	Electricity	Space Cooling	Other	Team Numbers
1	X	X	X	X		56
1	X	X	X		X	47
3	X	X	X			31, 35, 54
1	X	X		X		39
4	X	X				24, 36, 53, 59
1	X		X			33
1	X				X	30
1	X			X		67
1		X		X		45
10			X			20, 23, 25, 27, 28, 29, 37, 40, 41, 50
10	X					26, 43, 44, 46, 48, 55, 57, 58, 60, 65
6		X				32, 34, 42, 62, 66, 68
2					X	22, 63
total 42	24	17	16	4	4	

EVALUATION

The main formal evaluation of team projects occurred in August, 1975, at the final test event. The Coordinating Committee requested four kinds of information from teams:

1. performance data collected at the home site
2. performance data collected at the final test site
3. marketing information and economic analysis
4. innovations and student experience.

The following sections explain the contents of each area, the process by which the data was collected, and what was done to evaluate it.

TEST DATA

Test data on project performance was collected at the home site and at the final test event. Teams used standardized test procedures, developed by the Coordinating Committee, as guides for the data collection process. The results were compared to known parameters (i.e. standard operating efficiencies, degree of complexity, etc.) and to the results of other projects.

In late May and early June, home site testing materials were sent to teams, outlining specific test procedures for energy collection devices (solar panels, wind turbines, anaerobic decay chambers), for storage facilities, and for output systems (air cooling, space heating, domestic hot water, or electrical outputs). The tests were aimed at establishing operating efficiencies for the various parts, and providing basic information (i.e. temperature or pressure drops, flow rates, wave form and frequency of electrical outputs, etc.) about the system operation. The home site testing materials were meant to be guides for the developmental testing of the projects, and indicate areas for improvement. Data submitted to the Coordinating Committee was to be the end result of the developmental period.

Preliminary, or home site testing, was to be performed prior to the final test event. The results were certified by both the team advisor and a professional engineer or other technically qualified person from outside the academic community. Conducting the tests at the home site supplied performance information about the system under the environmental conditions for which it was designed, since most of the teams felt more confident about designing for local conditions than designing for the representative input conditions of the Revised Specifications. Requiring an outside certifying official gave teams the immediate benefit of the insight and experience of a practicing engineer, as well as providing them with an important contact to the industrial setting.

The time period over which home site data was to be collected ran 24 hours. This was selected because of the diurnal nature of most environmental inputs and the output demands. An exception was made in the case of batch anaerobic decay chamber evaluation, which required testing over a detention period usually of the order of two to four weeks.

Teams were free to select test days with optimum input conditions. Since efficiencies and changes of energy were the important system parameters, the selection of a "good" day did not present a particular advantage. In fact, some teams tested on perfectly inclement days (in some cases causing serious damage to their equipment) in order to learn about their system's performance under adverse conditions.

Collection components were evaluated at the home sites for two reasons: the testing often required isolation of the collection component from output components and component evaluation would lengthen the duration of the final test event beyond reasonable limits. However, teams were permitted to test components at Sandia Labs during the test week on any day for which they were not scheduled to do final testing. This provided teams with additional time to obtain component evaluation data.

Specific components were evaluated as follows:

Solar collectors were evaluated on the basis of four parameters: the collector heat removal factor (F_R), the overall heat loss coefficient (U_L), the transmissivity-absorptivity product ( ), and the solar collector efficiency (N_L%). In addition, smaller value was placed on non performance parameters of emissivity, absorptivity, weight, and geographic versatility.

Wind turbine evaluations were based on five parameters: power out/unit swept area at differing wind speeds, power coefficient at differing tip speed ratios, rotor efficiency at varying wind speeds, starting characteristics, and installed cost/KW.

Anaerobic decay chambers for producing methane were evaluated as to gas composition (%CH_4), volatile solids destroyed, startup time, detention time, mixing intervals, maintenance, and compatibility with currently existing hardware.

Coal conversion source elements evaluation was based on ash produced per unit mass of coal consumed, analysis of exhaust gases compared to EPA standards, amount of particulate matter introduced into the air or effects of combustion products and soot on the heat exchanger mechanism, and a technical and economic analysis of any special processes required for fuel (such as solvent refining or powdering).

Formal guidelines were not established for the wave trapping project. In this case, the team was required to define and evaluate their project's important aspects.

Comparisons of performance and efficiencies were made only between source elements in the same category (i.e. solar collectors were NOT compared to wind turbines). Each type of source element was considered equally valuable and credit was awarded for multiple input capacity, since this generally reflected a more consistent output and represented more effort.

Home site output data was evaluated in a manner very similar to that used for final test site data. The procedure will be discussed in the following section.

At the Albuquerque test site, all projects underwent output testing of essentially the same form as homesite output testing. The major differences were that test periods were only twelve hours maximum, teams were not free to select any day other than the one for which they were scheduled, and all testing was to be done with the load equipment and measuring devices provided by Sandia Labs. Some reasonable exceptions were made in this last requirement. Only output testing was formally performed at the final test event.

Homesite output performance data and final test event output data were given equal weight. However, the individual outputs were ranked for difficulty of production and for desirability for home or small industrial use.

Sandia Labs measured total hemispherical radiation on a tracking surface and total beam radiation incident on a tracking surface. Both these values were integrated over each hour. Each team collected this data from the solar station, corrected it (according to standarized procedure) for fixed tilt, the diffuse radiation, and their total operation area, and obtained the value for their total available solar energy.

Wind speed data was taken at three places and two heights across the test field. Again, according to a standardized format, teams took hourly wind speeds and corrected the average values for spatial variation at their location on the field and differing height, and calculated an available kinetic energy.

Most temperature and flow measurements were sampled and recorded on a data logger. Channels were assigned to each measurement required for a given project. The samplings were taken at one, two, or three minute intervals (depending on the parameter) during the startup period to allow adjustment of input flow and project performance. After the projects reached a steady operating condition, the rate of sampling was decreased. Each team collected their data logger output and environmental input data to perform the calculations for efficiencies and total energy output. The calculations were then reviewed by the tech staff. Since some of the teams had done no preliminary testing and hence no preliminary calculations, a great deal of reviewing was required in some cases.

Evaluation of output was based on the following measurements and calculations:

Electrical: voltage, frequency, distortion from sinusoidal wave form, and voltage and frequency regulation for a varying load.

Airconditioning: total energy removed from air, with additional consideration for dehumidification and reasonable temperatures (not less than 13° C).

Space heat: total energy added to air, with additional consideration for humidification and safe (under 55° C) output temperature of heated air.

Hot water for domestic use: output volume (reflecting total added energy) and usable temperature (between 65° and 55° C).

The technology staff of the Coordinating Committee established the comparison scales, which were based on current standards in industry, the ERA specifications, and relative team performance. The tech staff also applied the scoring framework at the final test event (for details, see section on results).

The measurements were made in the following manner with the specified instrumentation:

During the test periods for electrical output, the frequency was checked on a digital counter, and pictures were taken of the oscilloscope display of the waveform.

Auxilliary consumption was monitored by standard power company meters at each project. Measuring equipment was provided by Sandia Labs to assure uniformity of measurements.

Teams provided the electrical loads (purely resistive, as are most home loads). Sandia Labs designed and built a unit to provide hot air (77°F) for airconditioning teams and cold air (60°F) for space heating teams by employing a 5 ton chiller. Pressure head could be adjusted in the ducting to each project with a damper. Since Albuquerque ambient air was drier than either the summer or winter input specs allowed, the unit also humidified to 68% relative humidity for summer mode and 53% for winter mode.

Teams were not penalized for building systems larger or smaller than ERA specs. Each team's energy output was normalized to the full scale ERA design specs for a one day period. Since teams demonstrated variable output capability, the normalized values were used to point-check consistency of output capability and also indicated when the system dropped below desired output levels due to equipment failure or storage drain.

SUBJECTIVE EVALUATION

The second area of evaluation was concerned with subjective parameters not measurable by meter nor calculable in any manner, such as engineering decisions and adherence to competition goals. This evaluation was done by panels of four to five judges which included representatives from government agencies, private solar and wind energy firms, and the heating, ventilating and airconditioning industry selected for their experience and knowledge in energy related fields. Team members supplied the information in two different presentations, each evaluated by a different set of judges.

A team's performance presentation was intended to demonstrate the technical feasibility of the project and was aimed at engineers. The evaluation was based on:

: supplying usable form of energy, with relatively few intermediate steps between capture and usable output
: utilizing a well integrated storage system
: responding to variable output demands (i.e. control system) with variable input
: simplicity of operation equal or better than present day conventional systems for the same purpose
: reasonable maintenance requirements, both in lack of complexity and demand of time
: quality of the system design
: safety in operation, such as shut down capability under overload.
: environmental effects, including depletion of resources and added turbulence and noise.

In order to better comprehent the team's design, judges inspected the hardware on the test field early in the morning of the day on which the project's presentation was given.

The marketing presentation provided consumer-oriented information. These presentations discussed:

: Economic feasibility as indicated by limited additional energy requirements (self sufficiency under normal operation) and backup capability (such as a conventional utility) in case of failure of both input and storage, or adequate assurance of the relative impossibility of such an occurrence
: safety of day to day operation
: geographic versatility as related to mass marketing

: ability to be integrated into conventional home design and currently existing structures

: relative cost of the alternative energy package versus a conventional system for the same purpose

: expected useful lifetime of the project

: reasonable interior and exterior space utilization

: general consumer appeal (packaging).

While specific outlines were given to the judges as an attempt to standardize their assessments, they also had substanial freedom to acknowledge features not anticipated by the Coordinating Committee in the development of the guides.

Lastly, innovation, student experience and benefit, and design decisions were evaluated by means of the Student Innovation Multiplier. This part of the evaluation was done by team captains at the final test event. Captains were though to be uniquely qualified for this because of their own realizations of the limitations under which they had to work. Part of this evaluation was viewed in terms of source capture components (the most strongly innovative part of the hardware) and part viewed the system as a whole.

Innovations in components included:

: attempting untried ideas- based on what actually appeared at the final test event, regardless of the functionability at that time

: significant advancement to the state of the particular technology

: unusual modification of a standard design, with improvement of performance

: versatility in size, preferably modular to allow easy scaling

: simplicity of design

: incorporation of easily available materials

: amount of design effort or modification done by students

: amount of construction done by students.

With respect to the work devoted to integrating systems, innovation credit was also given for system decisions and parameters such as:

: availability of the selected source of energy, independent of fossil fuel-related or non-existent distribution methods

: exhaustibility of the selected source

: clearly alternative nature of the selected source, as well as non-conventionality regardless of the practicality

: usability of the outputs for home or light industry

: creativity in defining additional outputs which could be utilized

: amount of student effort apparent in the design and construction

: contributions to the state of technology for system integration

: attempting untried ideas in system integration, or using unusual modifications

: simplicity of design

: availability of required materials

: innovations in convenience to the homeowner or businessman.

Each project was evaluated by captains from similar projects where possible and at least five captains evaluated each project. The captains were expected to visit and to discuss, with the team captain, the projects they were evaluating. Because of time demands on captains, this was not always the case.

SUMMARY

The various quantities and their relative values used to evaluate the technical quality and engineering performance of projects are summarized in the following table. In some cases, similar factors were evaluated by more than one group. The combination scheme for determining scores will be explained in the chapter on results.

PARAMETER		MAXIMUM POINTS	PERCENT
PERFORMANCE RESULTS			
Collection Components			
solar collectors		200	8.0
wind turbines		200	8.0
anaerobic chamber or other		200	8.0
Output Performance			
electricity		250	10.0
airconditioning		250	10.0
space heating		190	7.6
hot water		80	3.2
Overall Efficiency		250	10.0
	Subtotal	1620	64.8%
SUBJECTIVE EVALUATION			
Energy allocation and distribution (including controls)		150	6.0
Design decisions (simplicity, versatility, safety, environmental impact)		340	13.6
Consumer impact (including maintenance)		150	6.0
Marketability (including cost and retrofit)		240	9.6
	Subtotal	880	35.2%
	MAXIMUM TOTAL RAW SCORE	2500	100.0%

STUDENT INNOVATION MULTIPLIER PARAMETER		MAXIMUM POINTS	PERCENT
COMPONENT SIM (per input component)			
Selection Credit		0.4	20
Design Decisions		0.5	25
Construction Effort		1.1	55
	TOTAL	2.0	100%
SYSTEM SIM (per project)			
Source Selection		0.4	20
Output Usefulness		0.2	10
Construction Effort		0.4	20
Design Decisions		1.0	50
	TOTAL	2.0	100%

RESULTS AND SCORES

Two scores were the bases for awards given out in the competition: a final component score and a final project score. The final component score A was derived from the formula:

$$A = \sum_i C_i (SIM_i^C)$$

i=number of components (source capture elements-- solar, wind, methane, other).

C_i=total points earned from component performance testing for component i.

SIM_i^C=student innovation multiplier assigned by team captains for component i.

In the case of multiple kinds of one component (i.e. three varieties of solar collector), the best source was used and considered as one component. At the end of the competition, no team brought more than two components. Since each component could earn a maximum of 200 performance points, and a maximum SIM of 2.0, the maximum A possible was 800 points. The maximum A earned by any team was 358 points, by the University of Wisconsin-Milwaukee.

The final project score K, was derived as follows:

$$K = [C + (\sum_i W_j)_{hs} + (\sum_i W_j)_{ft} + P + M]\ SIM^S$$

where:

A=final component score, maximum 800

j=number of outputs (electrical 250, airconditioning 250, space heat 190, hot water 80)

W=total points earned for the i^{th} output

hs=homesite testing results

ft=final test results

P=points earned from performance presentation (maximum of 370)

M=points earned from marketing presentation (maximum of 510)

SIM^S=student innovation multiplier earned by total project, assigned by team captains (maximum of 2.0)

Consequently, a team which performed both home site testing and final site testing received credit for each. The maximum K earned by any team was 2210 by the Illinois Insititute of Technology.

Only teams which underwent testing received scores. Consequently, the teams listed below are the teams which actually competed for awards. Other teams built hardware as described in the hardware chapter, but did not compete for various reasons ranging from severe equipment breakdown to inability to participate in August.

OVERALL PROJECT SCORES

TEAM NUMBER	SCHOOL	NO. OF POINTS
24	Illinois Institute of Technology	2210
32	University of California-Berkeley	2156
42	Wichita State University	1948
46	Concordia University	1702
59	University of Wisconsin-Milwaukee	1588
20	Oakland University	1573
53	University of New Mexico	1557
56	Iowa State University	1497
39	University of Texas at Austin	1429
60	University of Oklahoma	1361
35	Michigan State University	1282
36	University of Alabama at Huntsville	1250
43	Massachusetts Institute of Technology	1209
68	University of New Brunswick	1175
33	Rennsselaer Polytechnic Institute	1111
30	University of Oklahoma	1035
54	University of Florida	1022
65	California State University-Long Beach	990
34	University of Wisconsin-Madison	914
41	Wichita State University	839
25	University of Toronto	798
26	University of Houston	776
31	University of Oklahoma	768
45	Tufts University	759
48	Loughborough University, England	753
55	Drexel University	674
57	Washington State University	671
47	Pennsylvania State University	611
23	Massachusetts Institute of Technology	606
67	California State University-Northridge	585
58	University of Hartford	572
62	Fairfield Senior High School	568
66	University of Colorado	534
44	North Carolina State University	478
27	University of Houston	378
50	University of Wisconsin-Green Bay	374
28	University of Houston	348
29	University of Houston	279

TEAMS		COMPONENTS				OUTPUTS			PRESENTAT.		OVERALL	
Name	Number	Total	Number	Score	SIM	Number	Score	Efficiency	Performance	Marketing	SIM	Total Score
Oakland U.	20	320	1	185	1.73	1	280	24.9	182	228	1.61	1573
MIT	23	29	1	22	1.30	0	0	0	197	296	1.18	606
IIT	24	413	1	330	1.25	2	385	43.2	246	340	1.70	2210
								26.4				
U. of Toronto	25	96	1	147	.65	1	364	0	222	264.7	.80	798
U. of Houston	26	0	1	0	1.40	1	122	25.5	177	312	1.27	776
U. of Houston	27	0	1	0	1.50	1	0	0	111	179.7	1.30	378
U. of Houston	28	0	0	0	1.20	1	0	0	162	153.7	1.10	348
U. of Houston	29	0	0	0	1.35	0	0	0	79	174.5	1.10	279
U. of Okla.	30	0	1	0	1.57	0	39	16.2	281	358.2	1.42	1035
U. of Okla.	31	0	1	0	1.50	0	0	0	212	393.2	1.27	768
U. of Cal, Berk	32	232	1	166	1.40	1	423	31	245	398.5	1.55	2156
								31				
RPI	33	0	1	0	1.53	3	127	44	170	319.7	1.80	1111
UW-Madison	34	0	1	0	1.10	1	237	47	208	278.3	1.27	914
Mich. State U.	35	0	2	0	1.35	3	373	4.4	223	316	1.29	1282
				86	1.43							
U. of Alabama	36	141	1	101	1.40	2	253	10.4	247	339.2	1.20	1250
U. of Tx, Austin	39	0	2	0	1.24	2	428	24.4	245	354.7	1.39	1429
								7.9				
Wichita State	41	0	1	0	1.40	1	125	0	204	282.7	1.37	839
Wichita State	42	181	1	123	1.46	1	468	0	257	367	1.46	1948
MIT	43	0	1	0	1.70	1	124	24.8	265	343.3	1.59	1209
N. Car. State	44	0	1	0	1.01	2	0	0	137	241.5	1.26	478
Tufts U.	45	0	1	0	1.45	1	0	0	258	358.5	1.23	759
Concordia U.	46	178	1	120	1.32	1	278	61.6	205	330.7	1.62	1702
				127	1.48			24.4				
Penn. State	47	0	2	0	1.53	3	0	0	203	313.7	1.18	611
					1.43							
Loughborough U.	48	0	1	0	1.50	0	0	0	251	337.5	1.28	753
UW-Green Bay	50	0	1	0	1.20	1	0	0	193	147	1.10	374
U. of New Mex.	53	0	1	0	1.05	2	570	30.6	270	472.2	1.03	1557
								25.5				
U. of Florida	54	0	2	0	1.50	3	156	0	199	365.7	1.42	1022
					1.23							
Drexel U.	55	0	1	0	1.37	1	0	0	199	345	1.29	674
Iowa State	56	0	2	0	1.49	3	290	12.9	259	380.7	1.61	1497
					1.57			3.5				
Washington St.	57	0	1	0	1.30	1	0	0	260	309.2	1.17	671
U. of Hartford	58	0	1	0	1.50	1	0	0	161	239	1.43	572
UW-Milw.	59	146	2	148	.99	2	523	29.2	211	306.7	1.06	1588
		211		159	1.33			19				
U. of Okla.	60	238	0	140	1.70	0	0	0	321	478	1.45	1361
Fairfield Sr. H.	62	0	1	0	1.50	1	0	0	188	167	1.60	568
Cal, Long Beach	65	98	1	90	1.09	1	187	52.4	183	290	1.31	990
U. of Colorado	66	0	1	0	1.18	2	0	0	208	225.7	1.23	534
Cal, Northridge	67	0	1	0	1.27	1	0	0	205	276.3	1.22	585
U. of N. Bruns.	68	0	1	0	1.43	1	260	20	272	338	1.35	1175

ENERGY RESOURCE ALTERNATIVES

AWARDS

<u>SPECIAL RECOGNITION</u>

#30 University of Oklahoma

#53 University of New Mexico

#67 California State University at Northridge

<u>COAL UTILIZATION AWARD</u>

#34 University of Wisconsin-Madison

<u>ANAEROBIC DECAY CHAMBER AWARD</u>

#60 University of Oklahoma

<u>WIND COMPONENT</u>

#25	University of Toronto	3rd Place
#59	University of Wisconsin-Milwaukee	2nd Place
#20	Oakland University	1st Place

<u>SOLAR FOCUSING COLLECTOR</u>

#36 University of Alabama-Huntsville

<u>SOLAR FLAT PLATE COLLECTOR AWARD</u>

#24	Illinois Institute of Technology	2nd Place
#32	University of California-Berkeley	1st Place

SYSTEMS AWARDS

Electrical Output

#20 Oakland University

Domestic Hot Water

#46 Concordia University

Space Heating

#32 University of California-Berkeley

Space Heating & Domestic Hot Water

#24 Illinois Institute of Technology

Electricity, Air Conditioning & Space Heating

Michigan State University

Electricity & Air Conditioning

#56 Iowa State University

Hot Water & Air Conditioning

University of Texas-Austin

STUDENT INNOVATION MULTIPLIER AWARD

#46 Concordia University #20 Oakland University #43 Massachusetts Institute of Technology #56 Iowa State University #62 Fairfield Senior High School	3rd Place
#24 Illinois Institute of Technology	2nd Place
#33 Rensselaer Polytechnic Institute	1st Place

EFFICIENCY AWARD

#34	University of Wisconsin at Madison	3rd Place
#42	Wichita State University	2nd Place
#46	Concordia University	1st Place

GRAND AWARD

#46	Concordia University	4th Place
#42	Wichita State University	3rd Place
#32	University of California-Berkeley	2nd Place
#24	Illinois Institute of Technology	1st Place

TEAM DESCRIPTIONS

AN ALPHABETICAL LISTING OF TEAMS IN THE ERA I COMPETITION

SCHOOL	TEAM NUMBER
Alabama, University of at Huntsville	36
Alabama, University of at Huntsville	37
California, University of at Berkeley	32
California State University, Long Beach	65
California State University, Northridge	67
Carnegie-Mellon University	40
Clemson University	22
Colorado, University of	66
Concordia University	46
Drexel University	55
Fairfield Senior High School	62
Florida, University of	54
Forsyth Technical Institute	63
Hartford, University of	58
Houston, University of	26
Houston, University of	27
Houston, University of	28
Houston, University of	29
Illinois Institute of Technology	24
Iowa State University	56
Loughborough University, England	48
Massachusetts Institute of Technology	23
Massachusetts Institute of Technology	43
Michigan State University	35
New Mexico, University of	53
New Brunswick, University of	68
North Carolina State University	44
Oakland University	20
Oklahoma, University of	30
Oklahoma, University of	31
Oklahoma, University of	60
Pennsylvania State University	47
Rensselaer Polytechnic Institute	33
Texas, University of at Austin	39
Toronto, University of	25
Tufts University	45
Washington State University	57
Wichita State University	41
Wichita State University	42
Wisconsin, University of at Green Bay	50
Wisconsin, University of at Madison	34
Wisconsin, University of at Milwaukee	59

This section includes a description of each of the entries in Energy Resource Alternatives. The project summary identifies input and output selection, describes energy flow and allocation, and/or specifies use for a special application project. The other sections describe the following technical information:

1. Description of major components
2. Construction methods and materials
3. Energy size and physical dimensions
4. Innovations and results

Each description attempts to describe the team's major efforts and was not meant to describe all considerations and research activities in detail. More information can be obtained by contacting the schools directly.

All information was obtained directly from final reports submitted by each team. The sketches are representations of the systems only and might not depict actual hardware appearance.

This section describes all hardware developed for entry into the ERA I competition. Check the scoring section for an official entry and testing breakdown.

SCHOOL: Oakland University, Rochester, Michigan 48063
TEAM NUMBER: 20 TEAM CAPTAIN: Robert MacFarland
FACULTY ADVISOR: Profs. R.H. Edgerton and G.L. Wedekind
TELEPHONE: (313) 377-2213

PROJECT SUMMARY

The windmill 'FLAPPER' transmits energy to a three stage gear and gear belt transmission which drives two 36 volt DC generators. Electrical energy is stored in a series of storage batteries and can be tapped as 110 volt AC sine wave with an inverter.

INPUT COMPONENT

The sail wind machine is constructed with a vertical 6.71 m (22 ft.) steel frame and an aluminum spoked panemone assembly which supports three 2.13 m x .91 m (7 ft. x 3 ft.) aluminum sail frames with dacron sails. Wind striking a sail causes it to swing into a drive position (along the radius of the machine) whereby the mill turns until another sail catches. The sail flaps open and returns through a path parallel to the wind. The driving swing is dampened by sponge rubber covered stops. The outside swing is dampened by rubber shock cords.

STORAGE

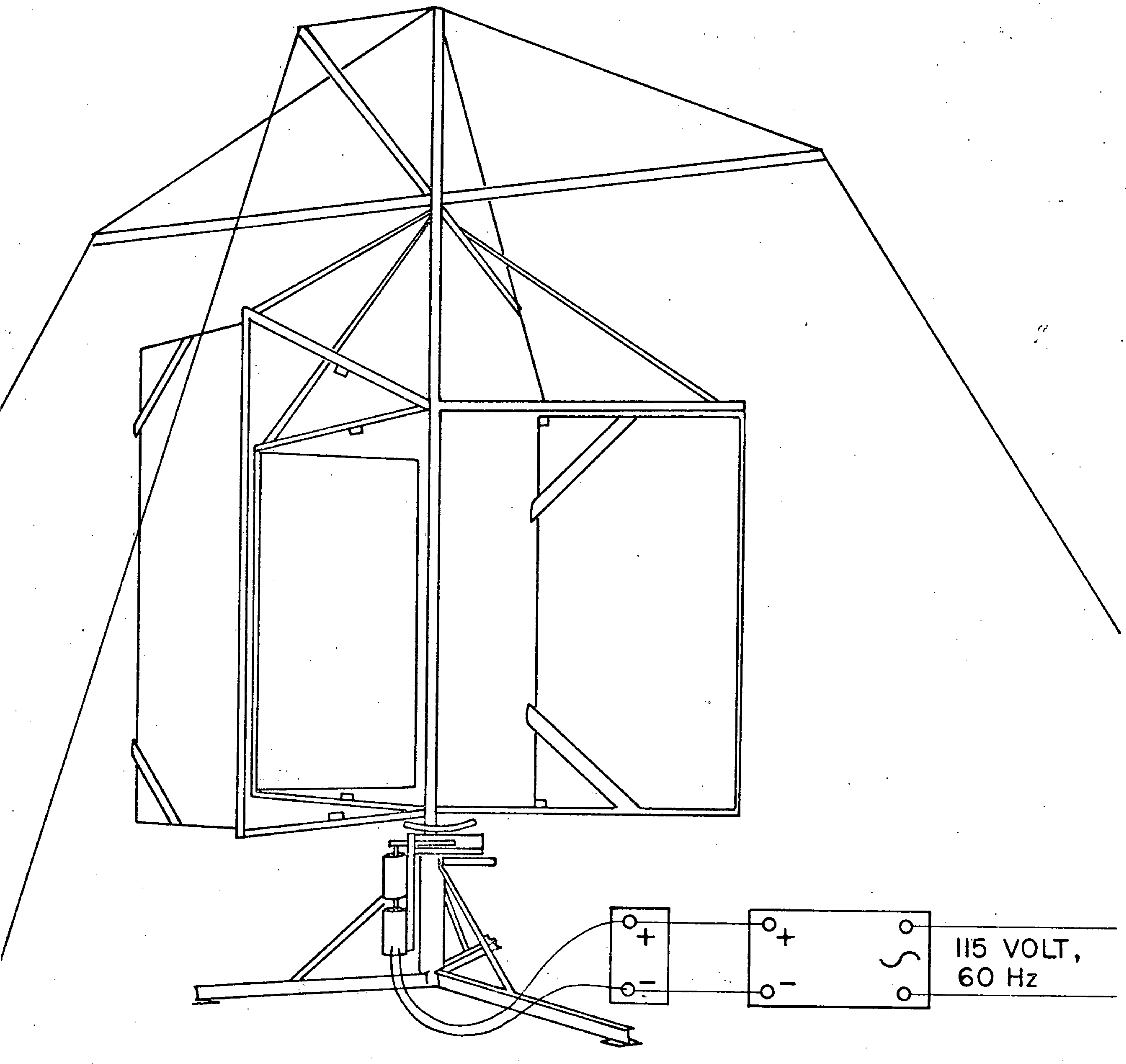
Three 12 volt lead-acid batteries are used providing 3.6 kwh of storage.

OUTPUT CONTROL

Produces 110 volt AC, 60 Hz, sine wave from a special 1000 watt inverter. Frequency is controlled by a 42,000 Hz G-cut crystal oscillator and voltage was regulated by an automatically controlled, motor-driven variable transformer.

INNOVATIONS AND RESULTS

: Students obtained frequency control of $\pm$ .01% and voltage regulation of $\pm$ 1%.
: Their tests showed most household appliances can run on pulsed DC.
: The windmill and output control were designed and built by students.
: They selected a low distortion conduction angle of 130° to minimize harmonics caused by the pulsed DC portion of the inverter.
: Modified the ott filter design for sine waves to minimize the no load current.
: Tests showed three sails to be better than six.


+
−
+
−
115 VOLT,
60 Hz

SCHOOL: Clemson University
Clemson, South Carolina 29631
TEAM NUMBER: 22 TEAM CAPTAIN: Bert Cornelisen
FACULTY ADVISOR: Prof. Parviz Rad
TELEPHONE: (803)656-3000

PROJECT SUMMARY

A continuous feed anerobic decay chamber turns dairy cow manure into bio-gas (75% methane). The gas is stored in a storage tank system until used. The average retention time is 40 days and 3780 liters (1000 gals.) of slurry is continously being digested.

INPUT COMPONENTS

A 5.66 kl (1500 gal.) concrete septic tank was modified for this project. The inside was tarred to seal it. On the bottom, 30.3 m (100 ft.) of copper tubing was laid to heat the slurry mixture. A .215 m^3 (7.66 $ft.^3$) plywood hopper feeds the methane digester. The hopper is located on the top of the tank and the inlet pipe enters 45.7 cm (18 in.) into the slurry mixture so not to allow oxygen into the tank. One and one half hoppers of slurry, 190 liters (50 gals.), must be added every two days. A mechanical stirring mechanism has three aluminum blades, 1.21 m (4 ft.) long, radially spaced 120° apart which are mounted on a 2.72 m (9 ft.) solid steel shaft. The shaft goes through an air-tight seal to a 90 cm (3 ft.) long handle at the top. The tank must be stirred twice a day to promote gas production. The slurry outlet pipe is located 30 cm (1 ft.) from the bottom of the tank and a 71.1 cm (28 in.) diameter access hole in the top of the tank is covered with a stainless steel sealed hatch. The heating coils use hot water from a solar collector and maintain the tank at 35° C (95° F). The entire tank is insulated by 60 cm (2 ft.) of sawdust.

STORAGE

Two .48 m^3 (17 $ft.^3$) storage vessels were built and connected in series. Each vessel consists of two steel tanks each with one end open. Both are 1.22 m (4 ft.) tall. One is 79 cm (31 in.) and the other is 71 cm (28 in.) in diameter. The large tank is filled with water and the other tank is inverted and floated in the large tank. Six 2.5 cm x 2.5 cm (1 in. x 1 in.) angle steel strips .9 m (3 ft.) long were welded to the inside of the large tank to keep the smaller tank from tipping when completely filled with gas.

Pipes and gas cocks connected to the tops of the floating vessels allow gas in and out. When more gas is produced than the storage capacity, the gas bubbles from under the floating tank to the atmosphere.

OUTPUT

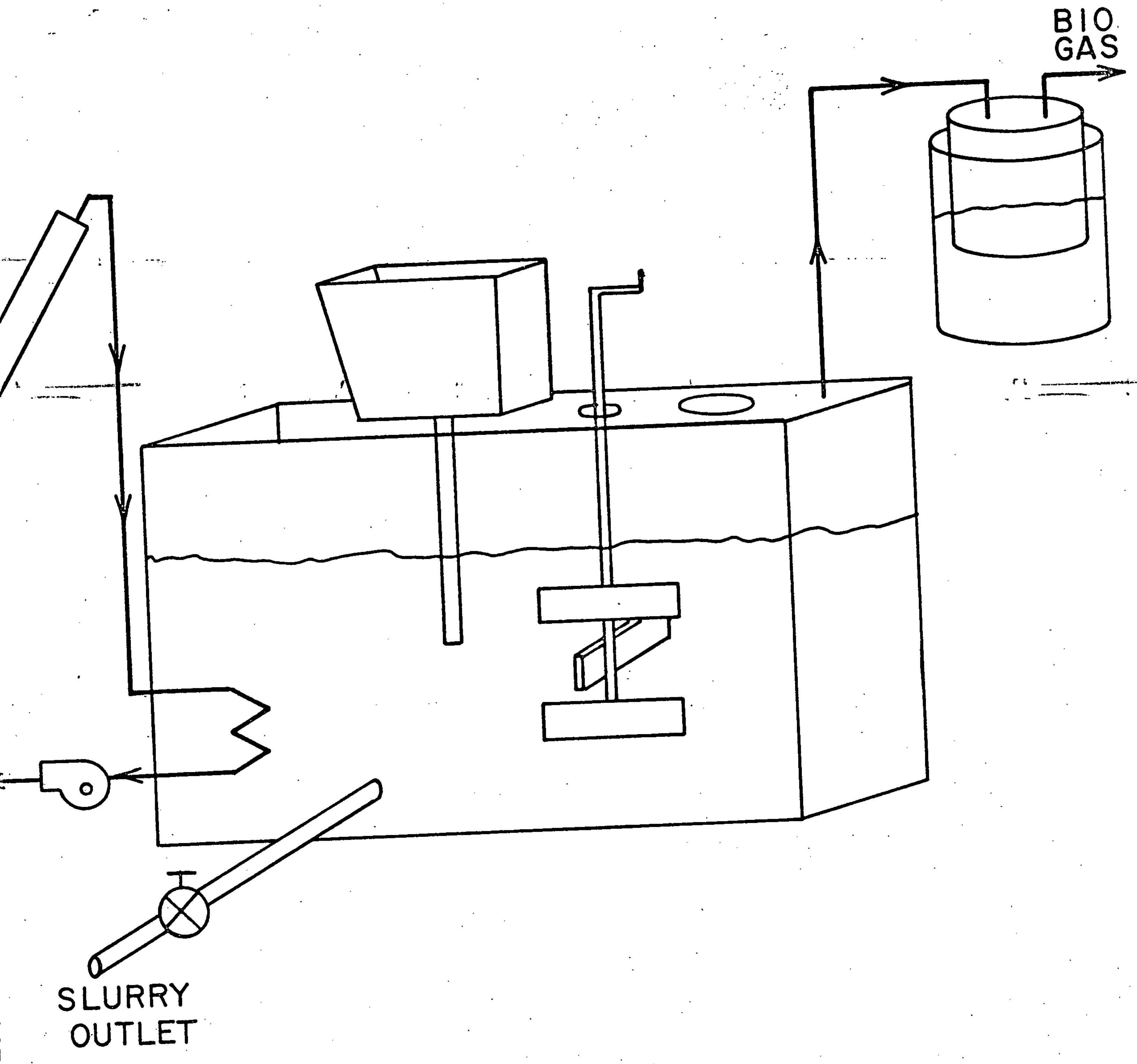
Bio-gas is available from the storage vessels and the used slurry is a high quality nitrogen fertilizer.

INNOVATIONS AND RESULTS

: The digester, hopper, stirring mechanism, and storage vessels were designed and built by students.

: The team took many safeguards to make sure the system was sealed properly to safeguard against explosions.

: The digester was built on a local dairy farm.


BIO
GAS
SLURRY
OUTLET

SCHOOL: Massachusetts Institute of Technology
Cambridge, Massachusetts 02139
TEAM NUMBER: 23 TEAM CAPTAIN: Herman Drees
FACULTY ADVISOR: Prof. W.L. Harris
TELEPHONE: (617) 253-1388

PROJECT SUMMARY

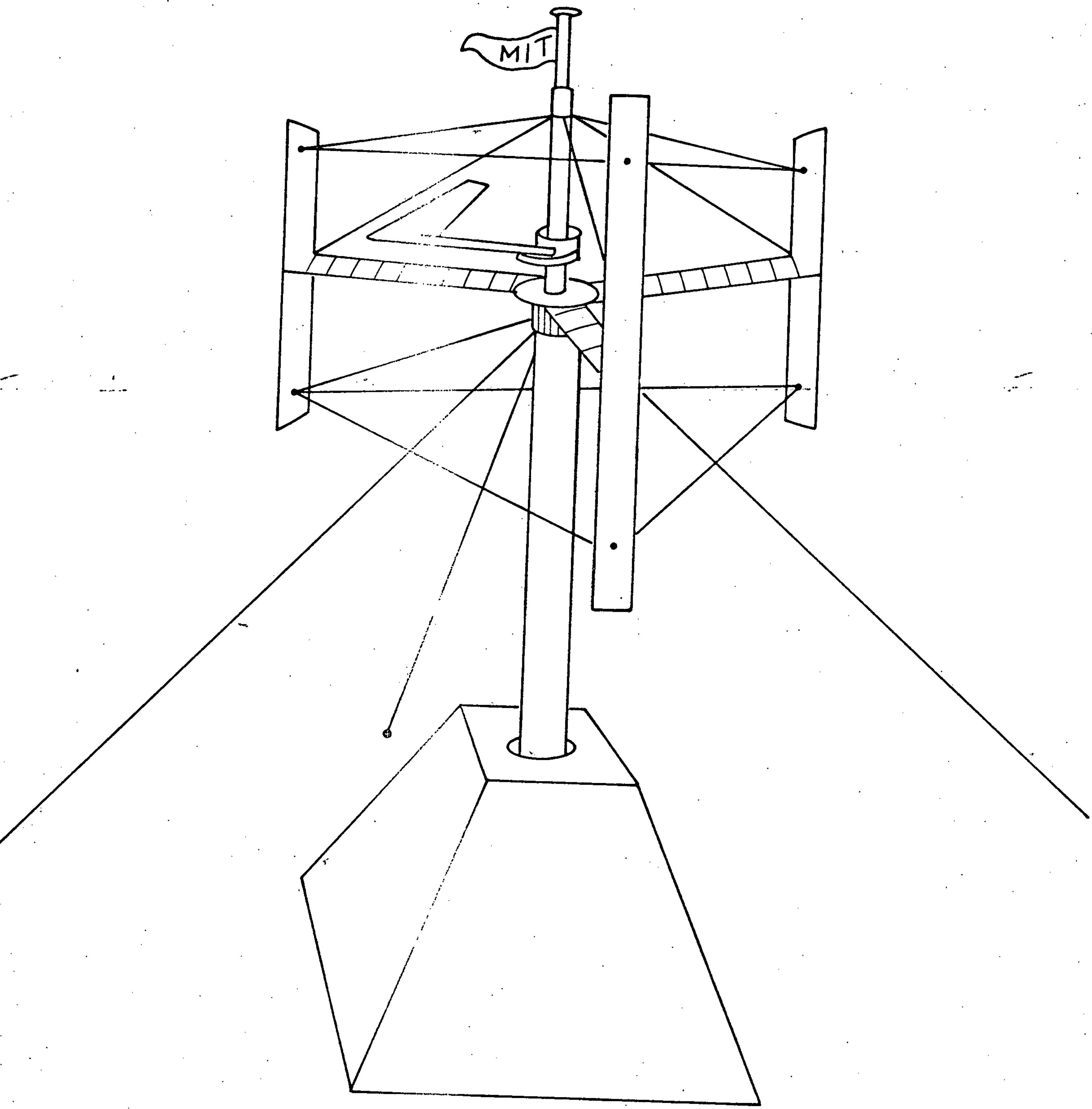
A straight bladed Darrieus wind machine drives a generator to produce electricity.

INPUT COMPONENT

Three 2.44 m (8 ft.) vertical straight blades are each attached to the shaft by 2.29 m (7.5 ft.) airfoil support arms. Each blade has a chord length of 27.9 cm (11 in.). A weather vaning device orients the eccentric bearing which drives pushpull rods for blade pitching. At 4.92 m/s (11 mph), 73 watts of power was produced.

INNOVATIONS AND RESULTS

: Blade pitching design self-starts a Darrieus in a 1.34 m/s (3 mph) wind.
: Tests showed efficiency increases with wind speed.
: Straight blade design simplifies construction and blade fatigue problems.
: The wind machine was designed and built by students.


MIT

SCHOOL: Illinois Institute of Technology
Chicago, Illinois 60616
TEAM NUMBER: 24 TEAM CAPTAIN: Alan Boxenbaum
FACULTY ADVISOR: Profs. A. Lavan, R. Porter, T. Torda
TELEPHONE: (312) 225-9600

PROJECT SUMMARY

Each of two sets of six flat plate collectors heats the working fluid (water) and passes it through a heat exchanger coil to heat the 113 liter (30 gal.) domestic hot water supply. Each set has two parallel groups of three collectors in series, with a flowrate of .80 liters/min through each collector. The exit of each coil goes to the top of an 80 gallon storage tank. Water from the tanks is pumped through a fixed tube radiator and air is forced over the coil by a fan.

INPUT COMPONENT

Each of the 12 collectors is .61 m x 1.22 m (2 ft. x 4 ft.) with a .10 mm (.004 in.) aluminum absorbing surface and copper tubing soldered to the downside. The bottom is insulated with 6.35 cm (2.5 in.) of fiberglass and 5.08 cm (2 in.) of styrofoam. 3M Nextel Brand Black Velvet series 301-C10 coating and Alcoa selective coating were compared as selective coatings. Half of the collectors have two layers of Tedlar film 2.54 cm (1 in.) apart and the other half have 3.18 mm (1/8 in.) glass and Tedlar film 2.54 cm (1 in.) apart. The collector cabinets were made of wood.

STORAGE

The storage vessels are two 302 liter (80 gal.) cylindrical steel tanks of 1.52 m (60 in.) height, 50.8 cm (20 in.) diameter, 1.59 mm (1/16 in.) walls and have concave end caps. The tanks are insulated with fiberglass and foam rubber to give the tank a time constant of 194 hours. A 113 liter (30 gal.) drum was used for the domestic hot water tank and inside the heat exchanger are two coils of 15.2 m (50 ft.) copper tubing. This tank is insulated with fiberglass and foam rubber.

OUTPUTS

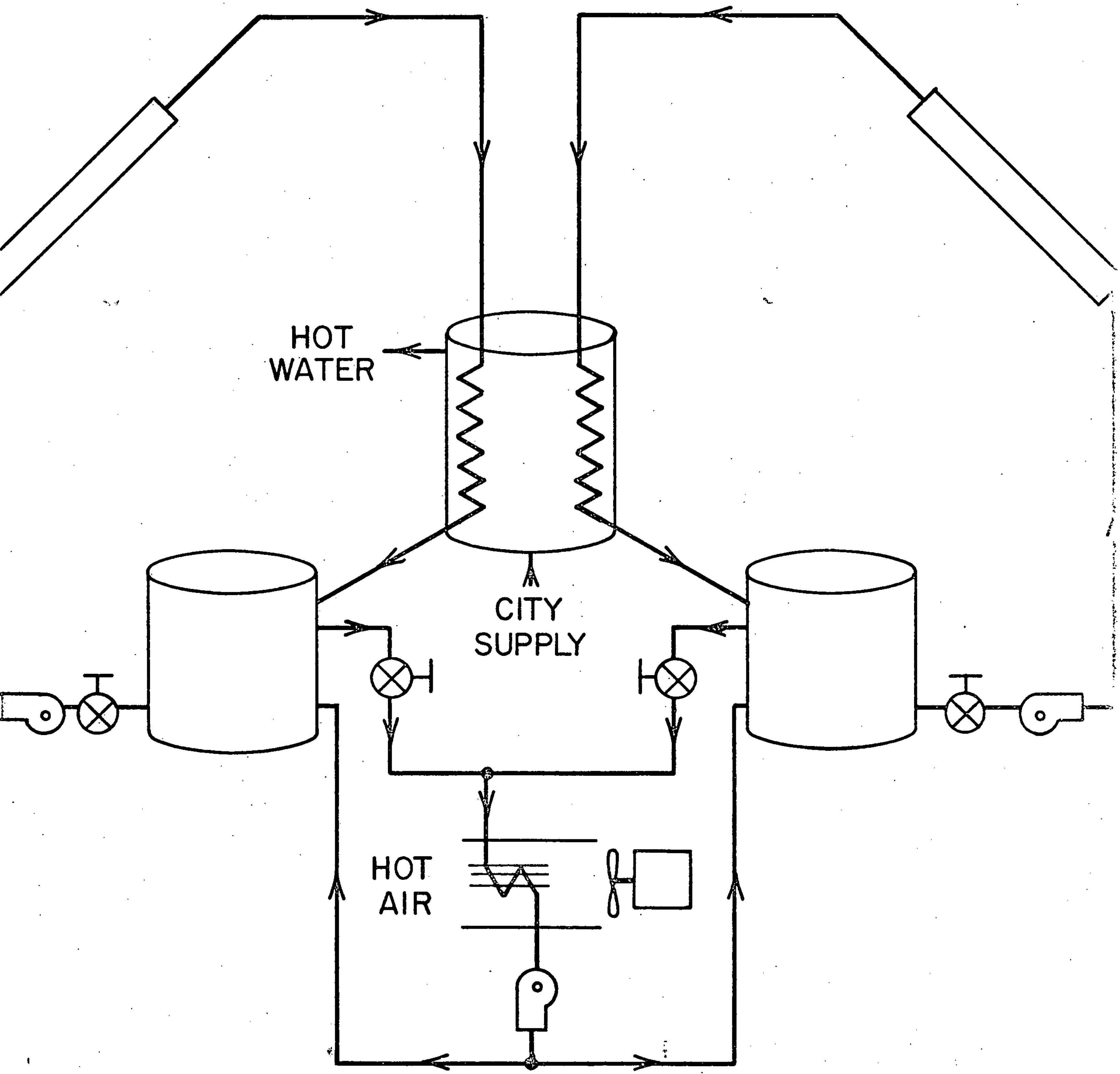
Hot water is available from a 113 liter (30 gal.) tank with the heating coils in it. The forced air heating system delivers air at .094 m^3/s (200 cfm).

INNOVATIONS AND RESULTS

: The collectors, storage, and control system were desgined and built by students.

: Tests showed 3M Black Velvet paint superior to another selective coating.

: Flow distributors directing water toward the storage vessel end caps caused very little mixing hence does not degrade the stored energy.


HOT
WATER
CITY
SUPPLY
HOT
AIR

SCHOOL: University of Toronto, Toronto, Canada M5S 1A4
TEAM NUMBER: 25 TEAM CAPTAIN: John Orian
FACULTY ADVISOR: Prof. I.W. Smith
TELEPHONE: (416) 928-3051

PROJECT SUMMARY

Energy passes from the three propellor windmill through a right angle drive which is an inverted 35 hp outboard engine. The kinetic energy is transmitted to the ground by a 3.17 cm (1.25 in.) mechanical tubing downshaft. The second right angle drive, a Boston spiral miter gear box, drives the DC machine through an electric clutch. The DC machine drives the alternator at a constant speed via a V belt to produce 60 Hz, 120 volt AC. The control system monitors the wind speed and alternator rps and controls the electric clutch and the field voltage for the DC machine.

INPUT COMPONENT

The self-feathering Australian made propellor is 3.05 m (10 ft.) in diameter and was modified to allow adjustable pitch control. The aluminum alloy blades have a 20 degree twist and the pitch can vary from 3 degrees to 30 degrees at the tip of the blade.

STORAGE

Ten 12 volt lead-acid batteries are used providing 12 kwh of storage.

OUTPUT

Electricity of 60 Hz, 120 volt AC is available with a steady state frequency control regulated to ± 1%. The voltage of the AC generator is self regulated to within ± 5%.

INNOVATIONS AND RESULTS

: Electric machines and control were combined to produce 60 Hz AC.

: Different kinds of rotors can be installed on the tower without affecting performance.

: Students modified the hub to allow adjustable pitch control.

: Ground mounted electrical equipment allows easy maintenance or change in electrical system.

: The tower and electrical control system were designed and implemented by students.

SCHOOL: University of Houston, Houston, Texas 77004
TEAM NUMBER: 26 TEAM CAPTAIN: Reed Collins
FACULTY ADVISOR: Prof. Arthur Paul
TELEPHONE: (713) 749-2546

PROJECT SUMMARY

Six east-west semifocusing collectors connected in series heat the working fluid (water) to 93°-98° C (200°-210° F). This heated water is stored in a water storage tank or can be used to run an airconditioning unit.

INPUT COMPONENT

Each flat collector 88.9 cm x 195 cm x 16.9 cm (35 in. x 77 in. x 6.5 in.) contains ten 7.62 cm (3 in.) wind trapezoidal grooves with highly reflective side-walls made of bent anodized polished aluminum sheets. The absorer is copper tubing running serially between each groove. The collector boxes are made of galvinized steel and the two cover plates are glass.

STORAGE

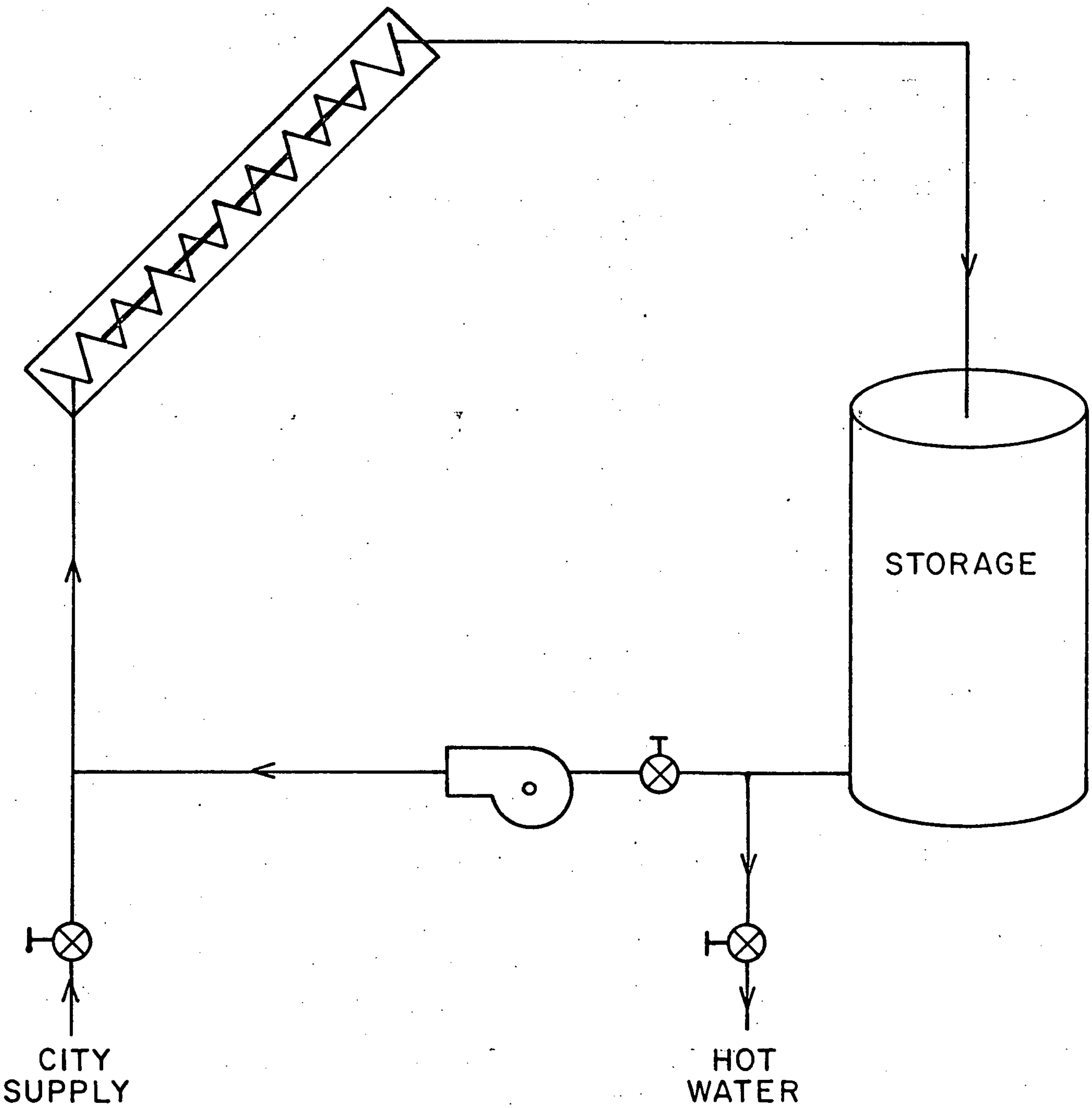
A tank was used to store the water.

OUTPUT

Hot water at 93°-98° C is available from the storage tank.

INNOVATIONS AND RESULTS

: The collectors were designed and built by students.
: High collector outlet temperatures, capable of running an airconditioning unit were produced using the trapezoidal groove concept.
: The project emphasized construction simplification for the collectors.
: The collectors were designed to operate a Sol-air airconditioning unit.


STORAGE
CITY SUPPLY
HOT WATER

SCHOOL: University of Houston, Houston, Texas 77004
TEAM NUMBER: 27 TEAM CAPTAIN: James Smith
FACULTY ADVISOR: Prof. Arthur Paul
TELEPHONE: (713) 749-2546

PROJECT SUMMARY

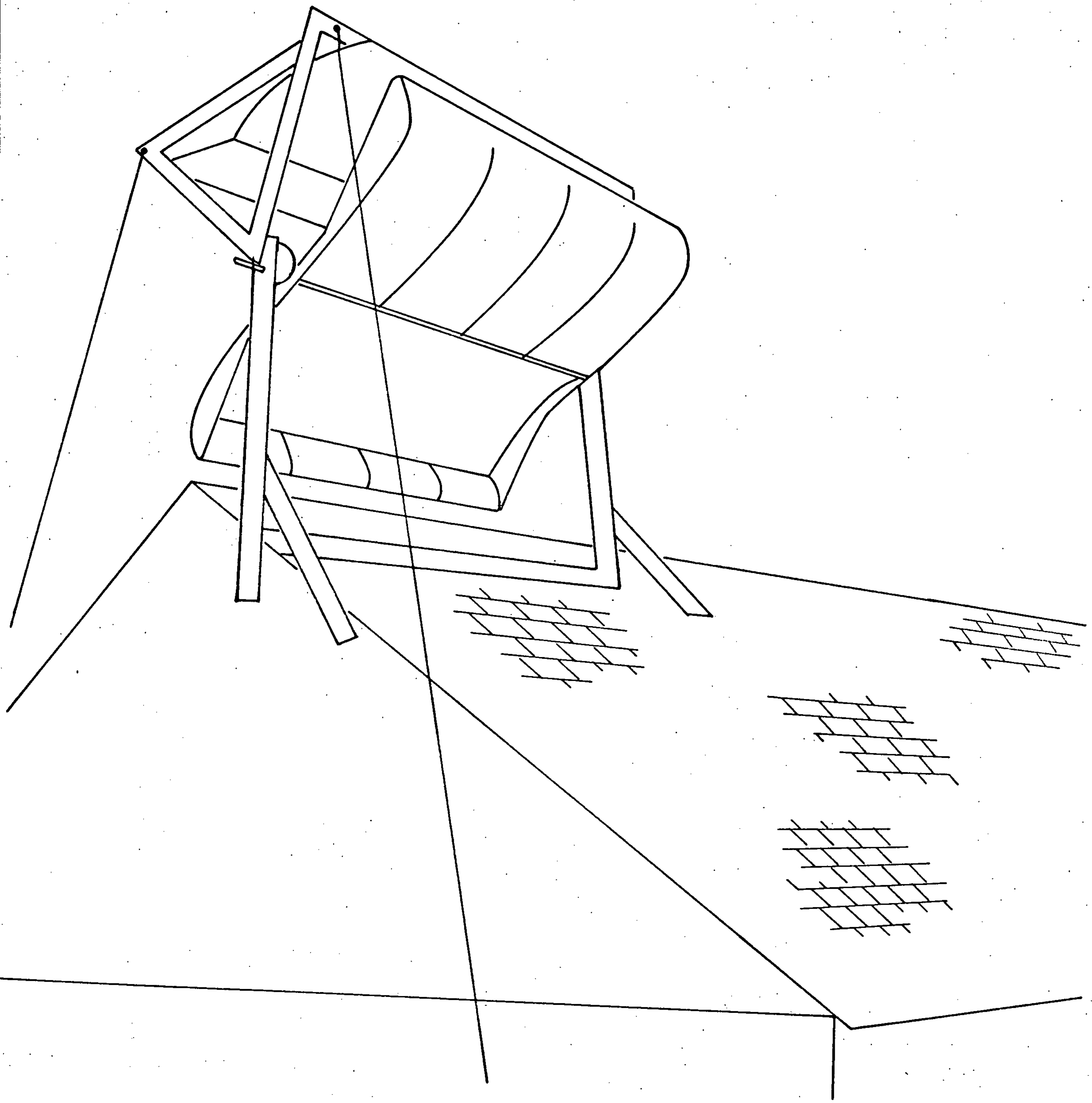
The roof mounted, shrouded Horizontal Savonius rotor turns a 12 volt DC automobile generator. Electrical energy is stored in three 12 volt automobile batteries. An inverter is used to produce 60 Hz, 110 volt electricity. This project is most useful where there is a prevailing wind from one direction.

INPUT COMPONENT

This horizontal Savonius rotor has two blades made of corrogated aluminum sheets 2.44 m (96in.). The blade diameter is 2.29 m (90 in.). A top shroud increases the effective blade area. A mechanical crank controls the shroud for shut down in high winds. This machine is mounted on the down wind side of the roof peak.

INNOVATIONS AND RESULTS

: This design uses the roof of a house to increase effective area.
: Wind tunnel tests showed a 40° angle roof gave best results.
: The rotor comes in light weight 2.44 m (8 ft.) modular sections.
: Wind tunnel tests showed that a three bladed Savonius has little advantage over a two bladed model.
: Top shroud can close to control speed.
: No rotor end cups allow air to fill partial vacum in the trailing tube.
: The rotor was designed and built by students.



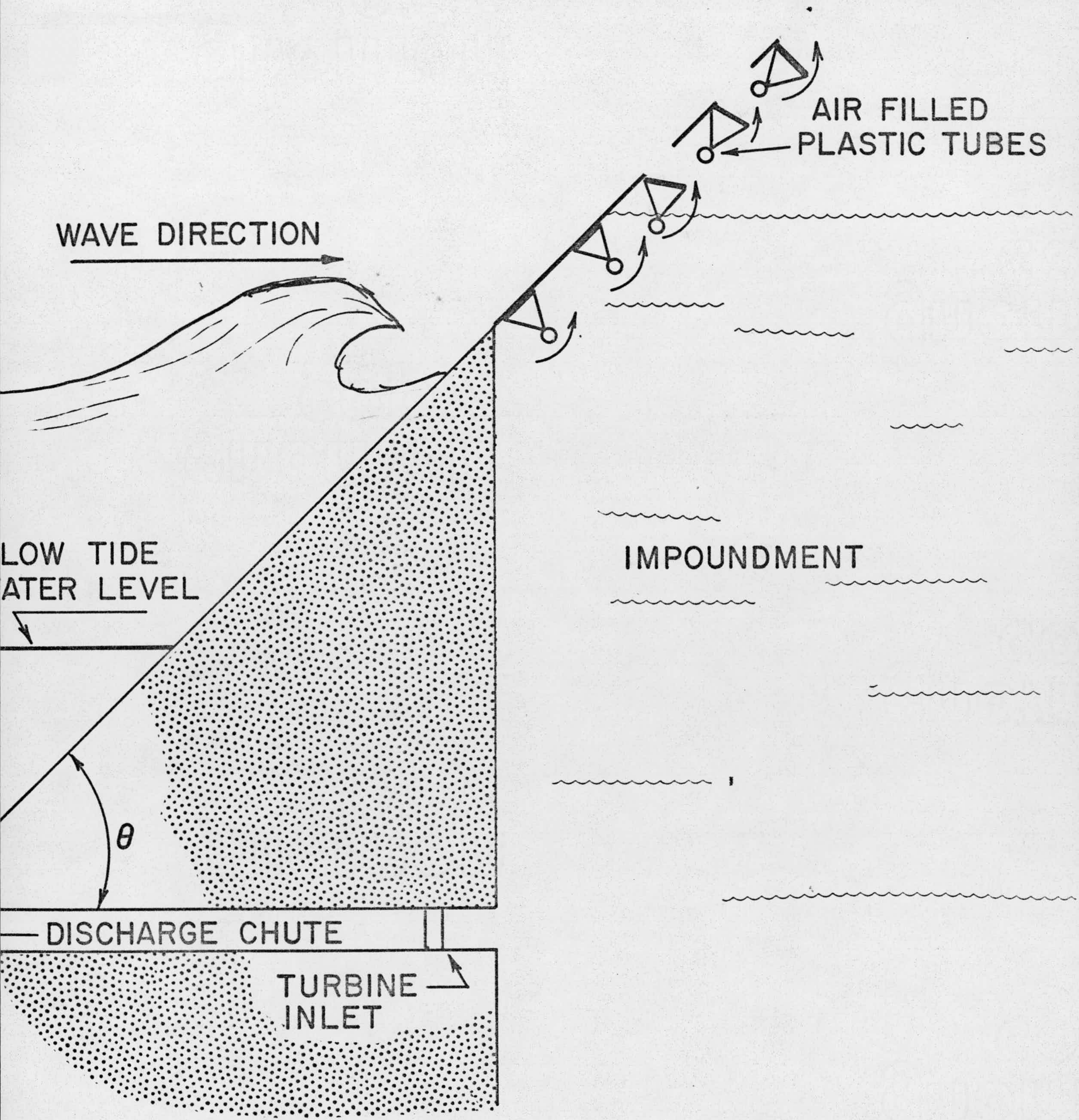
SCHOOL: University of Houston, Houston, Texas 77004
TEAM NUMBER: 28 TEAM CAPTAIN: Raymond Payne
FACULTY ADVISOR: Prof. Arthur Paul
TELEPHONE: (713) 749-2546

PROJECT SUMMARY

An inclined plane placed below the surface of the water can make a wave higher by a factor of x times the height of the built up wave above still water depth, thus increasing its potential head. A series of trap doors installed on the surface of the runup plane allows the water to flow into an impoundment. The trap doors automatically close when water inside reaches that height so this keeps the water in the impoundment at various higher levels than the surrounding still water. A turbine can operate from this low potential head to produce electricity.

INNOVATIONS AND RESULTS

: A trap door design that can automatically adjust for different inside water heights.
: Innovative concept of building up wave heads to capture the kinetic energy in the form of potential energy.
: Ocean tests showed a build up factor of over three times the wave height for 41.5° and 33° ramps in stillwater depths of 45.7 cm (18 in.) and 53.3 cm (21 in.).
: Tests showed an offshore current running parallel to the shore can increase the apparent potential head by creating a venturi suction at the exudor of the discharge chute.


AIR FILLED
PLASTIC TUBES
WAVE DIRECTION
LOW TIDE
ATER LEVEL
IMPOUNDMENT
θ
DISCHARGE CHUTE
TURBINE
INLET

SCHOOL: University of Houston, Houston, Texas 77004
TEAM NUMBER: 29 TEAM CAPTAIN: John Lupear
FACULTY ADVISOR: Prof. Arthur Paul
TELEPHONE: (713) 749-2546

PROJECT SUMMARY

The downwind three bladed windmill transfers power to a belt and pulley system. A generator connected to the pulley generates electric power. The wires pass down the center of the tower consisting of interchangeable aluminum pipes. The battery series is charge from the electric power. An inverter supplies AC power.

INPUT COMPONENT

The three 2.44 m (8 ft.) blades are made of honeycomb wood covered with fiberglass. The design is a modified cutta foil with a wing tip at the end of the blade for an airbrake. The hub is a car front wheel assembly with the brakes operating for emergency shutdown. The generator is an ONAN DC generator.

STORAGE

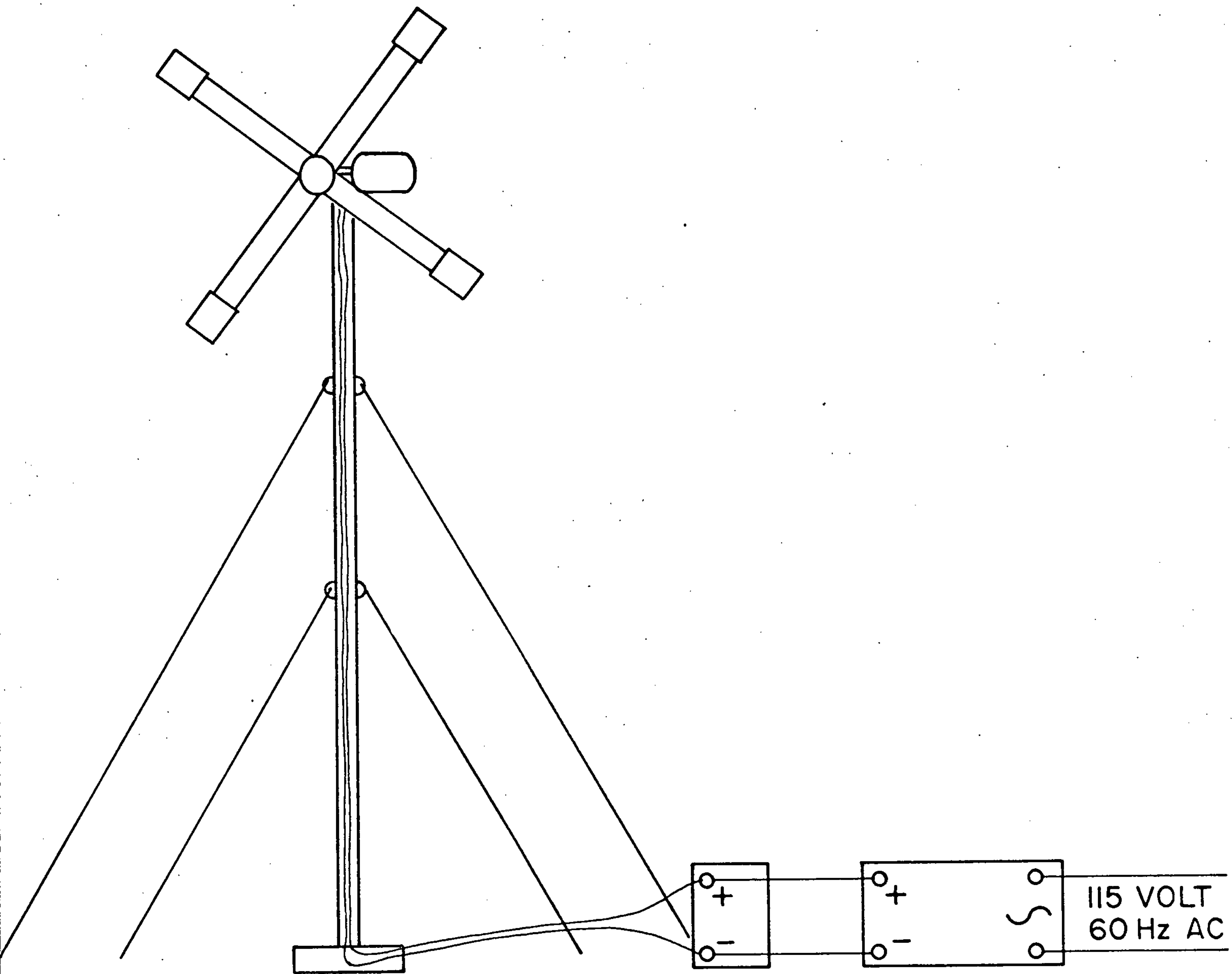
Three batteries are connected in series.

OUTPUTS

A 500 watt inverter produces AC power from the batteries. 32 volt DC power can be obtained directly from the battery terminals.

INNOVATIONS AND RESULTS

: The blades and portable tower were designed and built by students.


+
−
+
−
115 VOLT
60 Hz AC

SCHOOL: University of Oklahoma, Norman, Oklahoma 73069
TEAM NUMBER: 30 TEAM CAPTAIN: William Bohon
FACULTY ADVISOR: Prof. John Francis
TELEPHONE: (405) 325-5011

PROJECT SUMMARY

A parabolic cylindrical focusing solar collector heats water in a pressurized system to 204° C (400° F). The closed collector-storage loop is maintained at 250 psi allowing high quality energy storage in a low volume. Working fluids are passed through heat exchangers within the storage tank to produce steam. The steam can be used for space heating, heating a domestic hot water supply, steam cooking, space cooling by means of a absorption refrigeration unit, or for powering a steam powered go-cart.

INPUT COMPONENT

The collector has a silvered glass michrosheet supported by a sprayed chopped-fiberglass backing. Five modular collector panels 54.5 cm (21.5 in.) wide are bolted together. The aperature is 1.58 m (62 in.), the focal length is 39.4 cm (15.5 in.) and the target tube is 1.27 cm (1/2 in.) in diameter giving a concentration ratio of 124:1. The target is a thin walled tube capable of withstanding 250 psi. Modular coaxial glass vacuum jackets slide over the target for insulation. The tracking system is driven by a small electric motor controlled by a photo-sensitive transistor at the bottom of a light well.

STORAGE

Five high pressure storage tanks each of .016 m^3 (1000 $in.^3$) capacity have an inside diameter of 15.24 cm (6 in.). Operating between 204° C (400° F) and 21.1° C (70° F) saturated liquid water can store 782 J/g (336 Btu/lb m). A second shell is around the inner tank and the space between them is evacuated for insulation. A 56.8 liter (15 gal.) galvanized vacum tank is used for the domestic hot water storage. A pump is activated when the temperature falls below 65.6° C (150° F).

OUTPUTS

Domestic hot water is available from the hot water tank and steam is fed to a special saucepan for cooking.

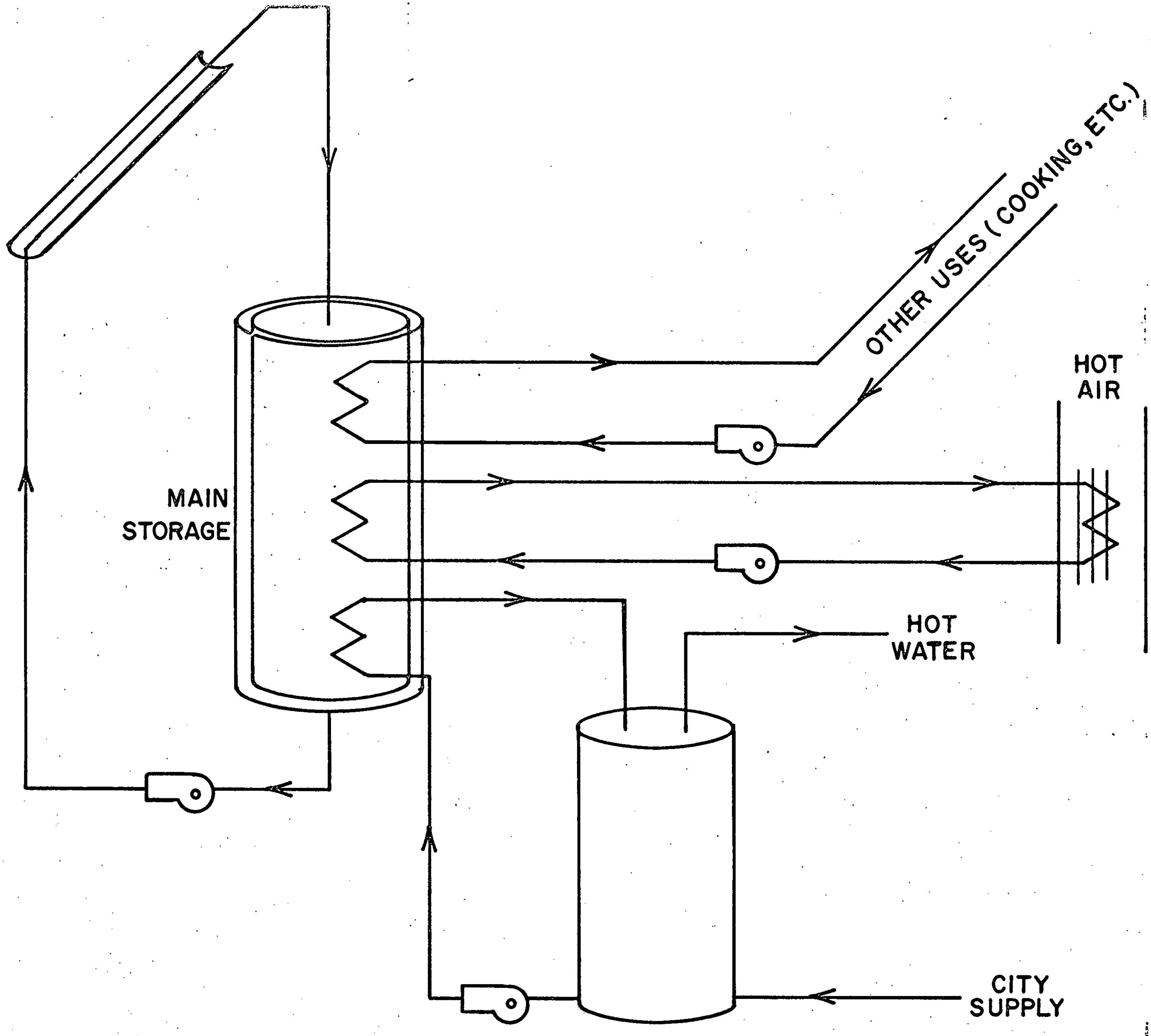
INNOVATIONS AND RESULTS

: The system operates at 250 psi to allow for 204° C water storage.

: The collector, high pressure storage system, steam saucepan, and go-cart were student designed and built.

: Worked on manufacturing simplification employing such features as sprayed chopped-fiberglass backing, glass michrosheet, modular collector construction, and short glass vacuum jackets.

: Modified a two cylinder, four cycle gasoline engine to run on steam for a demonstration go-cart.


OTHER USES (COOKING, ETC.)
HOT
AIR
MAIN
STORAGE
HOT
WATER
CITY
SUPPLY

SCHOOL: University of Oklahoma, Norman, Oklahoma 73069
TEAM NUMBER: 31 TEAM CAPTAIN: Jerome Sartor
FACULTY ADVISOR: Prof. K. Bergey, M. Jischke
TELEPHONE: (405) 325-5011

PROJECT SUMMARY

A two bladed downwind "WINDY SOONER" drives a 42 volt DC generator through 9:1 ratio helical gear reducer. This power is used to heat water. Some of it is used to generate 60 Hz electricity by means of a solid state inverter.

INPUT COMPONENT

Each 1.52 m (5 ft.) blade is casted of solid plastic using a GA(W)-1 airfoil geometry. A mechanical control system, directed by two fly ball arms, pitch the blades at different wind velocities. The modified Hobart generator supplies up to 125 amp at 42 volts DC and weighs 138 kg (305 lbs.). A control system changes the field current to optimize the output voltage profile with respect to wind speed. This optimizes the power output of the windmill for maximum loading. The windmill is supported by a metal cap on top of a guyed 23 cm (9 in.) diameter wooden utility pole.

STORAGE

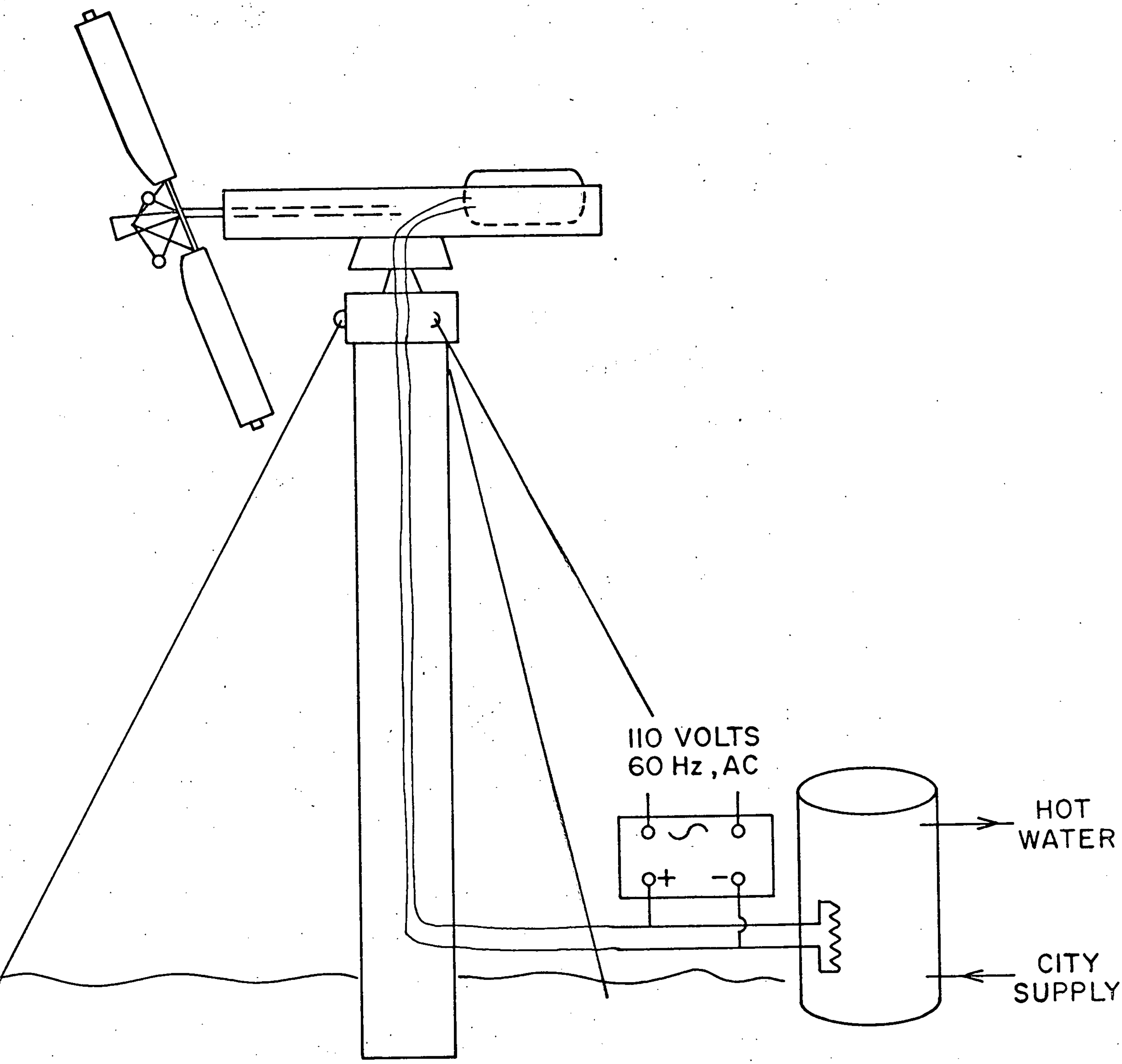
Two 208 liter (55 gal.) tanks are used to store the hot water.

OUTPUTS

Up to 500 watts of AC power is available from an inverter and domestic hot water and some space heating is available from the storage tanks.

INNOVATIONS AND RESULTS

: Blades, pitch control, tower structure, and output control were designed and built by students.
: DC generator was student modified to reduce its weight.



110 VOLTS
60 Hz , AC
+
−
HOT
WATER
CITY
SUPPLY

SCHOOL: University of California-Berkeley
Berkeley, California 94720
TEAM NUMBER: 32 TEAM CAPTAIN: Donald Parker
FACULTY ADVISOR: Prof. C. Miller
TELEPHONE: (415) 642-4933

PROJECT SUMMARY

A set of fixed angle plate collectors collects energy and passes it to the paraffin wax storage. Near constant temperature water passes from the storage tanks to the water to air heat exchanger used by the forced air heating system. The control system, consisting of two tryak circuits, determines the position of the three solenoid valves and the on/off state of the system pump.

INPUT COMPONENT

Five .93 x 2.5 m (3.05 x 8.22 ft.) collector panels have black painted aluminum Roll-Bond absorbing surfaces. Each collector glazing consists of 24 clear glass tubes, each 3.81 cm (1.5 in.) in diameter and 2.48 m (8 ft.) long. 2.54 cm (1 in.) solid polyurethane is layered for insulation and for mounting the glass tubes. The collector casing is plywood and the system working fluid is 1% sodium silicate in water.

STORAGE

The 1.18 m (45.5 in.) long x 49.5 cm (19.5 in.) x 1.24 m (48.7 in.) high plywood storage container is lined with fiberglass resin and is filled with paraffin wax. Galvinized steel heat exchanger panels, similar to the Roll-Bond absorber surface, form the storage heat exchangers. The exit fluid has a near constant temperature of 50° C- 65° C (122°F- 149° F). This is the temperature range where the wax releases energy with a heat of fusion of 167 J/g (40 cal/g). Another release temperature is between 30°C-40° C (86° F-104° F) where 50 J/g (12 cal/g) is released.

CONTROL SYSTEM

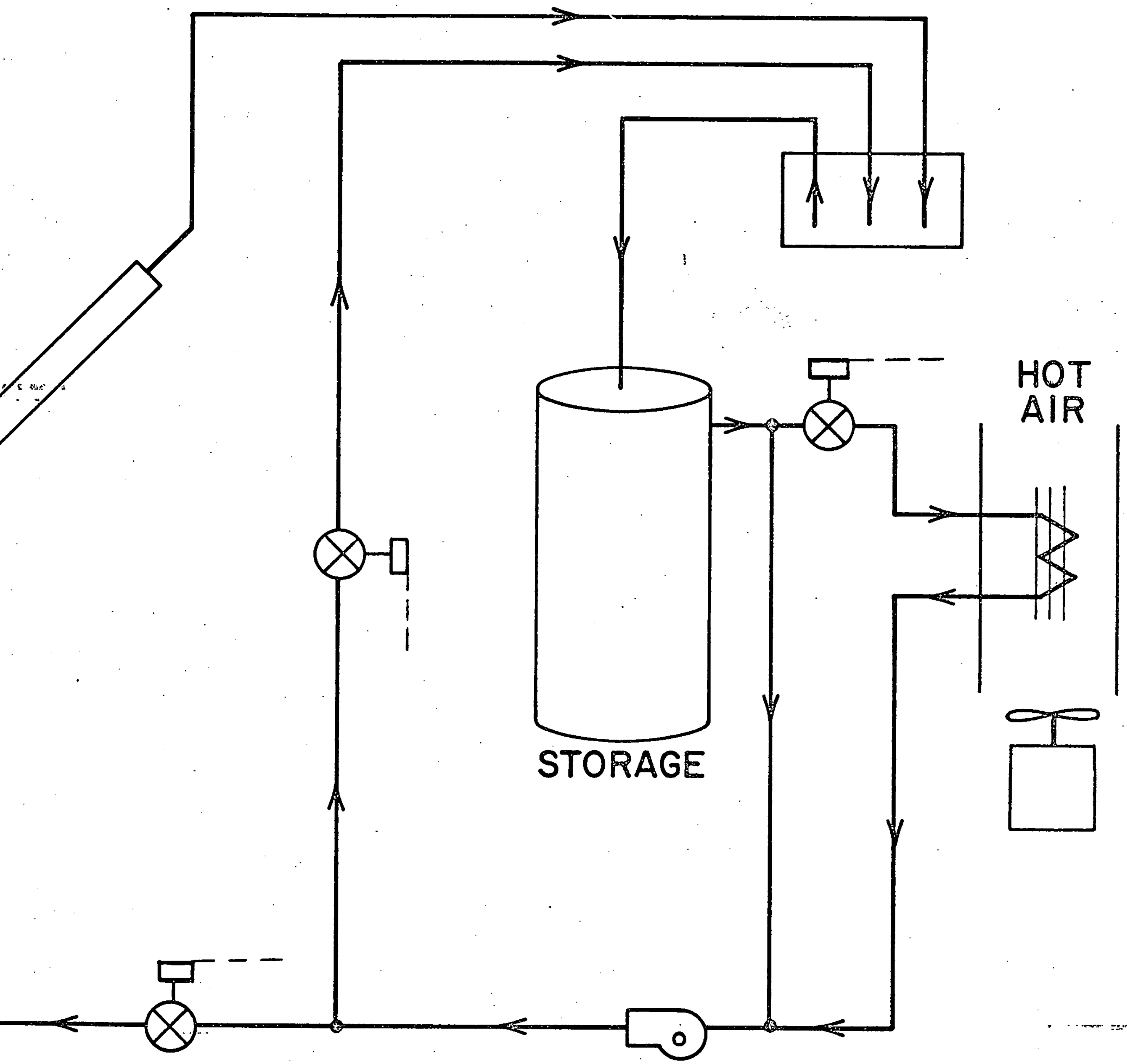
Two tryak circuits compare temperatures from thermistors and control the pump and solenoids if the temperature differential is high enough. When the temperature between the fluid in the collector and the fluid in the storage is above a certain limit, the first tryak energizes a relay that turns on the water pump, opens the collector line solenoid, and closes the collector by-pass solenoid. The second tryak circuit opens the solenoid to the water-to-air heat exchanges and activates the fan when the temperature difference between the house and the storage tank is high enough. The solenoid valves use 24 volts for safety.

OUTPUT

The forced air heating has a constant speed fan blowing across a water-to-air heat exchanger.

INNOVATIONS AND RESULTS

: The project emphasized low cost.
: Clear tubing for $4.62/m^2 (\$.43/ft.^{2}), including shipping, is used for glazing.
: Heat of fusion of paraffin wax is used to store 40 cal/g over the temperature range of 50°C-65°C.
: Studies showed cheap glazing replacement because not all tubes would break at one time.
: Tests showed no super cooling problems with paraffin because it solidifies over a range of 10°C-15°C (50°F-59°F).
: The collectors, storage, and control system were entirely student designed and 90% student built.


HOT
AIR
STORAGE

SCHOOL: Rennssalaer Polytechnic Institute
Troy, New York 12181
TEAM NUMBER: 33 TEAM CAPTAIN: William Rogers
FACULTY ADVISOR: Prof. F.J. Bordt
TELEPHONE: (515)270-6545

PROJECT SUMMARY

The bank of 350 mirrors focuses the sun into a boiler unit and produces superheated steam. This steam powers a steam turbine/generator producing electricity. The steam would then pass through a heat exchanger and heat water to be used for domestic hot water and space heating. The condensed steam is recycled through the boiler feed pump back to the boiler.

INPUT COMPONENT

Sixteen mirrors, each 17.8 cm x 17.8 cm (7 in. x 7 in.) are fastened to each of 22 aluminum downspouts each 3.05 cm (10 ft.) long. Tabs were cut out and bent to hold the individual mirrors and carpet tape was used to fasten the mirrors to the tabs. The shafts, 20.3 cm (8 in.) pieces of stainless steel tubing, were attached to the bent closed ends of the aluminum columns and were set in nylon bearings. Each column is connected to the control link via an arm and aluminum bracket. A small motor powers the control line through a 2 million to 1 gear reduction.

Three 6.1 m (20 ft.) lengths of 6.35 cm (2.5 in.) galvanized electrical tubing froms the adjustable tripod tower structure. A hand operated hoist raises the boiler to the apex of the tripod. The boiler is a 20.3 cm (8 in.) hollow sphere made of .95 cm (3/8 in.) material. One 45.7 cm (18 in.) long, 2.54 cm (1 in.) diameter stainless steel tube feeds the boiler and 24 3.18 mm (1/8 in.) diameter tubes, 1.83 m (6 ft.) long leave the boiler from the top and wind around the boiler until they end in a header and relief valve. A flux trap in front of the boiler redirects any improperly aimed solar radiation into the boiler cavity. An inverted garbage can contains fiberglass insulation and houses the boiler.

OUTPUT

Electricity is generated using the superheated steam to run a turbine. A heat exhanger condenses the steam by heating water up to be used for domestic hot water.

INNOVATIONS AND RESULTS

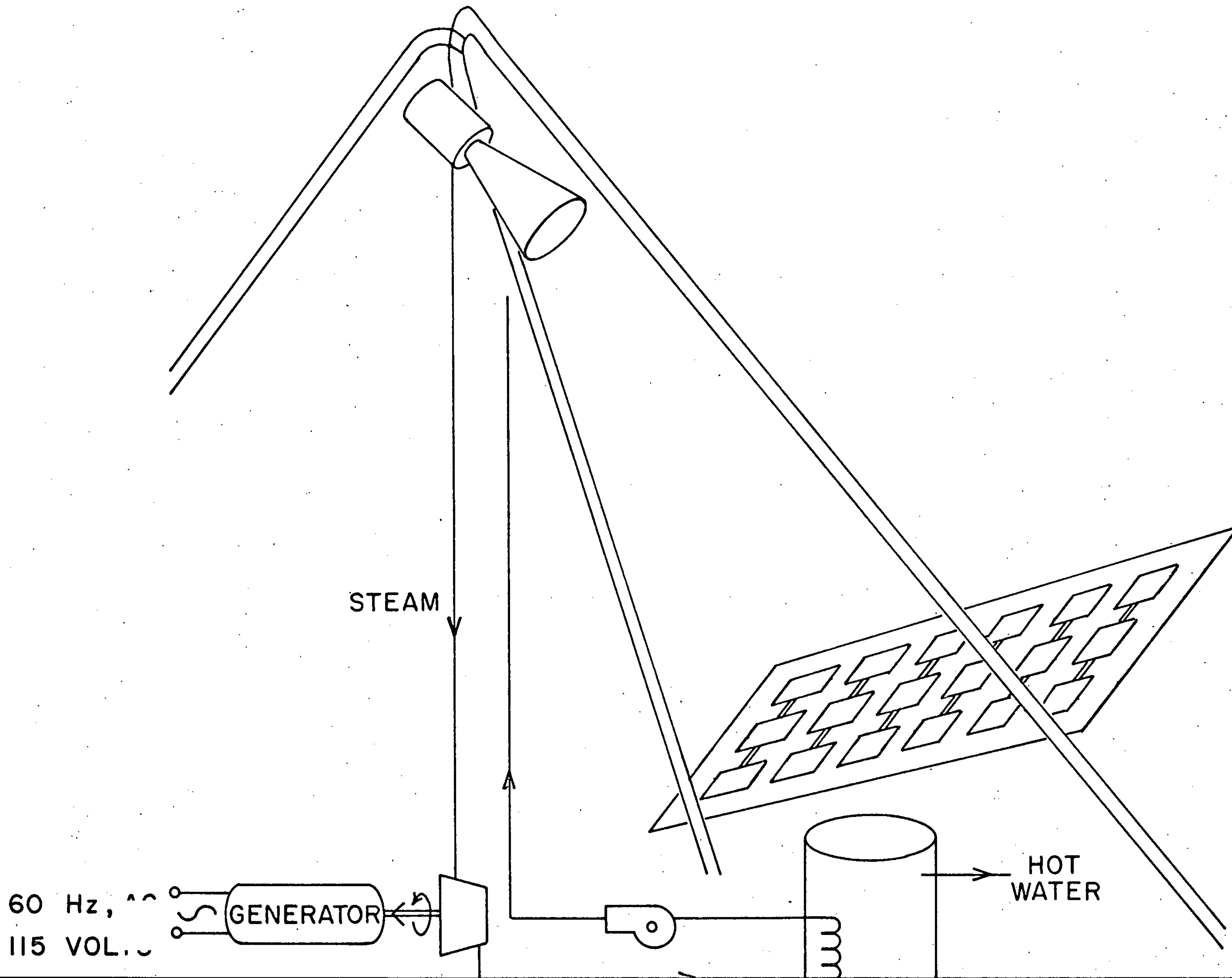
: The project is innovative as applied to a small application.

: The mirror array, control link, tower, and boiler were designed and built by students.

: The tower's south leg is hinged to allow seasonal adjustments.

: A mechanical control system controls the focusing of all the mirrors throughout the day.

: The team studied a salt storage system.


STEAM
HOT WATER
GENERATOR
60 Hz,
115 VOL

SCHOOL: University of Wisconsin-Madison
Madison, Wisconsin 53706
TEAM NUMBER: 34 TEAM CAPTAIN: Ken Kriesel
FACULTY ADVISOR: Prof. Ali Seireg
TELEPHONE: (608) 262-3594

PROJECT SUMMARY

Powdered coal is fed into a modified oil furnace with an auger system. The auger unit is fed from a hopper/storage tank. The rest of the furnace operates the same except the flue gases flow into two scrubbers in series which remove the ashes and pollutants. The scrubbed gases then pass to the chimney. A residue container collects the ash and sludge while the scrub water flows to the drain line or water treatment and recirculating unit.

INPUT COMPONENT

The coal hopper/storage container is 61 cm (24 in.) in diameter and 76.2 cm (30 in.) high with a conical bottom for delivering the coal to the auger. The auger is built from a 1.27 cm (1/2 in.) steel rod with a 3.17 mm (1/8 in.) wire coiled around it. A 28 volt, 1/8 hp universal motor rotates the auger through a gear reduction at 120 rpm and delivers .92 g/s (7.32 lb/hrs) of coal. The screw is in a tube 76.2 cm (30 in.) long x 1.98 cm (25/32 in.) inside diameter. A water coil, using 5.26 ml/s (5 gals/hr) cools the end of the auger and tube inside the furnace, thus preventing coking of the coal or tar buildup. An 18.9 liter (5 gal.) drum holds heating oil which is used for the 30 second start up.

SCRUBBER

Each of the two cyclone scrubbers is a 208 liter (55 gal.) drum with a conical bottom. Flue gases enter at the side of the first drum and leave at the center of the top. A torus made of a 9.53 mm (3/8 in.) copper tube has .38 mm (.015 in.) diameter holes drilled at 7.52 cm (3 in.) intervals. This provides 26.3 ml/s (20 gal/hr) to scrub the gases. The second identical scrubber condenses the water vapor, collects any suspended particles missed in the first scrubber, carries more heat away from the flue gases, and acts as a reserve compartment for additional spray for coal with unusually high ash content. Pressure drops across the scrubbers are accounted for by incorporating an exhaust fan at the exit of the second scrubber.

OUTPUT

The forced air system delivers 69 MJ/hr (65.4 KBtu/hr).

INNOVATIONS AND RESULTS

: Uses coal for heating a home with little pollution effects.

: Automatic controls as in conventional furnaces.

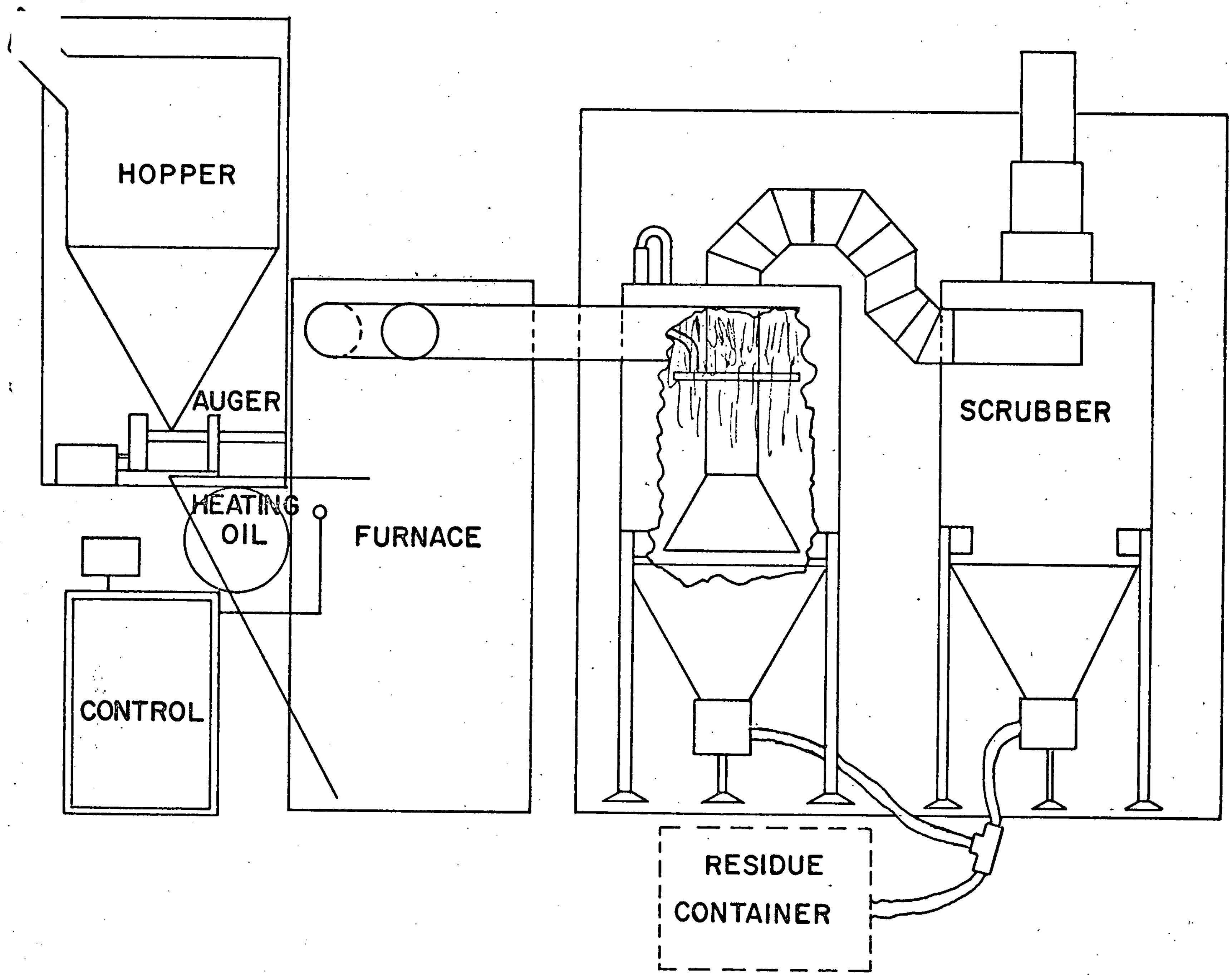
: Can be cheaply retrofitted into houses with oil furnaces.

: Variable motor control accomodates different grades of coal.

: Scrubber tests showed very effective fly ash removal.

: Students modified an oil furnace for this project.

: The scrubbers, auger, and control system were completely designed and built by students.


HOPPER
AUGER
HEATING
OIL
FURNACE
CONTROL
SCRUBBER
RESIDUE
CONTAINER

SCHOOL: Michigan State University, East Lansing, Michigan 48832
TEAM NUMBER: 35 TEAM CAPTAIN: James Militello
FACUTLY ADVISOR: Prof. H.R. Zapp
TELEPHONE: (517)355-5211

PROJECT SUMMARY

This multi system project incorporates four different solar collectors and two different windmills. The collectors pass heat to either a hot water storage or stearic acid storage. Hot tap water and forced air space heating outputs are obtained from the hot water storage tank, fed by solar energy on sunny days and by stearic acid or resistive heating on cloudy days. The vertical axis Darrieus and the horizontal three-bladed conventional wind machine drive voltage alternators for direct use or for storage in batteries. A minicomputer monitors all parts of the system and controls energy allocation for the entire system.

INPUT COMPONENTS

A 1.22 m x 2.44 m (4 ft. x 8 ft.) steel collector plate with copper tubing and a .9 m x 3 m (3 ft. x 10 ft.) copper collector plate with copper tubing both have 10 cm (4 in.) of fiberglass insulation, Black Velvet painted plates, and a serpentine tube design. Tedlar was mounted on a heavy duty screen door for the glazing. A quilted unfinished "Tranter" steel collector plate was painted and enclosed in a frame for comparison purposes. A flat plate concentrator collector uses three 1.22 m (4 ft.) etched evacuated pyrex tubes with black painted copper tubing inside. A reflector is under each glass tube. A three-bladed horizontal axis wind generator uses the blade design of an Australian Dunlite machine. Each 1.65 m (5.5 ft.) blade is mounted on a fixed pitch hub that has a turnaway feathering system. This feathering system uses the gravitational force on the tail vane to turn the blade plane away from the wind direction. A Leece-Neville alternator rated at 14 volts, 75 amps is driven via a 9.86:1 double step-up timing belt drive system. Rectangular aluminum troposkien blades were built for a Whirlpool (14 ft.) Darrieus wind turbine. A 7:1 step-up belt drives a 125 volt DC generator. The Darrieus starts by operating the generator as a motor under computer control.

STORAGE

340 kg (750 lbs) of stearic acid with a melting point at 68.2°C (154°F) and a heat of fusion of 43.4 J/g (18.7 Btu/lb) were melted into two 208 liter (55 gal.) drums. Each drum utilizes 30 m (100 ft.) of copper tubing for a heat exchanger and 2.5 cm (1 in.) layer of styrofoam. A large lead-acid battery stores electrical energy as 12 volts or 24 volts. The hot water tank is a modified 208 liter (55 gal.) drum.

OUTPUTS

The battery storage provides 12 or 24 volt power and 110 volt power is available from an inverter. Hot water and space heating are obtained from the hot water storage tank.

INNOVATIONS AND RESULTS

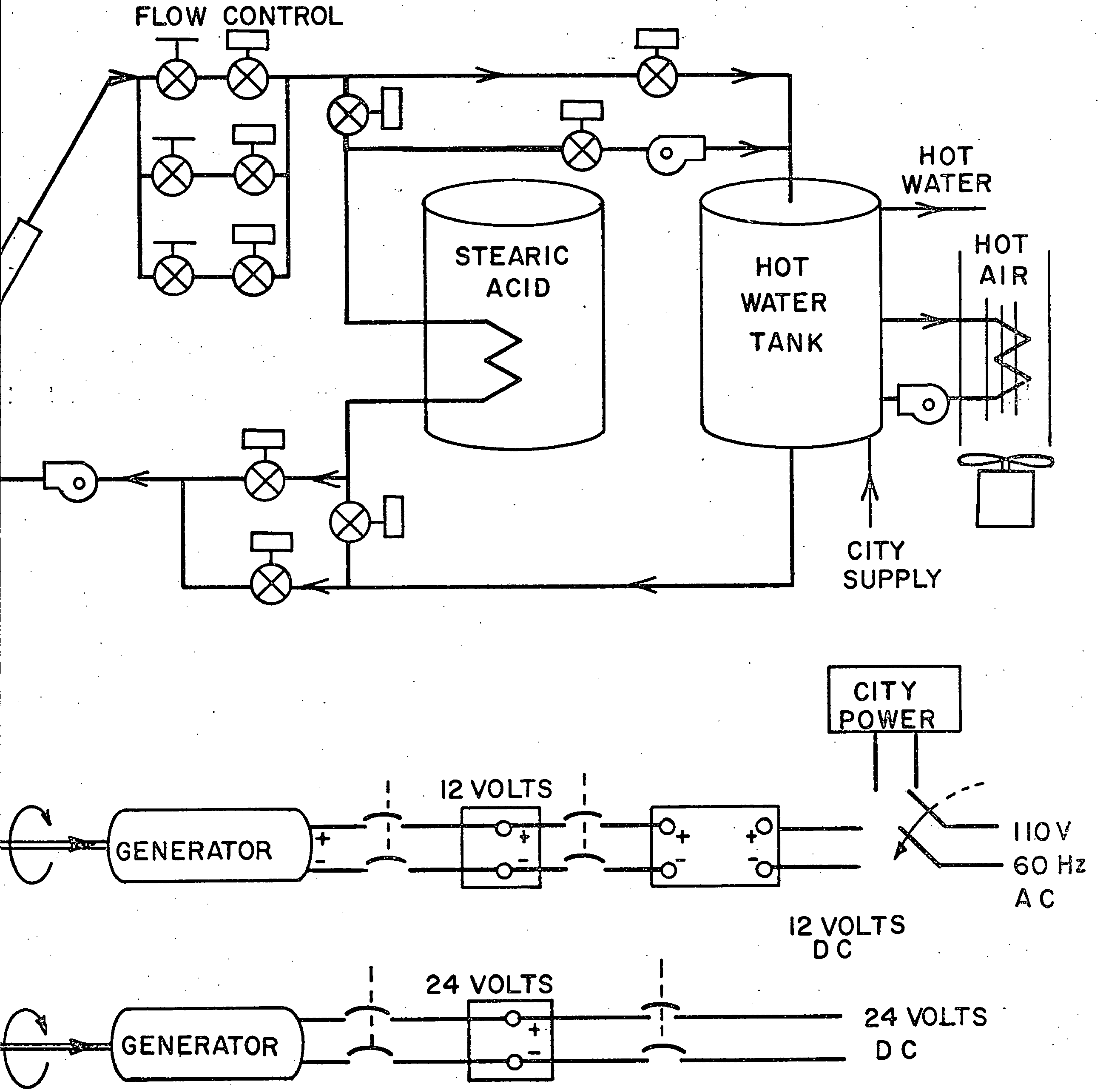
: The team also did development work on wind powered electrolysis, hydrogen storage in La-Ni-5 hydride bed, and underwater hydrogen burning for heating hot water.

: The team also designed and built a methane generator with a plastic diaphragm top to produce gas for home cooking needs.

: Designed and built two small concave solar ovens for demonstration purposes.

: The team used an Alpha LSI-2 minicomputer to monitor all energy inputs and flow rates and regulate flow. The information will eventually allow a program to allocate energy for the entire system.

: The horizontal windmill, collectors, storage, and control system were designed and built by students.



FLOW CONTROL
STEARIC ACID
HOT WATER TANK
HOT WATER
HOT AIR
CITY SUPPLY
CITY POWER
GENERATOR
12 VOLTS
110 V
60 Hz
A C
12 VOLTS
D C
GENERATOR
24 VOLTS
24 VOLTS
D C

SCHOOL: University of Alabama in Huntsville
Huntsville, Alabama 35807
TEAM NUMBER: 36 TEAM CAPTAIN: D.G. Green
FACULTY ADVISOR: Profs. D.B. Wallace and J.J. Brainerd
TELEPHONE: (205) 895-6323

PROJECT SUMMARY

Parabolic-trough collectors heat up a main hot water storage tank, located inside the main tank, allows domestic hot water to be heated before passing to the conventional hot water tank. A standard water to air heat exchanger in a heating duct supplements the heating system using hot water from the main storage tank.

INPUT

52 square meters (560 ft.^{2}) of collector area was constructed. The troughs have wooden housing and curved aluminum sheet metal reflectors. A black pipe at the focal axis serves as the target and the axle. The concentration ratio is 14. The tracking system uses two photo diodes with a sun shield between to control the hydraulic position cylinder.

STORAGE

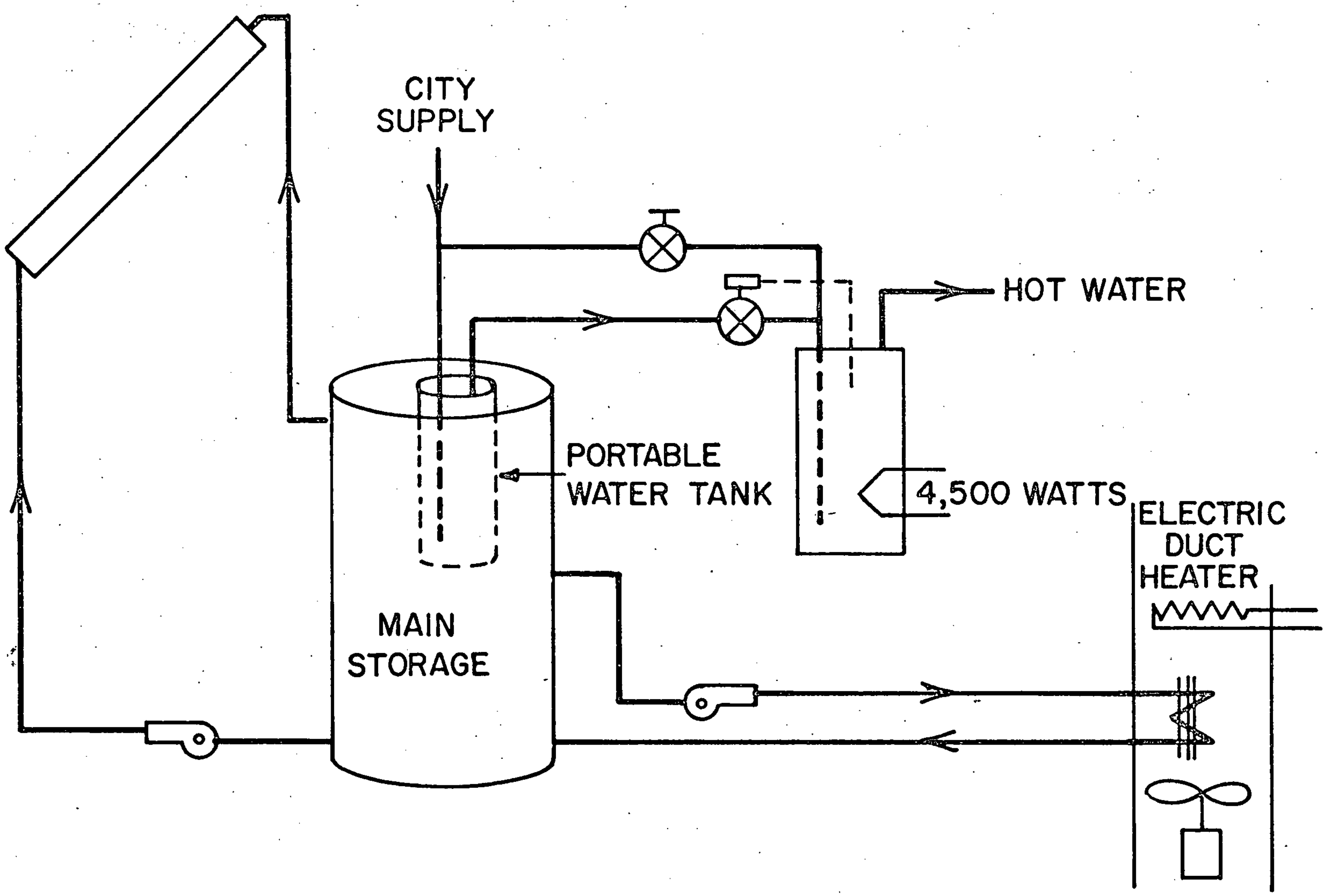
The 1.89 kl (500 gal.) main steel storage tank is insulated with fiberglass batting. The small stainless steel tank has a 113 liter (30 gal.) capacity. Total energy storage capability is 397 MJ (375 KBtu) with a maximum tank temperature of 93.3° C (200° F).

OUTPUT

The fan supplies air at .156 m^3/s (330 cfm) and the water rate is .158 liters/sec (2.5 gpm) through the heat exchanger for the forced air output. Domestic hot water is available from the small storage tank.

INNOVATIONS AND RESULTS

: Collectors and the control system were designed and built by students.
: The students built and tested flat plate collectors before utilizing trough collectors of Team Number 37.


CITY
SUPPLY
HOT WATER
PORTABLE
WATER TANK
4,500 WATTS
ELECTRIC
DUCT
HEATER
MAIN
STORAGE

SCHOOL: University of Alabama in Huntsville
Huntsville, Alabama 35807
TEAM NUMBER: 37 TEAM CAPTAIN: Frank Putman
FACULTY ADVISOR: Profs. S.T. Wu and J.J. Brainerd
TELEPHONE: (205)895-6120

PROJECT SUMMARY

Parabolic trough collectors heat up a main storage tank. This water is pumped to a freon heat exchanger/boiler. The super heated freon vapor powers a turbine. The shaft power from the turbine can run a generator to produce electricity.

INPUT COMPONENT

52 square meters (560 ft.^{2}) of collector area was constructed. The troughs have wooden housing and curved aluminum sheet metal reflectors. A black pipe at the focal axis serves as the target and the axle. The concentration ratio is 14. The tracking system uses two photo diodes with a sun shield between to control the hydraulic position cylinder.

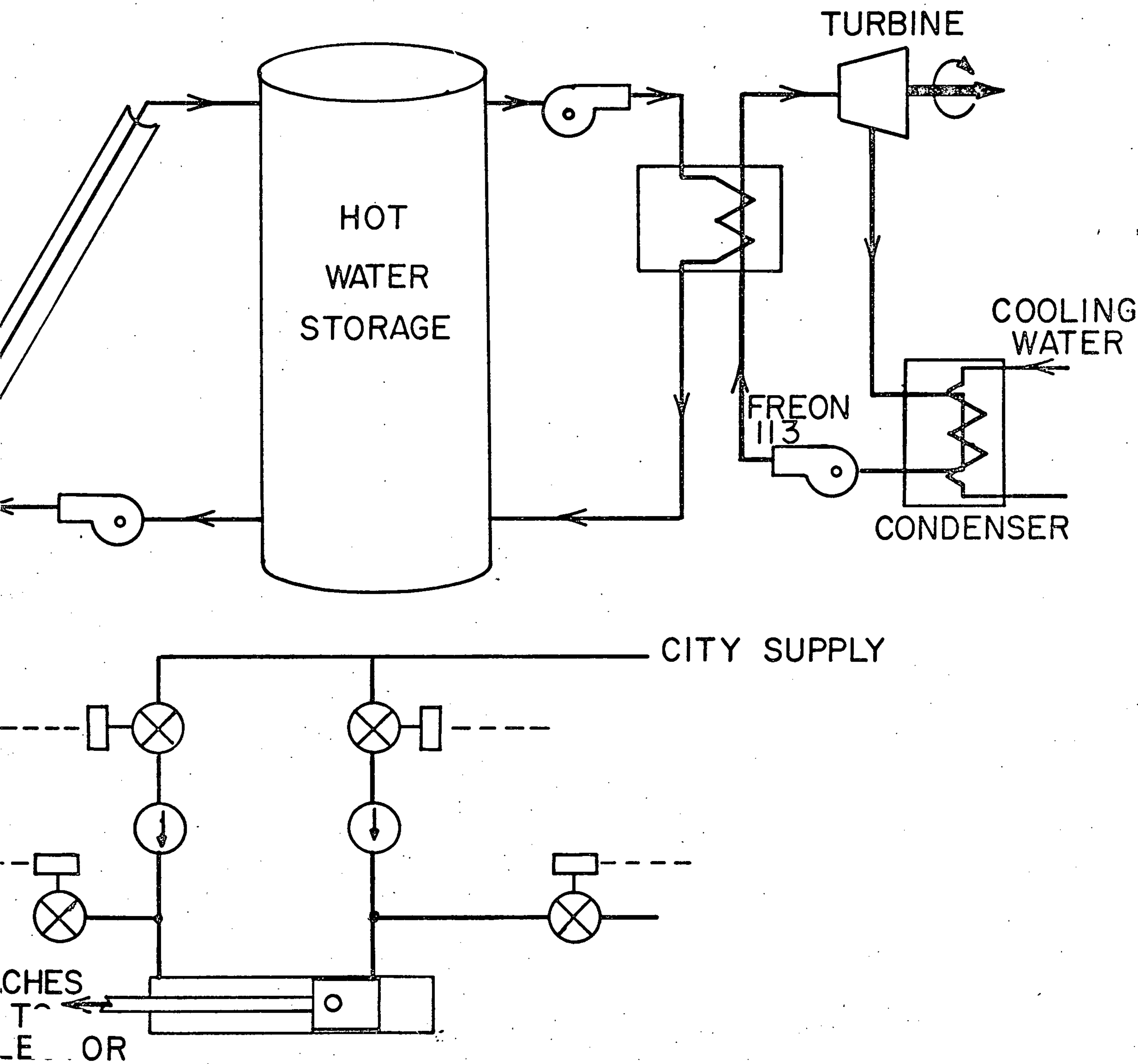
STORAGE

The 1.89 kl (500 gal.) main steel storage tank is insulated with fiberglass batting. The small stainless steel tank has a 114 liter (30 gal.) capacity. Total energy storage is 397 MJ (375 KBtu).

INNOVATIONS AND RESULTS

: Used the city water supply pressure to power the collector tracking cylinder.

: The collectors and tracking system were designed and built by students.



TURBINE
HOT
WATER
STORAGE
COOLING
WATER
FREON
113
CONDENSER
CITY SUPPLY
CHES
T
LE OR

SCHOOL: University of Texas at Austin, Austin, Texas 78712
TEAM NUMBER: 39 TEAM CAPTAIN: Mike Hart
FACULTY ADVISOR: Prof. G.C. Vliet
TELEPHONE: (512) 471-4584

PROJECT SUMMARY

Solar energy from the 8.35 m^2 (90 $ft.^2$) of collectors is stored in a 378 liter (100 gal.) storage tank. This hot water flows to a water to air heat exchanger. This hot air is used for space heating during the winter and the regenerate the desiccant wheel of the dehumidification unit during the summer. The regenerating air must have a high temperature to effectively regenerate the desiccant so additional electric heaters of 3.5 kw and 1.75 kw were added as boosters. The desiccant wheel dries the process air and passes it to an evaporator where it is cooled. The used hot regenerating air passes through a heat exchanger and heats the domestic hot water supply.

INPUT COMPONENTS

The project utilized three different types of flat plate collectors. The first type is a student built .914 m x 1.83 m (3 ft. x 6 ft.) collector called "SCRUB I". The absorber is heavy gauge stainless steel sheets which have been seam welded into 18 equal strips and then expanded at 100 psig to bulge the flow channels. Standard brass fittings and flat black paing (Krylon) finish the absorbers. The cabinet is 18 gauge galvanized steel with aluminum angle used to support two tempered glass covers. 5 cm (2 in.) of styrofoam form the edge insulation and 2.54 cm (1 in.) of fiberglass are in the bottom. Three collecters were made of the "SCRUB II" design, which has plywood cabinets and copper Roll-Bond for absorbing panels. The glazing and insulation are similar to the "SCRUB I" design. One PPG commercial collector was also used in the system.

STORAGE COMPONENT

Two 208 liter (55 gal.) steel barrels were welded together and insulated with an 8.89 cm (3.5 in.) layer of fiberglass followed by a 1 in. polystyrene moisture barrier and another 8.89 cm layer of fiberglass. The tank can store 42.2 MJ for tank temperature changes of 93° C (200° F) to 65.5°C (150° F).

OUTPUTS

The desiccant dehumidification/evaporative cooling system provides up to 14 MJ/day of cooling capacity at .633 m^3/J (70 cfm) of air. When heating, the system has an air flow rate of .047 m^3/J (100 cfm) supplying a maximum of 33.8 MJ/day. By changing some ducting the humidifier can be used in the heating mode. The domestic hot water supplies 13.6 liters/day (3.59 gals./day).

INNOVATIONS AND RESULTS

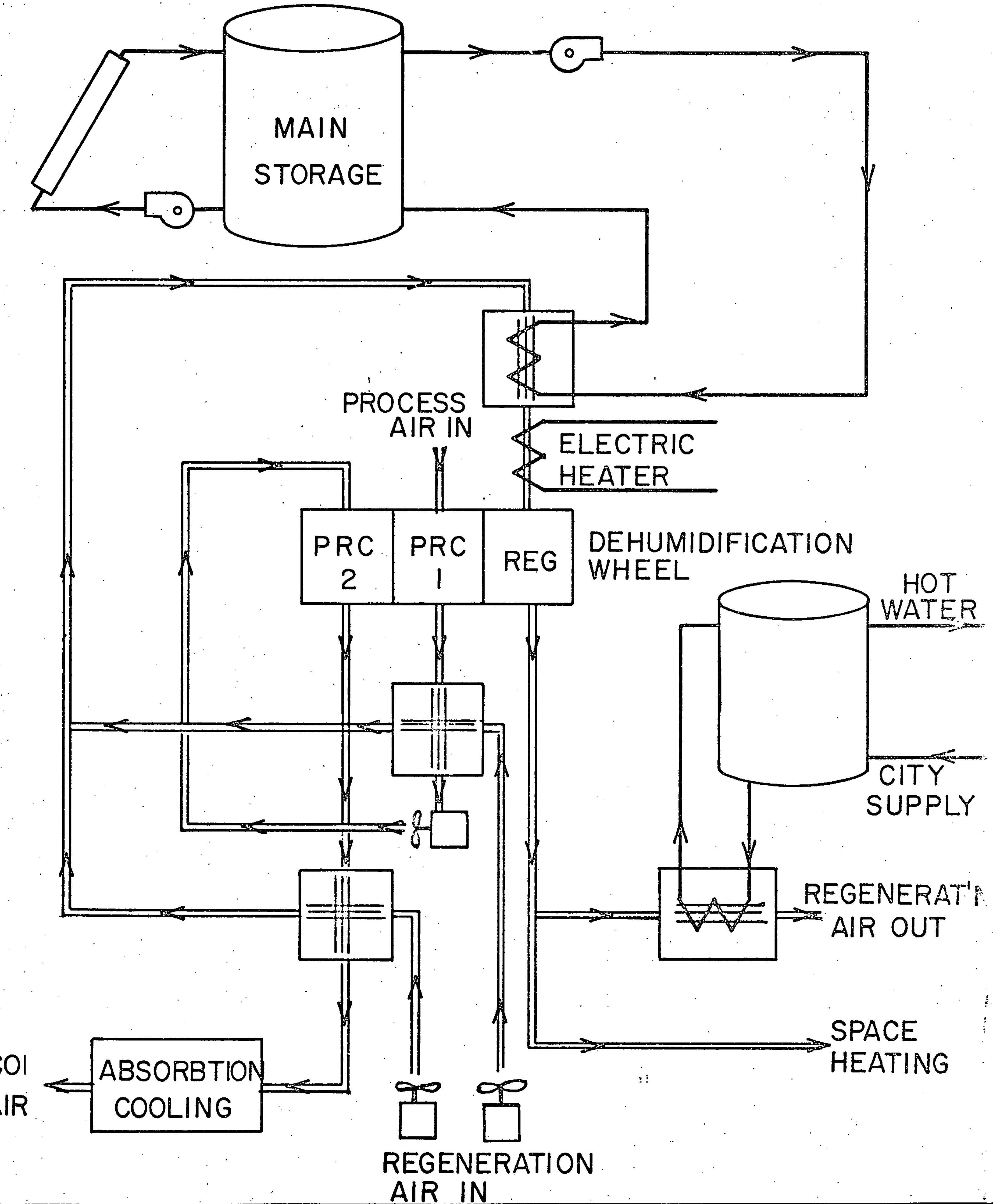
: Used solar energy to produce hot regeneration air for a desiccant dehumidification/evaporative cooling system.

: Students modified the desiccant dehumidifier to allow two parallel passes through the desiccant bed and to provide intercooling for the air in between passes.

: The dehumidifier was modified to perform space heating and humidifying duties also.

: The students developed a solar powered water circulation pump which operated on a Freon Rankine cycle between the temperature difference of the collector input and output. Studies showed the pump would be self starting and self modulating without using an electrical control system and would give a constant outlet temperature.

: The collectors and storage were designed and built by students.


MAIN
STORAGE
PROCESS
AIR IN
ELECTRIC
HEATER
PRC
2
PRC
1
REG
DEHUMIDIFICATION
WHEEL
HOT
WATER
CITY
SUPPLY
REGENERAT'N
AIR OUT
SPACE
HEATING
ABSORBTION
COOLING
REGENERATION
AIR IN

SCHOOL: Carnegie-Mellon University
Pittsburgh, Pennsylvania 15213
TEAM NUMBER: 40 TEAM CAPTAIN: F. Berkheimer,
A. Konnerth III
FACULTY ADVISOR: Dr. Nelson Macken
TELEPHONE: (412) 621-2600, Ext. 243

PROJECT SUMMARY

A Savonius rotor is connected by a belt to an alternator which drives a flywheel. The flywheel drives two automobile alternators with rigidly connected shafts. These alternators have the diodes removed and are series wired to produce high voltage, high frequency, 3 phase AC. A solid state frequency converter creates a 60 Hz single phase square wave regulated to 110 volts.

INPUT COMPONENT

The double stacked Savonius rotor is 3.05 m (10 ft.) high and 1.22 m (4 ft.) in diameter and supported at both ends with a Unistrut steel channel frame. The shaft is a piece of 5.08 cm (2 in.) aluminum tubing 3.05 m (10 ft.) long. Aluminum angle supports the three fiberglass discs of 127 cm (50 in.) diameter. Each of the four fiberglass wings were shaped into a semicylindrical shape with a 33 cm (13 in.) radius. Each pair of wings was rotated by 90° and has a 30% overlap. The car alternators connect to the shaft by a belt.

STORAGE

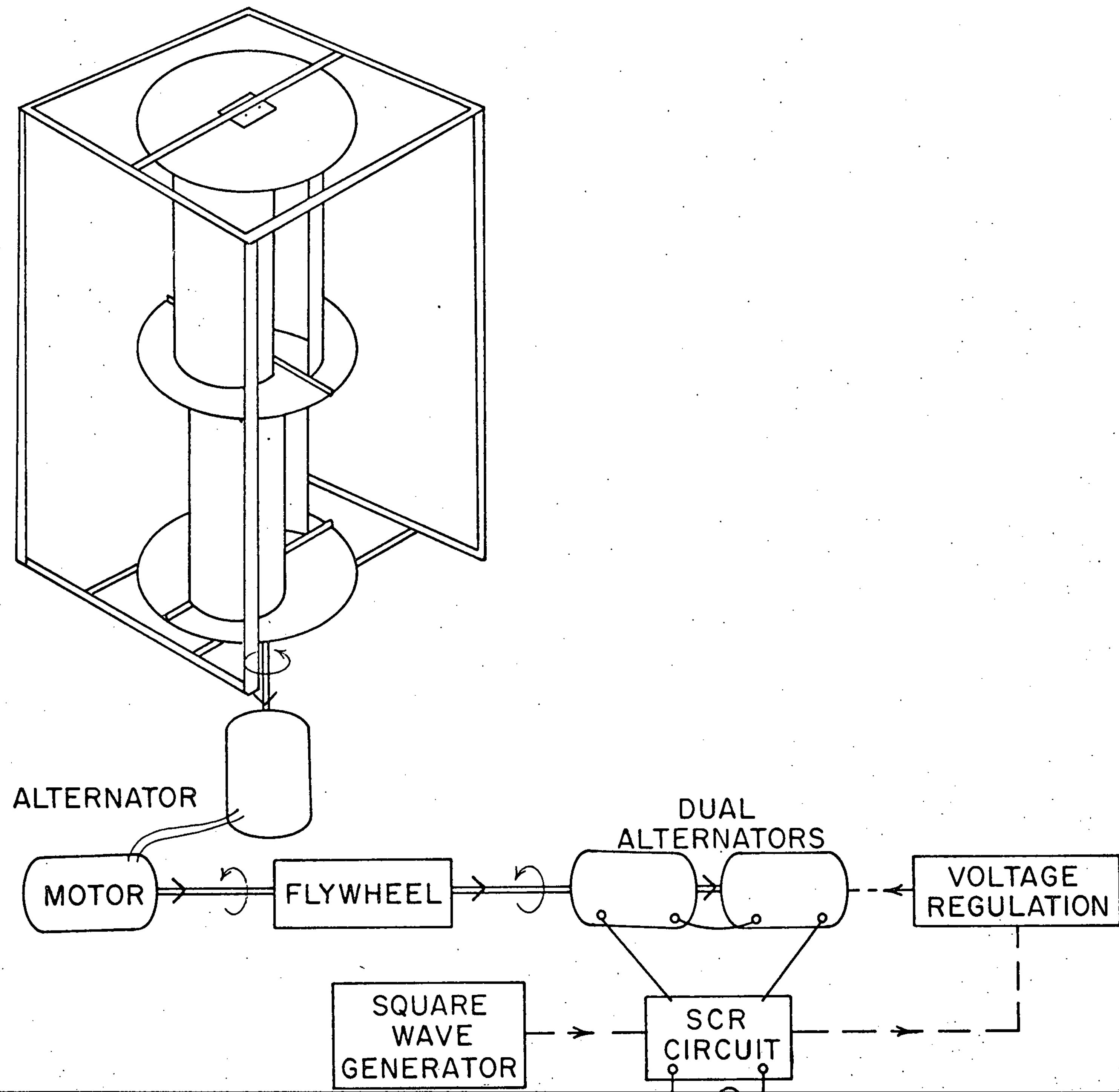
The 113 kg (250 lbs.) flywheel is eight automobile engine flywheels laminated together on a single shaft. This assembly was balanced and mounted on a frame by two self aligning double ball bearing pillow blocks. The nominal operating velocity is 2000 rpm.

OUTPUT CONTROL

An SCR circuit, driven by a timing circuit, turns the 600 Hz, 3 phase signal into a 60 Hz square wave with a high frequency ripple. A feed back circuit controls the alternator field voltages to maintain a 110 volt output.

INNOVATIONS AND RESULTS

: An anemometer was designed, built, and calibrated by students.
: Students designed and built rotor, flywheel, and electrical system.


ALTERNATOR
MOTOR
FLYWHEEL
DUAL
ALTERNATORS
VOLTAGE
REGULATION
SQUARE
WAVE
GENERATOR
SCR
CIRCUIT

SCHOOL: Wichita State University, Wichita, Kansas 67208
TEAM NUMBER: 41 TEAM CAPTAIN: Frank Dunn
FACULTY ADVISOR: Prof. Dunn
TELEPHONE: (316)689-3415

PROJECT SUMMARY

A two-bladed horizontal shaft wind turbine drives a three phase wound rotor induction machine via a main drive train assembly with a step-up ratio of 1:24. The 220 volt, three phase power is fed into the power grid and a reversible electric meter could be used for metering the net power flow.

INPUT COMPONENT

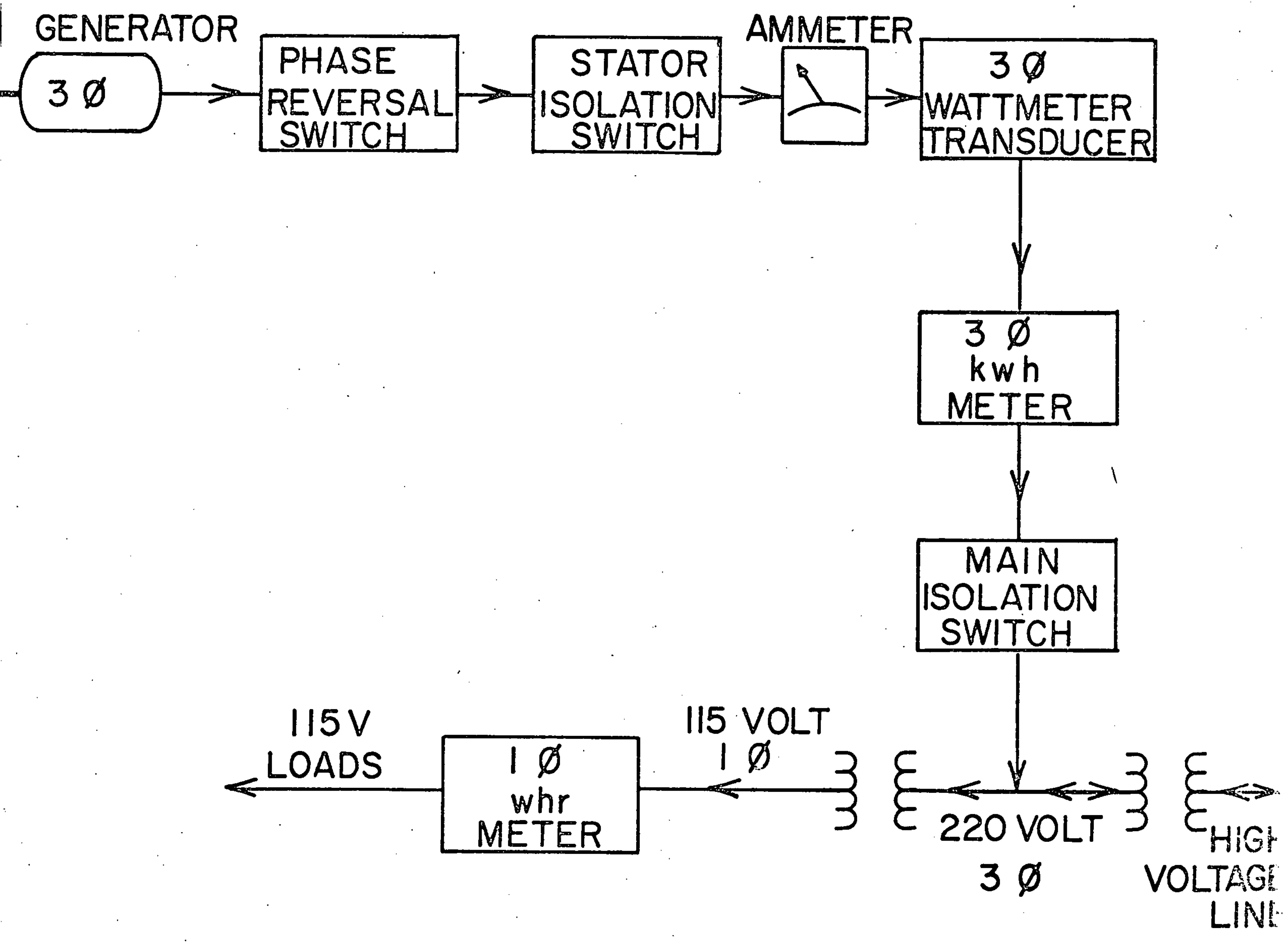
The airfoil design is GA(W)-1 and each 2.72 m (9 ft.) blade is made of spruce over an aluminum blank blade. A pitch controller positions the blades to maintain a constant rotational speed utilizing a tachometer feedback servo control. A 1.51 m x 1.51 m (5 ft. x 5 ft.) platform supports the main drive assemble, generator, and weather vane mast. A 3.02 m (10 ft.) vertical hollow shaft mounted on bearings in the tower supports the platform. A weather vane, on a 4.5 m (15 ft.) mast above the platform, senses the relative wind direction and controls a reversible constant speed drive motor. This motor drives the 3.02 m (10 ft.) platform main shaft to the correct azmuth position. The azmuth circuitry can be adjusted for position error (2° to 30°) and time delay (2 to 15 sec) prior to rotation. The 12.1 m (40 ft.) tower consists of three main support members arranged in a tripod fashion.

OUTPUT AND STORAGE

The power grid is used to store excess power and provide wave form and frequency stability. When local power consumption is higher than the wind generator output, the power grid makes up the difference. The system will deliver 1.5 kw at 0.85 PF in a 8.65 m/sec (19.3 mph) wind.

INNOVATIONS AND RESULTS

: The tower, turbine blades, support platform, and azmuth control system were designed and built by students.


GENERATOR
3 Ø
PHASE REVERSAL SWITCH
STATOR ISOLATION SWITCH
AMMETER
3 Ø WATTMETER TRANSDUCER
3 Ø kwh METER
MAIN ISOLATION SWITCH
115V LOADS
1 Ø whr METER
115 VOLT 1 Ø
220 VOLT 3 Ø

SCHOOL: Wichita State University, Wichita, Kansas 67208
TEAM NUMBER: 42 TEAM CAPTAIN: Eugene Glover
FACULTY ADVISOR: Prof. A.R. Graham
TELEPHONE: (316)689-3402

PROJECT SUMMARY

A flat plate solar collector heats the hot water storage tank. This hot water is pumped to a water to air heat exchanger to supply forced air heating.

INPUT COMPONENT

Two parallel connected .9 m x 2.44 m (3 ft. x 8 ft.) collectors have aluminum absorber surfaces with aluminum tubing attached to the back. Fiberglass is used to insulate the wooden collector casing and two layers of glass form the glazing.

STORAGE

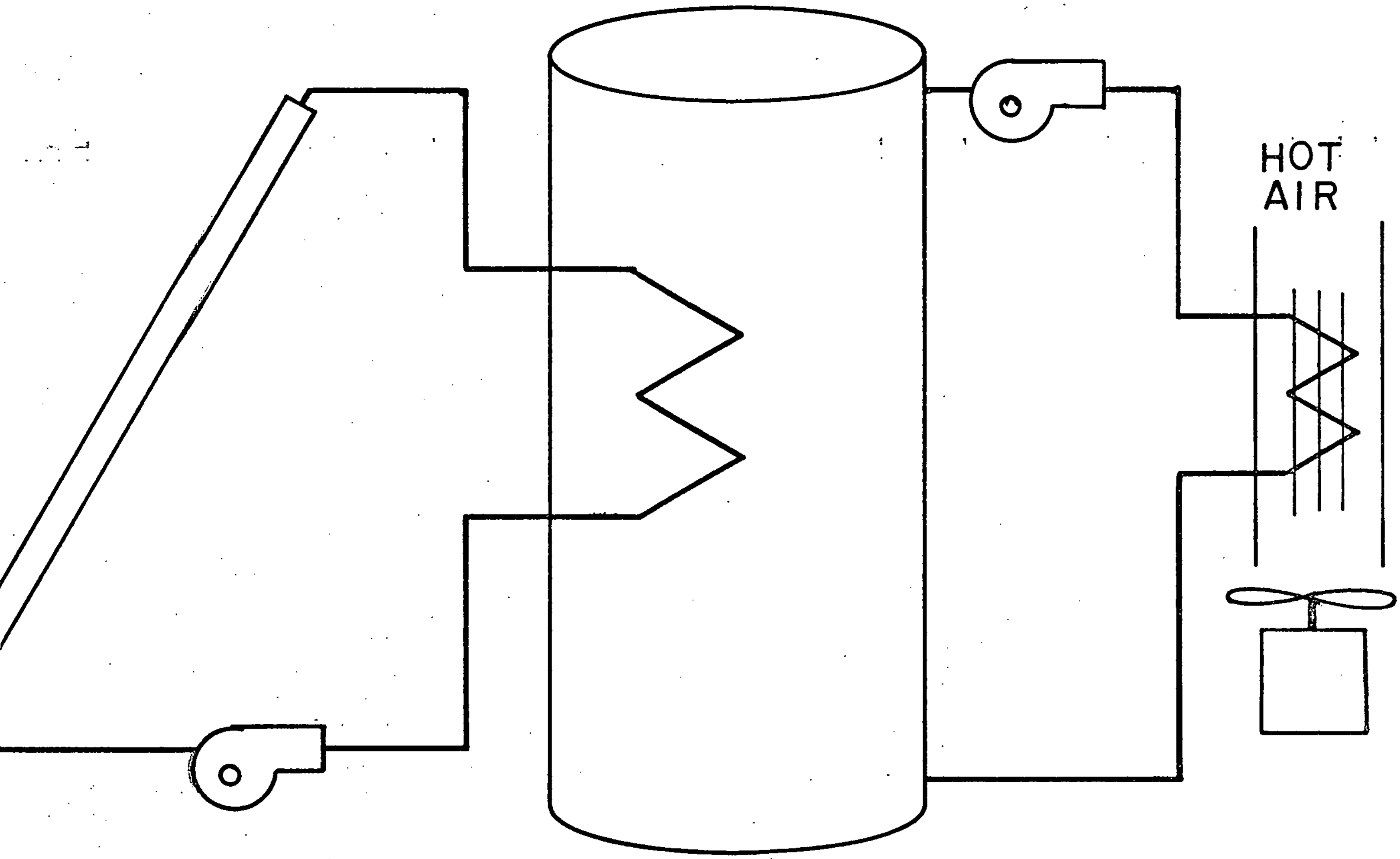
A 113 liter (30 gal.) storage tank is insulated with styrofoam. A water to water heat exchanger is located inside for the closed collector loop.

OUTPUT

Forced air heat is available on demand.

INNOVATIONS AND RESULTS

: The project was designed and built by students.


HOT AIR

SCHOOL: Massachusetts Institute of Technology
Cambridge, Massachusetts 02138
TEAM NUMBER: 43 TEAM CAPTAIN: J.D. Bryan
FACULTY ADVISOR: Prof. T. Johnson
TELEPHONE: (617) 253-5965

PROJECT SUMMARY

This inverted solar water heater has an adjustable front door. The mirrored inside of this door reflects sunshine up to an absorbing plate. A water bag resting on this absorbing plate collects and stores water to be used for domestic hot water. The water flows in one end and out the other.

INPUT AND STORAGE COMPONENT

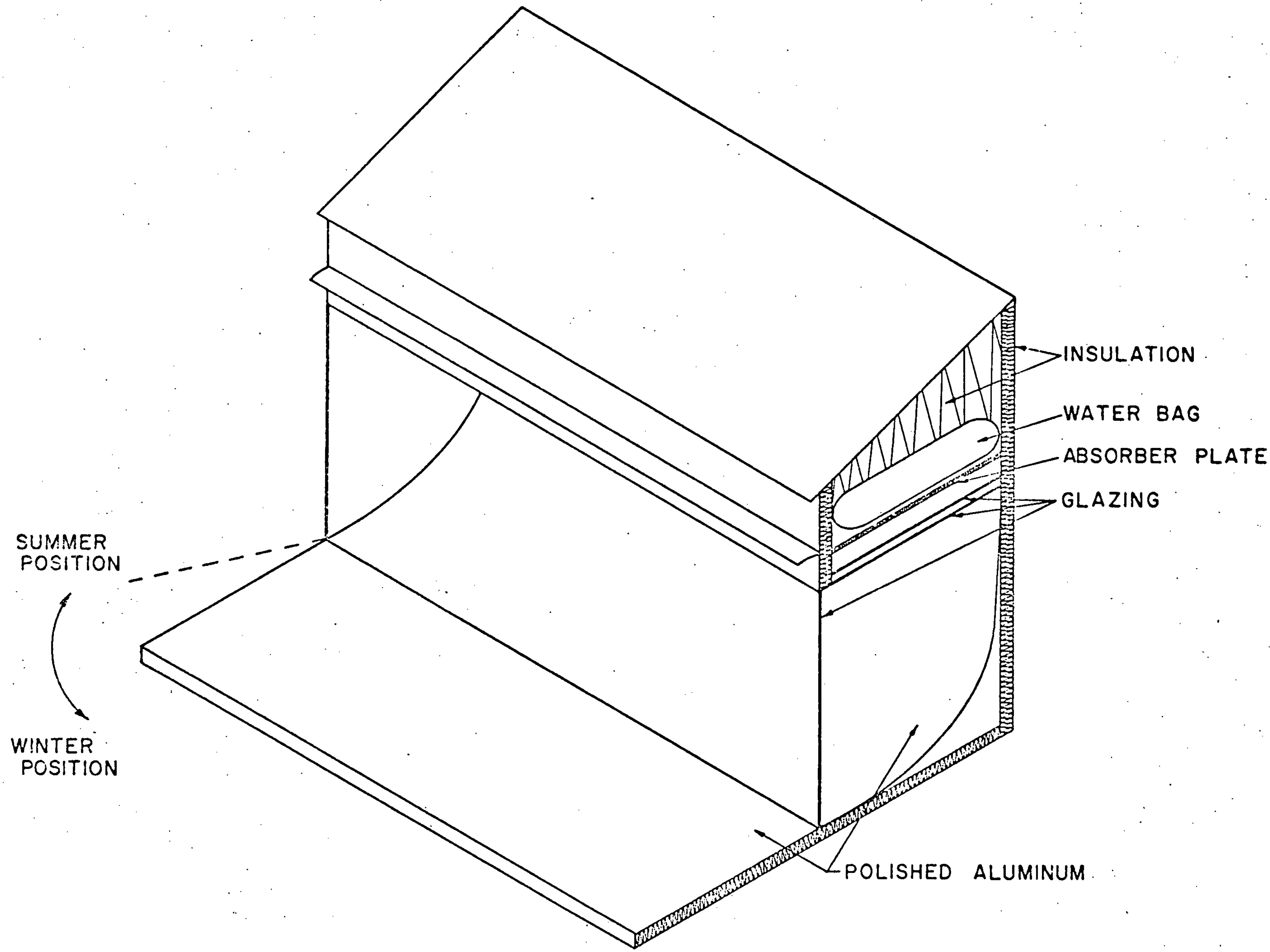
The modular unit is 2.43 m (8 ft.) long, 114 cm (45 in.) high, and 61 cm (24 in.) wide. The adjustable door is hinged at the bottom and has a 71.1 cm (28 in.) by 2.43 m (8 ft.) sheet of polished aluminum attached to the inside. Another curved inner reflector reflects the light up through two layers of glazing to the black absorber plate. A reinforced PVC 75.7 liter (20 gal.) water bag rests on top of the absorber plate. 20.3 to 30.5 cm (8 to 12 in.) of fiberglass insulation above the water bag and 3.81 cm (1.5 in.) of polyurethane on the sides minimize heat losses. A vertical piece of solar membrane covers the door opening for operation during snowy weather.

OUTPUT

Two units can supply 155 liters (40 gals.) of hot water.

INNOVATIONS AND RESULTS

: The concept of an inverted water heater that utilizes the concept that heat rises and prevents top loses.
: The concept of having storage in the collector.
: The heaters were entirely designed and built by students.
: Tests showed a temperature drop of .68° C/hour with the door closed.


INSULATION
WATER BAG
ABSORBER PLATE
GLAZING
SUMMER POSITION
WINTER POSITION
POLISHED ALUMINUM

SCHOOL: North Carolina State University
Raleigh, North Carolina 27607
TEAM NUMBER: 44
FACULTY ADVISOR: Prof. F. Smetana
TELEPHONE: (919) 737-2365

PROJECT SUMMARY

"SOLWIN" is a wind-powered, solar assisted heat pump. The 8.26 m^2 (89 $ft.^2$) of flat plate collector vaporizes the refrigerant at low pressure. A compressor compresses it and passes the refrigerant to the condenser immersed in a water tank. The water is heated as the vapor is condensed and then the freon vapor passes to an expansion valve to complete the cycle. The vertical windmill was designed to run an air compressor through a transmission. This pressurized air would be stored and used to power the compressor in the heat pump cycle.

INPUT COMPONENTS

The vertical shaft windmill is designed similar to the design of a cup anemometer. Pairs of large fiberglass cones are supprted by steel angle-iron arms. Four supporting arms are stacked on the 5.82 m (19 ft.) by 8.9 cm (3.5 in.) diameter aluminum main shaft. Each arm is staggered radially by 45°. The top of the main shaft is supported by three compression members and guy wires. The 8:1 transmission is geared to the bottom of the shaft and a compressor is attached. The collector surfaces are Roll-Bond, the glazing is one sheet of Tedlar PVF plastic and the insulation is polyureathane foam.

STORAGE

The hot water staorage tank/condenser is fabricated from two 208 liter (55 gal.) oil barrels. The condenser elements are two automotive airconditioning units mounted in the tank and the compressor is a standard automotive unit. Polyureathane foam insulates the tank.

OUTPUT

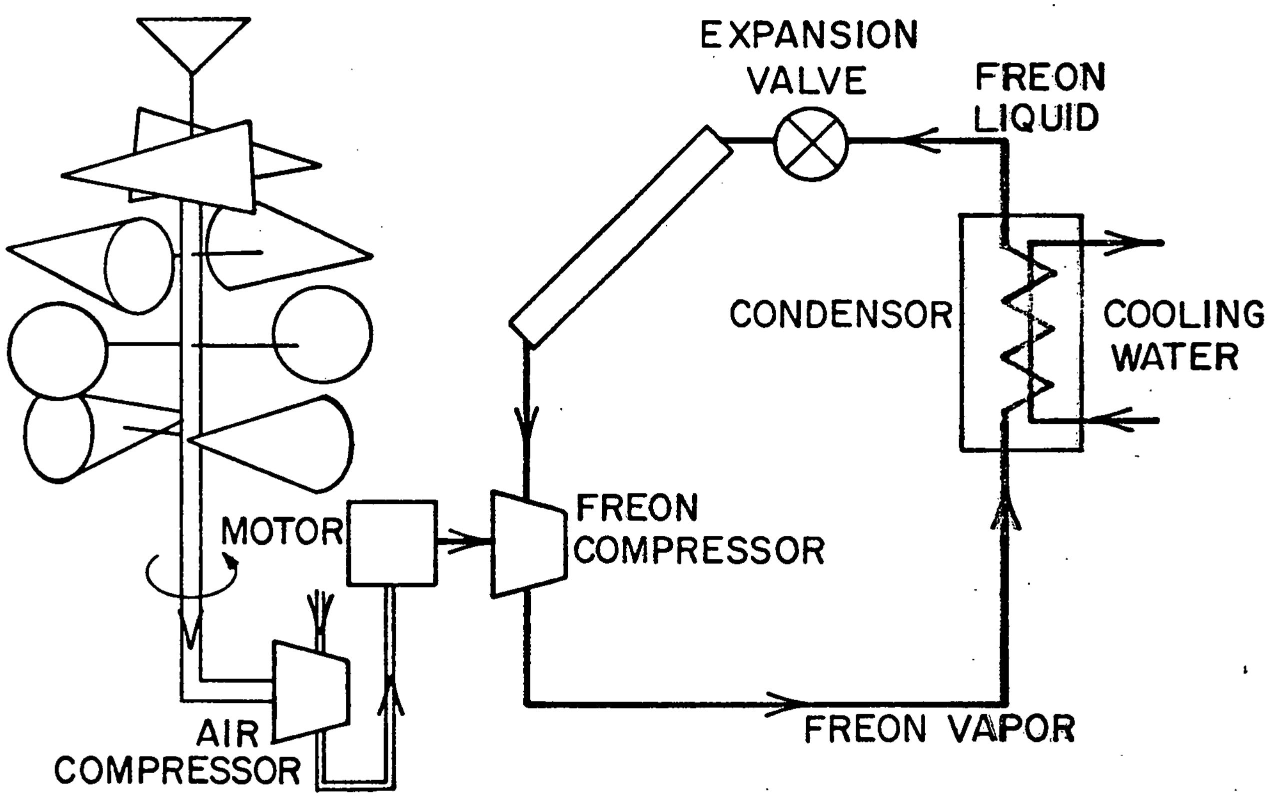
Domestic hot water can be obtained from the storage tank.

INNOVATIONS AND RESULTS

: The team used vertically stacked, radially displaced cones for a wind machine design.

: The windmill and heat pump cycle were student designed and built.

: Tests using an electric motor to run the compressor showed a Coefficient of Performance of over 4.


EXPANSION
VALVE
FREON
LIQUID
CONDENSOR
COOLING
WATER
MOTOR
FREON
COMPRESSOR
AIR
COMPRESSOR
FREON VAPOR

SCHOOL: Tufts University, Medford, Massachusetts 02155
TEAM NUMBER: 45 TEAM CAPTAIN: Thomas Yule
FACULTY ADVISOR: Prof. J. Sununu
TELEPHONE: (617) 628-5000,Ext. 268

PROJECT SUMMARY

The project objective was to provide low cost air-conditioning by utilizing solar energy. The solar heated transfer fluid is pumped to a freon boiler. The evaporated freon runs the turbine end of an automobile turbo-charger. The freon finishes the cycle by preheating the freon entering the boiler and dissipating more heat through a heat exchanger. The compressor end of the turbo-charger is the second stage of a two-stage air compression cycle. The compressed process air is then cooled and polytropically expanded to provide the refrigerated air. The expansion work in the air cycle is fed back into the cycle because the air turbine is coupled to the first stage compressor of the air cycle (another turbo-charger).

INPUT COMPONENT

Three 1.22 m x 2.44 m (4 ft. x 8 ft.) collectors sealed together and covered with a layer of black wool felt operate upon the water-wich approach. Two layers of Mylar S seperated by a dead air space form the glazing. The back is insulated with fiberglass. A trough at the bottom of the collectors collects the heated water.

STORAGE

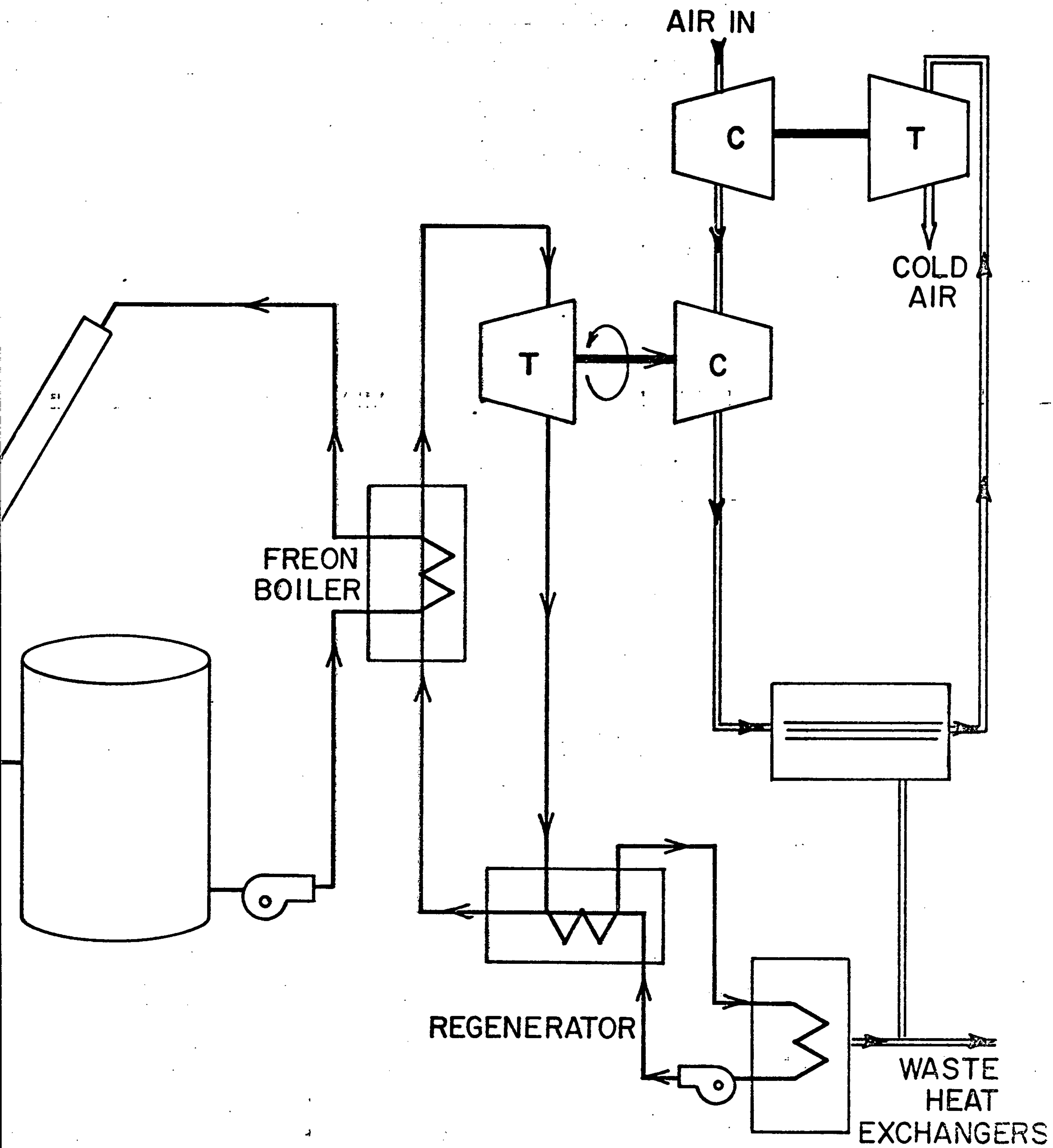
A small tank stores the heated transfer fluid.

OUTPUTS

The project can produce airconditioning and by rearranging some components, the system could operate as a solar heat pump for space heating.

INNOVATIONS AND RESULTS

: Using modified low cost turbo-chargers results in matched power turbines and compressors for an airconditioning cycle.
: The students modified the bearings and nozzle assembly to allow one end of a turbo-charger to operate on freon.
: The team used the water-wich approach for collector cost reduction.
: Component rearrangement allows space heating or air conditioning.


AIR IN
C
T
COLD AIR
T
C
FREON BOILER
REGENERATOR
WASTE HEAT EXCHANGERS

SCHOOL: Concordia University, Montreal, Canada H3G 1M8
TEAM NUMBER: 46 TEAM CAPTAIN: Paul Kiang
FACULTY ADVISOR: Prof. H.J. McQueen
TELEPHONE: (514)879-5870

PROJECT SUMMARY

Three different designs of solar collectors heat the transfer fluid (water) and a bilevel storage tank stores it. The tank stratifies the water with the hottest water rising to the upper level tank until it is used for domestic hot water.

INPUT COMPONENTS

The first collector is a conventional flat collector with copper tubes soldered to a black-painted plate. The second collector consists of an array of flattened copper tubes soldered into headers and finished with a selective coating. The third collector is a stationary cylindrical parabolic reflector. The frontal areas of the flat collectors are about 1 m^2 (10.7 $ft.^2$) each and the area of the focusing collector is 1.72 m^2 (18.4 $ft.^2$). The flat collectors use 5 to 7.5 cm (2 to 3 in.) of glass wool insulation where the focusing collector uses 5.0 cm (2 in.) of styrofoam. All cabinets are made of wood and all glazing consists of two sheets of normal clear glass.

STORAGE

The compartmentalized storage tank consists of a 19 liter (5 gal.) upper tank connected at the bottom by two pipes attached to the top of the lower 38 liter (10 gal.) tank. The inlet and outlet pipes for the solar collectors are in the bottom tank. The domestic hot water outlet is at the top of the upper tank and the cold water supply inlet is located at the bottom of the lower tank. Both tanks were placed in an outer shell consisting of a 170 liter (45 gal.) tank and were insulated with 5 cm (2 in.) of styrofoam on the top, bottom, and between the tanks and the rest of the volume was insulated with fiberglass.

OUTPUT

Domestic hot water is available from the bilevel storage tank.

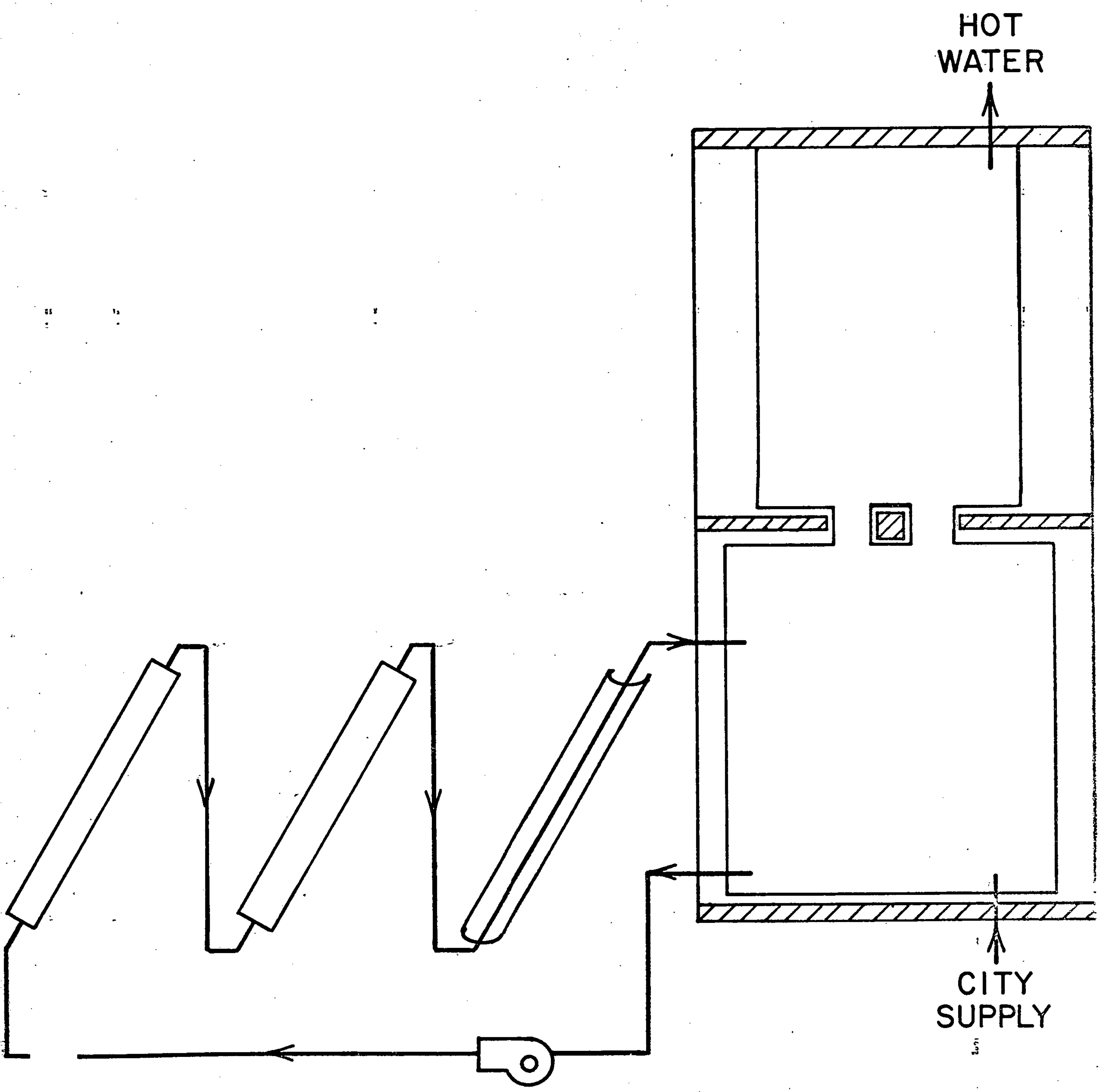
INNOVATIONS AND RESULTS

: Flattened copper tubing design eliminates the collector plate.

: A bilevel storage tank physically seperates the hottest water from the mixing action.

: One connection for the upper tank is located directly above the entrance from the collector. This allows hot water from the collectors to be stratified more directly.

: The collector and storage tank were designed and built by students.


HOT
WATER
CITY
SUPPLY

SCHOOL: Pennsylvania State University
University Park, Pennsylvania 16802
TEAM NUMBER: 47 TEAM CAPTAIN: John Crouse
FACULTY ADVISOR: Prof. Neilly
TELEPHONE: (814) 865-9031

PROJECT SUMMARY

The system contains a flat plate collector, a focusing collector, and a Savonius wind machine. The flat plate collector captures energy to be used for domestic hot water or space heating. The focusing collector stores energy in a salt mixture and is used for cooking when needed. The three stage Savonius transfers energy to a generator via a 1:23.5 ratio transmission. An inverter produces 110 volt, 60 Hz, AC directly from the generator output.

INPUT COMPONENENTS

Two glass panels from the glazing for the 3.24 m x 1.18 m (8 ft. x 46.5 in.) flat plate collector. The casing is plywood, the absorber is three aluminum troughs connected in parallel and fiberglass insulates the collectors. Highly reflective Alcoa aluminum was glued to the parabolically shaped wooden physical backing. A motor drives the tracking system for the 1.22 m x 2.44 m (4 ft. x 8 ft.) focusing collector. The 3.7 m (146.5 in.) Savonius rotor consists of three stages, lagged 120° per stage. The steel pipe axle is mounted from the bottom in a 3.12 m (123 in.) high angle iron stand. Plywood discs seperate the sheet metal blades.

STORAGE

The salt storage container is a 21 liter (22 quart) pressure cooker with aluminum pipe coils in the center. The salt is a mixture of 20% $NaNO_2$, 30% $NaNO_3$, and 50% KNO_2. The melting temperature is at 160° C (350° F) and with a heat capacity of 418 J/g° C (100 Btu/lb° F).

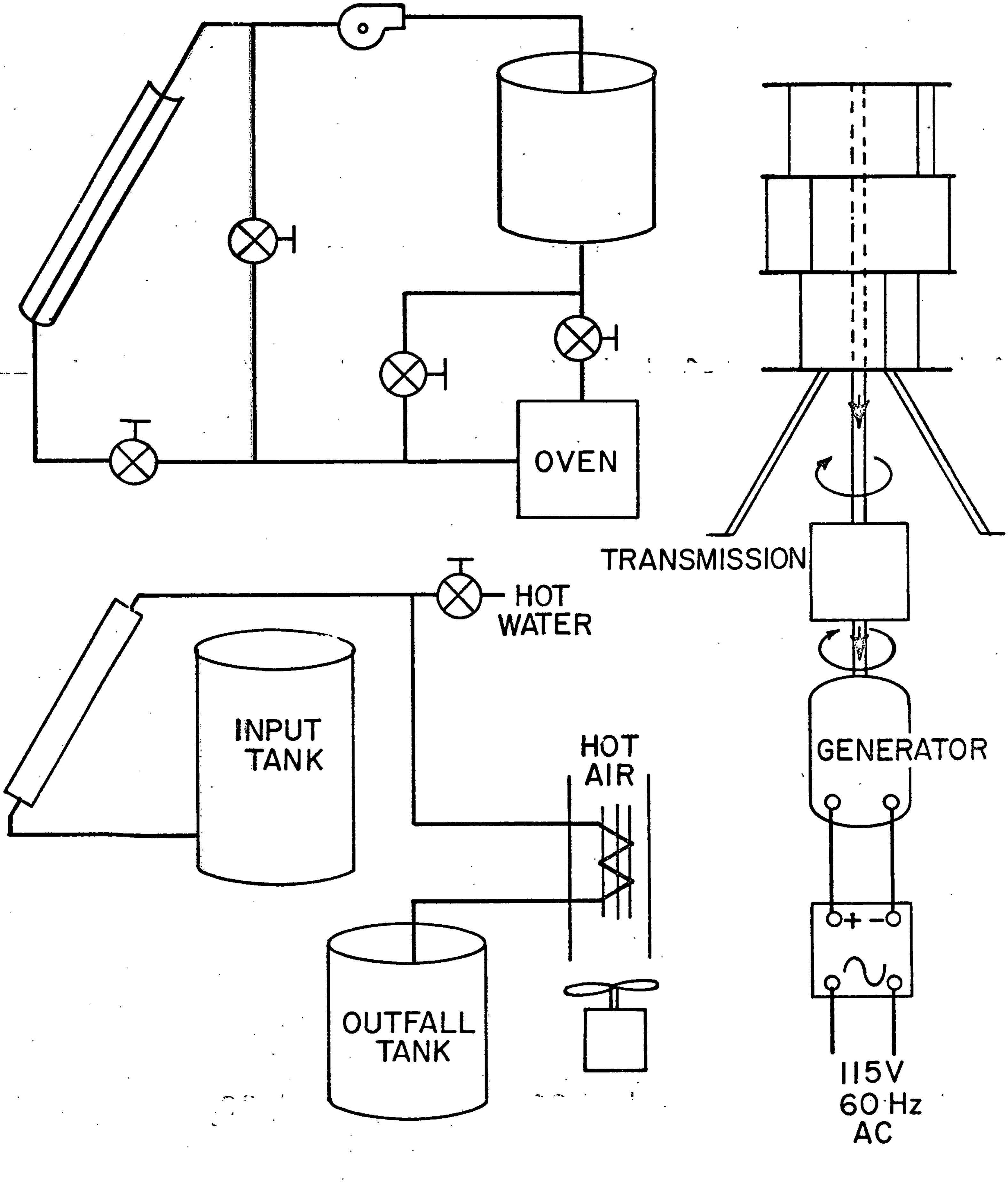
OUTPUTS

Domestic hot water or space heating is available from the flat plate collector. Cooking is accomplished in the solar oven. 110 volt, 60 Hz, AC is available from the inverter.

INNOVATIONS AND RESULTS

: All major components except the transmission, generator, and the aluminum panels were student designed and fabricated with the help of machine shops on campus.

: Wind tunnel tests showed a two-blade Savonius rotor produced more power than a three-blade rotor but with greater fluctuation.


OVEN
TRANSMISSION
HOT WATER
INPUT TANK
HOT AIR
GENERATOR
+ –
OUTFALL TANK
115V 60 Hz AC

SCHOOL: Loughborough University
Loughborough, Leicestershire, England LE11 3TU
TEAM NUMBER: 48 TEAM CAPTAIN: Robert Harland
FACULTY ADVISOR: J.E. Baker
TELEPHONE: Overseas Operator/0509-63171 telex 3-4319

PROJECT SUMMARY

A thermo-syphon solar water heater passes heat to the paraffin wax storage tank. Domestic hot water is obatined from this tank.

INPUT COMPONENTS

A polycarbonate with a 90-95% transmissivity allows light to be absorbed directly by the transfer fluid (blackened antifreeze solution). The fluid channel backing is formed fiberglass. The top glazing is glass and 200 cm of polystyrene was used to insulate the back of the 1 m^2 collector. The collector itself is 41.5 mm thick.

STORAGE

The cylindrical main tank holds 47.4 liters and is 311 mm in diameter and 622 mm high. A coil of copper tubing 3 m long is placed in the bottom and a paraffin tank is placed inside the main tank above the heating coil. The main tank is then connected to the city supply and the hot water lines.

OUTPUT

Domestic hot water is available from the main storage tank.

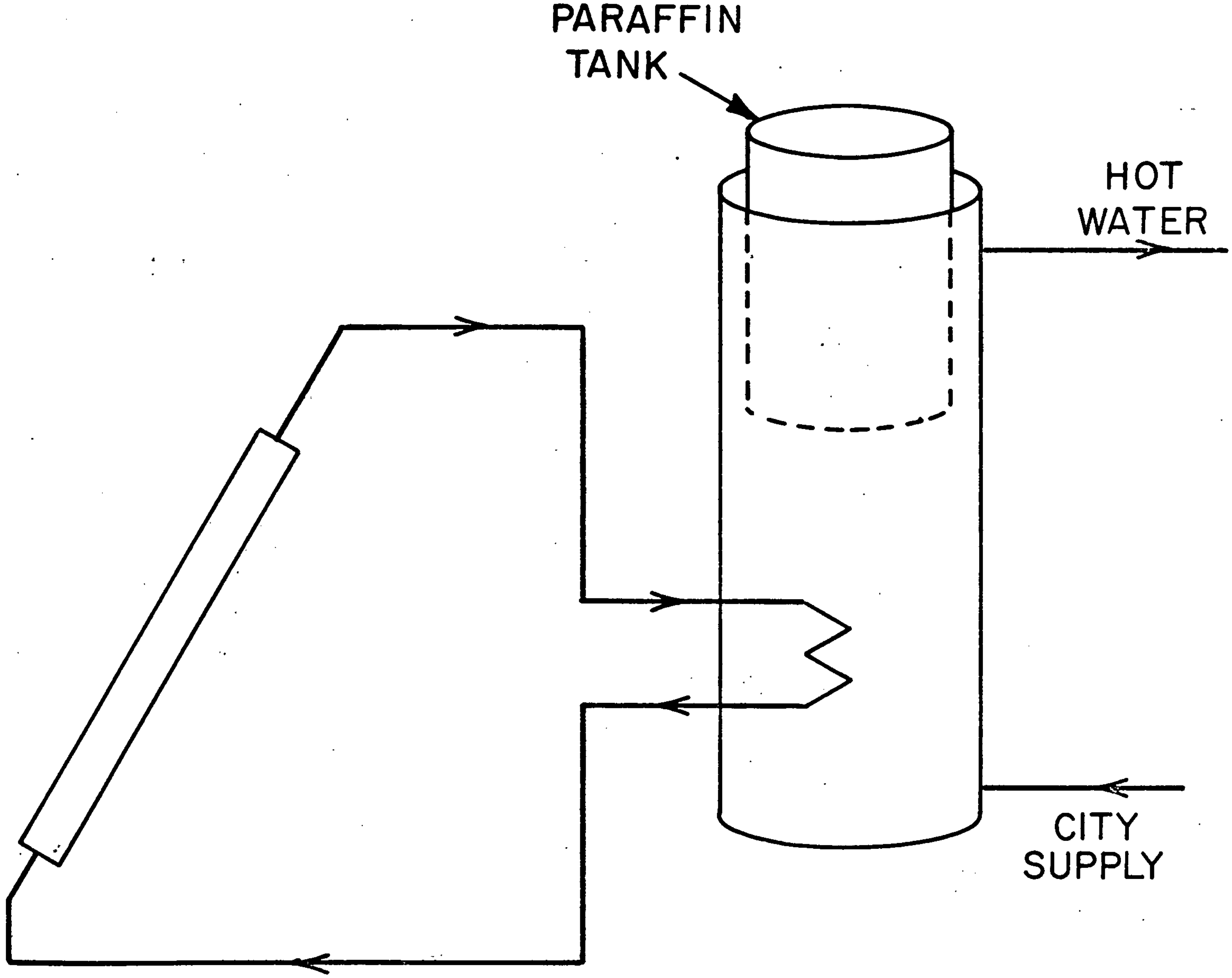
INNOVATIONS AND RESULTS

: The students developed the "heat trap" design that utilized direct absorption of the solar energy by an opaque transfer fluid contained by a thin film over a fiberglass channel.

: The students designed the fiberglass backing structure with integral flow channels, manifolds, and structural stiffening. The lightweight structure could be stiff enough to use as roofing panels.

: Tests showed that water is as opaque to infrared radiation as dyed water.

: Paraffin wax latent heat of fusion is used for storage. This gives a near constant 57° C (134° F) storage outlet temperature.


PARAFFIN
TANK
HOT
WATER
CITY
SUPPLY

SCHOOL: University of Wisconsin-Green Bay
Green Bay, Wisconsin 54302
TEAM NUMBER: 50 TEAM CAPTAIN: Gary Garriott
FACULTY ADVISOR: Prof. T.F. Abelas
TELEPHONE: (414) 465-2260

PROJECT SUMMARY

Direct current is produced utilizing an alcohol-water mixture as inputs. A reformer produces hydrogen gas from the fuel mixture and fuel cells convert the gas to electricity. This electric power is stored in lead-acid batteries.

INPUT COMPONENT

A liquid fuel mixture containing 1.5 moles water and 1.0 mole CH_3OH (methanol) is gravity fed into the outer heat exchange chamber filled with 166° C (350° F) copper-coated steel shot. The steam produced passes to a 61 cm (24 in.) spiral column maintained at 205° C (400° F) and packed with pellets of Girdler Corp. Number G 66-BRS copper/zinc oxide catalyst. The steam is reformed to hydrogen, oxides of carbon, and residual fuel mixture. The gas then enters the inner heat exchange chamber and passes over a second bed of G66-BRS catalyst bed at 166° C (350° F). The water-gas shift reaction takes place here which turns the remaining CO to CO_2 to preserve the fuel cell catalyst life. The reformate passes through condensate traps enroute to the fuel cells. Bunsen burners provide the heat for the chambers.

STORAGE

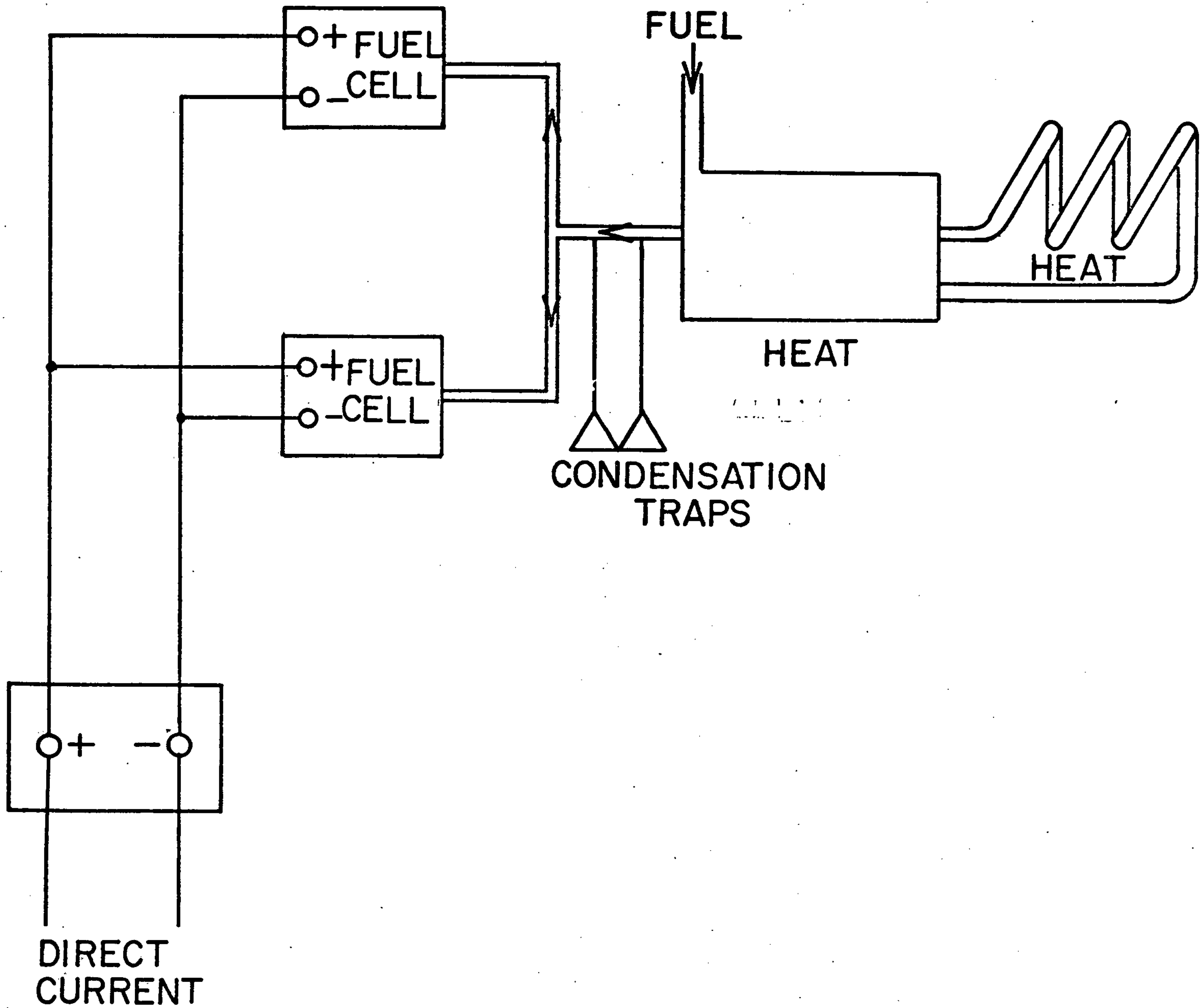
Twelve Exide 2 volt, long life lead-acid batteries are used giving a total of 720 amp hours of storage.

OUTPUT

Two Engelhard Model 15 fuel cells each produce 12 watts continuously at 6 volts.

INNOVATIONS AND RESULTS

: The project utilizes the concept of making electricity from alcohol- a biologically derived source.
: Gas chromatography results showed reformate hydrogen concentration at 50%.
: The team also used ethanol for a fuel.


+ FUEL
– CELL
+ FUEL
– CELL
FUEL
HEAT
HEAT
CONDENSATION
TRAPS
+
–
DIRECT
CURRENT

SCHOOL: University of New Mexico
Albuquerque, New Mexico 87106
TEAM NUMBER: 53 TEAM CAPTAIN: Perry Mathews
FACULTY ADVISOR: Prof. C.G. Richards
TELEPHONE: (505)277-2605

PROJECT SUMMARY

Flat plate collectors connected in parallel heat the transfer fluid in the closed collector loop. The fluid passes through a heat exchanger to a storage tank. This hot water is used for space heating. Another set of collectors heats water for domestic hot water uses.

INPUT COMPONENT

Six collectors, each of 1.53 m^2 (16.5 $ft.^2$) have absorber surfaces made by Sunsource, Inc. The top glazing is glass and the collector transfer fluid is 50% ethylene glycol and 50% water solution. The solar hot water preheater has 1.86 m^2 (20 $ft.^2$) of Roll-Bond collector surface with a flat black finish.

STORAGE

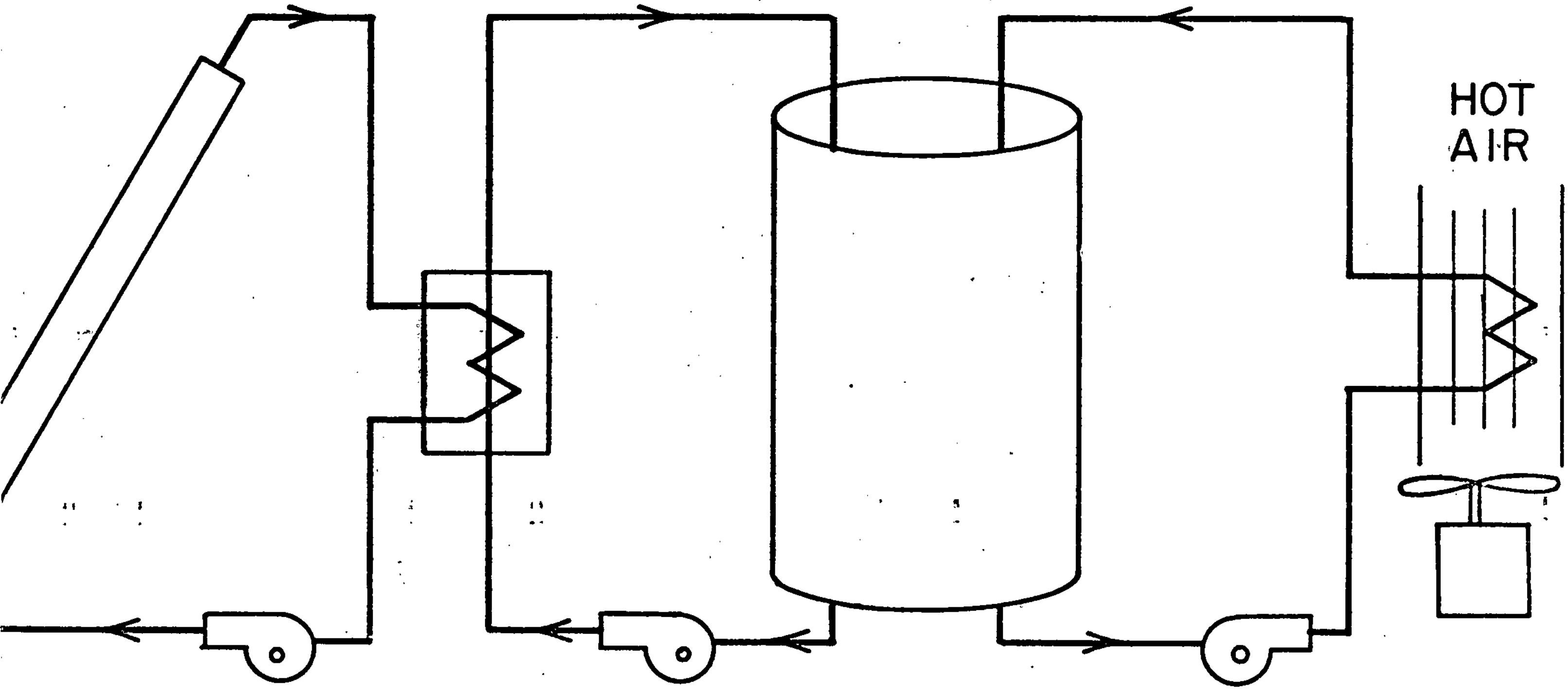
The heating system main tank capacity is 1130 liters (300 gals.) and the domestic hot water tank capacity is 113 liters (30 gals.).

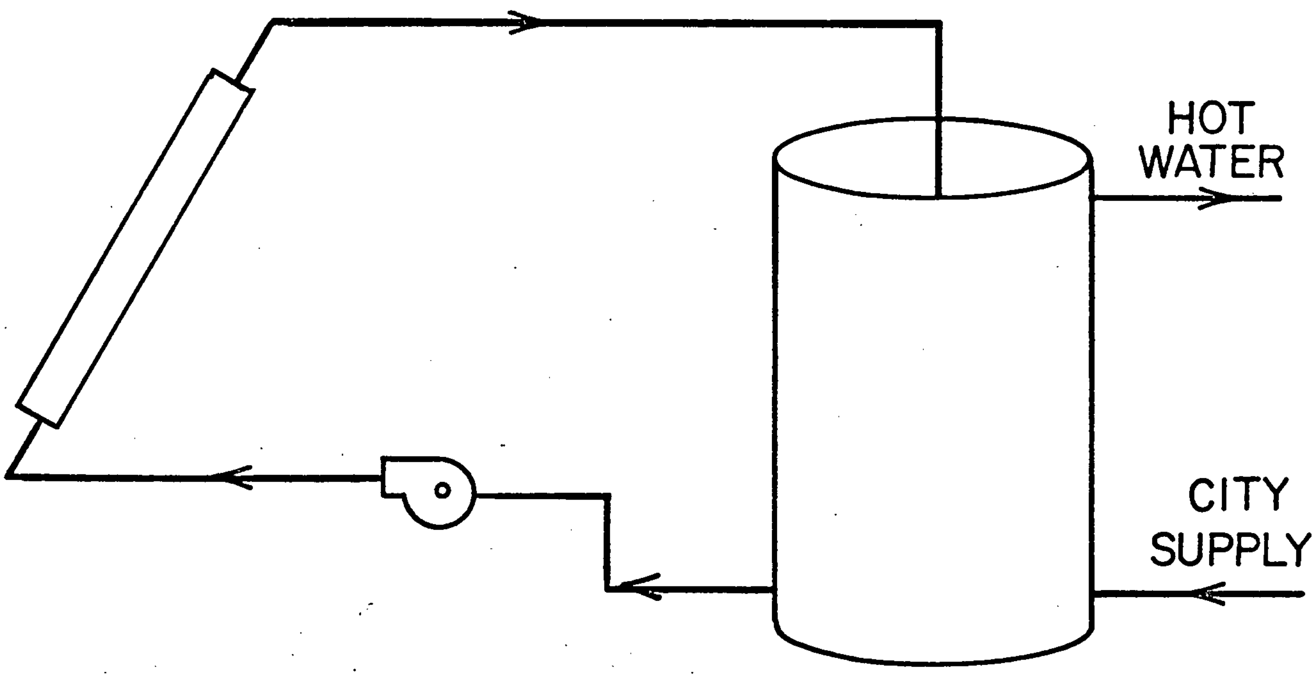
OUTPUTS

The space heating system can deliver 7.35 MJ/hr (6.95 KBtu/hr) and 64 liters (17 gals.) of hot water is produced each day.

INNOVATIONS AND RESULTS

: The project emphasized retrofitting to existing structures.
: The team took a survey of consumer interests in solar energy systems.
: The team was involved heavily in public relations and consumer information activities.
: A student independently designed and built TCS-1, a chip that controls the system.


HOT
AIR


HOT
WATER
CITY
SUPPLY

SCHOOL: University of Florida, Gainesville, Florida 32611
TEAM NUMBER: 54 TEAM CAPTAIN: Joe Hinson
FACULTY ADVISOR: Prof. V.P. Roan
TELEPHONE: (904)392-0808

PROJECT SUMMARY

A flat plate collector stores energy in a storage tank until used for domestic hot water and space heating. A horizontal windmill produces electricity. This electric power is stored in batteries and an inverter converts it to 110 volt, 60 Hz, AC.

INPUT COMPONENTS

Four flat plate collectors have aluminum Roll-Bond absorber plates. The housing is made of 2.5 cm x 7.5 cm (1 in. x 3 in.) aluminum channels. The insulation is two-part, pour type "Flexipol" foam which expands and hardens. The glazing is a single layer of glass with an additional removable layer of DuPont Tedlar mounted on a lightweight frame for use in winter months. The upwind three-bladed windmill has a standard NACA 4415 airfoil design. Each blade consists of six 30 cm (1 ft.) long sections of low density urethane foam, covered with fiberglass cloth and polyester resin, staggered along a piece of tubing to obtain the correct twist rate. The cast aluminum hub transfers power to the Motorola RA 12N453 generator by a chain-drive linkage with a step-up ratio of 40:1. A 10 m (33 ft.) tripod tower was designed for portability.

STORAGE

Three 12 volt batteries connected in parallel are used for storage. A fiberglass-insulated, portable swimming pool was used for the water storage tank.

OUTPUTS

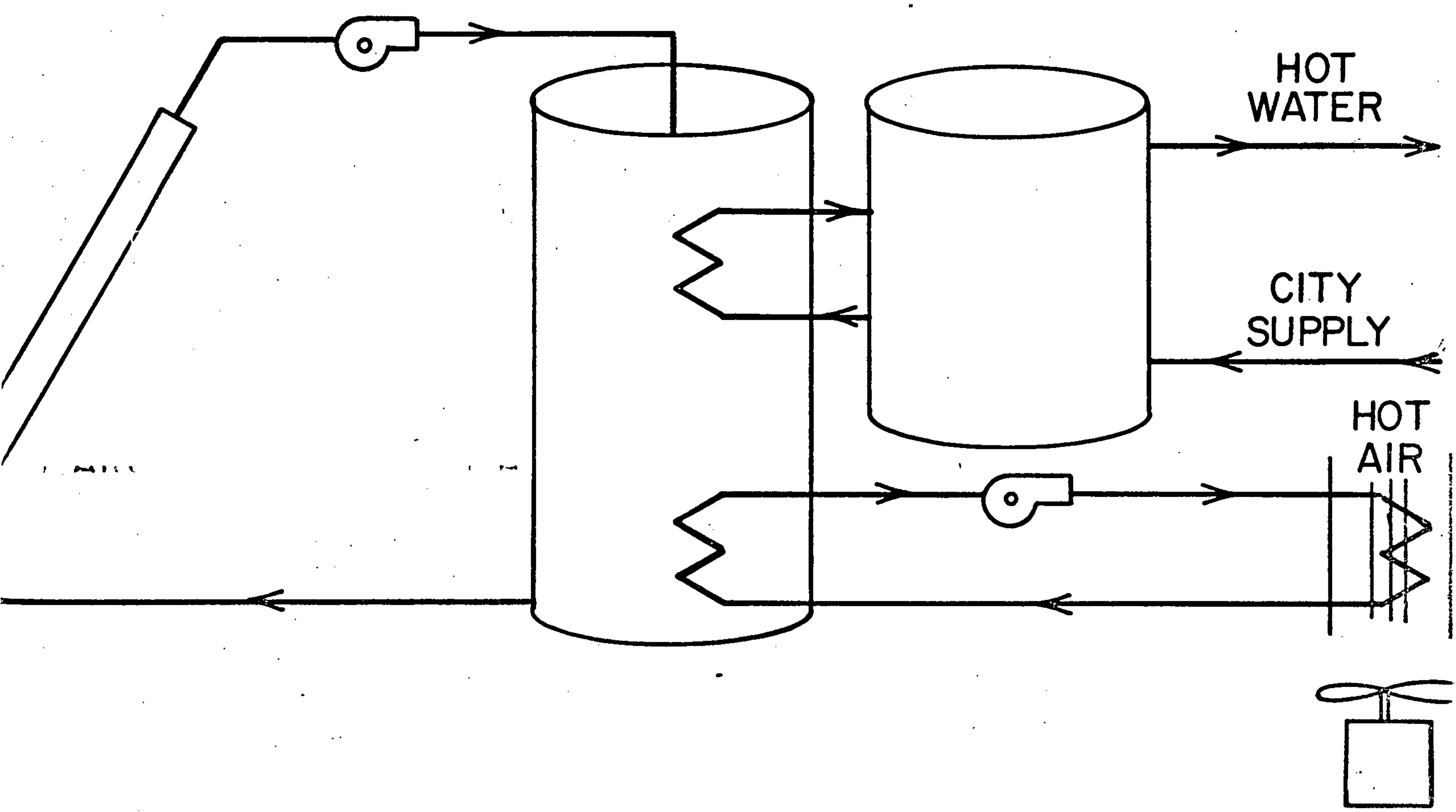
A 500 watt inverter provides 110 volt, 60 Hz square wave. An ott filter produces as approximate sine-wave output. Hot water and forced air heat are available from the stored energy.

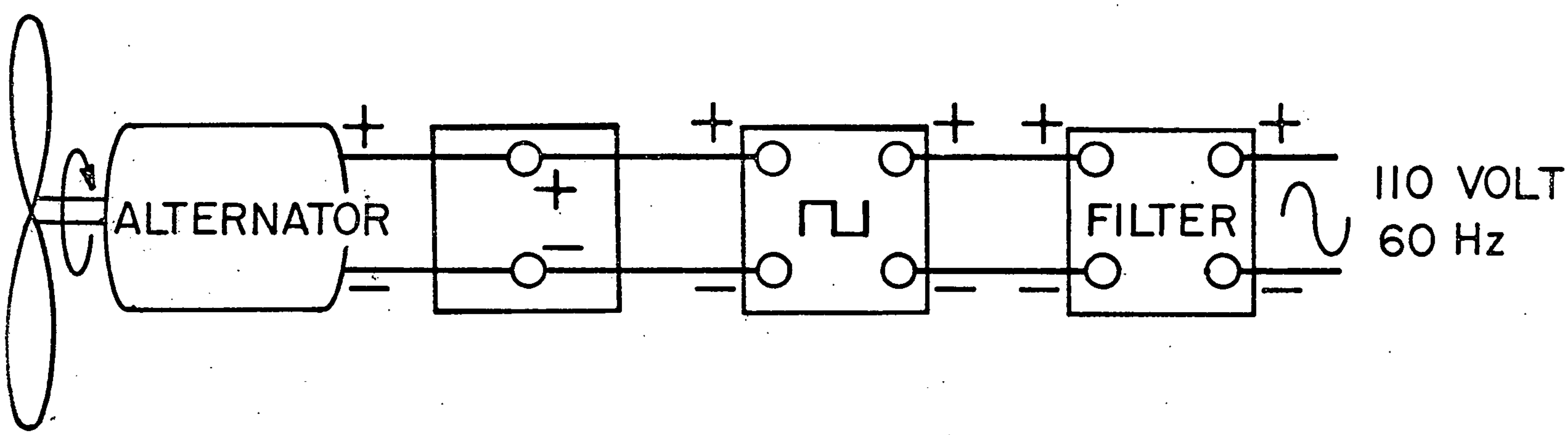
INNOVATIONS AND RESULTS

: Segmented blade design results in easy adaptation to different wind conditions with the same hardware.

: The team designed and partially constructed an airconditioning system using a R11 rankine cycle and solar energy.

: Winter collector efficiency was increased by utilizing a removable second layer of glazing.
: The team used computer simulations to determine the size requirements for various components of their system.
: The windmill, solar collectors, and electrical system were designed and built by students.


HOT
WATER
CITY
SUPPLY
HOT
AIR


ALTERNATOR
FILTER
110 VOLT
60 Hz

SCHOOL: Drexel University
Philadelphia, Pennsylvania 19104
TEAM NUMBER: 55 TEAM CAPTAIN: Steven Robusto
FACULTY ADVISOR: Profs. C.W. Savery and J.K. Knude
TELEPHONE: (215)895-2294

PROJECT SUMMARY

A solar system or waste heat source would produce the energy needed to vaporize a working fluid in a heat pump cycle. The two-stage, double-condenser heat pump system heats up water from 65° C (150° F) to 92° C (200° F). This hot water could be used in industrial processes.

HEAT PUMP

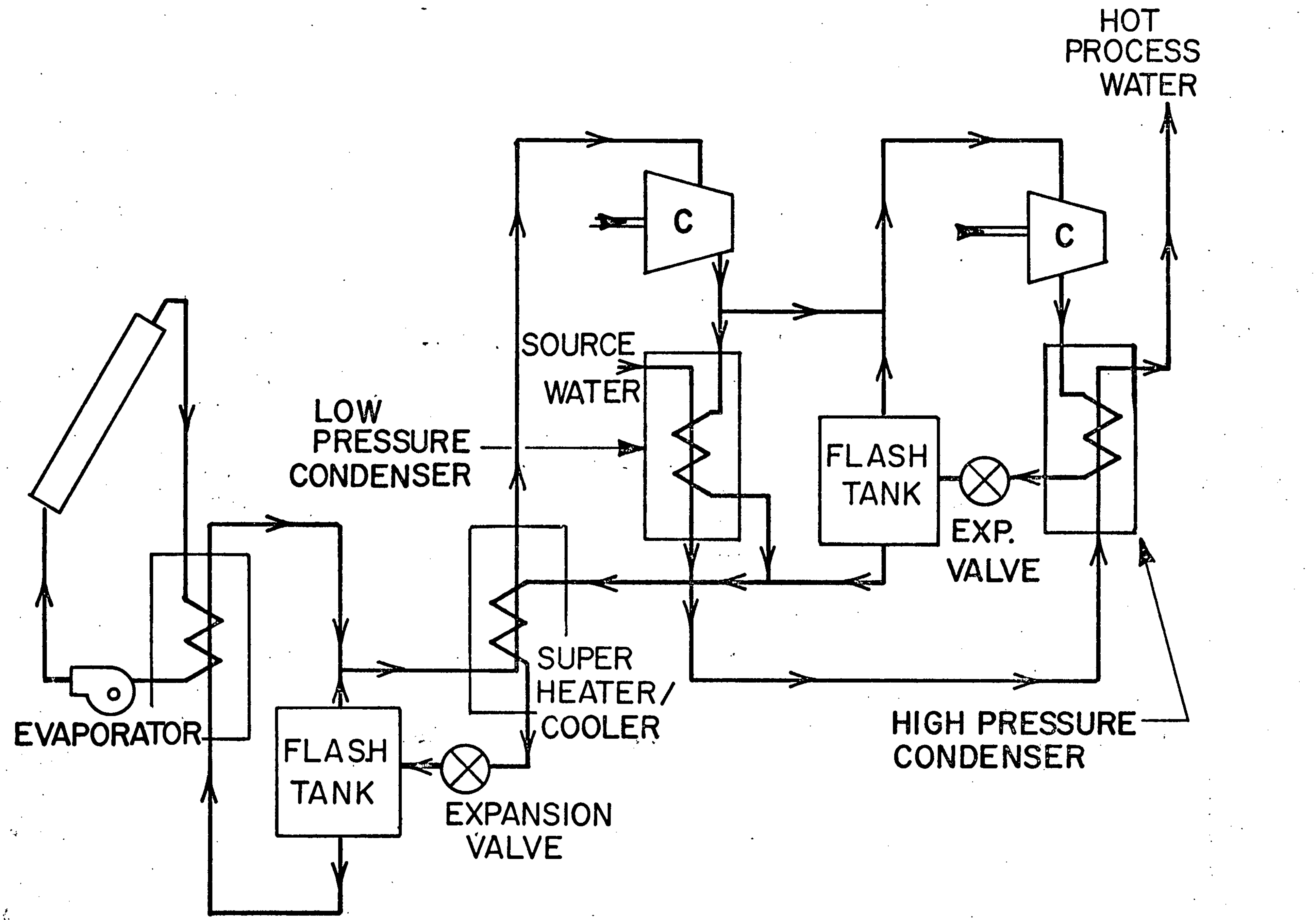
The refrigerant R11 is vaporized in the evaporator and is superheated in the subcooler. Next, the fluid is compressed and some of it is used to heat up the process water in the low pressure condenser and the rest continues on to the second compressor. The refrigerant then passes to the high pressure condenser where it heats up the process water to the 92° C outlet temperature. The refrigerant expands through an expansion valve, continues to the first flash tank, goes to the subcooler, expands through a second expansion valve, continues to a second flash tank, and back to the boiler. Each flash tank allows the vapor to be fed back into the loop while pumping the liquid refrigerant back to the evaporator.

OUTPUT

Hot (92° C) water for industrial applications is produced.

INNOVATIONS AND RESULTS

: The team modified a conventional two-stage, double-condenser heat pump design to include a subcooler and a second flash tank to increase the overall efficiency.
: The heat pump was designed and constructed by students.
: The design used gravity flow in all liquid lines.
: They maintained a low oil level in the compressors to minimize oil migration into the compressors.


HOT
PROCESS
WATER
C
C
SOURCE
WATER
LOW
PRESSURE
CONDENSER
FLASH
TANK
EXP.
VALVE
SUPER
HEATER/
COOLER
HIGH PRESSURE
CONDENSER
EVAPORATOR
FLASH
TANK
EXPANSION
VALVE

SCHOOL: Iowa State University, Ames, Iowa 50010
TEAM NUMBER: 56 TEAM CAPTAIN: Michael Jensen
FACULTY ADVISOR: Profs. J. Woods and A. Potter
TELEPHONE: (515)294-1423

PROJECT SUMMARY

Energy is collected by a compound parabolic reflector and a horizontal upwind windmill. Steam produced in the collectors powers either an absorption refrigeration unit or a steam engine which drives an alternator to make electric power. The exhausted steam in both cases is them pumped to a condenser in a hot water storage tank. The hot water tank supplies hot water to a heat exchanger in an air duct for space heating and also heats domestic hot water via a heat exchanger in the storage tank. The absorption refrigeration unit, which runs on steam or commercial power, provides evaporative cooling directly to the air duct or chills water in chilled water storage during off-peak times. The chilled water storage helps meet peak load demands by circulating chilled water through a heat exchanger in the air duct. The windmill drives a 24 volt alternator and a second 24 volt alternator engages when blade speed exceeds 120 rpm. All the alternator outputs are stored in a 24 volt series battery arrangement. The 24 volt power runs a motor-generator set which produces 115 volt AC or can be delivered as 24 volt DC to heating elements. A control system allocates the energy where it is needed.

INPUT COMPONENTS

The compound parabolic reflector consists of many light, trough-like reflecting channels which are able to concentrate direct radiation and can collect a limited amount of diffuse radiation. The concentration ratio is 15 and the collector loop pressure is 75 psi. The troughs were made of polished aluminum sheet, rolled and installed on an oak frame, and covered with glass glazing. The 2.12 m (7 ft.) wind turbine blades are constructed of styrofoam with a fiberglass overlay and mounted on a 5.44 m (18 ft.) pole. A chain drive transmits the blade motion to the alternators via a 1:10 step-up and a centrifugal clutch engages the second alternator.

STORAGE

Two 208 liter (55 gal.) tanks welded together form the hot water storage. The tank has 5 cm (2 in.) of fiberglass insulation, a heat exchanger which serves as the domestic hot water heater, and one 24 volt and one 115 volt immersion heater. The chilled water storage tank is a modified 1040 liter (275 gal.) fuel tank, insulated with 5 cm (2 in.) of fiberglass. Two parallel banks of four 6 volt lead-acid batteries each are wired in series to provide 24 volt output and 720 amp-hours of storage.

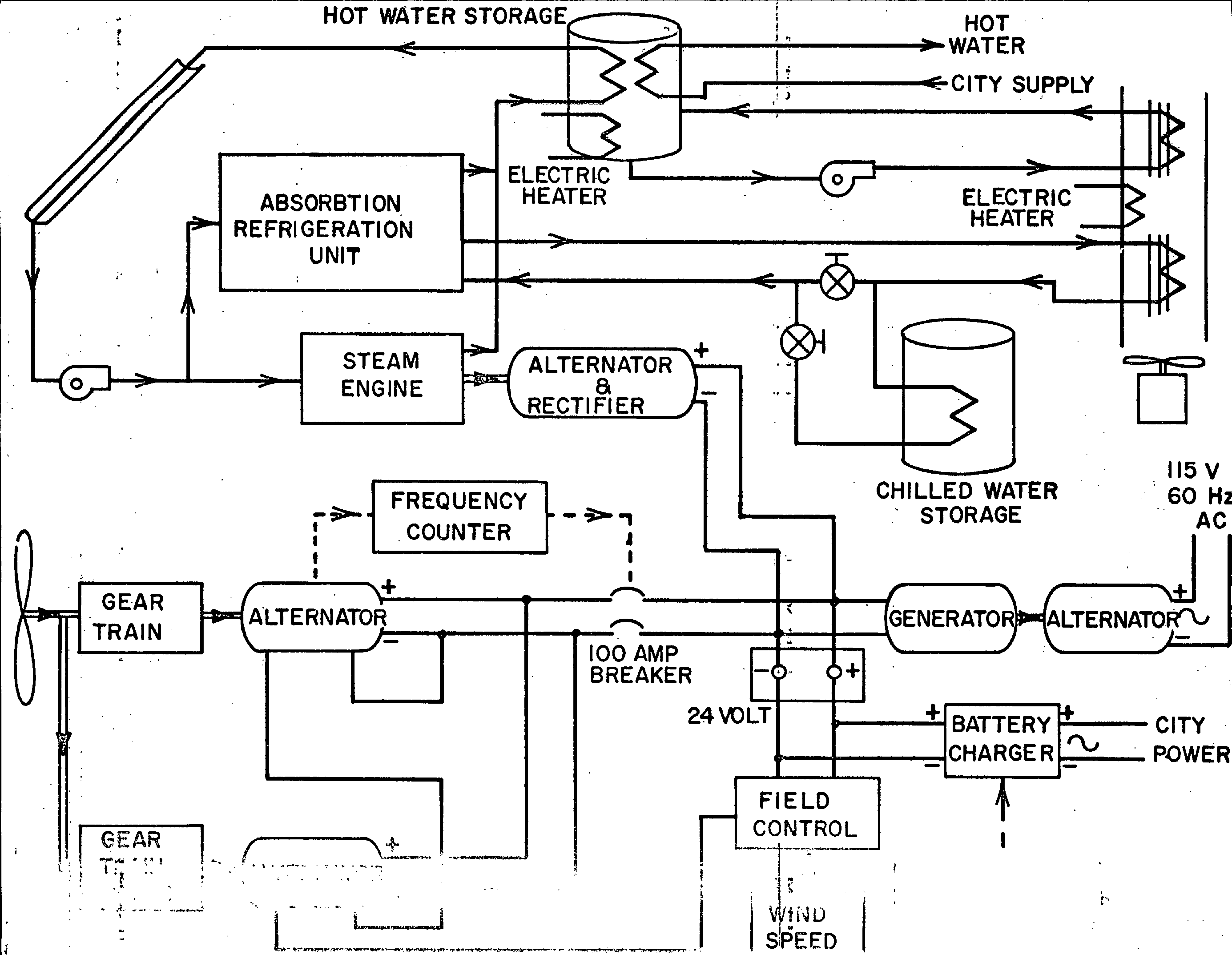
OUTPUTS

A rapid recovery hot water system provides domestic hot water. A fin and tube heat exchanger, a 24 volt resistance heater, and a 115 volt resistance heater in the air supply duct supply space heating. An absorption cooling system and chilled water storage provide airconditioning. 110 volt or 24 volt electric power is available.

INNOVATIONS AND RESULTS

: The project is a package that supplies four desirable outputs to a residence.

: The wind turbine, solar collectors, storage, and automatic output control were designed and built by students.


HOT WATER STORAGE
HOT
WATER
CITY SUPPLY
ELECTRIC
HEATER
ABSORBTION
REFRIGERATION
UNIT
ELECTRIC
HEATER
STEAM
ENGINE
ALTERNATOR
&
RECTIFIER
+
−
CHILLED WATER
STORAGE
115 V
60 Hz
AC
FREQUENCY
COUNTER
GEAR
TRAIN
ALTERNATOR
+
−
100 AMP
BREAKER
GENERATOR
ALTERNATOR
+
−
24 VOLT
BATTERY
CHARGER
CITY
POWER
FIELD
CONTROL
GEAR
WIND
SPEED

SCHOOL: Washington State University
Pullman, Washington 99163
TEAM NUMBER: 57 TEAM CAPTAIN: Ivar Husa
FACULTY ADVISOR: Prof. David Stock
TELEPHONE: (509)335-3223

PROJECT SUMMARY

Solvent-refined coal (SRC) burns in a low temperature fluidized bed to provide hot air for space heating. Propane is used to preheat the bed before the coal is fed in.

INPUT COMPONENT

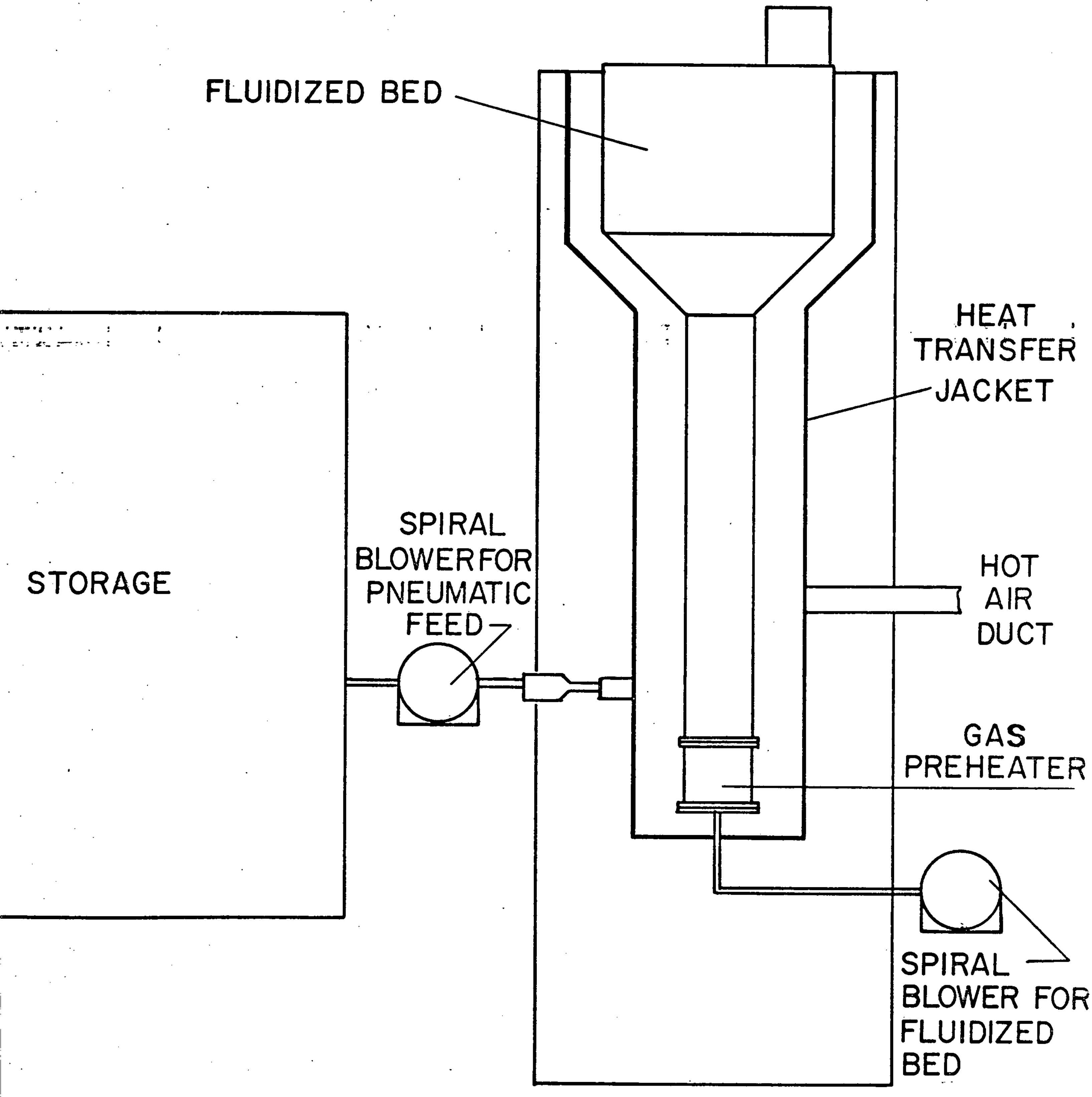
The fluidized bed has an internal diameter of 11.5 cm (4.5 in.) and sand is the fluidizing medium. A stainless steel screen keeps the bed from falling into the blower outlets. An auger brings the SRC from the storage bin into a pressurized feed tube where it is pneumatically injected at high velocities into the bed. The feed tube is water-cooled because SRC melts at 176° C (350° F) and the resulting liquid is extremely viscous. A spiral blower produces the fluidizing air and the bed temperature is 1000° C (1800° F) during combustion.

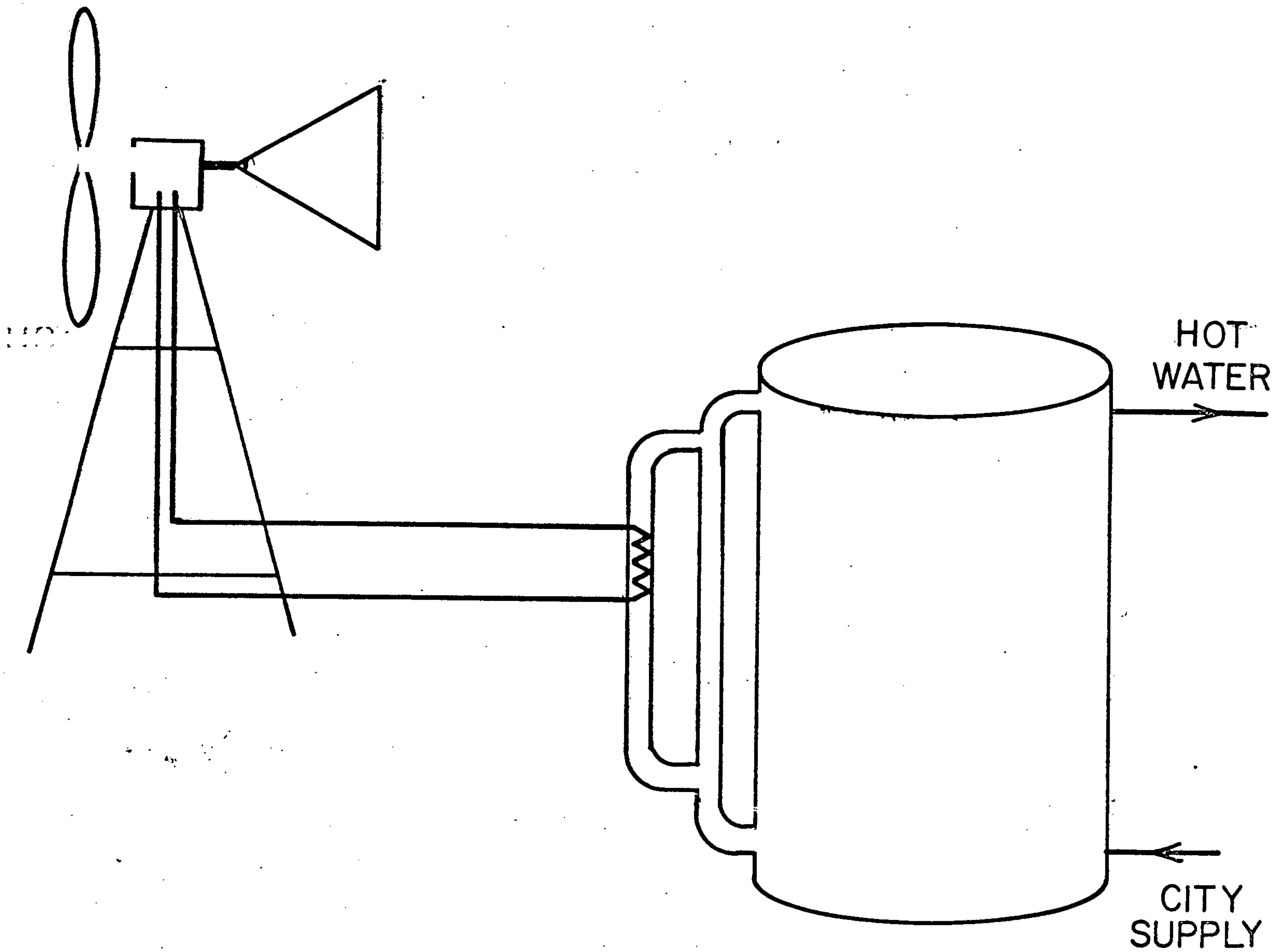
OUTPUT

Air forced around the combustion chamber will heat the house.

INNOVATIONS AND RESULTS

: Developed and utilized a fluidized bed concept to burn solvent-refined coal for home heating.
: Studies showed minimal pollution because solvent-refined coal has ash and sulfur removed and only small amounts of NO_x will be produced due to low burning temperatures.
: Used high velocity pneumatic feed for injection into bed.
: Studies showed that the fluidized bed has long residence times which would enable complete combustion to take place.
: The fluidized furnace was designed and built by students.


FLUIDIZED BED
HEAT TRANSFER JACKET
STORAGE
SPIRAL BLOWER FOR PNEUMATIC FEED
HOT AIR DUCT
GAS PREHEATER
SPIRAL BLOWER FOR FLUIDIZED BED


HOT
WATER
CITY
SUPPLY

SCHOOL: University of Wisconsin-Milwaukee
Milwaukee, Wisconsin 53201
TEAM NUMBER: 59 TEAM CAPTAIN: James Garland
FACULTY ADVISOR: Prof. V. Pavelic
TELEPHONE: (414)963-4970

PROJECT SUMMARY

A three-bladed upwind horizontal windmill and a flat plate collector heat up water in a storage tank. Domestic hot water and forced air space heating are available from this bilevel storage tank.

INPUT COMPONENTS

The windmill is mounted on a portable tower 6.5 m (20 ft.) tall. Three 2.05 m (6.8 ft.), Jacob windmill blades governed by a centrifugal feathering hub drive a modified Sears 4-pole, single-phase alternator via a 1:6 step-up timing belt and pulley mechanism. The alternator, running at a maximum speed of 1440 rpm and with a field current of 4 amps, delivers 1500 watts to the storage tank resistors. An external 36.8 volt DC power supply produces the field coil excitation when the rotor speed is above a certain limit. This power supply is shut off when the external power draw is geater than the power produced by the rotor. The 1.22 m x 2.44 m (4 ft. x 8 ft.) diffuse type collector consists of a black painted sheet of corrugated sheet steel on top of a flat sheet of steel. Water flows between the two pieces of sheet steel, back and forth through the pipe like corrugations. Four sections of 1.21 m x .6 m (4 ft. x 2 ft.) double glass pane were used for glazing and 10 cm (4 in.) of fiberglass insulate the collector back. A pump, activated by a float switch in a surge tank, fills the surge tank when the collector is hot. The surge tank was developed to control the slow flow rate through the collector with a head of water rather than with the pressure of the pump.

STORAGE

Two 190 liter (50 gal.) drums are mounted sideways on top of each other in a wood frame and insulated with 10 cm (4 in.) of fiberglass. The two parallel connected 9 ohm resistive heating coils are located in the upper tank. The collector outlet feeds into the upper tank and the heating system draws water from the upper tank. All other cooler lines are connected to the bottom tank.

SCHOOL: University of Hartford
West Hartford, Connecticut 06117
TEAM NUMBER: 58 TEAM CAPTAIN: Paul Erhartic
FACULTY ADVISOR: Prof. E. Gardow
TELEPHONE: (203)243-4852

PROJECT SUMMARY

A three-bladed horizontal downwind windmill produces electricity from an alternator. This electric power is fed to a sidearm water heater with a resistor in it to help supplement the water heating of the house.

INPUT COMPONENT

Three 2 m (6.5 ft.) polystyrene blades with wooden ribs are covered with aluminum screening and coated with four layers of polyester resin. Each blade has a twist of 3° at the tip to 17° at the root and weighs 2.62 kg (5.75 lbs). The blades slip right over nylon rods, mounted on the aluminum hub and are bolted in place. Galvanized steel cables restrain the blades for additional rigidity. An aluminum chassis supports the sealed shaft bearings, the 1:10.7 step-up belt transmission, and the alternator. Shut down is accomplished by a swinging tail vane. A hydraulic door spring automatically shuts the machine down except when the tail is physically pulled straight behind the chassis. The guyed 4.65 m (15 ft.) galvanized steel tube tower is placed in two block bearing attached to the 113 kg (250 lb) base.

OUTPUT

A .86 ohm resistor is located in the copper sidearm heater attachment and supplements the water heating of the home. The attachment connects easily to the standard 3/4" water pipe.

INNOVATIONS AND RESULTS

: Produced aerodynamically sound blades that weigh 2.62 kg each.
: Calibrated the alternator output and matched a resistor for the heater to give maximum efficiency.
: The blades, hub, chassis, vane, and heater attachment were designed and built by students.
: Used a hydraulic door spring for an auto shutdown safety feature.

OUTPUTS

A fan blows over a radiator with heated water circulating through to provide forced air heat and domestic hot water can be drawn directly from the upper tank.

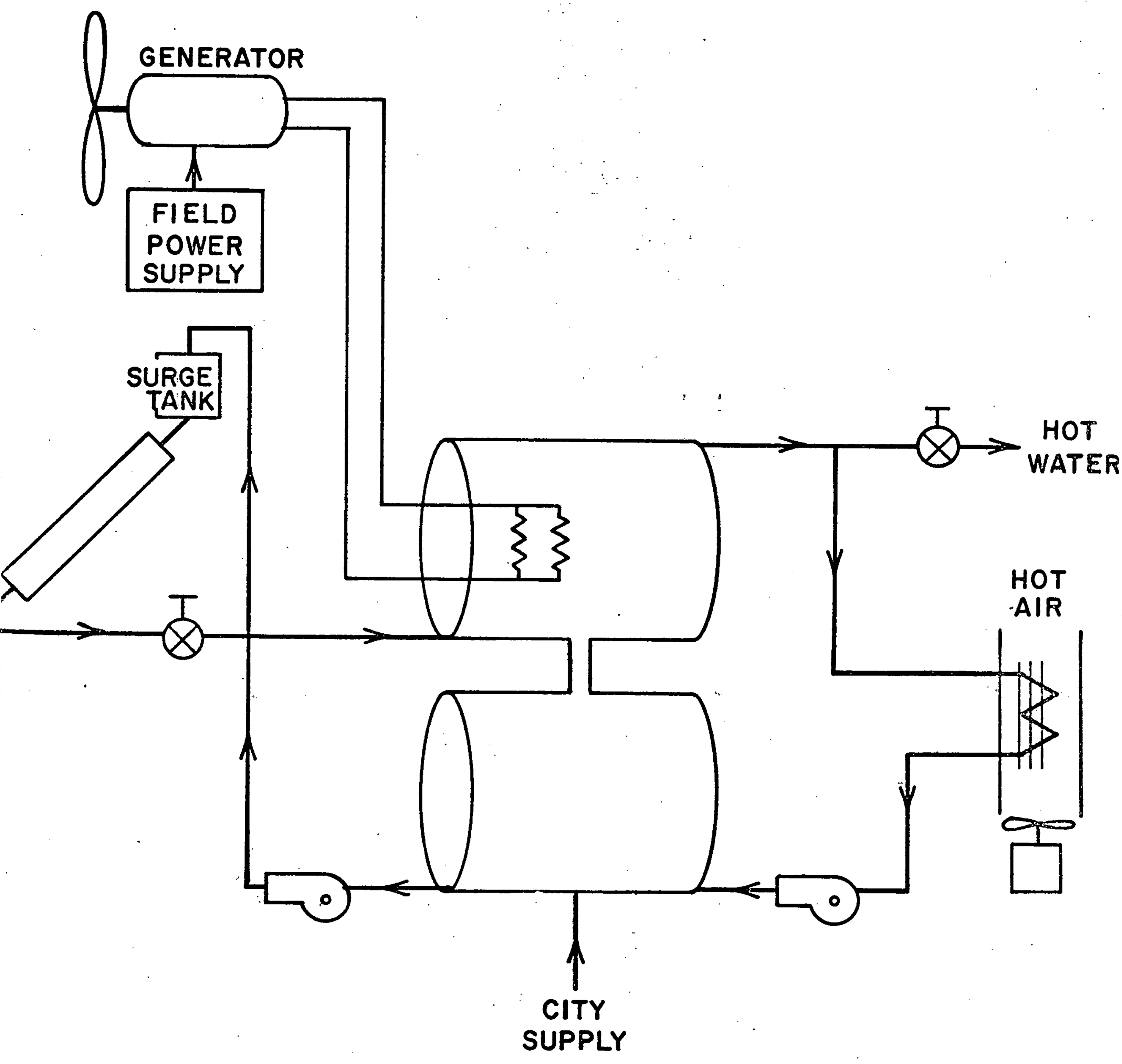
INNOVATIONS AND RESULTS

: The students modified a single-phase alternator because the designed operating speed could not be achieved. Originally, the alternator field coils were shunt-connected to the brushes via an internal power rectifier. This rectifier circuitry was replaced by the external DC power supply.

: The students used residual magnetism in the alternator core and an amplifier circuit to detect the rotor speed.

: The students used a surge tank for regulating the water flow through the collectors. By using this concept and a comparison circuit the pump will only be activated when the "batch" of water in the collector is hotter than the storage tank.

: The solar collector, storage, and control system were designed and built by students.


GENERATOR
FIELD POWER SUPPLY
SURGE TANK
HOT WATER
HOT AIR
CITY SUPPLY

SCHOOL: University of Oklahoma, Norman, Oklahoma 73069
TEAM NUMBER: 60   TEAM CAPTAIN: Michael Brule
FACULTY ADVISOR: Prof. S. Sofer
TELEPHONE: (405)325-5811

PROJECT SUMMARY

Equal amounts of manure and warm water are mixed together in a sump. 380 liters (100 gals.) of slurry mixture are pumped daily through a heat exchanger into the main anaerobic digester. Gas produced is piped to two floating storage tanks located in a bio-pond. The gas from the tanks goes through a H_2S stripper before being burned. Used slurry is spread daily onto a sand covered drying bed, where the moisture percolates through the sand and drains into the bio-pond. The floating storage containers collect additional gas released in the bio-pond.

INPUT COMPONENT

The aluminum sump has a volume of 1354 liters (48 $ft.^3$) and is located near the milk barn for easy loading with manure and hot drain water. A positive displacement slurry pump driven by a 1.5 horsepower, single-phase electric motor pumps slurry through the 5 cm (2 in.) PVC lines at 75.6 liters (20 gals.) per minute. A shell and tube, single-phase heat exchanger controls the temperature of the incoming sluury. If the slurry is warm enough, it bypasses the heat exchanger. A 5750 liter (1525 gal.) high-density, cross-linked polyolefin tank was modified for the anaerobic digester. The 7.5 m x 9.1 m (25 ft.x 30 ft.) drying bed is lined with polyethylene sheets and covered by a 15.2 cm (6 in.) layer of sand. The hydraulic retention time is 15 days.

STORAGE

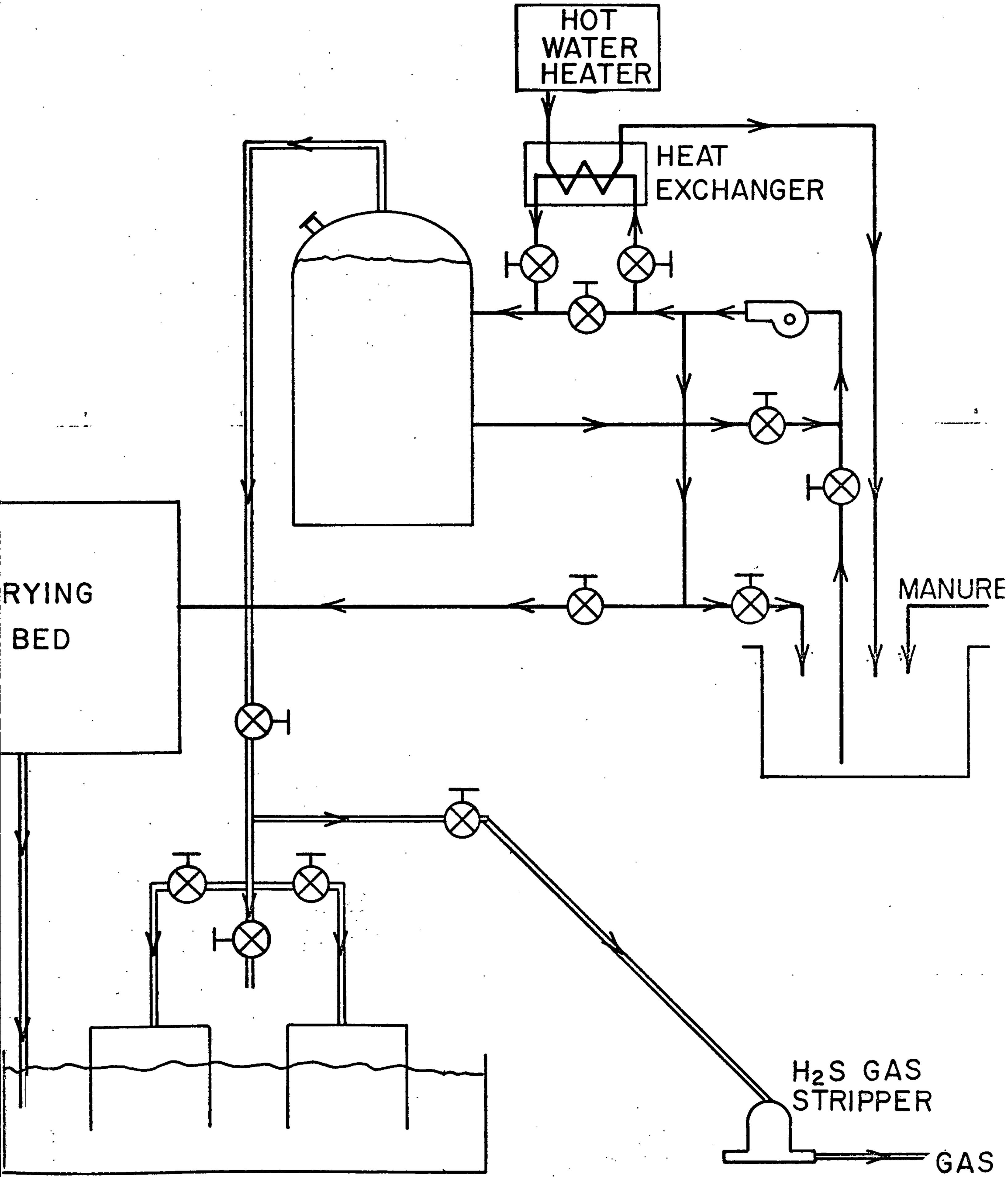
Two 5750 liter (1525 gal.) polyolefin tanks had the tops removed to be used for the floating storage. Seven 7.5 cm (3 in.) schedule 80 pipes guide the wooden retainers mounted above the inverted floating tanks. On top of each retainer pallet, approximately 453 kg (1000 lbs) of surplus iron weights were placed to provide a line pressure of .21 to .3 in. of mercury (3 to 4 in. of water). Flexible PVC tubing is used for the gas lines to the tanks. Each tank has a capacity of 5.66 m^3 (200 $ft.^3$).

OUTPUT

A hydrogen sulfide stripper was made from a 19 liter (5 gal.) 2.5 cm (1 in.) thick steel cylinder filled with wood chips and impregnated with iron oxide. The gas is used to heat water during two 4-hour milking periods at a rate of 10 MJ/hr (9.5 KBtu/hr). Digester gas production (about 75% methane) is .37 m^3 (13 $ft.^3$) per hour with a heating value of 22.4 MJ/m^3 (600 Btu/$ft.^3$).

INNOVATIONS AND RESULTS

: Low cost polyolefin tanks that weigh only 158 kg (350 lbs) were utilized.
: A "de-rocker" was designed and built to prevent rocks in the slurry from damaging the pump.
: A bio-pond was used by the floating storage to increase production.
: A single pump provides all slurry handling including heat exchanger passes to heat tank slurry.
: Tests showed the daily pump agitation was sufficient to mix the tank thoroughly.
: The sump, digester, storage tanks, drying bed, and H_2S stripper were designed and built by students.
: The digester produces .14 m^3 (5 $ft.^3$) of gas per .453 kg (1 lb) of dry manure digested.


HOT
WATER
HEATER
HEAT
EXCHANGER
MANURE
RYING
BED
H2S GAS
STRIPPER
GAS

SCHOOL: Fairfield Senior High School, Fairfield, Ohio 45014
TEAM NUMBER: 62 TEAM CAPTAIN: Michael Williams
FACULTY ADVISOR: Thomas Woodward
TELEPHONE: (513)863-8000

PROJECT SUMMARY

A flat plate collector heats a water storage tank. Space heating is the end result. The project thrust is absorber surface and casing research and development.

INPUT COMPONENT

The absorber is made of 50% waste materials. Used motor oil is heated to 150°C and combined with a mixture of carbon, sand, aluminum oxide to form an ultra high viscosity liquid. The liquid is placed in a mold and heated to form a very black, porous solid slab. Embedded in the absorber is a wire screen and coolant tubes. The casing consists of fiberglass and low density polyurethane foam insulates the collector. The glazing is a combination of glass and plastic and the air space is filled with nitrogen or moisture free air. Each collector is .75 m x 1.08 m (2.5 ft. x 3.6 ft.)

STORAGE

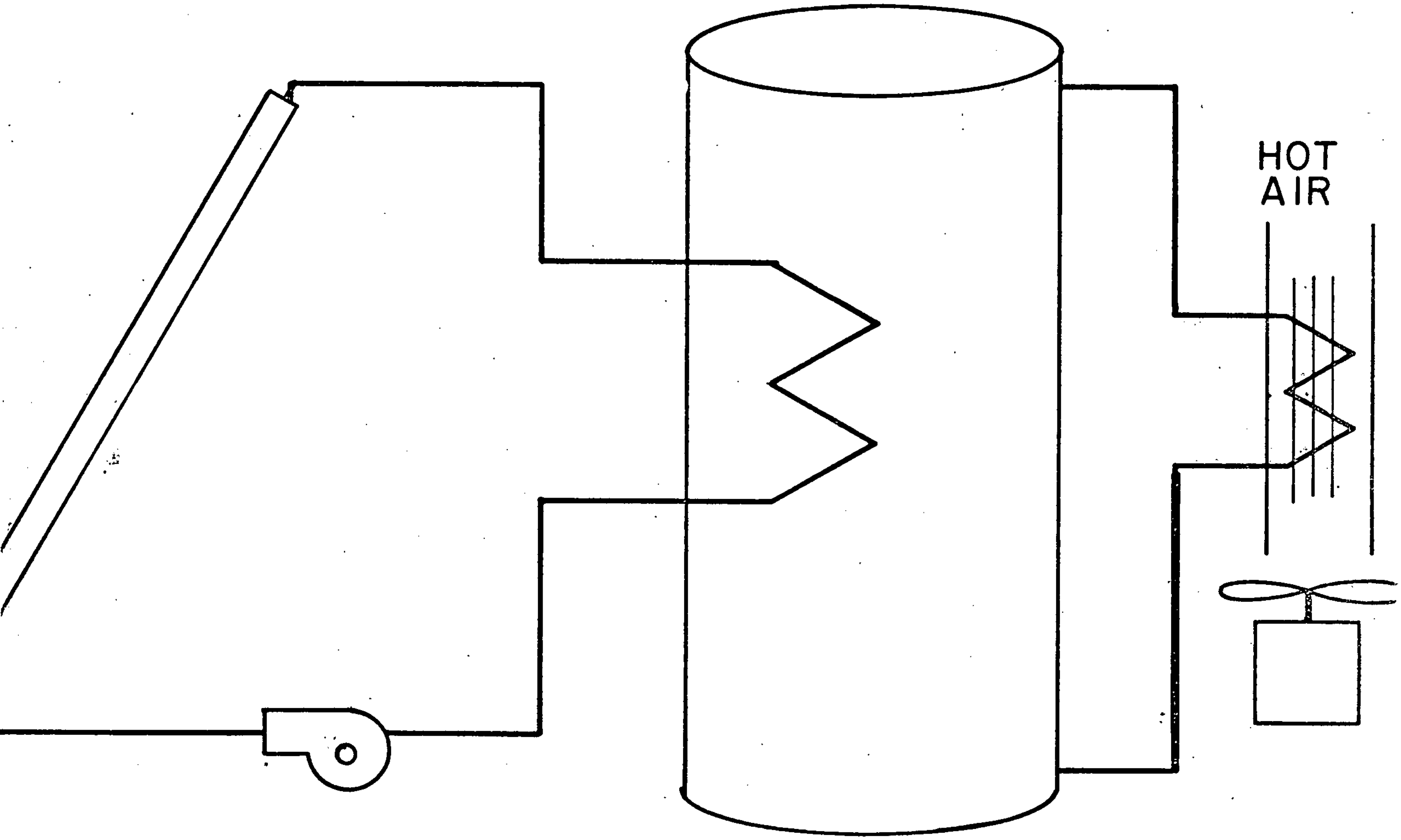
A drum was used for a storage tank.

OUTPUT

Space heating is accomplished with the hot water.

INNOVATIONS AND RESULTS

: Used waste materials to make cheap absorber plates.
: The project was designed and built by students.


HOT
AIR

SCHOOL: Forsyth Technical Institute
Winston-Salem, North Carolina 27103
TEAM NUMBER: 63 TEAM CAPTAIN: Charles McKenzie
FACULTY ADVISOR: Prof. John Beeson
TELEPHONE: (919)723-0371

PROJECT SUMMARY

An anaerobic digester converts cow manure into methane gas. A solar collector would provide the digester with the energy needed to maintain its' operating temperature. Gas is stored in a floating storage tank. An auger system aids in the removal of solidified wastes.

INPUT COMPONENT

A 1040 (275 gal.) oil tank was modified for the main digester unit. Galvanized pipe was placed in the tank as a heating element. The auger is supported by a pad mounted inside the tank and the other end extends through the tank shell. An airtight cover is removed from over the auger when it is in operation. The operating temperature is 35° C (95° F).

STORAGE

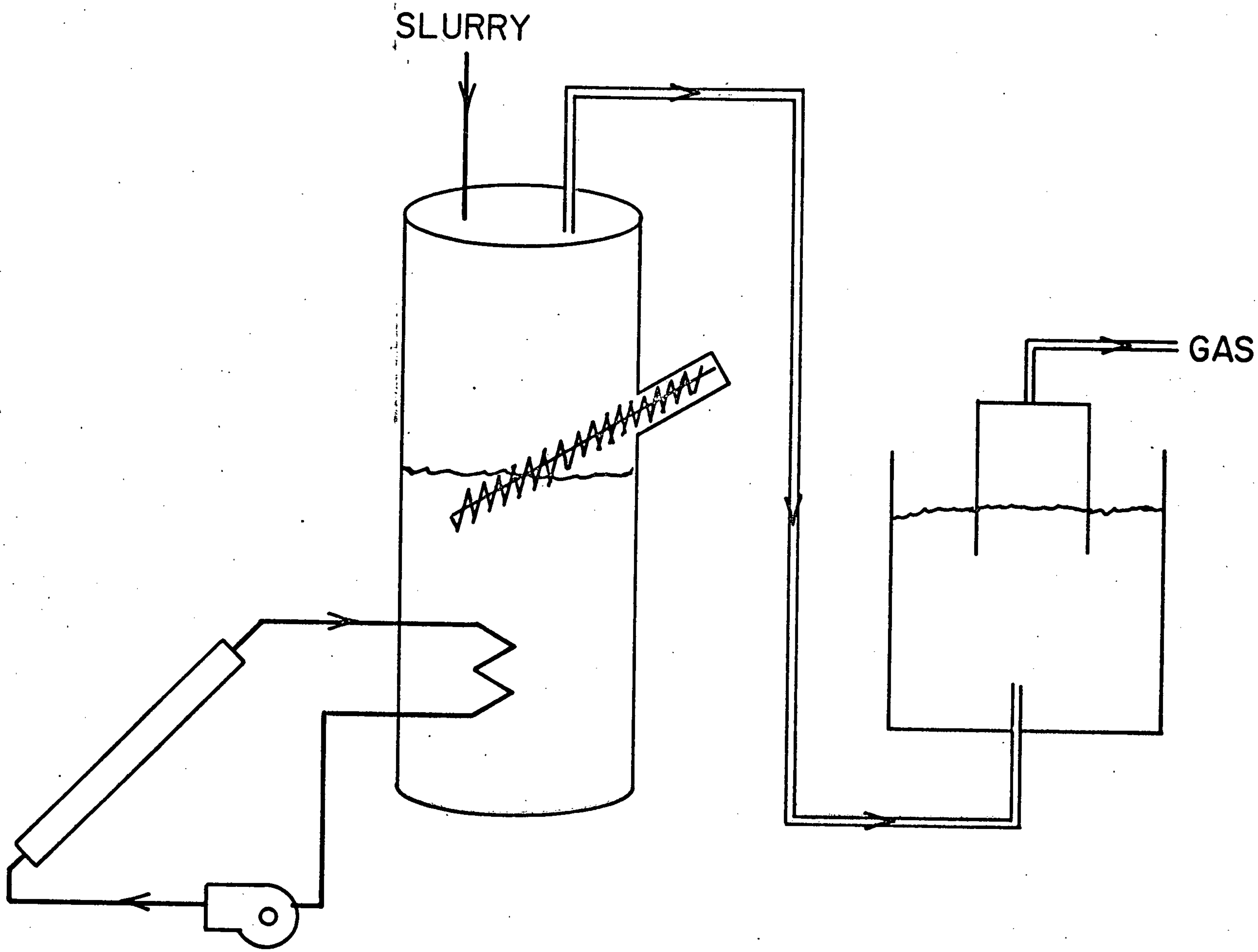
An inverted 113 liter (30 gal.) drum floats in a 208 liter (55 gal.) drum filled with water. Gas is allowed to flow through the water, thus providing some cleaning of the gas.

OUTPUT

Gas is available from the storage tank.

INNOVATIONS AND RESULTS

: Solar panels were tested to be used for heating the digester.
: The digester and storage tank were designed and built by students.


SLURRY
GAS

SCHOOL: University of California at Long Beach
Long Beach, California 90840
TEAM NUMBER: 65 TEAM CAPTAIN:
FACULTY ADVISOR: Prof. Sabri Sungu
TELEPHONE: (213)498-5136

PROJECT SUMMARY

Solar collectors heat a water storage tank. This tank preheats water going into a conventional hot water heater.

INPUT COMPONENT

Each of two collectors has copper tubing attached to the back of a copper plate. Glass is used for the glazing, the casing is wood, and an asbestos compound insulates the back.

STORAGE

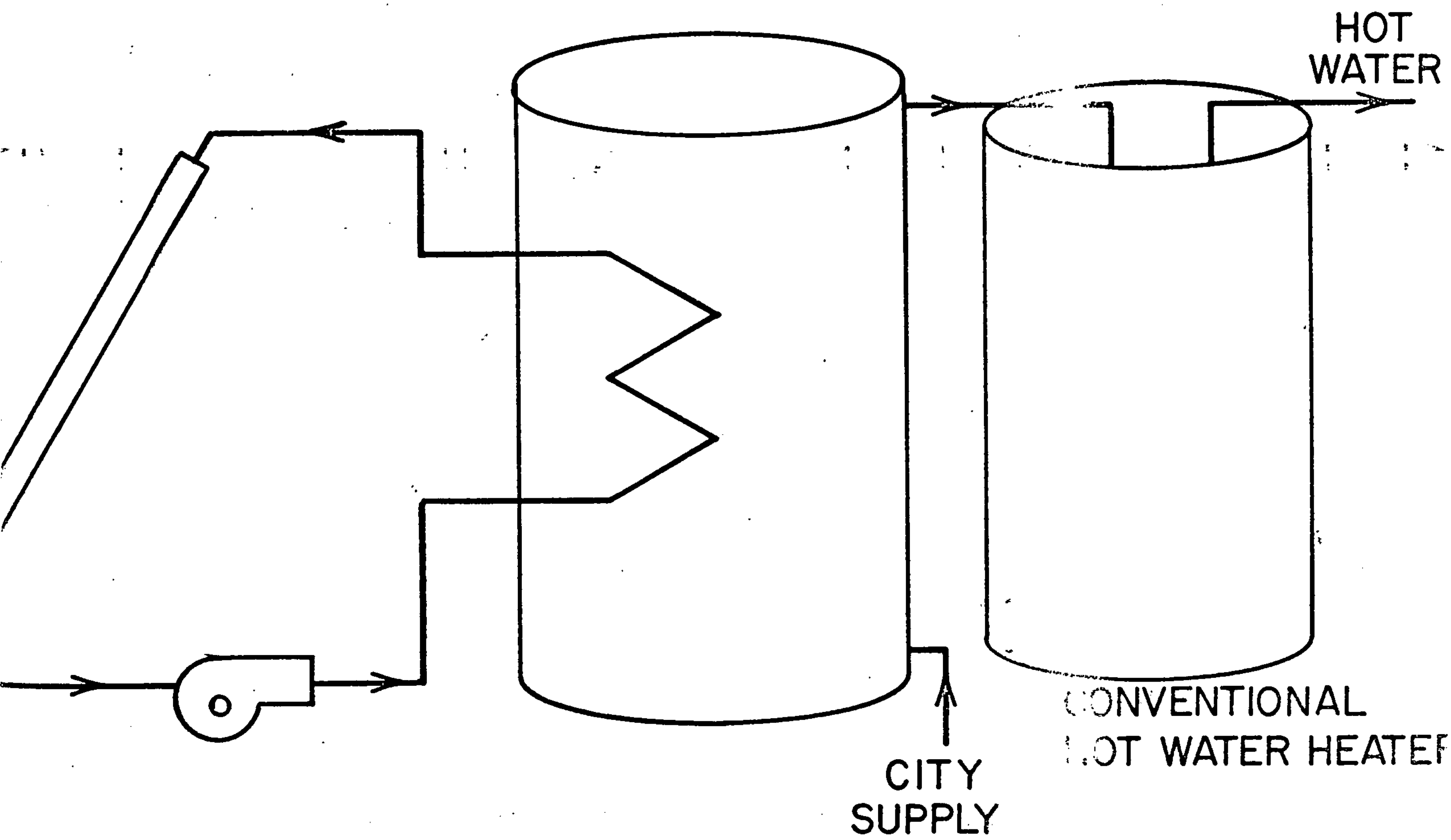
A 208 liter (55 gal.) insulated drum contains the collector loop heat exchanger. The water is preheated in this drum before going to the conventional heater.

OUTPUT

Preheated water is available from the drum.

INNOVATIONS AND RESULTS

: The project was designed and built by students.


HOT
WATER
CONVENTIONAL
OT WATER HEATE
CITY
SUPPLY

SCHOOL: University of Colorado, Boulder, Colorado 80302
TEAM NUMBER: 66 TEAM CAPTAIN: Peter Armstrong
FACULTY ADVISOR: Prof. B. Spurlock
TELEPHONE: (303)492-7586

PROJECT SUMMARY

Two collectors of the ideal concentrator type heat a water storage tank. Hot water is used for space heating.

INPUT COMPONENT

A large parabolic trough of 2.053 m^2 (22 $ft.^2$) area uses Alcoa type 1 lighting sheet as a reflective surface. The absorber is a quilted flow panel painted flat black. Four concave concentrating cylinders form a compound parabolic trough. The absorber pipe is connected serially between the four troughs. The transfer fluid is water and the support structure is plywood.

STORAGE

A tank stores hot water.

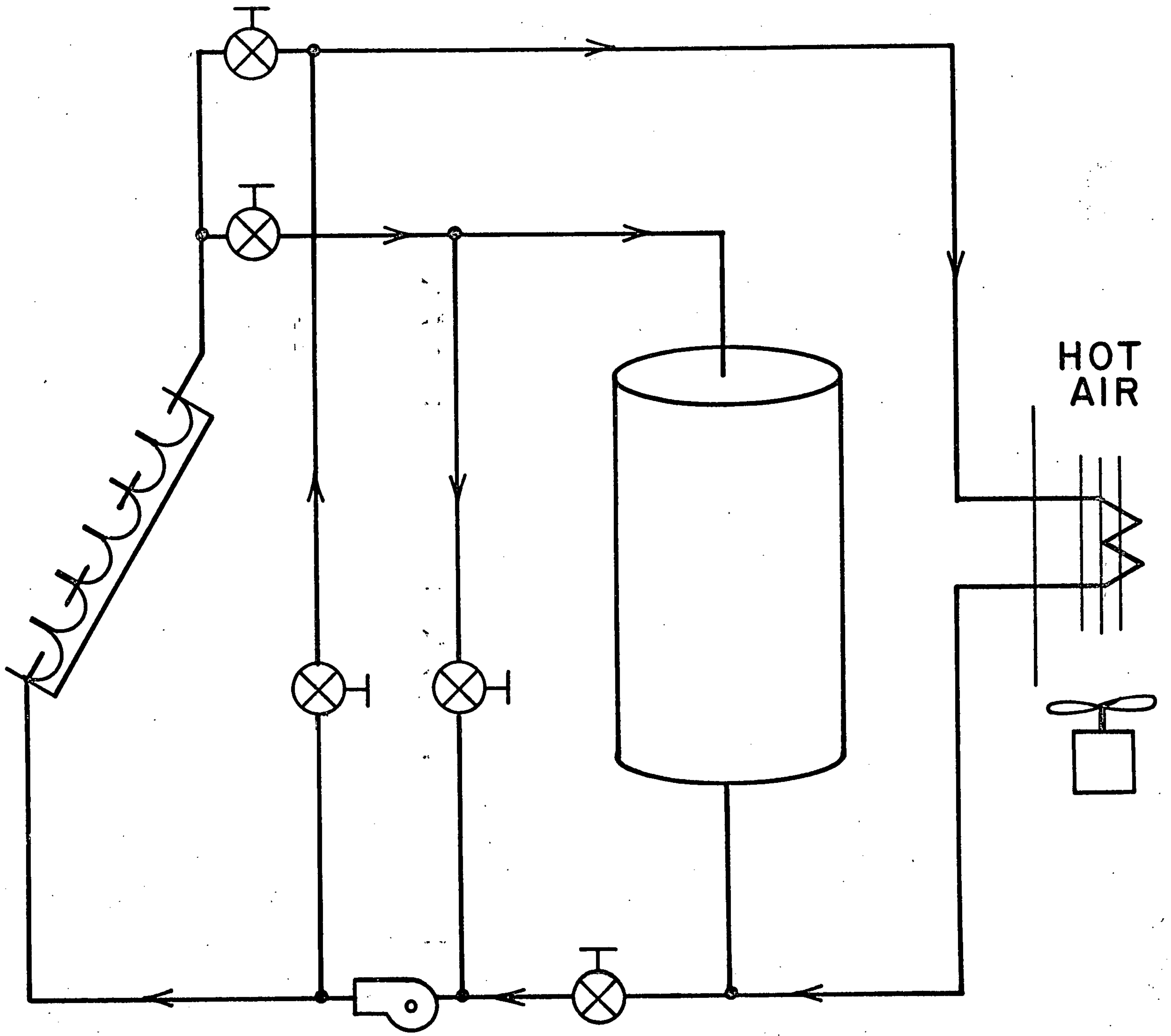
OUTPUT

Forced air heat is available by pumping hot water through the water to air heat exchanger.

INNOVATIONS AND RESULTS

: The team also partially constructed a lithium bromide absorption column and a low power consuming cooling tower.

: The collector and storage system were designed and built by students.


HOT
AIR

SCHOOL: California State University at Northridge
Northridge, California 91324
TEAM NUMBER: 67 TEAM CAPTAIN: Gilberto Morey
FACULTY ADVISOR: Prof. R. Lockwood
TELEPHONE: (213)885-2007

PROJECT SUMMARY

Flat plate collectors with a liquid transfer fluid heat water in a storage tank. Domestic hot water or space heating is obtained from the storage. A lithium bromide absorption cooling system operates from the storage during the summer months.

INPUT COMPONENT

Two 1.22 m x 2.44 m (4 ft. x 8 ft.) solar collectors utilize blackened corrugated steel for the absorber surface.

STORAGE

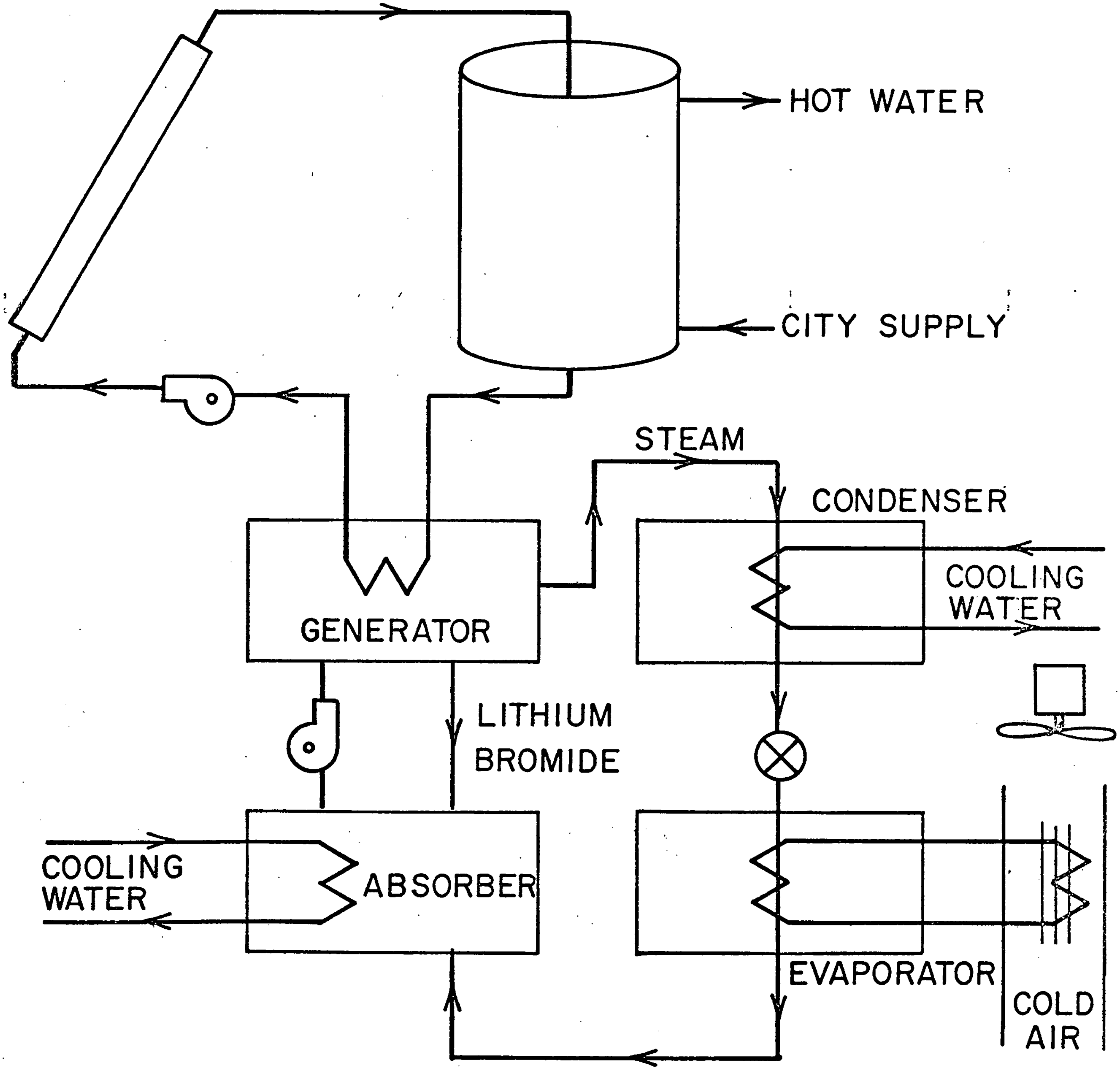
A 3.8 cubic meter insulated tank forms the storage system.

OUTPUTS

Domestic hot water and natural convection space heating are provided. Space cooling is accomplished with the absorption cooling system.

INNOVATIONS AND RESULTS

: The project was designed and built by students.


HOT WATER
CITY SUPPLY
STEAM
CONDENSER
COOLING
WATER
GENERATOR
LITHIUM
BROMIDE
COOLING
WATER
ABSORBER
EVAPORATOR
COLD
AIR

SCHOOL: University of New Brunswick
Fredericton, New Brunswick, Canada
TEAM NUMBER: 68 TEAM CAPTAIN: Rheal Desjardins
FACULTY ADVISOR: Profs. V. Ireton and J. Venart
TELEPHONE: (506)453-4279

PROJECT SUMMARY

The heat pump assisted solar flat plate collector system uses the collector as the evaporator. Vaporized freon leaves the collector, passes to the compressor, and then goes to a heat exchanger in the storage tank. The hot gas gives up heat to the water, condenses, and returns to the collector through an expansion valve.

INPUT COMPONENT

The aluminum collector surface is bonded to the copper fluid pipes with liquid aluminum bonding agent. A single layer of glass glazing, sealed with a silicon caulking agent, covers the collector. Plywood and 2.5 cm (1 in.) syrofoam backs the collector. The collector operates at a slight vacum, .91 atm (13.4 psi), and the refrigerant is R11. A freon receiver built from 40 cm (15 in.) long allows only liquid to return to the solar panel. The high pressure side is at 6.1 atm (90 psi).

STORAGE

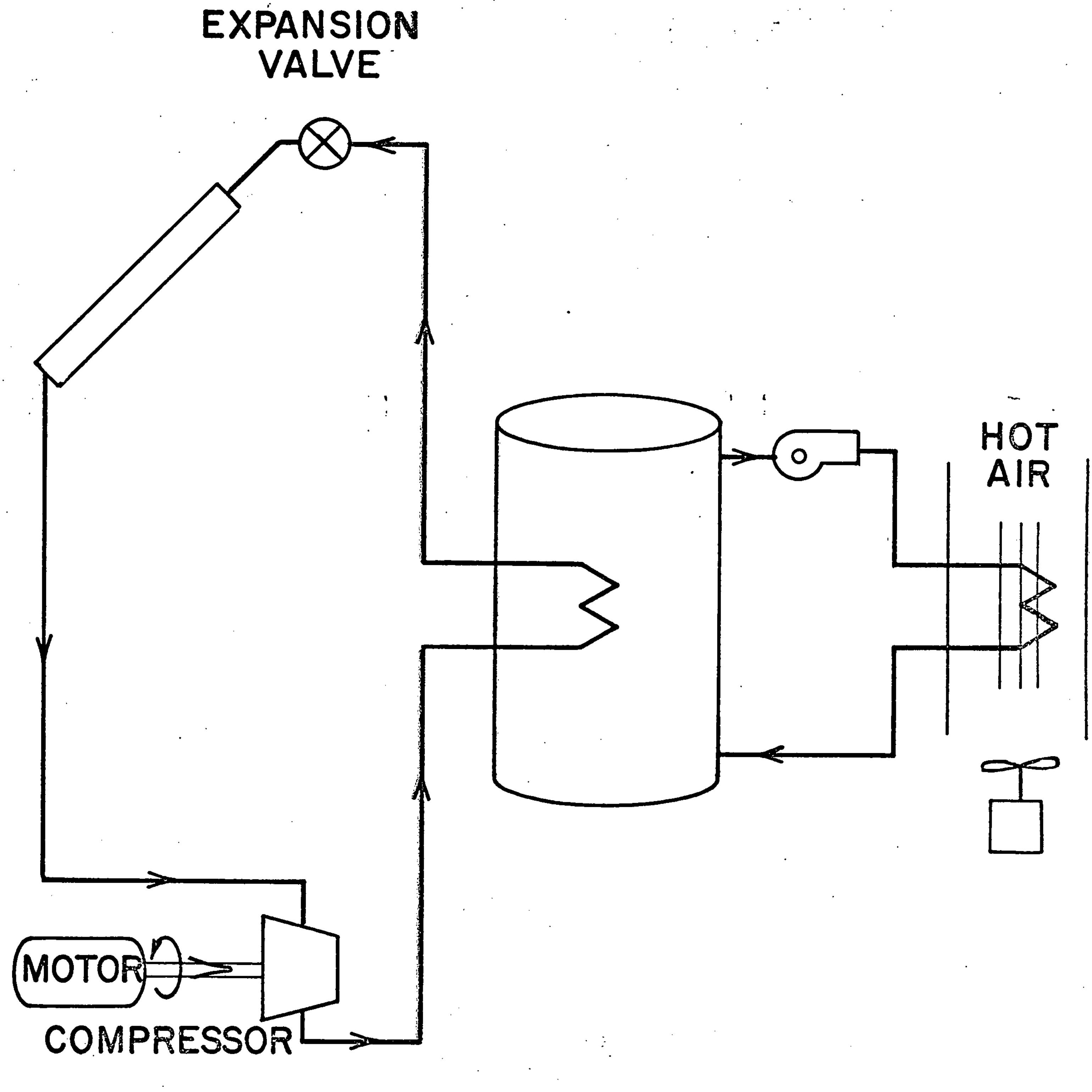
A 136 liter (36 gal.) galvanized steel water tank has four 1.22 m (4 ft.) sections of baseboard radiator located inside. Wooden dowels in copper pipes from cores for inside the condenser pipes, in order to reduce the mass of freon needed.

OUTPUT

Hydronic space heating uses hot water in the storage tank and pumps it to the radiators. Loads were simulated by placing the radiator in a cold water tank.

INNOVATIONS AND RESULTS

: The team designed the collector to serve as the evaporator. This reduces cost because fewer pumps and heat exchangers are needed and no antifreeze solution has to be used.
: The solar collector, heat pump cycle, and storage tank were designed and built by students.


EXPANSION
VALVE
HOT
AIR
MOTOR
COMPRESSOR

MINUTES OF THE ERA ADVISORY BOARD MEETING

September 9, 1974
NSF Conference Room

Attendees:

R.A. Coit, Shell Oil Co.
E.C. Creutz, NSF
S. Golan, Bechtel Power Co.
S.W. Gouse, Dept. of Interior
J. Hammer, Honeywell
J.E. Snell, NBS
F. Harris, SCORE, MIT
M. Radtke, SCORE, MIT
D. Bachelder, ERA, Wisc.
D. Matzke, ERA, Wisc.
J.W. Mitchell, ERA, Wisc.
D. Osowski, ERA, Wisc.

1. GENERAL DISCUSSION

A general discussion of the current competition was held. Emphasis was placed on the design of a complete system as opposed to components. A strong feeling was expressed that students could only build a system with a single source and a single output. It was felt that a package is too ambitious for a student project.

2. DISCUSSION OF COMPETITION GUIDELINES

2.1 Discussion of specifications. The general feeling was that the design specifications require a project that would be too large to construct and transport to the test site. The time required for the system to come to equilibrium would be large also.

The general consensus was that the projects should be designed for the specifications, but the actual hardware could be scaled up or down for construction. No minimum should be specified. Students should math-model the operations and design of their project if the hardware has been scaled up or down.

The competition should allow students to focus on building those components not available. Specifically, students should not construct currently available devices.

2.1 Con't.

The current rules place too much emphasis on thermal storage systems. Conversely, not enough emphasis is placed on nonthermal storage systems. Specifically, electrical storage systems should be considered for their impact on off-peak power use and for increasing the load factor.

2.2 Discussion of scoring. Not enough emphasis is currently placed on the economics of the project. The current weighting is representative of what an engineer might be expected to design toward. A company would mainly consider the economics. Maybe the economic weighting should equal the performance weighting.

Specifically, for solar energy, cost effectiveness is much more important than performance. However, for some fuels (coal, electricity) performance is a controlling factor.

Institutional (legal) and esthetic factors should be included in the scoring. Architectural considerations should possibly be included.

2.3 Students should design tests for preliminary evaluation of their project. These tests should be conducted under rigorous and controlled test conditions.

3. DISCUSSION OF THE SYMPOSIUM

The following names were suggested for symposium speakers:

Lloyd Herwig - solar voltaic cells, NSF
Jerry Weingard - solar enthusiast, Cal. Tech.
Jerry Layton - solar house, HUD
Darwin Wright - solar, EPA
Duane Spencer - solar, EPRI
William Herronimous - wind
Derrick Greggory - hydrogen, Inst. Gas Tech.
Art Squires - coal and coal gas, IGT & CCNY
Matthew Riley - multiple integrated utility system, NAE
Myron Tribus - keynote, Xerox-MIT
Chauncey Starr - keynote, EPRI
Charles Berg - overall, Oak Ridge
Jim Comley - thermal systems, GE
Dave Ragone - batteries, Michigan
John Sawhill - overview
Gulf Oil - hydrogen

4. DISCUSSION OF FINAL TESTING SITE

Consensus was to try to get a national laboratory:

Bureau of Mines, Pittsburgh
Oak Ridge
AEC, Sandia, Alberquerque
NBS
NASA, Houston
NASA, Lewis
Carrier Corp.

5. DISCUSSION OF FINAL TESTING PROCEDURES

Various viewpoints were discussed, namely that:

5.1 Each team conduct tests at their own site under certification. Final competition would be limited to a few (10) teams; or

5.2 All projects be tested at home sites, but be brought to a final testing site for competition and judging; or

5.2 Each team develop and construct their own test equipment and bring it with their project to the final testing site for judging.

The ERA Coordinating Committee sincerely appreciates the enthusiastic participation of the Advisory Board.

Energy Resource Alternatives

SYMPOSIUM II

Friday, March 21

8:30 Arrive & Welcome Room 109

8:45 Keynote-Dean W. R. Marshall
SCORE Board of Directors

9:30 Purpose & Description

10:00 Break

Morning Time Blocks:

10:30 Workshops
- A: Methane Production (testing & scoring)
- B: Electrical Production Room 2
- C: Solar Construction (Flat Plate) Room 3

12:00 Lunch

Afternoon Time Blocks:

1:00 Workshops
- A: Wind (testing & scoring) Room 1
- B: Solar Simulation Program Description Room 2
- C: Auxiliary & Storage Equipment Room 3
- D: Bus Tour-Methane Production Equipment Bus leaves at 12:45 from Union South, back by 2:30

2:30 Break

Wind Works Tour-leave Union South, return by 7:30

3:00 Workshops
- A: Solar (testing & scoring) Room 1
- B: Control Systems Room 2
- C: Hot air & hot water (Heat pumps) Room 3

Evening:

7:00 B et-Sponsored by SCORE

Saturday, March 22

8:00 Wind Works Tour-leave Union South, return by 1:00 p.m.

Morning Time Blocks:

8:30 Workshop
- A: Hot water (testing & scoring) Room 1

10:00 Break

10:30 Workshops
- A: Electrical Systems (testing & scoring) Room 1
- B: Solar Construction (Flat Plate) Room 2
- C. Bus Tour-Methane Production Equipment Bus leaves Union South, back by 12:00

12:00 Lunch

Afternoon Time Blocks:

1:00 Workshops
- A: Auxiliary & Storage (testing & scoring) Room 1
- B: Electrical Equipment Room 2
- C: Hot air & hot water (Heat pumps) Room 3

2:30 Break

3:00 Workshops
- A: Heat & Air Conditioning (testing & scoring) Room 1
- B: Control Systems Room 2
- C: Auxiliary & Storage Equipment Room 3

Sunday, March 23

10:00 Testing & Scoring Discussion; Final Test Site Considerations; Portability Room 109

11:00 Break

11:15 Finances Room 109

12:00 Farewell

*All sessions are held at Union South. Room assignments will be given at the opening session Friday. All testing and scoring sessions are scheduled only once. All design and construction sessions are scheduled twice. You may go to either of the design and construction sessions depending upon your choice.

Information Room: An information room is located in Room 225 of Union South where ERA staff members are available to answer questions. Coffee will be available in the information room for your refreshment.

A SCORE ogram

SUMMARY OF THE ENERGY RESOURCE ALTERNATIVES SYMPOSIUM II

on

March 21-23, 1975

Held at the

University of Wisconsin

College of Engineering

Madison, WI

Summary of Events at ERA Symposium II

The symposium was opened with a keynote address from Dr. W. R. Marshall, Dean of Engineering, University of Wisconsin. Dr. Marshall, also a member of the SCORE Board of Directors, discussed the ERA competition with respect to SCORE's goal, society's needs and experience available to participating students.

Following was a statement by Doug Matzke, ERA Communications Chairman, on the objectives of the symposium. These were: to present the teams with the initial work the ERA staff has done with regard to the homesite testing procedure and data collection which will be required of the teams, and to give team members an opportunity to talk with other team members guided by professors and graduate students with experience in each field about the project construction problems. Additional symposium scheduling information was also discussed.

Dave Stipanuk of the ERA staff introduced the concept of homesite testing and discussed certification possibilities for the home site tests. In order of preference these would be: a member of industry, a faculty member from another university, or a faculty member of same university not associated with the ERA project. He also discussed the real need of information on the physical size and energy capacities of the systems in lieu of final test site logistics and load planning. Tests that were not requested of the teams at home site testing will not be "sprung" at the final test event. He also presented a sample of a homesite data reporting sheet. Testing documents will be out in May and will be due with the final report at ERA Headquarters several weeks before the final test event.

<u>Construction Sessions</u>:

<u>Tours</u>: Some of the discussion sessions included tours of pilot projects and the following is a summary of the questions and important details raised.

Hans Meyer at Windworks, Box 329, Route 3, Mukwanage, WI (53149) gave a very interesting tour of his work. He collects old windmachines and studies and builds other windmills. He is working on two phases: 1) to show how readily available materials such as car differentials and electric conduit could be used to harness wind energy in underdeveloped areas and 2) to improve construction techniques and reduce cost of wind machines for small scale electric generation.

Hans has a working 2.5 kw generator on a 60 foot octahedron tower and 1 hp sail windmill on a 42 foot octahedron tower. They presented a slide show describing the history, advancements and present state of windmill technology. They also talked about the work they have done on fiberglass over honeycombed wood for lightweight blades. These 4 lb-4 ft blades are easily built and have good aerodynamic characteristics because the honeycombed wood can be twisted before being fiberglassed. The octahedron tower, also developed at Windworks is free standing, modular, and 30-40% lighter than conventional truss towers. They are presently working on a better hub design for feathering the blades - an essential in high wind safety.

Jim Converse conducted the tours of a pair of anaerobic digesters being studied at the University of Wisconsin. The project has 2 - 500 gallon stainless steel tanks, one thermophilic and the other mesophilic. He discussed how the tanks are studied, the equipment used including drying ovens and gas chromatographers, how the manure is handled, and the total energy balance of the system, including increase of handling costs because of the larger volume. The students were particularly interested in the testing equipment. The input was a 50/50 mix of manure and water, the output was predominantly methane with some CO_2 and the tanks were electrically heated. Students were also surprised that the influent and affluent volume and consistency were almost identical.

<u>Other construction discussion sessions:</u>

The solar construction session brought up a wide range of discussions. Questions were on materials for the collectors, systems design and practical problems such as paint, surface materials and draining. The students knew the basic equations but seemed not very far on actual hardware construction. In general the level of questions indicated the projects were still very much in the design phase and not as far as we had anticipated for the symposium.

Some graduate students from the University of Wisconsin gave a presentation on a solar simulation program. This program would have each component of a solar system simulated with the flexibility to "interconnect" the various input, storage and load components. The discussion was centered on the potential of using a simulation program, how any one with programming experience could write one and how close a program can actually simulate a real system. More information on simulation and references on collector surfaces can be found in the 1974 Solar Energy Thermal Processes - by J. A. Duffie and W.A. Beckman.

At the storage session led by Professor Beckman from the University of Wisconsin again the types of questions indicated the groups were not in the construction phase as much as was hoped for. Questions pertained to appropriate salts for latent heat of fusion storage and finding a suitable salt with many duty cycles. The corrosion of storage containers was a big concern. The coal area was touched and discussion on the potential hazards of storing powdered coal was mentioned. In most cases the problems were materials problems and the discussion leader felt the students were overly optimistic about finding solutions.

The group leaders of the electric session said students were interested in how to build inverters and where to get parts at lower cost. The students were also asking why DC shouldn't be an allowable output due to lower costs due to not needing an inverter. (Explained later) One student was interested in how to build a generator. In this case and most others the students seemed to lack background in the electrical field. The types of questions were again more general design phase questions rather than construction problems. Most problems were types that would be covered in basic electric machine courses.

Professor Howard Harrison of the University of Wisconsin led the control systems discussions. Generally the students were interested in what instruments were needed to measure such quantities as speed, pressure, and flows and where to get them. Professor Harrison felt the students generally seemed to think towards using more complicated linear controls, instead of cheaper on/off types. There was a consensus that in many cases on/off controllers could be used. Most of the questions were those of persons realizing they need some control system rather than fault-analysis of a built control system.

The thermal systems and heat pump session discussed basics of a heat pump using a heat source. The students were reluctant to talk about their projects, and the understanding levels were diverse.

<u>Testing and Scoring Sessions</u>:

Home site testing documentations done by the ERA Committee were introduced at these sessions in each of the component areas. The feedback generated was very helpful to us. The procedures introduced were the first drafts, and the final documents will be out in May.

In the solar session, Tom Rietmann of the ERA staff talked about a 4 input fluid temperature method of determining the solar collector efficiency as a function of an appropriate $\frac{\Delta T}{I}$. The results when graphed would be a straight line of which the slope is some function of U_L, the heat transfer loss coefficient, and the y intercept is some function of $(\tau\alpha)_e$, the effective transmission - absorption factor. In reality U_L is not a constant but is a function of the temperature of the collector and of the ambient weather conditions. The product $(\tau\alpha)_e$ is also not a constant but varies with incident angle to the collector. The testing procedure and method of collecting data as well as the type of test instruments, their accuracy, precision, calibration and setup was also discussed. Recorded test data format sheets and other specific data format sheets to be used for homesite testing will be included in the final solar testing document.

Ravi Merchant of the ERA staff led the wind Testing & Scoring session starting with analysis of the towers and blades. The discussions were sidetracked for a while because teams didn't want to transport the towers to the final test site due to the additional cost and time. It was decided towers were a part of the project and were necessary for project performance and cost estimates. It would also be unfair to other non-wind projects if standard towers were supplied at the final test site.

There are two parts to all home site testing documents: actual data from test and analysis work for non-tested areas such as blade stress or tower stress. The ERA Committee is not requiring stress-till-breaking data but analysis on such crucial safety areas will be requested.

The question of awards in comparing wind projects in power per dollar against solar systems was discussed. It was again pointed out that awards would be given in a variety of sub-areas in addition to the overall awards.

The electrical Testing & Scoring introduced the important parameters that will be tested such as output voltage, frequency, stability, and waveform distortion. A big discussion about DC over AC output started. Most members claimed AC was nonecological, inverters cost a lot of money and could they get by with producing DC at some lower voltage. ERA's goal is not to change society's use of resources but to produce for the present society, keeping the cost as low as possible. It is very possible that the society will go DC but the appliance America today survives on AC.

Members asked if they could produce some AC and the rest DC. ERA members stated a possibility of written justifications to allow teams to stray from the original design specs. Such a justification might be that a house only requires 70% of its power in AC, the rest for resistant lighting and heating could be DC, or that homes in Arizona don't need dehumidification so this would not be included. In any case the judges will have the final decision on points for any project spec changes.

Dave Stipanuk of the ERA staff discussed water and air heating and air conditioning system tests for the homesite. This involves a system's view of the project and a total balance of energy in and out of the system - plus changes in the stored energy and auxiliary input energy. Homesite tests will run for long periods of time (possibly 24 hours) and the measurements of energy-in, energy-out and change in energy-stored will give a system efficiency rating. The system test data plus data on each component will be included in the final report which will be due before the final test event. In all system tests, a means of measuring the initial and final conditions of the storage is mandatory. Specifications on the location of measuring devices will be stated in the homesite test documents plus data calculations required.

Storage Testing and Scoring was led by Carol Berenson of the ERA staff. She introduced the calculations that would be necessary to find the stored energy, heat losses and test equipment to evaluate the storage component, such as thermocouples and strip chart recorders. Safety is an important part of storage components and she discussed reporting on the safety features of the units. It was decided that teams can erect some shade or shelter over the storage areas if it is crucial to the design. In general projects must be weatherproof enough to be tested at the final test site without faulting due to rain or dirt getting in the machinery.

The final wrap-up discussion included talks on finances, patents and other areas of questions. Mark Radtke, president of SCORE, discussed the financial situation and asked if teams could use more information packets or slide presentations to help with their local fundraising. In light of local fundraising Mark said they would be glad to help in any way they could and encouraged the team members to ask for materials from SCORE.

Mark mentioned the reason the patent clauses are in the funding documents is because of the educational tax exempt status that SCORE has. A series of questions were answered but all questions relating to patents or commercialization should be directed to the SCORE office. Mark made it clear that SCORE is in business for an educational purpose and does not want to get involved in the patent business.

Generally the teams' fundraising was very rough but they would most likely get by. SCORE's fundraising was going pretty well and if all the grants came through there would be additional money for equipment, transportation and possibly summer salaries. SCORE would let teams know of additional funding when available. Mark speculated that the money seemed definite and that there would be additional funding for the teams.

Discussions led to project decisions and not meeting certain requirements such as AC output. ERA's goals are to provide present household energy needs using the technology of nonconventional energy sources and all deviations from these goals must be justified in writing in the final report. Judges will decide on a one-to-one basis, if these justifications merit the points with regard to those deviations.

Some teams involved in complete package projects and having 20-30 active team members were encouraged to submit two or three budget proposals for funding purposes. Later these subsystems can be united for the testing and scoring phases and be eligible to enter as only one team. SCORE does not want to penalize large teams by limiting their funds.

Team members questioned the cost evaluation of the scoring procedure and what would be the scaling factors. The ERA staff stated due to nonlinearity in the projects the scaling factor would be defined as the number of identical such units needed to meet the requested (average) outputs as specified in the revised design specs.

The following two corrections were <u>again</u> stated. Two graphs were mislabeled and the corrections for the electrical output should be 0 to 2 kwatts and the hot water output should be 0 to 40 liters instead of 4 liters. All horizontal axes are 0 to 24 hours. The scoring will be set up to encourage full scale models and the unit scaling factor to be used in the cost/energy analysis to encourage scaled models near unity. In any case projects must be large enought to provide substantial test data.

Symposium statistics:

students and faculty members from teams were at Symposium II. Special thanks goes to those attending, the professors and graduate students of the University of Wisconsin, and the ERA and SCORE staff members who made the symposium such a success.

Alabama, University of -Huntsville	Team # 36	5 students
Alabama, University of -Huntsville	37	5
California State University -Northridge	67	3
Concordia University	46	2
Drexel University	55	4
Fairfield Senior High	62	2
Florida, University of	54	5
Hartford, University of	58	1
Houston, University of	26	2
Houston, University of	27	1
Houston, University of	28	2
Houston, University of	29	1
Iowa State University	56	3
Massachusetts Inst. of Tech.	23	1
Massachusetts Inst. of Tech.	43	1
Michigan State University	35	17
Michigan, University of	51	4

New Brunswick, University of	Team # 68	2 students
Oklahoma, University of	60	1
Pennsylvania State	47	2
Rensselaer Polytechnic Inst.	33	2
Texas, University of --Austin	39	3
Toronto, University of	25	1
Washington State	57	1
Wichita State University	42	8
TOTALS	Teams 25	79 Students

SCORE

The Energy Resource Alternatives Competition

ABSTRACT

This Document presents a general outline and the specific rules for the 1974-75 SCORE national student engineering design competition. The year long competition is directed toward the design and construction of energy packages to meet the needs of homes, farms, and light industry. The emphasis in the design of these packages will be on utilizing such nonconventional energy sources as wind, solar, or synthetic fuels. All students interested in developing their ideas are encouraged to pursue, with faculty guidance, their innovative solution to a national problem and submit it in competition with the ideas of other students from the United States and Canada.

As in the past SCORE competitions, seed money for the design and fabrication of student projects will be made available.

August 1974

ERA Coordinating Committee
College of Engineering
University of Wisconsin
1513 University Ave.
Madison, Wisconsin 53705

SCORE'S NEW ERA

To stimulate a project-oriented approach to engineering education;

To promote new approaches to solving relevant engineering problems;

To increase national awareness of the problem the competition addresses.

These statements summarize the objectives of Student Competitions on Relevant Engineering (SCORE), a student run, nonprofit corporation. The academic engineering community established SCORE in 1971 to sponsor national intercollegiate competitions. These engineering design and hardware fabrication competitions focus on areas where a technological solution to a significant contemporary problem is possible. In its first three years, over 3200 students from around the country have participated in the 1971-72 Urban Vehicle Design Competition (UVDC) and in the 1973-74 Students Against Fires (SAF) competition.

Now SCORE is announcing the 1974-75 Energy Resource Alternatives (ERA) competition. The year-long competition is directed toward the design and construction of energy packages to meet the needs of homes, farms, and light industry. The emphasis in the design of these packages will be on utilizing nonconventional energy sources (e.g., wind, solar, synthetic gas).

To aid in organizing and running the ERA competition, SCORE has selected the College of Engineering at the University of Wisconsin as the host school. The responsibility for organizing the competition is divided between the ERA Coordinating Committee (at the University of Wisconsin) and SCORE (the national organization). The ERA Coordinating Committee is responsible for writing the rules, organizing the competition, reviewing entries, making recommendations for funding, and handling the day to day details of the competition. SCORE is responsible for fund raising, handling national publicity, and providing ongoing administrative leadership.

STATE OF THE ART

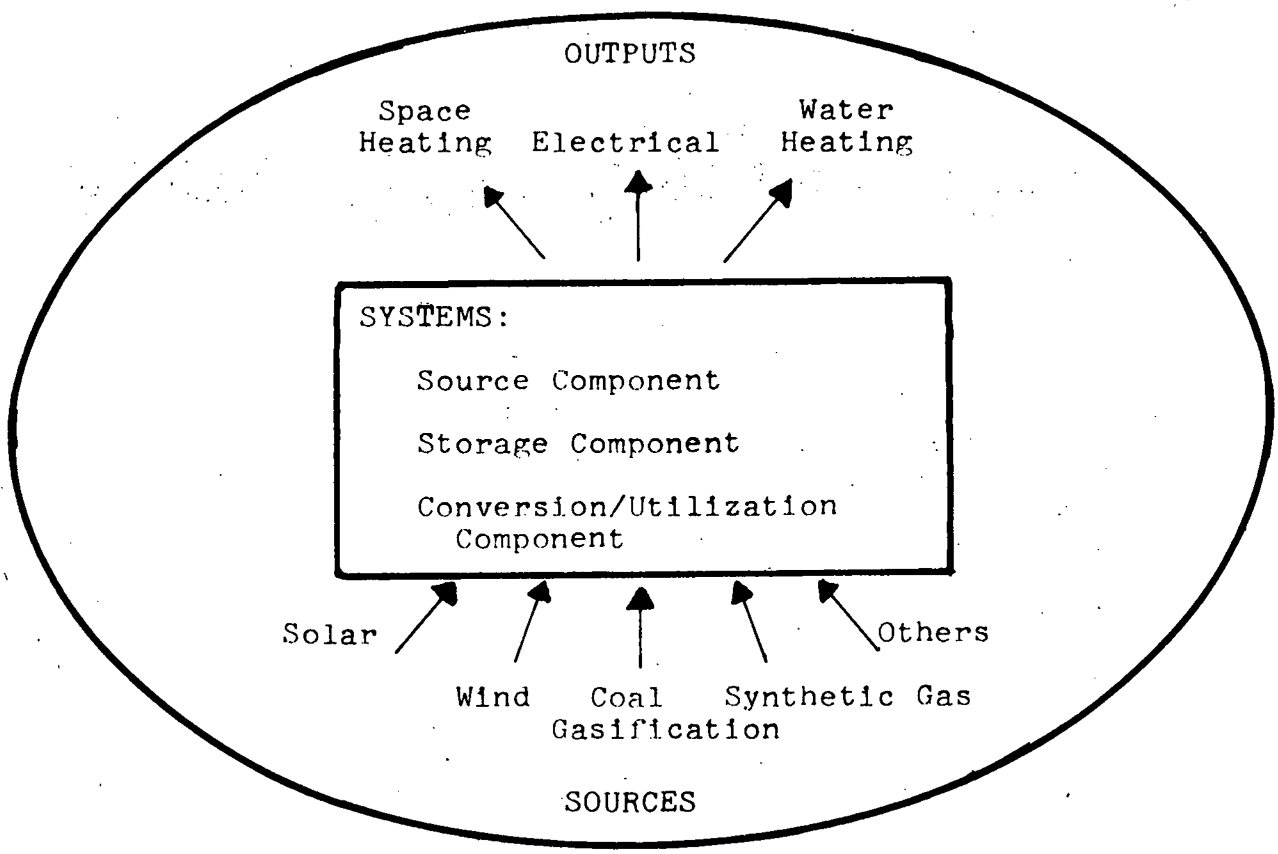
For the past three decades man has relied mainly on petroleum and natural gas to supply his energy needs. Now, in many countries, it has become painfully evident that the demand for these fossil fuels is approaching the upper limit of supply. Recent events have demonstrated that our natural petroleum reserves are being rapidly depleted. It is evident that we must develop alternative energy sources for the future.

The task of developing cheap and abundant energy is not easy. Engineers and scientists in increasing numbers are becoming involved in developing these alternate energy resources. The emerging technologies of solar and wind energy in combination with the developing technologies of coal gasification and nuclear fusion will help meet man's requirements for energy in the future.

We are witnessing the start of a new chapter in the evolution of energy sources. Just as the energy sources of the past gave way to the energy sources of today, so must the energy sources of today give way to those of tomorrow. Today's problem is real and sharply defined. The solution is diffused and multifacted. There is an urgency for action.

THE COMPETITION

An energy package must incorporate the facets of primary source utilization, conversion from one energy form to another, and production of usable output. Each facet must be designed and built using sound engineering principles with the total system able to meet desired load specifications. The diagram below illustrates the features of an energy package.



ENERGY PACKAGES

The source selection should be made with consideration for the availability of the energy source, efficiency of the conversion process and convenience for use in homes and light industry. The principle design goals are to generate power outputs in the forms most often utilized - space heating, electricity, and water heating.

The scoring for the final competition will be designed to encourage the ingenuity and innovation necessary if these new sources are to replace the energy sources of today. Points are given for creativity in areas such as nonconventional source selection, imagination and simplicity of design, safety, design for multiple energy outputs, and environmental impact as well as in the areas of production cost, efficiency, retrofitting, geographic versatility, and performance of the prototype system. To reward the innovative designer, the ERA Coordinating Committee will be using a Student Innovation Multiplier (SIM) in the scoring procedure.

The ERA competition will have two phases: a design phase and a hardware construction and testing phase. In the first, student teams will study the problem and the design objectives of the competition and then develop a design for their proposed hardware solution. In phase two, the hardware is built and tested to bring it as close to design specifications as possible.

At given intervals during the year the teams will be required to file reports on the progress of their entries. This will enable the ERA Coordinating Committee to remain updated on the projects, and will serve as the principal basis for grant considerations. SCORE grants are awarded based on an evaluation of a team's design proposal and reports and it's request for financial support for the actual construction of the project. These grants are not intended to finance the entire project, but with the current interest in energy, local sponsors should be readily available.

The ERA Coordinating Committee plans to hold two symposia to help inform student teams of the current state of energy technology, and to aid in solving design and construction problems. The first symposium, scheduled for October 19-20, 1974, will present experts from the field to discuss the present status of nonconventional energy systems. This should help provide basic knowledge for the teams to aid in developing their projects. The second symposium, planned for March, 1975, will provide answers to technical questions by giving team members the opportunity to discuss the problems in workshop sessions with other teams members and experts in the field.

Both symposia will include business meetings to discuss such matters as the competition's rules, timetables, and final testing procedures. If any changes in the basic rules are made, teams will be notified through newsletters which will be mailed regularly to keep teams informed on all competition news.

The culmination of the competition will be the Final Testing Event in August of 1975. All the teams and their projects will meet at a single test site for four days of testing and evaluation. The hardware will be tested under rigorous experimental conditions to accurately measure its performance. The test site will also be chosen to allow the solar, wind, hydrogen, synthetic gas and other power generating systems to be tested under real-world conditions.

During the final testing, the competing team members will give oral presentations before judges. These simulate a marketing presentation in which students try to "sell" their hardware design to the judges. Innovation, relevance, cost-effectiveness, and marketability should be among the design features emphasized. The judges will be research and practicing engineers, policy makers from government and industry, and professionals in the energy field.

The SCORE organization consists of the national SCORE office at MIT in Cambridge, Mass. and the ERA Coordinating Committee at the College of Engineering of the University of Wisconsin-Madison. For further information please contact the following people:

Executive ERA Coordinating Committee - University of Wisconsin-Madison

Dennis Bachelder
Doug Matzke
Doreen Osowski
(608)-262-2173

SCORE
MIT

Mark Radtke, President
Frank Harris, Vice President
(617)-253-6833

Chairman of the ERA Advisory Board and Faculty Advisor

John W. Mitchell

(608)-262-3594

Chairman of SCORE Board of Directors

John H. Sununu
Tufts University
(617)-628-5000, Ext. 268

COMPETITION RULES

1. TEAMS

1.1 All team members must be registered full or part time students currently enrolled in a degree program at an accredited educational institution. Participants may include:

a. Undergraduates and graduate students.

b. Co-op students who study full time (or equivalent) for at least six months of the year, June 30, 1974 to June 30, 1975, and work the remainder of the year.

c. Students who graduate in December, 1974 or anytime thereafter.

1.2 All teams must submit the attached entry form indicating affiliation with an accredited institution and signed by the President, Dean of Engineering, or a Department Head of that institution. An initial entry form must be submitted by Nov. 15, 1974. A final participation form will be required a month prior to the final testing.

1.3 All teams must have one or more faculty advisors whose name(s) and address(es) must appear on the entry form.

2. SPONSOR GUIDELINES

Entrant teams may solicit financial, technical, or other assistance from corporations, consultants, universities, governments and their agencies, other organizations, or individuals (referred to as "sponsors") according to the following guidelines.

2.1 A "sponsor" will be defined as all divisions and subsidiaries of one parent organization. No exception to this interpretation will be permitted unless expressly approved in writing by the Committee.

2.2 Teams may accept from sponsors any part, system, component, design, or idea (hereafter called "elements") to be used in their entry, subject to the following constraints:

a. No sponsor-supplied, commercially available, or non-student design element will be eligible for an award given for innovative student design.

2.2 (continued)

b. No sponsor-supplied element of a proprietary nature will be permitted in the competition.

c. Innovative combinations of modifications of existing elements will be eligible for design awards.

2.3 In order to determine the role of the sponsor all teams must submit an analysis of sponsor participation. A "Sponsor Participation Form" will be issued.

2.4 The Committee and its representatives reserve the right to inspect all components, technical drawings, and design work on an entry to evaluate the amount of sponsor participation. The decision of the Committee on this matter is final.

2.5 Except for items specified in section 2.2 sponsors may act only in an advisory capacity in the design of any component or system of an entry.

2.6 Advertising of industrial sponsorship or the use of supplied components via any media must be reviewed and approved by the ERA Coordinating Committee in writing prior to distribution or presentation. Advertising and sponsorship of a a component or system shall be limited to the following:

a. A maximum per sponsor of two decals (sticker, pictures, illustrations, or the like) not to exceed 6" in any dimension.

b. A maximum per sponsor of two lettered phrases, not to exceed 3" in height and 18" in length.

2.7 No exceptions to these guidelines will be permitted, and violation of them is sufficient grounds for disqualification from the competition.

3. DEFINITIONS

To clarify terminology in the sections which follow, these definitions have been adopted.

3.1 A package contains electrical, space heating, and water heating systems.

3.2 A system contains source, storage, and conversion components.

3.3 All projects less complete than packages or systems will be referred to as components.

4. PROJECT SPECIFICATIONS

All entries need to conform to the following standards to allow the projects to be load tested and to make comparisons equitable. Teams will be notified of additional specifications as they are developed.

4.1 An electrical system must provide a minimum of five (maximum of fifteen) kilowatts, continous output value using source energy only. The system must provide a half-hour peak output of three times the continous output value using storage capacity only. Electrical output must be 110 volts, 60 hz sine wave.

4.2 Space heating systems must meet a minimum of 10,000 BTU/hr. (maximum of 30,000) of continous space heating demand using source energy only. A heating system must also provide a half hour peak of three times the continuous output using storage capacity only. The heating fluid can be either water or air, and must be delivered at a temperature between 90 and 110°F. for air, and a minimum of 130°F. for water or steam.

4.3 Water heating systems must deliver a minimum of one gallon of water per minute for one half hour. The water temperature must be between 130°F. and 150°F. The water temperature drop over a period of ten hours must not exceed ten degrees.

4.4 All water and space heating outputs must use the following standard couplings:

water: 3/4" threaded pipes
air: 6" duct

4.5 A test load representative of the needs of homes, or light industry will be provided. The air from space heating will be returned from the load at 68°F.

4.6 The systems must be portable, at least to the extent that they be movable to the testing site.

4.7 Solar and wind powered systems are expected to meet the above criteria with average daily inputs of 1000 BTU/ft^2 and 10 mph winds, respectively.

5. PAPERS

Four papers or reports are required. All formal reports must be of professional quality. These reports are:

5.1 The Team Entry Form (attached).

5.2 As soon as possible after entering and before Nov. 15, 1974, each team is required to submit a design proposal and preliminary budget. This report will be used by the Committee as a basis for determining the funds granted by SCORE. It should include:

a. a detailed project description supplemented with block diagrams, schematics, and other drawings or illustrations to accurately describe the project.

b. an itemized budget.

c. a one-page abstract describing the project.

d. an updated team roster (including advisor) as on entry form.

5.3 Each team must submit a progress report postmarked no later than March 1, 1975. The progress report will assist the Coordinating Committee in planning the workshop sessions for the second ERA symposium. This report should include:

a. A one-page summary of the work completed to date.

b. All modifications to the original design proposal supplemented with photographs and revised drawings.

c. A revised budget and list of expenses incurred to date.

d. An updated team roster.

e. An enumeration and discussion of the problems the team has encountered with respect to their project, and with respect to the coordination of the competition.

5.4 One week prior to the final testing event, the ERA Coordinating Committee must have received two copies of each team's final project report. Reports will be read by the judges and used as part of the scoring procedure, and must accurately depict the hardware as delivered to the competition. Final reports should include:

a. A final design report supplemented with complete specifications, photographs and drawings of the project as actually constructed.

b. A final budget itemizing all expenditures.

5.4 (continued)

c. Sections describing the following:

1. Innovation - a description of the student-designed, modified and built components and how they compare to current market products.

2. Economics - estimated mass production cost of the project, exotic material requirements, cost-benefit analysis (including dollar value of fuel savings and period required to pay off the initial investment), and estimated operating costs.

3. Environmental Impact - a substantiated environmental impact statement. This should include both the environmental impact of the project in operation on site and depletion of resources used in construction.

4. Test Results - results of preliminary performance testing of the project.

5. Operating Instructions - a simplified set of instructions describing how to use the project.

6. Marketability - in what geographic areas can the project be used and what changes are necessary to optimize for other areas, installation instructions (including retrofitting) and anticipated maintenance schedule for potential buyers, and safety considerations in the use of the project.

7. Educational Impact - each team will receive a SCORE-ERA Educational Impact questionnaire in June, 1975. This questionnaire must be completed and included in the final project report as the educational impact section.

d. A three page summary of the project.

5.5 All documents required for entry as specified in section 5 must be received by the ERA Coordinating Committee before a project will be allowed at the final test event.

6. SCORING

All packages, systems, and components meeting the ERA competition requirements outlined in Sections 1 through 5 will be considered for judging. All scoring quantities will be measured at the final testing event.

Each entry will compete for the same maximum total score. The scoring procedure will be devised so that projects with more outputs (electrical, space and water heating) can win more points. All projects will be judged in the four judging areas described below. Weighting factors assigned to the judging areas indicate their relative importance in the scoring. The project's raw score is the product of the points awarded in each judging area and the weighting factor for that area. The project's total score is the product of the raw score and the Student Innovation Multiplier (SIM), described in Section 7.

Following are the four judging areas and <u>tentative</u> weighting factors:

6.1 35% performance - the projects will be tested to measure their ability to meet the specifications in Section 4.

6.2 35% Efficiency of Source Utilization - the projects will be tested to measure the overall efficiency of their energy conversion processes. The energy conversion efficiency is defined as the ratio of energy input to energy output.

6.3 15% Production Economics and Marketability - team members will discuss these aspects of the project in an oral presentation before the judges.

6.4 15% Retrofitting - this includes initial installation and changeover costs. Projects which are compatible with existing electrical, heating, and plumbing hardware will receive the best scores.

7. STUDENT INNOVATION MULTIPLIER

The Student Innovation Multiplier (SIM) will be used to award points for innovation in the project design. Points will also be given to encourage teams to actually build as much of the project (from individual parts to major components) as is practical. The SIM points are earned independently of the raw score which is described in Section 6. Again, it should be emphasized that the total score (by which all projects will be compared) is the product of the SIM and the raw score. SIM points will be awarded in the following areas.

7.1 Student designed and built hardware. Points will be awarded based on the degree of design innovation and student fabrication.

7.2 Modification - Points will also be given for innovative modification of commercially available parts or components.

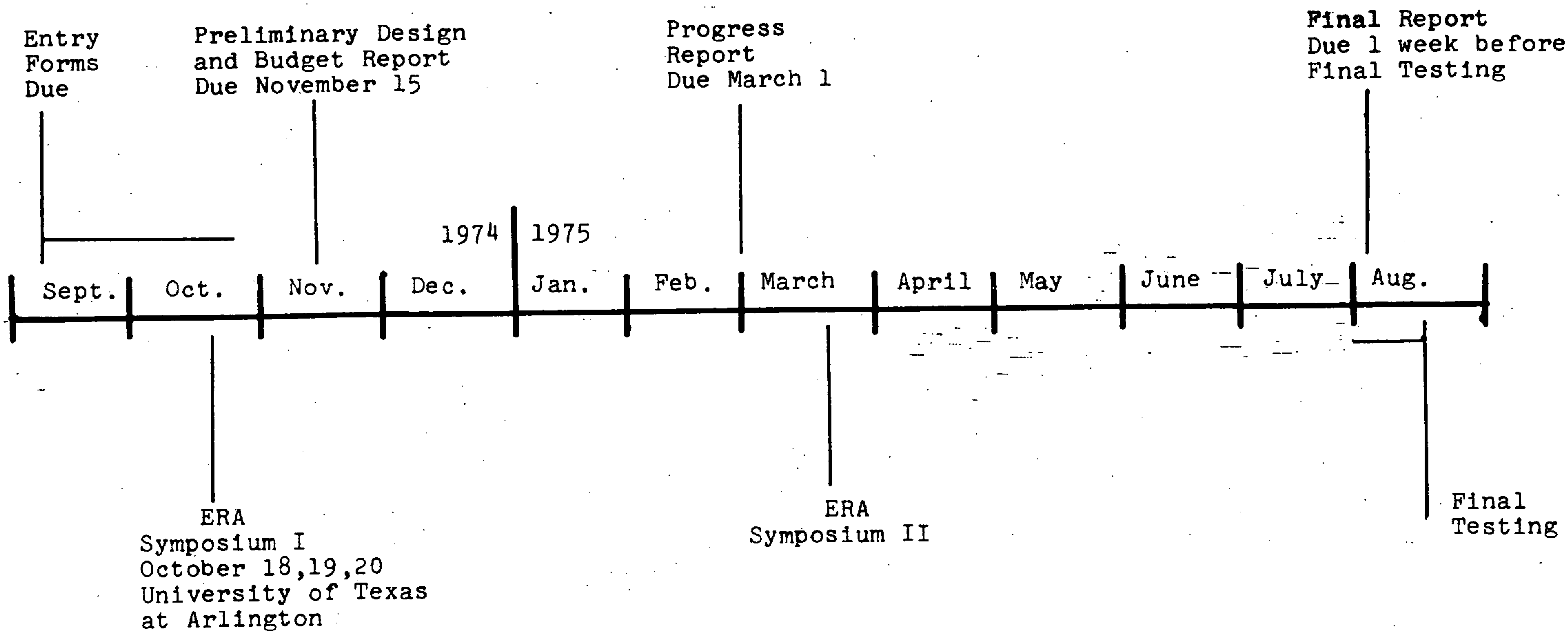
7.3 Nonconventional Source(s) - The ERA Competition focuses on utilizing nonconventional energy resources. Top points will be awarded to encourage the use of easily obtainable and non-depletable energy sources.

7.4 Multiple outputs - Projects will receive additional points for each additional output.

7.5 Safety - Consideration for safety in the project design will be the basis for awarding points in this area.

7.6 Environmental impact - Projects will be evaluated with respect to their depletion of natural resources, both in construction and in operation, as well as any detrimental effects or interactions they may have on the environment.

8. COMPETION TIMELINE



ENERGY RESOURCE ALTERNATIVES

TEAM ENTRY FORM

SECTION I Affiliation

Name of Institution ______________________________

Name of Authorizing Official ______________________________
(President, Dean of Engr., Dept. Head)

Signature of Authorizing Official ______________________ Date ______

SECTION II Faculty Advisor(s)

Name(s) ______________________________

Position(s) ______________________________

Address(s) ______________________________

SECTION III Team Roster

Name of Student	Year in School	Major	Area(s) of Project Participation	Home Town & Newspaper

SECTION IV Project Idea

SPONSOR PARTICIPATION FORM

1. This form should be used to keep a record of all sponsor donations (equipment, or services). This information must appear in the final project report.

SPONSOR NAME	DONATION	VALUE (RETAIL COST)

Energy

Resource Alternatives

Revised Design Specifications

November 1974

4. Project Specifications

All entries need to conform to the following specifications in order to conduct meaningful tests and to allow comparisons between different systems.

4.1 Output Requirements:

The desirable outputs are electricity, space heating, water heating, and air conditioning. These outputs are time dependent and given by the accompanying graphs (4.1A, 4.1B). These requirements are based on the winter day and summer day inputs given in section 4.2. These output requirements may be met with any combination of source and storage.

4.1.1 Electrical Systems:

The electrical output must be 110 volts, 60hz sine wave.

4.1.2 Space Heating Systems:

The fluids must be recirculated to the source and/or storage.

4.1.3 Water Heating:

Water heating systems must provide water at a temperature of between 55 and 66° C [131 and 151° F]. Water will be available from a supply at 10° C [50° F] and will be discharged to a sewer.

4.1.4 Air Conditioning:

The air must be recirculated with a makeup air fraction from the environment of 10-20 percent.

4.1.5 Hardware Specifications:

In order to be tested, the following output connections are required for each system:

Electrical systems:	Standard 110 V AC wall recepticle with ground
Fluid systems:	3/4 inch pipe coupling
Air systems:	6 inch duct

The systems must be portable, at least to the extent that they be movable to the testing site.

4.2 Environmental Specifications:

The systems must be designed to meet the above output requirements in the natural environments given by the graphs 4.2A and 4.2B.

4.2.1 Solar Input

The solar radiation intensity is divided into 80% beam radiation and 20% diffuse radiation. The intensity is that incident on a horizontal surface at 40° N Latitude.

4.2.2 Wind Input

The wind speed given is at the height of the wind machine, and is constant over the area of the machine.

4.3 Design and Scaling Procedure

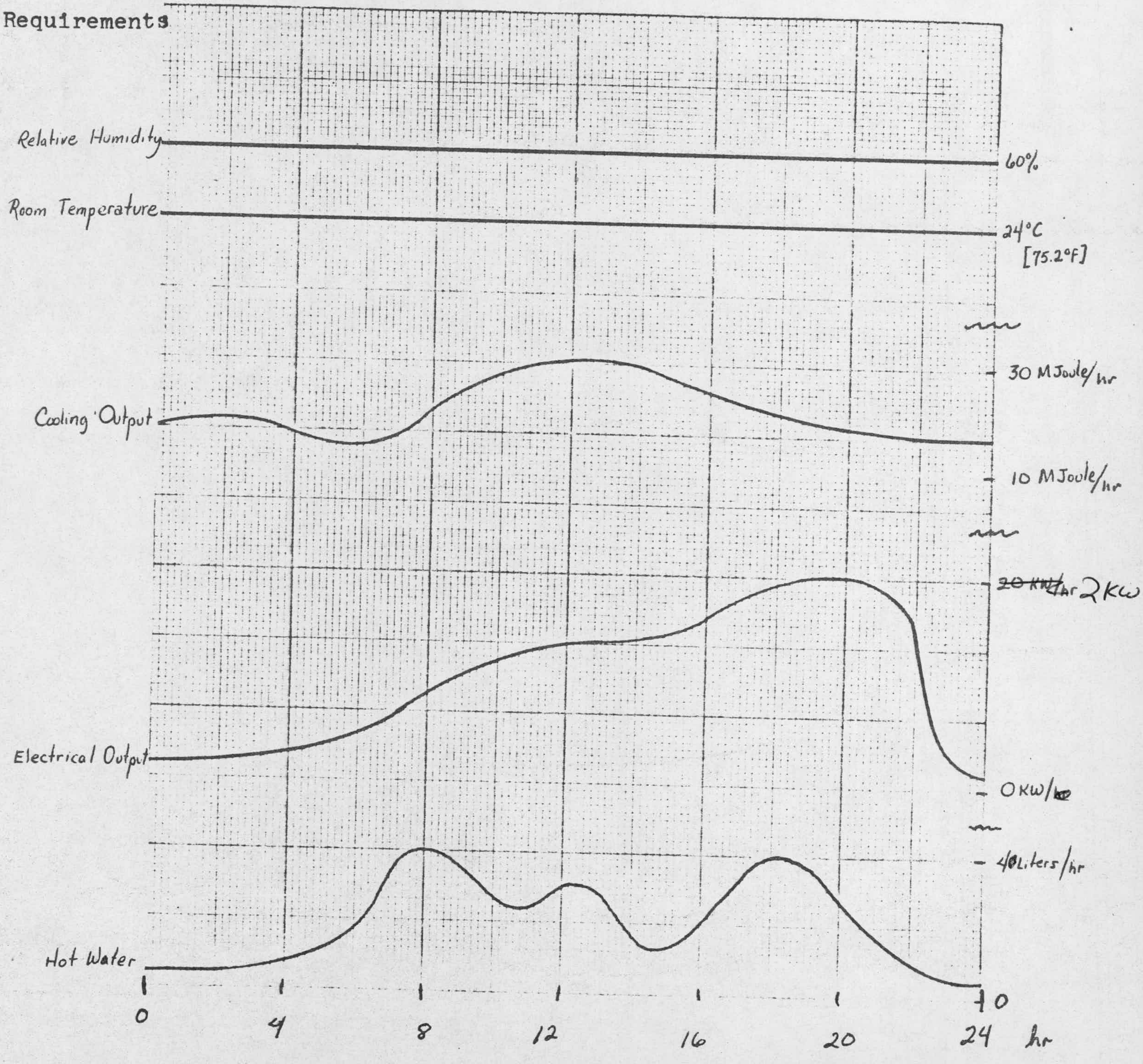
The systems must be designed to meet the above specifications. However, in order to accommodate the wide range of expected sources, full scale systems will not be required. The following procedure will allow comparison of scaled systems.

There is no restriction on the actual output of the system as built. However, for comparison with other team entries, the projects will have to be scaled up or down to meet the design output conditions. The scaling factor will be the ratio of the design output to the actual output. Thus, each project is treated as one module of the number necessary to meet the required loads.

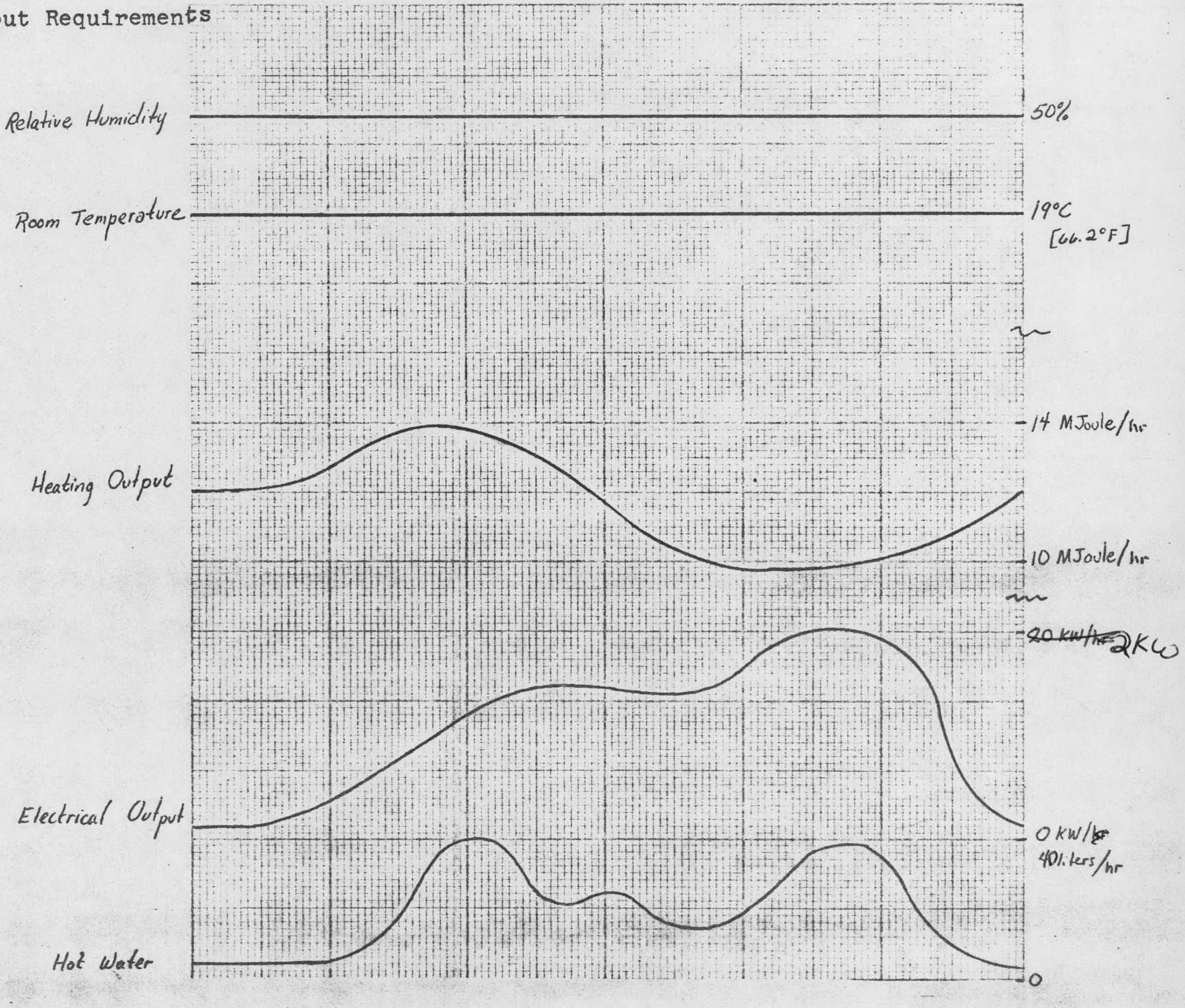
4.4 Project Testing

Each project will be required to undergo certified testing at the home school under a variety of environmental conditions. These tests will be required in order to document the actual performance of the system, and to provide a base for scaling the system to meet the required specifications.

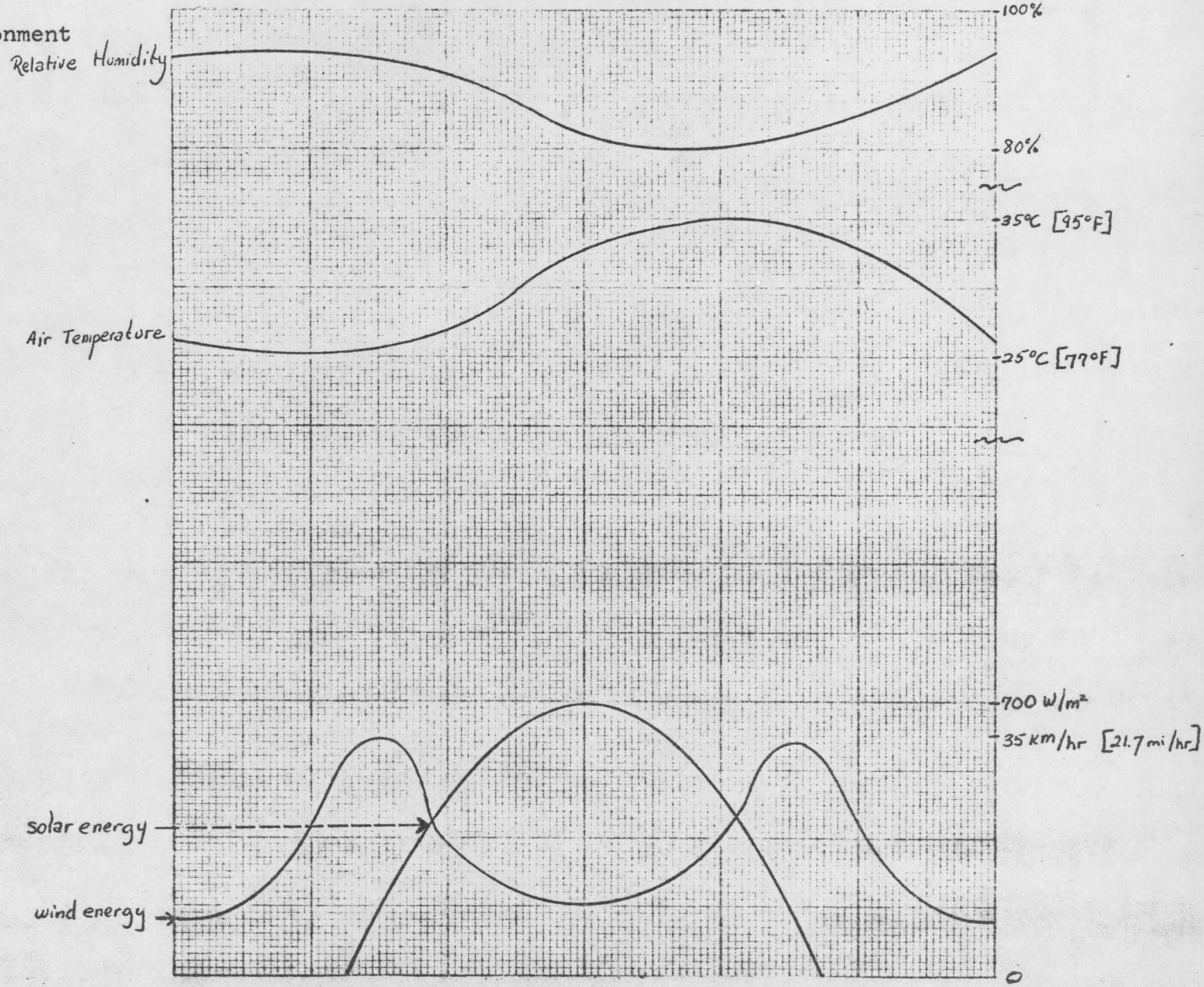
4.1A Summer Output Requirements



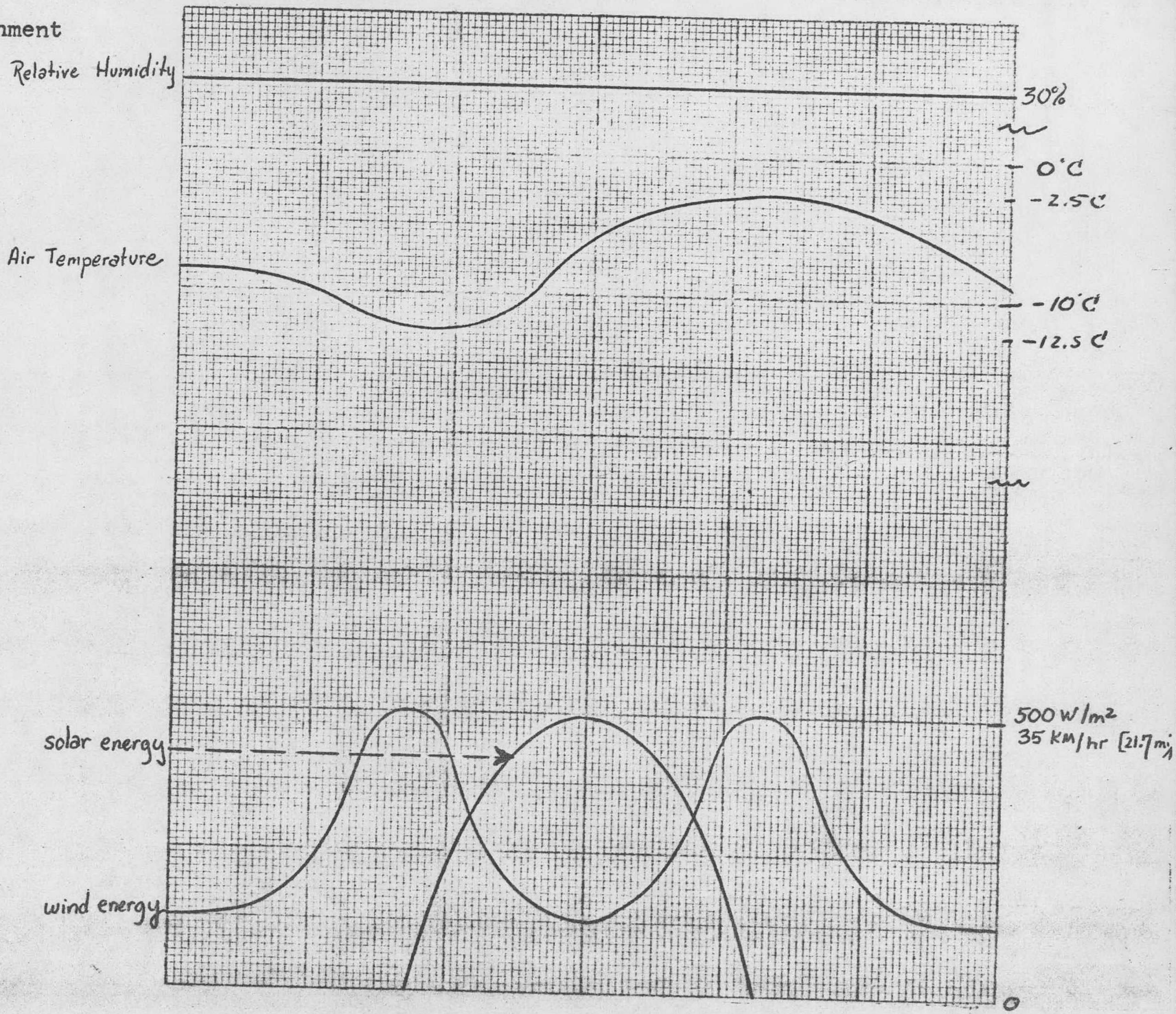
4.1B Winter Output Requirements



4.2A Summer Environment



4.2B Winter Environment



HOME SITE TESTING

I. OBJECTIVES

The objectives of home site testing are fourfold. First, the tests are necessary for teams to evaluate their own units in comparison with the established design criteria. In this way design modifications can be suggested to improve system operation. The second objective of home site testing is to provide the ERA staff with detailed information concerning the system scaling, performance, innovations and the related area of cost. Third, home site testing allows for longer term evaluation of component performance. This is very important for many items, especially methane generators. Finally, home site testing is necessary due to reasons ranging from difficulties in transportation to severe weather conditions limiting final site testing.

II. TERMINOLOGY - DEFINITION OF ERA ENTRY CATEGORIES

Our desired outputs have been defined as heating, cooling, hot water, and electricity. In the August ERA Bulletin a distinction was discussed concerning the words package, system, and components. It is the concern of this section to distinguish between these items.

A PACKAGE entry shall be any entry which provides all four of the outputs defined above. These outputs may come from any combination of source, storage and auxiliary input. The efficiency and innovative nature of use of these three energy sources will be used in scoring entries as will the effectiveness of the unit in meeting the desired output levels.

A SYSTEM entry shall be any entry which provides at least one but less than four of the desired outputs. The division of system entries will take the form shown below:

1. Entries providing cooling, heating and hot water only.
2. Entries providing heating and hot water only.
3. Entries providing cooling and hot water only.
4. Entries providing cooling and heating only.
5. Entries providing hot water only.
6. Entries providing cooling only.
7. Entries providing heating only.

8-13. 2-7 of the above with electricity added.

14. Entries providing electricity only.
15. Entries providing other miscellaneous outputs.

The Student Innovation Multiplier (SIM) will be graduated to provide a higher value for entries providing more outputs on a continuous and simultaneous basis. A package entry qualifies the entry for consideration for the highest SIM. A system with three outputs will potentially rate higher than one with two outputs, etc.

A <u>SYSTEM COMPONENT</u> shall be any major element of a system. These will consist primarily of source capture elements (i.e. solar collectors), source storage elements (i.e. water tanks) and conversion devices (i.e. air conditioners, and heat exchangers). This also includes units generating bio-fuels. Please see the appropriate judging criteria included in this bulletin for information on specific system test requirements.

<u>Output or Environment Modification</u>.

There was some discussion at Symposium II of modification of the existing output requirements or of the ambient environment based on local considerations or to meet a specific application. To do this requires:

a. A letter from your team stating your exact modifications, a document substantiating the need/reason for these modifications and finally any necessary "special" requirements of equipment you may require at the <u>final test site</u>.

b. In return, you must get a written O.K. from the ERA office in Madison. Hang onto copies of all letters to us and back to you in case of future problems.

c. This must be completed by June 15th. NO EXCEPTIONS.

III. ADDITIONAL DESIGN SPECIFICATIONS REQUIRED FOR OUTPUT TESTING

The testing process will vary depending on the nature of the entry. There are some considerations applicable to almost all entries which must be followed for output testing. These are listed below. We will inform you of modifications which may occur due to the type of equipment we secure and the nature of the final test site.

1. Each entry must have a single point of electrical (auxiliary) input. We must be able to easily measure the efficiency of your system and to do this requires that we be readily able to measure total auxiliary.

2. Air intake ducts must be on the north side of your entry, unless the ERA requests otherwise. This is necessary for loading and to avoid interference of the loading device with solar projects. Please locate at a reasonable (2' to 4') height. Sandia may have need of minor changes given the nature of the final test event.

3. All air output ducts must be on the south side of your entry, again unless siting requires otherwise. This should aid in keeping influences of one unit on another at a minimum and ease testing.

4. All ducts must extend a minimum of one (1) foot clear of the unit so that necessary loading and testing equipment can be attached.

5. All water inputs should be on the north side, if possible.

6. Please locate water output and input in very accessible locations. We anticipate a hose sy tem to provide water and to remove hot water.

Team Location: Test Date:

24 HOUR HOMESITE TESTING SUMMARY FORM

OUTPUT

Total Heating Output	________	MJoule	________	BTU
Total Cooling Output	________	MJoule	________	BTU
Total Water Heating (Total Volume delivered X C_p X T)	________	MJoule	________	BTU
Total Electrical Output	________	KW-HR	________	BTU

AUXILIARY

Total Auxiliary Required	________	MJoule	________	BTU

INPUT (See Component Documents for details of these)

Daily Total Solar Incidence	________	MJoule	________	BTU
Total Available Wind Energy	________	MJoule	________	BTU
Total Biogas Consumed X Theoretical Heat Generated	________	MJoule	________	BTU

Total Output Energy	________	MJoule	________	BTU
Total Input Energy Available (Including Auxiliary)	________	MJoule	________	BTU
Efficiency of Utilization (Output) / Input	________	%	________	%
Total Energy Change of Storage E (- if negative) (Attach explanation of calculation method)	________	MJoule	________	BTU
Adj. Efficiency of Utilization (Output + E of Storage) / Input	________	%	________	%
Scaling Factor Your Total Output / ERA Design Total Output	________	%	________	%

Signature of Certifying Official ________________

Affiliation of Certifying Official ________________

12 HOUR STORAGE EVALUATION TESTING

In order to assess the ability of storage to function during periods in which inputs are interrupted it is necessary to test units in the manner outlined below.

1) All energy inputs to the system with the exception of those used to provide pump, fan, etc. power and those needed for control are to be shut off.

2) The unit is to attempt to deliver the output shown on the output curves for the hours 6:00 AM to 6:00 PM. NOTE: the term "desired output energy" refers to ERA design energy times the scaling factor of your unit as calculated in the 24 hour test.

3) Bring your storage up to its maximum (fully charged) state before beginning the test.

4) The following charts must accompany the 12 hour interruptibility test form.

   a) Chart outputs in manner identical to ERA Design Specs. Place on same sheet of paper (as shown in specs) the hourly heating/cooling, hourly electrical, and hourly hot water delivered.

   b) Auxiliary consumption in manner identical to electrical output curve.

5) Remember to include the explanation of your storage energy change calculation.

6) Attach a brief statement of what a "fully charged" state is for your storage.

If you do not have a storage component, please fill in your team information at the top of the 12 hour form and mark "No storage component" on the form. Submit form with your Homesite Testing Documents.

STANDARDIZED OUTPUT & INPUT VALUES
ENERGY RESOURCE ALTERNATIVES DESIGN SPECS

To standardize the calculations teams will be doing regarding their system performance, scaling, etc. the following are to be used as values of total 24 hour design outputs for the two seasons of the year:

	WINTER		SUMMER
Hot Water	485 Liters	Hot Water	485 Liters
Space Heating	275 MJoule	Space Cooling	510 MJoule
Electricity	26 KW	Electricity	26 KW

To standardize the calculations done using input values the following are to be used as representing the 24 hour input energy values per the ERA design specs:

	WINTER	SUMMER
Solar	9.4 $\frac{\text{MJoule}}{m^2}$	24.4 $\frac{\text{MJoule}}{m^2}$
Available Wind	3.4 $\frac{\text{KWHR}}{m^2}$	2.9 $\frac{\text{KWHR}}{m^2}$

For the 12 hour (6:00 AM - 6:00 PM) storage evaluation use the following values of 12 hour design outputs for the 2 seasons of the year:

	WINTER		SUMMER
Hot Water	300 Liters	Hot Water	300 Liters
Space Heating	137 MJoule	Space Cooling	380 MJoule
Electricity	19 KW	Electricity	19 KW

Team Number:
Team Location:

Test Date:

12 HOUR INTERRUPTIBILITY TEST

(Period 6 AM to 6 PM)

OUTPUT

Total Heating Output	______	MJoule	______	BTU
Total Cooling Output	______	MJoule	______	BTU
Total Water Heating	______	MJoule	______	BTU
Total Electrical Output	______	KW-HR	______	BTU

AUXILIARY

Total Auxiliary required	______	MJoule	______	BTU

NOTE: All auxiliary used to directly provide outputs (i.e. resistance heaters) must be disconnected.

INPUT

NONE: This is a storage test only.

Total Output Energy	______	MJoule	______	BTU
Total Auxiliary	______	MJoule	______	BTU
Total Energy Change of Storage (Attach explanation of calculation method)	______	MJoule	______	BTU

Hour at which output drops to 15% below scaled desired output. ______ Indicate what type of output is not met (elec,etc.)

Conversion Efficiency $\left[\frac{\text{Total Output Energy}}{\text{Total Energy Change of Storage}}\right]$ ______ % ______ %

Output Efficiency $\left[\frac{\text{Total Output Energy}}{\text{Desired Output Energy}}\right]$ ______ % ______ %

Signature of Certifying Official ______________________

FINAL HOMESITE TESTING DOCUMENT FOR SOLAR COLLECTORS

Prepared by

The Energy Resource Alternative Competition
Student Competition on Relevant Engineering

ERA HEADQUARTERS
University of Wisconsin
College of Engineering
1513 University Avenue
Madison, Wisconsin 53706
608-262-2173

TABLE OF CONTENTS

SECTION 1. OBJECTIVE

The objective of this standard procedural format for homesite testing of solar collectors is to provide the Energy Resources Alternative Competition Committee with actual documented test data on the various solar collectors designed and entered in Student Competition on Relevant Engineering Program.

Because of the different designs, outputs, and performance characteristics of the various solar collectors designed and entered in the competition a single unbiased testing format procedure shall be used to evaluate all systems upon a uniform criteria.

The procedural method of obtaining the test data and the format of presentation to the Energy Resources Alternative Competition are described in detail in this document.

SECTION 2. - TERMINOLOGY DEFINITIONS

2.1 AMBIENT AIR

Ambient air is the outdoor air in the vicinity of the solar collector being tested.

2.2 ABSORBER

The absorber is that part of the solar collector that receives the incident solar radiation and transforms it into thermal energy.

2.3 APERTURE

The aperture is the opening or projected area of a solar collector through which the unconcentrated solar energy is admitted and directed to the absorber.

2.4 CONCENTRATING COLLECTOR

A concentrating collector is a solar collector that contains reflectors, lenses, or other optical elements to concentrate the energy falling on the aperture onto a heat exchanger of surface area smaller than the aperture.

2.5 CONCENTRATOR

The concentrator is that part of a concentrating collector which directs the incident solar radition onto the absorber.

2.6 FLAT-PLATE COLLECTOR

A flat-plate collector is a solar collector in which the solid surface absorbing the incident solar radiation is essentially flat and employs no concentration.

2.7 GROSS CROSS-SECTIONAL AREA

Gross cross-sectional area is the overall or outside area of a flat-plate collector. It is usually larger than the absorber area since it includes the framework to hold the absorber.

2.8 INCIDENT ANGLE

The incident angle is the angle between the sun's rays and the outward drawn normal from the solar collector.

2.9 INSOLATION

Insolation is the rate of solar radiation received by a unit surface area in unit time.

2.10 INSTANTANEOUS EFFICIENCY

The instantaneous efficiency of a solar collector is defined as the amount of energy removed by the transfer fluid per unit of transparent frontal area over a given 15 minute period divided by the total incident solar radiation onto the collector per unit area for the 15 minute period.

2.11 INTEGRATED AVERAGE INSOLATION

The integrated average insolation is the total energy per unit area received by a surface for a specified time period divided by the time period.

2.12 PYRANOMETER

A pyranometer is a radiometer used to measure the total incident solar energy per unit time per unit area upon a surface which includes the beam radiation from the sun, the diffuse radiation from the sky, and the shortwave radiation reflected from the foreground.

2.13 SOLAR COLLECTOR

A solar collector is a device designed to absorb incident solar radiation and to transfer the energy to a fluid passing in contact with it.

2.14 TOTAL INCIDENT INSOLATION

Total incident insolation is the total energy received by a unit surface area for a specified time period.

2.15 TRANSFER FLUID

The transfer fluid is the medium such as air, water, or other fluid which passes through or in contact with the solar collector and carries the thermal energy away from the collector.

2.16 TRANSPARENT FRONTAL AREA

The transparent frontal area is the area of the transparent frontal surface for flat-plate collectors.

2.17 STANDARD AIR

Standard air is air weighing 1.2 kg/m^3 (0.75lb/ft^3), and is equivalent in density to dry air at a temperature of 21.1 C (70°F) and a barometric pressure of 760.0 mm (29.92 in.) of Hg.

2.18 STANDARD BAROMETRIC PRESSURE

760.0 mm (29.92 in.) of Hg.

SECTION 3. TEST SETUP REQUIREMENTS

The solar collectors to be tested shall meet the following requirements and follow the specified setup arrangement stated in this section.

3.1 TYPE OF COLLECTOR

This document shall be used to test solar collectors in which the heat transfer fluid enters the device through a single inlet and leaves the device through a single outlet. Collectors designed for more than one inlet and/or outlet shall be tested by this document provided that the inlet and/or outlet piping can be connected in such a way that a single inlet and a single outlet shall have been determined.

This document shall be used to test flat plate collectors and concentrating collectors incorporating variable tilt angles as well as solar tracking capabilities. The heat transfer fluid shall be a gas or a liquid but not a mixture of the two.

3.2 SIZE OF COLLECTOR

The size of the collector tested shall be large enough so that the performance data obtained will be indicative of those that would be obtained when a full scale model is tested.

If the collector is modular and the test is being done on one module then the module should be mounted and insulated in such a manner that the back and edge thermal losses will be characteristic of those that occur in the modular structure.

3.3 TEST SURROUNDINGS

The collector shall be mounted and setup in such a way that there will be no significant energy reflected or reradiated to the collector from the surrounding structures and surfaces that are in the vicinity of the test area other than those structures incorporated in the design of the collector.

This section requirement will be satisfied if the ground and surrounding surfaces are diffuse with a reflectance of less than 0.20.

The test stand or any other structure or body shall be located such that a shadow will not be cast upon the collector at any time during the test.

3.4 WEATHER CONDITIONS

The test shall be conducted on days having weather conditions such that the 15 minute integrated average insolation measured in the plane of the collector or aperture is a minimum of 630 W/m^2 (199.8 BTU/HR FT^2).

3.5 WIND VELOCITY

The wind velocity across the collector surface of a flat-plate collector or aperture of a concentrating collector during the test shall be measured at a distance of approximately 1 meter (3.3 ft) from the collector along the direction it faces and at a height corresponding to the center of the collector panel.

3.6 SOLAR COLLECTOR SETUP

Stationary collectors shall be set up in a rigid framework at the predetermined tilt angle and anchored securely to a base foundation such that the collector can maintain the selected angular position against anticipated wind conditions or other forces which may occur during testing.

Variable angle flatplate collectors and solar tracking concentrating collectors shall also be securely anchored, and must follow their selected range of angular positions unobstructed during the test period against anticipated wind conditions or other forces which may occur during testing.

3.7 INCIDENT ANGLE

The orientation of the collector can have any desired incident angle during testing, but its fixed orientation angle, variable angles, or its tracking capabilities shall be stated in Section 8.

3.8 PYRANOMETER SETUP

The pyranometer shall be set up on a surface parallel to the collector surface in such a manner that it does not cast a shadow onto the collector surface at any time during the test. Precautions should be taken to avoid subjecting the pyranometer to mechanical shocks or vibrations especially during setup and testing. The pyranometer should be setup such that all electrical leads and connections are located north of the collector surface or are shaded in some manner.

The surface of the glass cover of the pyranometer shall be wiped clean and dry prior to the test, but care shall be taken not to scratch the glass surface. The under surface of the glass cover shall not have an accumulation of moisture or water vapor.

3.9 AIR DUCT REQUIREMENT

Solar collectors using air as the transfer fluid and incorporating an air flow measuring apparatus in the system shall have the same cross-sectional air duct dimensions at the inlet of the solar collector. The air outlet duct between the solar collector and the reconditioning apparatus shall have the same cross-sectional dimensions as the outlet from the collector.

Air leakage through the air flow measuring apparatus, air inlet ducting, the solar collector, and the air outlet ducting shall not exceed $\pm 1.0\%$ of the measured air flow.

SECTION 4. TEST INSTRUMENTS

NOTE: Identification of commercial test equipment or test materials does not imply recommendation or endorsement by the ERA testing committee but is stated only as a guide to suitable instrumentation or materials available.

4.1 PYRANOMETER

A pyranometer shall be used to measure the total short-wave radiation from both the sun and the sky. The pyranometer shall have the following characteristics:

4.1-1 Sensitivity and Ambient Temperature Range

The pyranometer used in the test shall either be equipped with a built-in temperature compensation circuit and have a temperature sensitivity of less than ±1 percent over the range of ambient temperatures encountered during the test or have been tested in a temperature controlled chamber over the same temperature range so that its temperature coefficient has been determined.

4.1-2 Spectral Response Variation

Errors caused by a departure from the required spectral response of the sensor shall not exceed ±2.0 percent over the range of interest. Pyranometer thermopiles which are "all black" and which are coated with Parson's black or 3M101C10 velvet black paint and which have selected optical grade hemispheres shall satisfy this requirement.

4.1-3 Nonlinearity of Response

Unless the pyranometer was supplied with a calibration curve relating the output to the insolation its response shall be within ±1 percent of being linear over the range of insolation existing during the test.

4.1-4 Time Response

The time constant of the pyranometer shall be less than 5 seconds.

4.1-5 Pyranometer Orientation

The calibration factor of a pyranometer can change when the instrument is used in other than the orientation for which it was calibrated. The instruments' calibration factor including corrections shall change less than ±0.5 percent when compared with the calibrated orientation and the test orientation.

4.1-6 Pyranometer Calibration

The pyranometer used in testing shall have been calibrated within six months of the collector test date against another pyranometer whose calibration is traceable to a nationally recognized calibration center. Meteorological centers commonly express calibration data in $cal/cm^2 min$ or in langleys/min, and some express them in $milliwatts/cm^2$. The following equivalent units shall be used for calibration purposes. $1 cal/cm^2 min$= 1 langley/min = 0.001434 W/m^2. $1 mW/cm^2$ = 0.1 W/m^2.

4.2 TEMPERATURE MEASURING INSTRUMENTS

4.2-1 Accuracy and Precision

The accuracy and precision of the temperature instruments and their associated readout devices shall be within the limits as follows:

	Accuracy	Precision
Temperature	±1.0°C(±1.8F)	±0.2C(±0.4F)
Temperature Difference	±0.2C(±0.4F)	±0.1C(±0.2F)

Where accuracy is the ability of the instrument to indicate the true value of the measurement, and precision is the closeness of agreement among repeated measurements of the same physical quantity.

4.2-2 Scale Division

The smallest scale division of any test instrument from which data values are to be obtained shall not exceed 2-1/2 times the specified precision. For example, if the specified precision is ±.2C (±0.4F), the smallest scale division shall not exceed 0.5C (0.1F).

4.2-3 Inlet and Outlet Fluid Temperatures

The temperature of the transfer fluid entering and/or leaving the solar collector shall be measured with one of the following

a. Thermocouples

b. Resistance thermometers
(only when the transfer fluid is a liquid)

Each resistance thermometer or each thermocouple shall be inserted into a well or test probe such that the fluid temperature can be measured. To insure good thermal contact and accuracy the wells or test probes shall be filled with light oil and insulated. The wells or test probes shall be located as near as possible to the inlet and outlet of the solar collector but such that they do not disturb the heat transfer fluid flow.

4.2-4 Temperature Difference Between Inlet and Outlet Fluid

The temperature difference between inlet and outlet fluid shall be measured with one of the following:

a. Thermopile (air or water as the transfer fluid)

b. Calibrated Resistance Thermometers connected in two arms of a bridge circuit (only when the transfer fluid is a liquid)

For solar collectors using a liquid as the transfer fluid the temperature difference of the transfer fluid between inlet and outlet of the collector shall be measured using either two calibrated resistance thermometers connected in two arms of a bridge or a thermopile made from calibrated copper-constantan thermocouple wire all taken from a single spool. The thermopile shall contain any even number of junctions. Each resistance thermometer or each end of the thermopile shall be inserted into a well or test probe such that the temperature of the heat transfer fluid can be measured. To insure good thermal contact and accuracy, the wells or test probes shall be filled with light oil and insulated.

For solar collectors using air as the transfer fluid the temperature difference of the transfer fluid between inlet and outlet of the collector shall be measured using a thermopile. It shall be constructed from calibrated copper-constantan thermocouple wire no heavier than 24 AWG and taken entirely from a single spool.

The thermopile shall contain any even number of junctions. These junctions shall be located at the center of equal cross-sectional areas and located as near as possible to the inlet and outlet of the solar collector. The air inlet and air outlet ducts shall be insulated such that the ambient air does not affect the temperature measurements.

4.3 LIQUID FLOW MEASURING INSTRUMENTS

4.3-1 Flow Rate

The liquid flow rate thru the solar collector shall be measured by one of the following methods:

a. weigh tank

b. positive displacement flow meter

c. turbine flow meter (only when the transfer fluid is pure water or the turbine flow meter has been calibrated with the transfer fluid mixture.

4.3-2 Accuracy

The accuracy of the liquid flow rate measurement using the calibration if furnished shall be equal to or better than ±20 percent of the measured value.

4.4 AIR FLOW MEASURING INSTRUMENTS

4.4-1 Mass Flow Rate

The mass flow rate entering the solar collector shall be determined from the equation $m = \rho AV$. The average duct flow velocity (V) near the inlet to the solar collector shall be calculated from at least six different pressure lead measurements obtained with a pitot tube located at the positions indicated in Figure IV, Section 10.

The pitot tube shall permit measurements of pressure to within ±1.0% absolute. The internal cross-sectional area (A) of the duct shall be calculated at the location of the pitot tube. The wet bulb and dry bulb temperature shall be measured at the location of the pitot tube such that the density of the entering fluid can be determined from a psychrometric chart provided that the psychrometric chart applies to the value of the barometric pressure during the test period, or a correction is made for the actual barometric reading during the test.

Other methods of measuring the air flow rate entering the solar collector such as an orifice, venturi tube or flow nozzle can be used provided that accuracy, pressure losses and flow disturbances are not affected adversly. Statement in writing of the procedure used if other than that described above shall be required in the final test report.

4.5 STRIP CHART RECORDERS

4.5-1 Accuracy

Strip chart recorders used to obtain data shall have an accuracy equal to or better than ±0.5 percent of the temperature difference and/or voltage measured. The time constant shall be 1 sec or less.

4.6 TIME AND WEIGHT INSTRUMENTS

4.6-1 Accuracy

Time and weight measurements shall be made to an accuracy of ±0.20 percent.

4.7 WIND VELOCITY INDICATOR

4.7-1 Accuracy

The wind velocity shall be measured with an instrument having an accuracy of ±0.08 m/s (1.8 mph).

SECTION 5. TESTING PROCEDURE

5.1 GENERAL METHOD

The test procedure shall be conducted such that an efficiency curve can be determined for the collector being tested. This shall be accomplished by using four different values of inlet fluid temperatures and one standardized value of the transfer fluid flow rate. The recommended values of the inlet fluid temperatures should correspond to 10, 30, 50, and 70C (18, 54, 90, and 126F) above the ambient temperature during the test. Because of particular collector designs and the various environmental and seasonal conditions at the different geographical test locations the four different inlet fluid temperatures stated above may not be feasible but the selected values for the test should be as close to the above requirements as possible for the particular site and collector being tested.

The recommended values of fluid flow rate per unit aperture area are 0.02Kg/s m^2 (14.7 lbm/HR ft^2) when a liquid is the transfer fluid and 0.01 m^3/s m^2 (1.96 cfm per ft^2) of standard air when the transfer fluid is air.

Two data values for each inlet fluid temperature shall be taken. One shall be taken before solar noon, and one shall be taken after solar noon. The time during which the two data values for a particular value of inlet fluid temperature are taken shall also be symmetrical to solar noon.

Two data values for each of the four fluid temperatures are therefore taken symmetrical to solar noon resulting in a total of eight data values symmetrical to solar noon.

A straight line representation shall be adequate for most flatplate collectors, but the equation of the curve for a concentrating collector shall be obtained using the standard technique of a least squares fit to a second-order polynomial.

5.2 GENERAL PROCEDURE

The test configurations for a flatplate collector using a liquid, a flatplate collector using air and a concentrating collector using a liquid are as shown in Figures I, II, and III respectively. In order to obtain sufficiently good data values it is recommended that the transfer fluid circulate through the collector at the appropriate temperature level for at least 30 minutes prior to the testing period. This warm-up time can be used to pre-test all equipment and a check or readjustment can be made on the required inlet fluid temperature and fluid mass flow rate.

5.2-1 Ambient Air Temperature

The ambient air temperature shall be recorded at the beginning and at the end of the 15 minute test period and recorded in Section 7.

5.2-2 Pyranometer

An integrated value of the incident solar energy over the 15 minute test period shall be recorded as data. A strip chart recorder with a recommended chart speed of 30 cm/hr is suggested to monitor the output of the pyranometer to insure that the incident radiation has remained relatively steady during the 15 minute test period. Data shall only be recorded in Section 7 for which the values of the incident energy remained relatively steady over the 15 minute test period.

5.2-3 Inlet and Exit Fluid Temperature

The inlet and outlet temperatures of the heat transfer fluid shall be taken as close as possible to the inlet and outlet of the solar collector or the absorber for the case of the concentrating collector. To minimize fluid temperature measurement error, each temperature probe shall be insulated such that the ambient air or surrounding conditions do not affect the fluid temperature measurement. Temperature measurements of inlet and exit fluid temperatures shall both be taken at the beginning and at the end of the 15 minute test period, and recorded in Section 7.

It is recommended that a strip chart recorder is used to monitor the inlet temperature to insure that it remains relatively constant during the 15 minute test period.

5.2-4 Temperature Difference Between Inlet and Exit Fluid

The temperature difference of the transfer fluid between inlet and exit shall be measured using the test instruments and probes for an air or liquid system as stated in Section 4.

The temperature probes shall be located as close as possible to the inlet and the outlet of the system and shall be insulated from the surroundings.

The temperature difference measurement between the inlet and exit fluid shall be measured at the beginning and at the end of the 15 minute test period and recorded in Section 7.

5.2-5 Mass Flow Rate of Fluid

The flow rate of the transfer fluid through the collector shall be standardized at one value for all data points. The recommended value of flow rate per unit transparent frontal area or aperture area is 0.02 Kg/s m^2 (14.7 lbm/hr ft^2) when a liquid is the transfer fluid and 0.01 m^3/s m^2 (1.96 cfm per ft^2) of standard air when the transfer fluid is air. It is recognized that in some design systems the collector will have been designed for a flow rate much different than specified above. In such cases the design flow rate shall be used if it is critical to the systems performance. However, the design flow rate used shall be standardized at one value for all data points. Notice shall also be given in the test report that the design flow rate was used and justification for its implication shall also be stated.

Any method using good engineering practice can be taken to insure that the recommended fluid mass flow is supplied at the required constant flow rate and at the required inlet temperature. Recirculating fluid systems can be used if test condition requirements are met.

SECTION 6. DATA CALCULATIONS

* Note that final calculation results shall be in metric units.

6.1 MASS FLOW RATE

The mass flow rate thru the solar collector using a liquid as the heat transfer fluid shall have determined by the measurement obtained from one of the following:

a. weigh tank

b. positive displacement flow meter

c. turbine flow meter

The mass flow rate thru the solar collector using air as the heat transfer fluid shall be determined from the standard equation:

$$\mathring{m} = \ell AV$$

where:

(A) is the inside cross-sectional area of the duct and is calculated by multiplying the inside duct width measurement times the inside duct height measurement.

(V) is the average flow velocity of the air as determined by averaging the six velocities obtained from the six pitot tube veolcity head measurements at the six locations in the duct. The standard equation for determining the velocity is the following:

$$V = Cp \left[\frac{2g(\ell_m - \ell)h}{\ell} \right]^{1/2}$$

where:

h is the monometer reading

ℓ_m is the density of the monometer fluid

ℓ is the density of the air flow fluid

Cp is the pitot-tube coefficient and corrects for friction and turbulence effects and is determined by calibration. The usual range of Cp is from .98 to 1.02.

g is the constant

The density of the air flow can be determined from a psychrometric chart provided that it applies to the value of the barometric pressure during the test period or a correction is made for the actual barometric reading.

6.2 SPECIFIC HEAT COEFFICIENT (Cp)

The values of the specific heat coefficient for the air or liquid can be obtained from any standard engineering text listing the value as a function of temperature.

6.3 APERTURE AREA (Aa)

This area is not the absorbing surface area but is the transparent frontal area of the solar collector that receives the incident solar energy.

6.4 EFFICIENCY (η)

The efficiency shall be determined from the following equation taken from reference (1).

$$\eta = \frac{\frac{\mathring{m}\, Cp}{Aa} \int_{t_1}^{t_2} (T_{f,o} - T_{f,i})\, dt}{\int_{t_1}^{t_2} I\, dt}$$

SECTION 7. RECORDED SOLAR COLLECTOR DATA FORMAT

	v_w WIND VELOCITY M/sec.	Ta AMBIENT TEMP °C	$T_{f_1 i}$ INLET FLUID TEMP °C	$\dot{m}$ FLUID FLOW RATE Kg/sec	$T_{f_1 e}$ OUTLET FLUID TEMP °C	ΔT OUTLET AND INLET FLUID TEMPERATURE DIFFERENCE °C	I INCIDENT SOLAR RADIATION W/m^2
TEST TIME t_1							
TEST TIME t_2							
INTEGRATED VALUE							

DATE: __/__/__ TEST LOCATION ____________________ TEAM # ____

LONGITUDE ________________

LATITUDE ________________

BAROMETRIC PRESSURE _____________ mm Hg

TEST TIME t_1							
TEST TIME t_2							
INTEGRATED VALUE							

where:

$\overset{\circ}{m}$ is the mass flow as determined from Section 6.1

Cp is the specific heat as determined from Section 6.2

Aa is the aperture area as determined from Section 6.3

$\int_{t_1}^{t_2} (T_{f,0} - T_{f,i})dt$ is the integrated value of the inlet and exit fluid temperature that occurred over the test period as measured in Section 7.

$\int_{t_1}^{t_2} I\,dt$ is the integrated value of the incident solar energy that occurred over the test period as measured in Section 5.2-2 and recorded in Section 7.

The value of the appropriate $\frac{\Delta T}{I}$ for each inlet temperature test can be obtained from the following equation taken from reference (1).

$$\frac{\Delta T}{I} = \frac{\frac{T_{f,i} + T_{f,0}}{2} - Ta}{I}$$

where:

$T_{f,i}$ is the inlet fluid temperature

$T_{f,0}$ is the outlet fluid temperature

Ta is the ambient fluid temperature

I is the incident solar energy

SECTION 8. TEST REPORT

The final test report data and information sheets to be submitted to the ERA Headquarters shall include a data sheet for each of the four test temperatures on the format sheets provided in Section 7, an efficiency graph on the format sheet provided in Section 10, and the completed collector specification sheets on the format sheets provided in Section 8.1. Any additional information, conclusions, results, comments, or explanations shall be included on additional typewritten pages.

8.1 COLLECTOR SPECIFICATIONS

Team No. ________

Solar collectors' primary output(s) in the designed system and method(s) used to obtain desired output(s) (e.g. outputs: heat, hot water, air conditioning, electricity, heat pump).

DIMENSIONS:

Overall length (L) ________

Overall width (W) ________

Gross Area (W X L) ________

Thickness ________

Height from inlet to exit connection (fixed angle collectors only) ________

ORIENTATION:

Longitude ________

Latitude ________

Elevation above Sea Level ________

Barometric Pressure ________

Incident Angle (fixed, variable angle range, tracking capabilities) ________

COVER PLATE(S)

Total Transparent Frontal Area ______________

Material(s)

Optical Properties

Construction Technique

REFLECTOR

Aperture Area ______________

Diameter or significant dimension(s) ______________

General Shape or Configuration

Materials

Optical Properties

ABSORBER

Surface Area ______________

Dimensions ______________

Absorptivity to short wave radiation ______________

Emissivity for long wave radiation ______________

Description of coating(s) if used

Flow path configuration

AIR SPACE(S)

Thickness ______________

____

____

Description of contained gas, evacuated, or other significant design construction

INSULATION

Material ______________

Thickness ______________

Thermal Properties ______________

TRANSFER FLUID

Type (air or water)

Properties (Boiling point, Freezing Point)

WEIGHT AND VOLUME

Weight of collector per square meter of gross cross-sectional area with contained transfer fluid ____________

Net weight of collector per square meter of gross cross-sectional area without any transfer fluid ____________

Volumetric capacity of the collector per square meter of gross cross-sectional area ____________

TEMPERATURE

Normal operating temperature range of inlet fluid ____________

Normal operating temperature range of exit fluid ____________

Designed environmental temperature range ____________

PRESSURE

Normal inlet operating pressure ____________

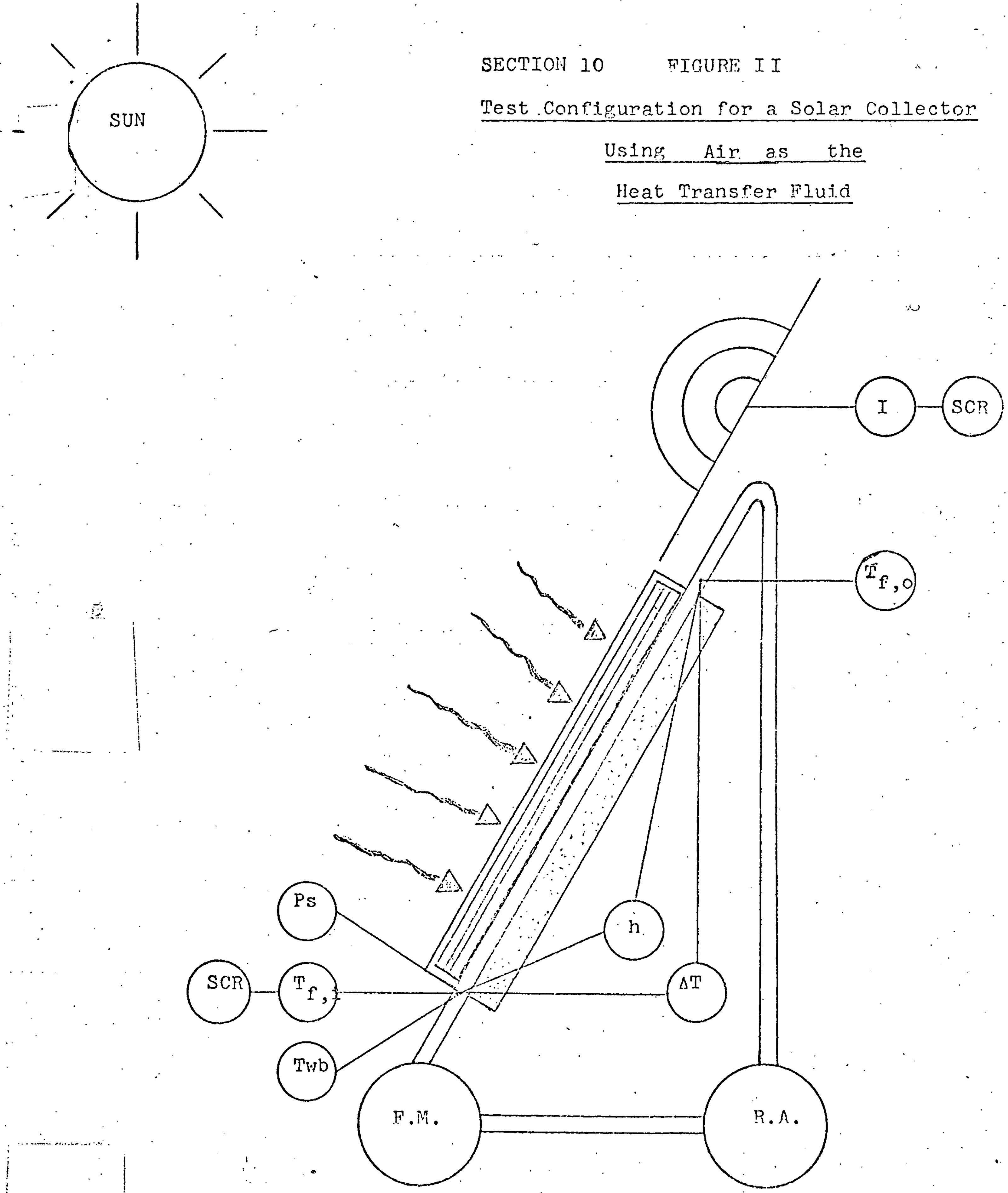
Normal pressure drop across collector ____________

SECTION 9. NOMENCLATURE

A	Gross cross-sectional area.
Aa	Transparent frontal area for a flatplate collector or aperture area for a concentrating collector.
Ar	Absorbing or receiving area of the concentrating solar collector.
Cp	Specific heat value of the transfer fluid.
g	Gravitational constant.
h	Manometer fluid height difference.
I	Total solar energy incident upon the plane of the solar collector per unit time per unit area.
$\mathring{m}$	Mass flow rate of the transfer fluid.
t_1	Time at the beginning of the test period.
t_2	Time at the end of the test period.
Ta	Ambient air temperature.
T_{f_1e}	Temperature of the exit heat transfer fluid.
T_{f_1i}	Temperature of the inlet heat transfer fluid.
ΔT	Temperature difference between the inlet and exit fluid.
V	Velocity of the heat transfer fluid.
V_w	Wind velocity.
ℓ	Density of the transfer fluid.
ℓ_m	Density of the manometer fluid.
η %	Solar collector efficiency

SECTION 10 FIGURE II

Test Configuration for a Solar Collector Using Air as the Heat Transfer Fluid



SECTION 10. NOMENCLATURE Figures I, II, III

F.M. Flow meter to measure the mass flow rate of the heat transfer fluid.

h Pressure drop across collector

I Solarmeter or pyranometer to measure the incident radiation on the plane of the collector.

R.A. Reconditioning apparatus to be used only in recirculatory systems.

SCR Strip Chart Recorder used to monitor the inlet fluid temperature and incident solar radiation.

ΔT Temperature difference of the heat transfer fluid across the collector.

$T_{f,i}$ Temperature of the inlet fluid.

$T_{f,o}$ Temperature of the outlet fluid.

Ps Static Pressure at the inlet of the solar collector

SECTION 10. GRAPH I

The efficiency graph to be presented in the test report shall have the abscissa in the SI units of °c m^2/w. The scaling factor for the abscissa and ordinate shall be as shown on Graph I in Section 10. The "fitted" efficiency curve shall be drawn such that the abscissa and ordinate intercepts have been determined. The value of the (y) intercept and the slope of the curve (if linear) shall also be stated on the graph.

NO. 341-10 DIETZGEN GRAPH PAPER
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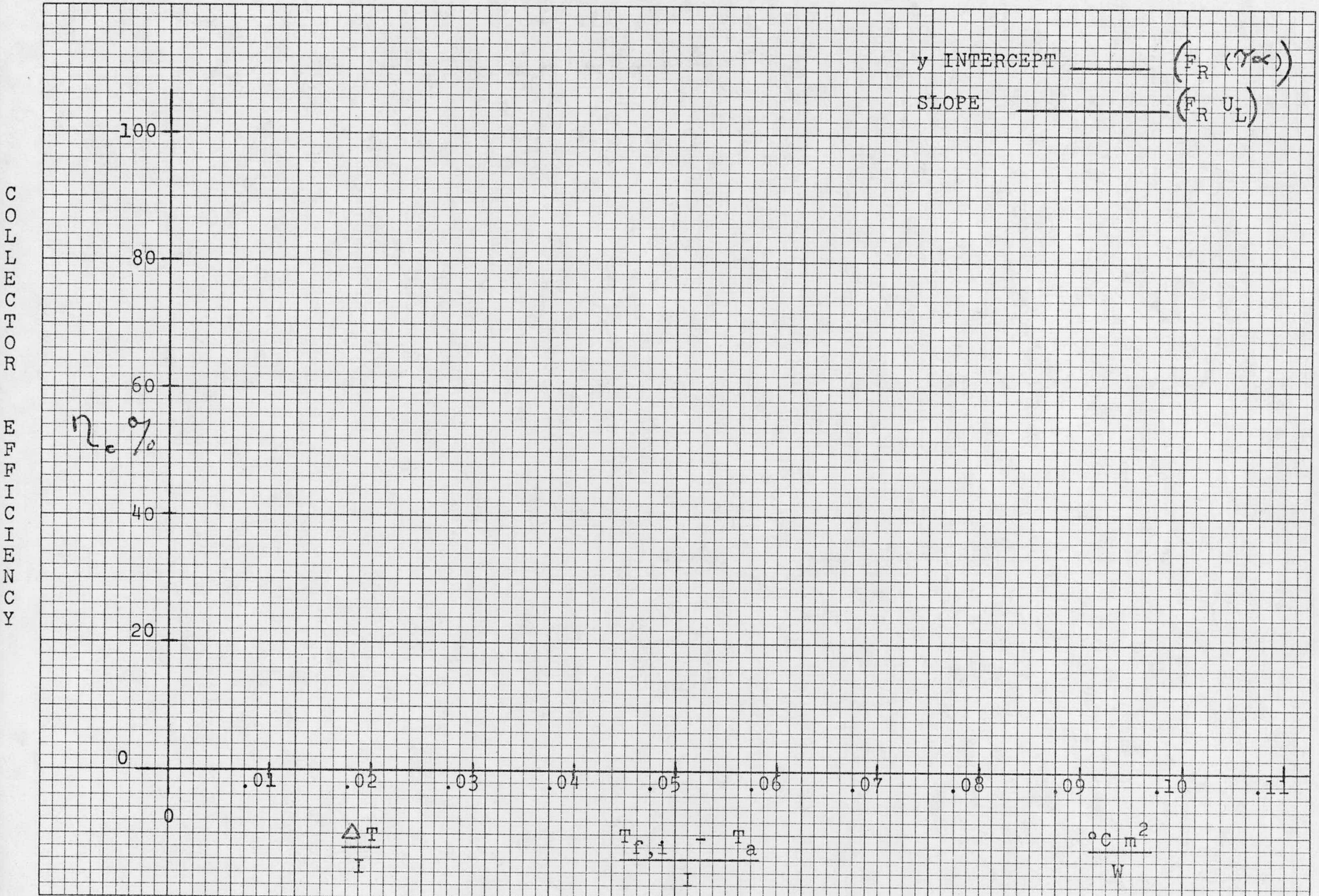
SECTION 10. FIGURE IV



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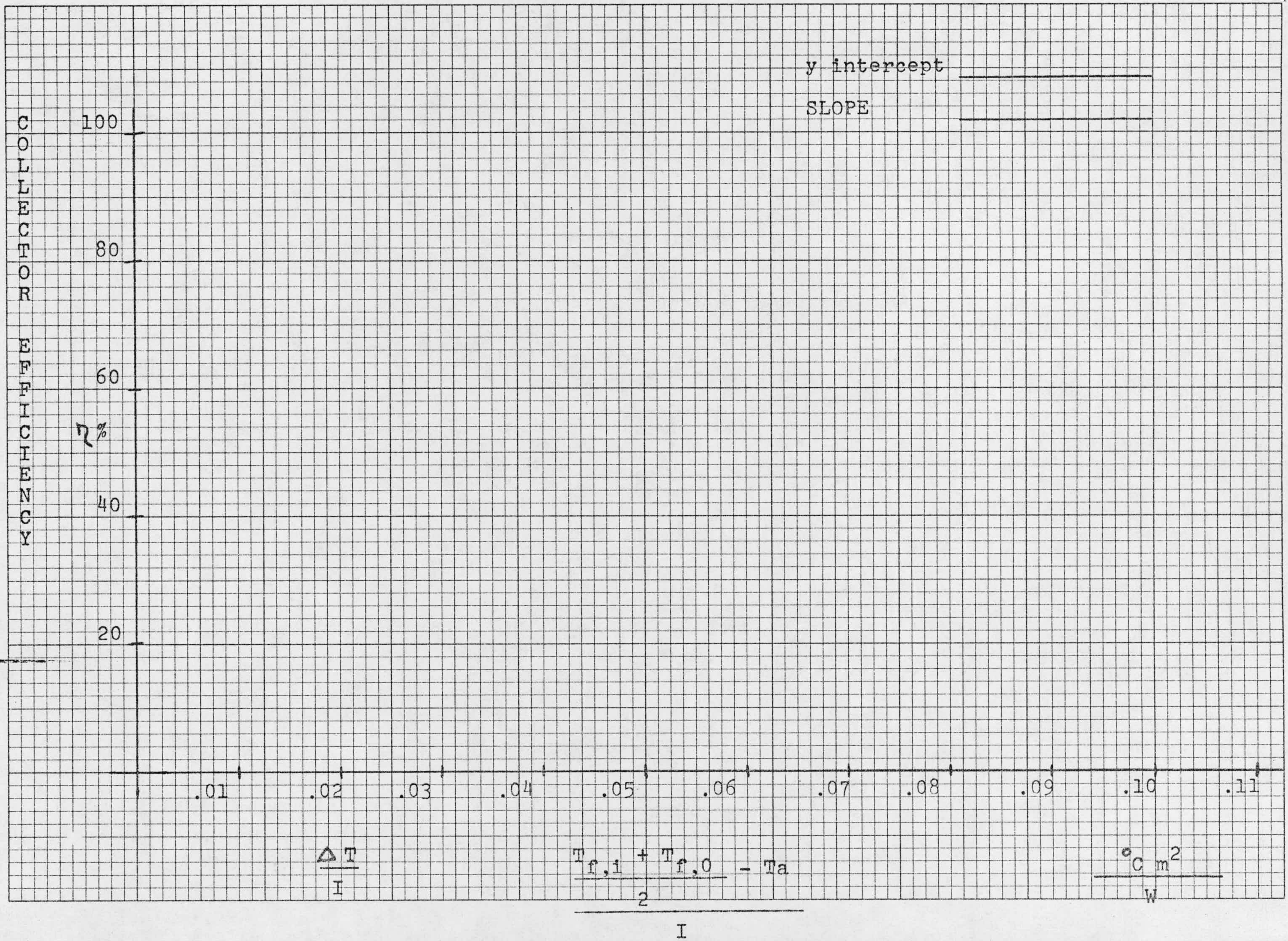
SECTION 10. FIGURE IV

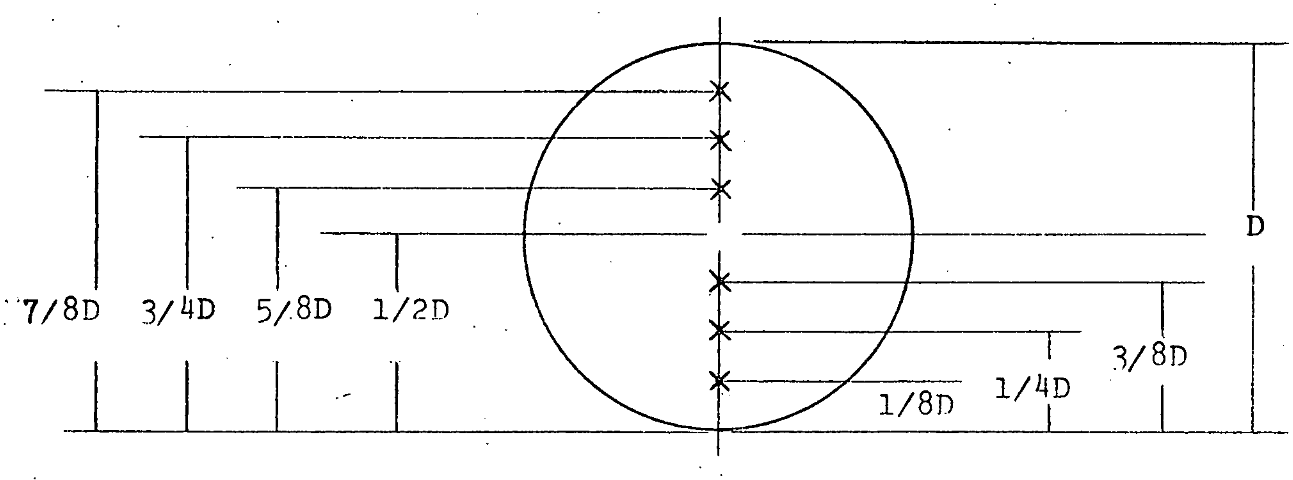


SECTION 10 FIGURE V

Test Positions of Pitot Tube

Traversing Positions for Circular Ducts

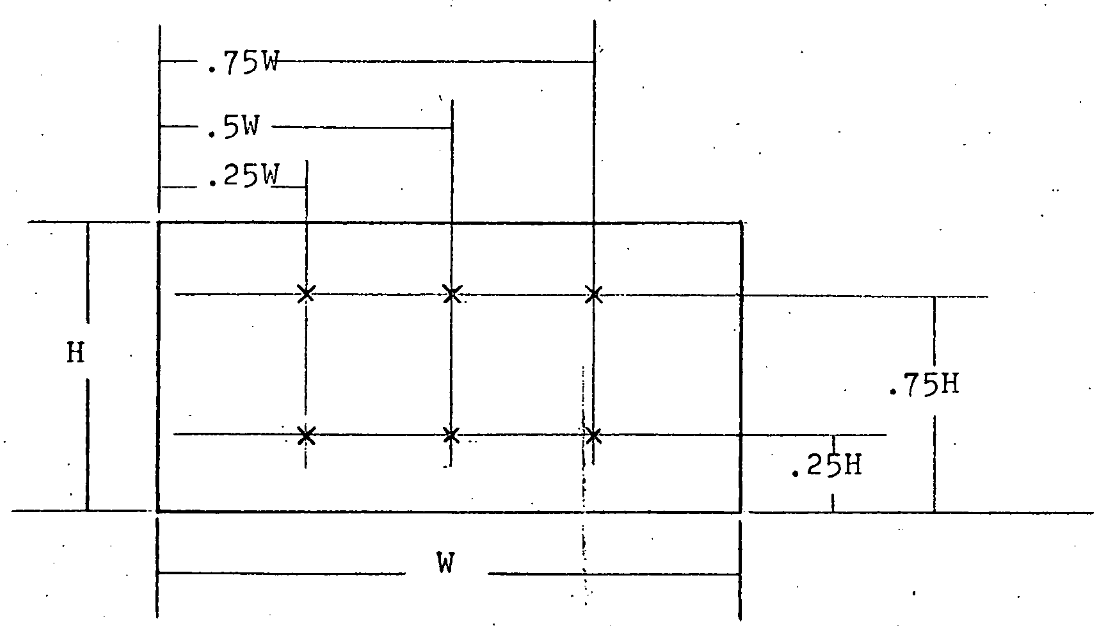
where: D is the internal diameter of the duct



Traversing Positions for Rectangular Ducts

where: W is the internal width of the duct

H is the internal height of the duct



SECTION 11. REFERENCES

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ENERGY RESOURCE ALTERNATIVES

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A SCORE Program

ENERGY RESOURCE ALTERNATIVES

(ERA)

FINAL TEST EVENT

SCHEDULE OF EVENTS

August 9-11	Teams arrive; Projects set up
<u>Monday</u> August 11	Morning - Teams complete set up Afternoon - Judges Meeting-Coronado Club Evening - Kick-off Bar-B-Q at Coronado Club-7 PM
<u>Tuesday</u> August 12	Morning - Welcoming Meeting and Team Orientation in Auditorium, Bldg. 815-9:00 AM Morning - Press Conference in Auditorium, Bldg. 815 - 10:00 AM All Day - Performance testing begins Oral Presentations begin Afternoon - Sandia Tours Evening - Seminar-Bldg. 815 Auditorium 7:30-9 PM (Al Narath-"Research at Sandia Labs")
<u>Wednesday</u> August 13	All Day - Performance Testing Oral Presentations Tour of LASL Afternoon - Sandia Tours Evening - Seminar-Bldg. 815 Auditorium 7:30-9 PM (Bill Spencer-"Microelectronics at Sandia Labs")
<u>Thursday</u> August 14	All Day - Performance Testing Oral Presentations Afternoon - Tour of AFWL Sandia Tours Evening - Seminar-Bldg. 815 Auditorium 7:30-9 PM (Al Toepfer-"Fusion Research at Sandia Labs")
<u>Friday</u> August 15	All Day - Performance Testing Oral Presentations Tour of LASL Afternoon - Tour of AFWL Sandia Tours Evening - Seminar-Bldg. 815 Auditorium 7:30-9 PM (Dr. Gil Yanow-"Alternative Consumer Energy Society - ACES")
<u>Saturday</u> August 16	All Day - Test Site Open House and Publicity Demonstrations for the Press (10 AM-4PM) Evening - Awards Banquet-Kirtland AFB Officers Club West. 6:30 PM - No Host Cocktails. 8:00 PM - Dinner
<u>Sunday</u> August 17	Afternoon - Tour of Solar Homes and Offices in the Albuquerque area - 1-4 PM