4th International Conference on Mechanical Engineering, December 26-28, 2001, Dhaka,Bangladesh/pp.39-51

Keynote Paper

TECHNICAL ASSISTANCE TO DEVELOPING COUNTRIES THROUGHAPPROPRIATE TECHNOLOGY

Izumi Ushiyama*, Yuichi Nakajo, Yasuyuki Nemoto and Tsutomu Dei**
Mechanical Engineering Department, Ashikaga Institute of Technology
268 Omae-cho, Ashikaga-city, 326-8554, Japan

Abstract Development of devices that utilize renewable energy was conducted with "appropriate technology" (AT) in mind as a part of technology assistance scheme to developing countries. Some of the research results are practically adopted by developing countries and achieved fruitful success.

Keywords: Developing countries, Appropriate technology, Renewable energy, Technical assistance

1. INTRODUCTION

Today, the population of the world is six times high as the population at the time of Malthus, known for his dire predictions on population. Earth's population is expected to grow to some 10 billion around the year 2050. The rapid expansion of the population will bring increases in demand for food, explosion in energy consumption, and pollution of the environment. The population expansion has been especially fierce in the last 100 years, growing 3.7 times or by about 4.5 billion people. On the other hand, the growth in the amount of energy used to support this level of human activity is even more phenomenal. Total human energy consumption has increased nine fold in the last century.

Therefore, a priority issue for the 21^{st} Century is to assure enough energy and water in the developing countries needed for increased agricultural output and to stop population increases at the same time.

In this paper, the authors present several case studies based on our experiences of technical assistance for developing countries which were based on a concept of appropriate technology.

2.WHAT IS "APPROPRIATE TECHNOLOGY"

From our previous experiences, in technological support for developing countries, there is a concept that can be called "appropriate technology" (AT) which is best fitted to the environment and conditions of the regional society and in answering the needs there. Therefore, the receptive technologies best fitted to the actual conditions in a given developing country must be selected, transferred, and diffused. But the countries that require technological assistance have multitudes of different conditions and a success of a given technology in a given country does not assure success in a different country.

For example, when planning to pump up water using a wind-powered pump, the combination of windmills and pumps to use will depend on the wind conditions of the site, average precipitation, the conditions of rivers, underground water tables, and other water sources. Furthermore, the technological level of the region, the available types of windmills and pumps, and even the practices and traditions of the local people could affect the design. As described above, AT does not exist as a universal one as there are no common appropriate technologies applicable to all developing countries. Thus, AT can be traditional or modern, small scale or large scale. Its only quality is that it is perfectly appropriate to the individual conditions of the people of the region who need the technology.

3.CASE STUDIES BASED ON APPROPRIATE TECHNOLOGY

The authors introduce case studies of technological cooperation projects in developing countries in which we were personally involved. These technologies were based on renewable energies: solar, wind, biomass, and water.

3.1 Wind Powered Water Pumping: Horizontal-Axis Sailwing Type

Wind energy can be used in applications requiring mechanical or electrical input such as crop drying, threshing and grain grinding, irrigation pumping etc. A wind energy conversion system is especially attractive for agricultural applications because it can provide direct mechanical shaft power that minimizes the conversion losses for pumping, grain grinding etc.

Email:*ushiyama@ashitech.ac.jp, **nakajo@ashitech.ac.jp

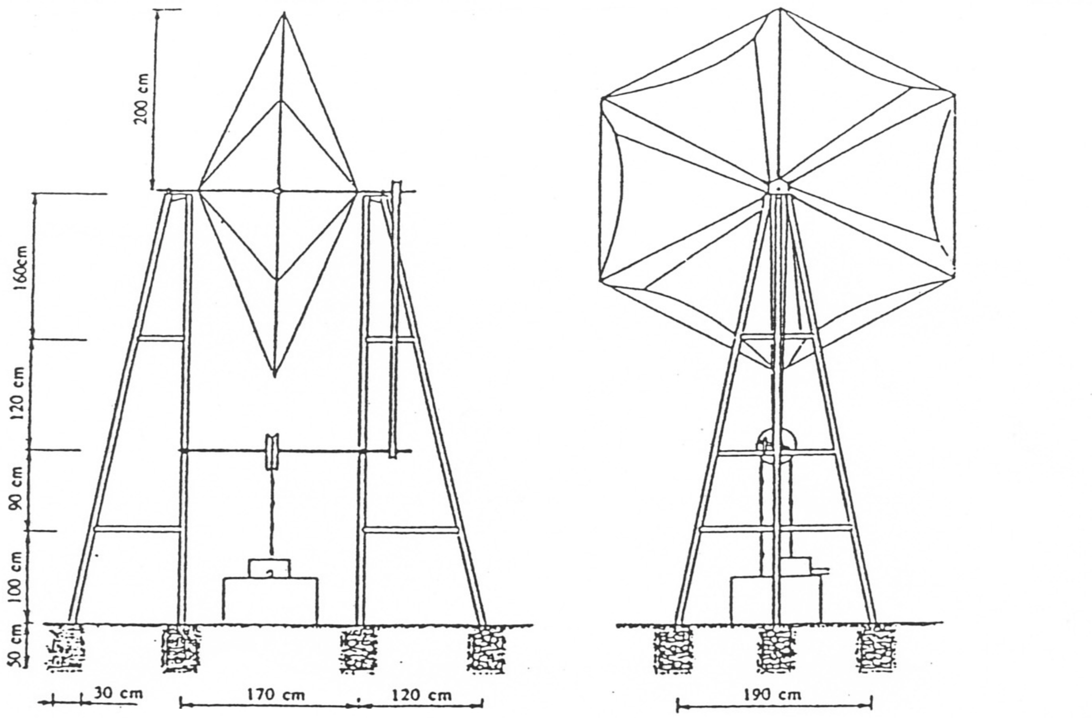

Fig. 1 Rope type pump driven by Cretan-sail wing windmill.

In order to utilize land area that lies along the coast in the district of Kabupaten Kulonprogo (southern coastal area of central Java in Indonesia), the government encouraged farmers to cultivate vegetable crops. The most important crop recommended by the government is garlic. This crop usually grows during the dry season, in the period from May to October. During that period the ground water level does not exceed a depth of 4 meters, while the wind blows at an average velocity for irrigation pumping by means of windmills.

This two year project (from January 1988 to December 1989) was managed by Assoc. Prof. T.Pruwadi and agricultural engineering researchers affiliated to the Department of Agricultural Engineering, Faculty of Agricultural Technology, Gadja Mada University in Indonesia. One of the authors Prof. Ushiyama participated in the project as a Japanese counterpart. The financing of the project was provided by The Hitachi Scholarship Foundation in Japan.

The project was concerned with the following six activities. 1) To identify potential areas where wind energy applications can be cost-effective and to select a suitable site within these areas for conducting the project. 2) To design and construct windmills based on adequate information about the existing wind energy potential. 3) To test and evaluate the performance of the windmills. 4) To make appropriate design modifications in the windmill constructions in the windmill construction based on preliminary tests. 5) To test and reevaluate the performance of the re-designed windmills. 6) To introduce the recommended windmill to farmers.

Fig. 2 Cretan type windmill in central Java

In the first year, three different windmill prototypes were designed and fabricated; they were two Savonius type windmills with metal frame and with rattan frame, and a Cretan type sailwing windmill. Both the metal and rattan frame Savonius type windmills were 2x2 buckets with design features as follows: the rotor buckets area was 3.22m^2/bucket, the rotor bucket chord was 1.50m,

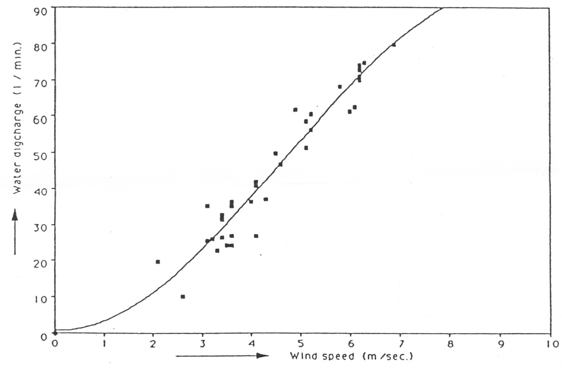

Fig. 3 Water discharge vs. wind speed by Cretan type windmill

and the rotor height was 2.15m. The windmill was used to operate a reciprocating pump that requires 2.14kgm of torque at a shaft rotational speed of 20rpm.

On the other hand, the Cretan type sailwing windmill was fabricated with design features as follows: the sail number was 6, the diameter of the rotor was 3.5m, and the swept area was 6.4m^2. This windmill was used to drive traditional rope type (chaplet type) pump.

After the windmills had been constructed in the field, the technical check and the performance test were conducted. From the results of the field test, the Cretan type windmill had a better performance pumping up 55-60l/min of water compared to the Savonius type windmill that only pumps 39-42l/min of water. The construction cost of the Cretan type windmill is less than that for the Savonius type around 40%. Moreover, the Cretan type sail wing windmill has a good matching between the output of the windmill and the power requirement of the rope type pump.

In the second year, three Cretan type windmills, as shown in Figs.1 and 2, have been redesigned and constructed based on the first year's experience. Testing results corresponding to the Cretan type windmill are plotted in Fig. 3. This figure shows that the water discharge capacity of the windmill operating at a daily average wind speed of 5m/s is 50-60 liters/min. Since wind energy at the site is available 10hours per day, this means that the windmill can deliver 30 to 36 tons of water per day. This water was enough for irrigation of approximately 1 hectare of garlic crop. As a result, the Cretan type sailwing windmill operated together with a rope type pump is favorable for introduction to the local farmers. (1)

3.2 Wind Powered Water Pumping: Vertical-Axis Sailwing Type

Water pumping system is essential to the people in developing countries. It should be simple in design and should be made from indigenous and low cost materials. For this purpose, sailwing windmills are the most suitable type. There are two types of sailwing windmills. One is horizontal-axis wind rotor as mentioned in Section 3.1, and the other is vertical-axis one. The performances on the former type have been reported, but not on the latter type. Therefore, the authors conducted the model tests in a wind tunnel to clarify the aerodynamic performance of the vertical-axis wind rotors.

On the basis of the experimental studies in a wind tunnel, a four-sail windmill with rectangular shape was determined to fabricate in actual size as shown in Fig. 4. To clarify the water discharge capability and starting characteristics of the vertical-axis sailwing water pumping system, experimental studies were carried out. The performance of vertical-axis sailwing water pumping system were compared to those of Savonius water pumping system, of which performances had already clarified at Ashikaga Institute of Technology in 1985.

As for the vertical-axis sailwing rotor, the aerodynamic surfaces are self-forming and it has a degree of self-regulation. When the wind impinges on the sailwing, it takes up an airfoil shape with a concave surface facing into the wind. During rotation the sailwing becomes like an airfoil shape with continuously changing angle of attack, and in one complete revolution of the rotor, the sailwing switches the concave surface from one side to other twice automatically. This enables the rotor to develop a positive torque even at low rotational speed for regardless of positions of the rotor. Therefore, the sailwing rotor has an ability of self-starting unlike the Darrieus rotor and an ability to accept wind from any direction.

From the model tests in a wind tunnel, it was shown that the rectangular shape with four sail has most suitable performance for the water pumping system. Vertical-axis sailwing water pumping system has self-starting characteristics, and arrives the maximum number of revolution within 20 second at 4m/s wind velocity as shown in Fig. 5. The maximum number of revolution is larger than that of Savonius type windmill at same wind velocity. Water discharge capacity of V-axis sailwing pump is larger than that of Savonius type windmill as shown in Fig.6. V-axis windmill has capability to pump up 25 l/min. of water at 6 m/s wind velocity. It can be conclude that V-axis sailwing water pumping system has not only the good performance, but also the simplicity in design. Thus, it is very suitable for the introduction to the people in developing countries. Figure 7 shows the windmill installed in Peru by one of the author T. Dei in mid 1990s.

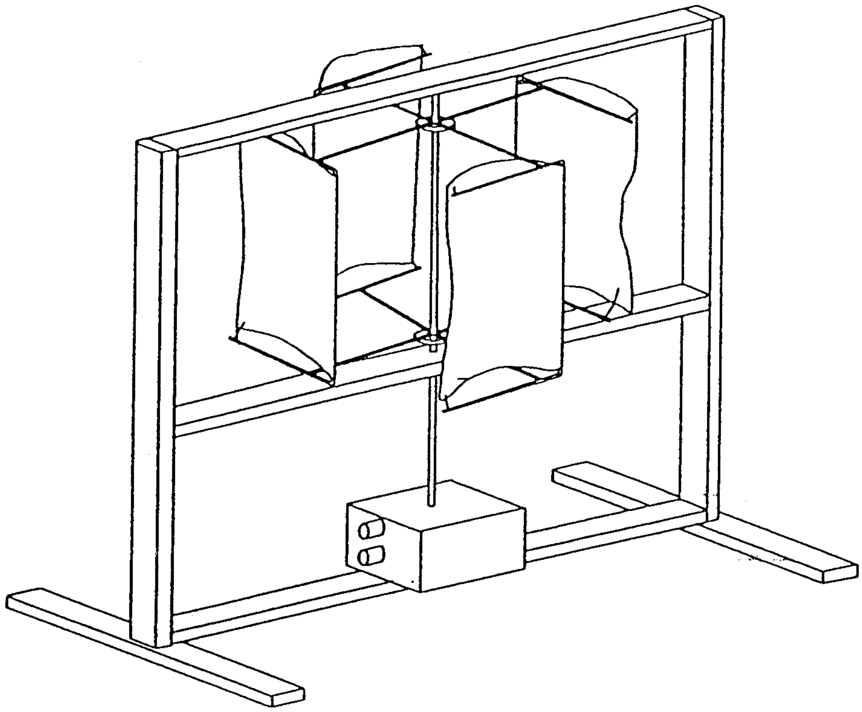

Fig. 4 Vertical-axis sail wing windmill

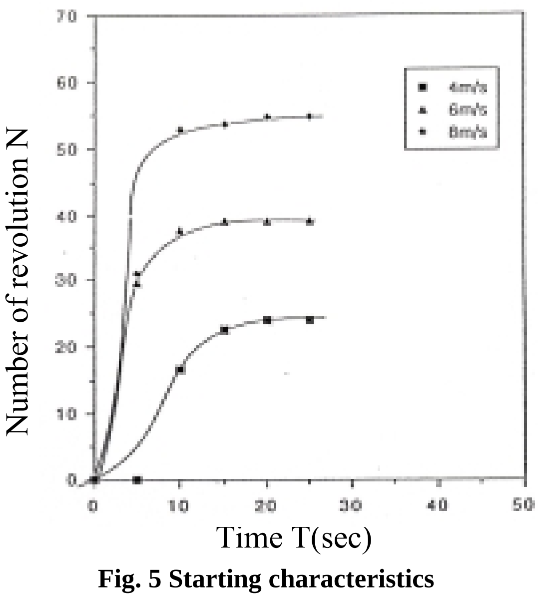

Fig. 5 Starting characteristics
(V-axis connected water lifting pump)

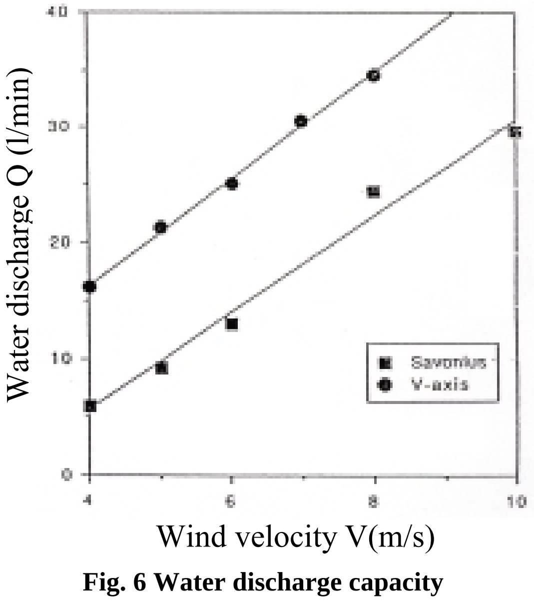

Fig. 6 Water discharge capacity
vs Wind speed

3.3 Wind Powered Electric Generation

There are numerous off-grid-areas in developing countries. Considering the back ground of the infrastructure of these countries, it is desirable to introduce a small scale generation of electricity, such as wind, solar, small hydro and so on, rather than a large scale power station.

As a stand-alone power source in developing communities, the authors proposed a small scale wind powered generation system based on a design concept of an AT. The concept was geared toward simplicity, low cost, easiness to maintain, and reliability. Components used can all be affordable off-the-shelf or be manufactured in a workshop with limited facilities. In planning to manufacture a wind driven generator by oneself, the generator is the most essential component. As to it, an automotive alternator was adopted because of availability in any place even in developing countries. Moreover, the alternator is one of the most versatile electric power sources, with its proven record of reliability, lends itself ideally to be used as a component in remote power supplies.

Fig. 7 V-axis sail wing windmill in Peru

However, in adopting an alternator to the wind driven generator, two major problems must be solved. One is that the rated rotational speed of the alternator is much higher than that of the wind turbine rotor. The other is that an excitation to the alternator has to be done corresponding to the rotational speed of the wind turbine or wind speed. The former is relatively simple process because the speed-increasing device incorporates those features. However, to overcome the latter needs some innovative thinking.

There are a few cases on excitation methods based on each experience, however, no systematic research had reported. Therefore, the authors made an investigation and evaluation on conventional excitation methods, then, summarized the results systematically. Furthermore, the authors proposed novel excitation current control circuits and the improvement of conventional circuits.

When an alternator is adopted in the wind-powered generator, excitation current is required to flow through the field coil. However, if the excitation is not switched off during periods of low wind speeds or when no wind blows the battery would not continue to supply the current to the field coil and would eventually become flat. To overcome this an excitation current control circuit is required. Therefore, the authors first made an investigation and evaluation on conventional excitation methods, then proposed a novel method and the

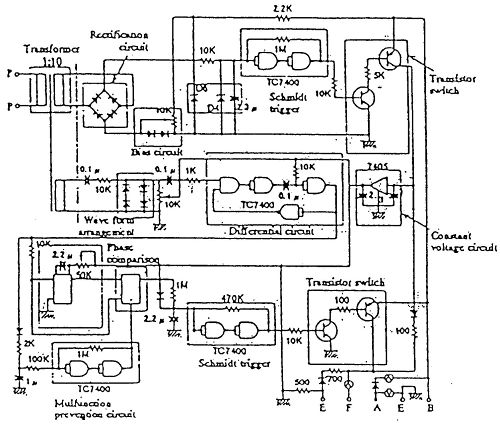

Fig. 8 Residual magnetism type

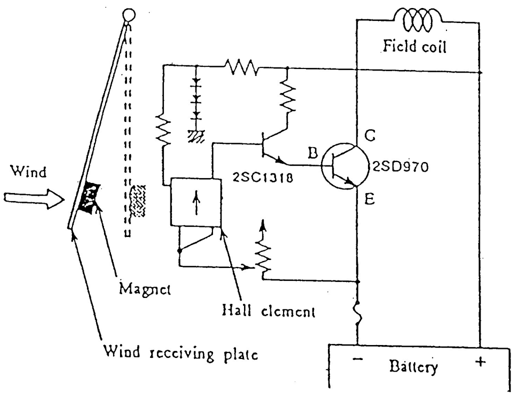

Fig. 9 Wind pressure switch type

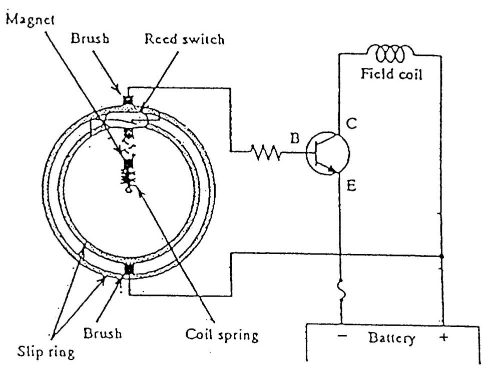

Fig.10 Centrifugal force switch type

improvement of the conventional circuits as follows.
(1) Residual magnetism of the alternator type. This circuit is shown in Fig. 8. This control circuits works exactly, however, it is rather complicated and a lot of parts are needed. (2) Wind pressure switch with a Hall

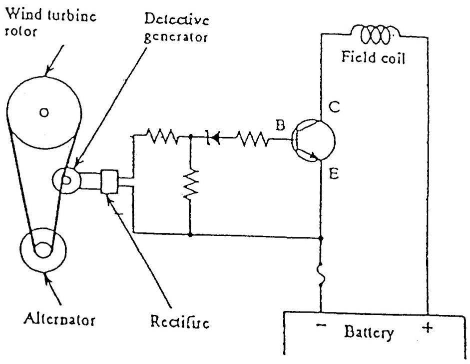

Fig.11 Speed detective generator type

element type. This circuit is shown in Fig. 9. This circuit is simple and the working principle is also simple. Special feature of the circuit is an adaptation of a Hall element that detects magnetism. (3) Centrifugal force switch type. This circuit with reed switch is shown in Fig.10. This is the most simple and reliable circuit and suitable for developing countries. (4) Rotational speed detective generator type. This circuit is shown in Fig.11. This is also simple but it needs separate generator to detect the rotational speed.

In order to meet the demands of the developing communities, the authors designed and fabricated a 300W class wind driven generator, as shown in Fig.12, equipped with a speed-up mechanism and the excitation current control circuit triggered by the residual magnetism of the alternator. A wind tunnel test was conducted to clarify the performance of the generator. Test result was shown in Fig. 13. Moreover, the authors confirmed that the excitation current control circuit worked well and also confirmed that a satisfactory agreement was obtained between the rotational speed of the wind turbine rotor and that of the alternator.

Thus, from the viewpoint of AT, the automotive alternator may be an excellent compromise as a generator for small-scale wind powered generation.

3.4 Wind and Solar Hybrid Generation System (WISH BOX)

The authors proposed a portable type wind and solar hybrid (WISH) system. Especially, this system is contained in a small box, so we call this “WISH BOX”. The system consists of a small wind powered generator of 300W class and photovoltaic panels of 100W. This unique hybrid generation system is suitable for a small-scale stand-alone power source in an emergency in a stricken district as so called “life-spot”, or no-power source districts in developing countries. Through this system, minimum requirement of the electric power output for lighting and information, or radio and mini-television will be provided. These power sources are indispensable for the people living there. In developing countries, this system is useful not only for lighting and

Fig.12 Small Wind Driven Generator

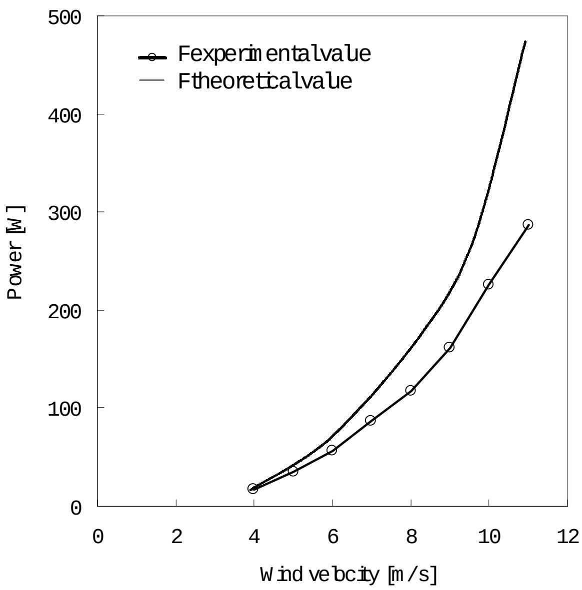

Fig.13 Power output vs. Wind velocity

information, but also the power source of a refrigerator for vaccines. Moreover, the WISH BOX is characterized by its cleanliness and noiselessness compared with engine powered portable type generators. Therefore, the system is also suitable for the outdoor use such as a power source for camping life.

The system layout of the WISH BOX is shown in Fig. 14. The WISH BOX consist of a small scale wind powered generator, photovoltaic panels, an over-charge/-discharge controller, and a battery. The wind-

Fig.14 WISH BOX in Operation

powered generator is AIR 303 is used temporary because of its lightweight as light as 6kg. The photovoltaic panels have 100W peak output consist of two 50W modules. The circuit controller of the system developed by ourselves is shown in Fig.15. The output of the wind powered generator and the photovoltaic cells is provided to the storage battery through this controller. The WISH BOX utilizes a complementary relationship between wind energy and solar energy. Thus, the stable output could be available from this hybrid system and the capacity of the battery could be decreased as small as 12V 20Ah.

3.5 Wind and Solar Hybrid Generation System (Savonius Type)

It is well known that there is a complementary relationship between solar energy and wind energy. Then, if we construct a generation system that combines these two energy sources, it is possible to acquire a stable energy throughout the year. The wind and solar hybrid generation system currently in use consists of independent wind powered generator and photovoltaic modules. However, the authors proposed a unique hybrid system that integrates the windmill and photovoltaic modules. The windmill called Savonius type of which large buckets are attached by flexible amorphous photovoltaic modules. The system is named the Savonius type WISH system. The experimental windmill installed in the demonstration field of Ashikaga Institute of Technology is the Savonius rotor with two half-cylinder section type. Fig. 16 shows the schematic diagram of the Savonius type WISH system. The external appearance of the system is shown in Fig. 17. The lower part of the windmills are connected with low-speed permanent magnet DC generator of 36W rated power through chain and sprocket of speed

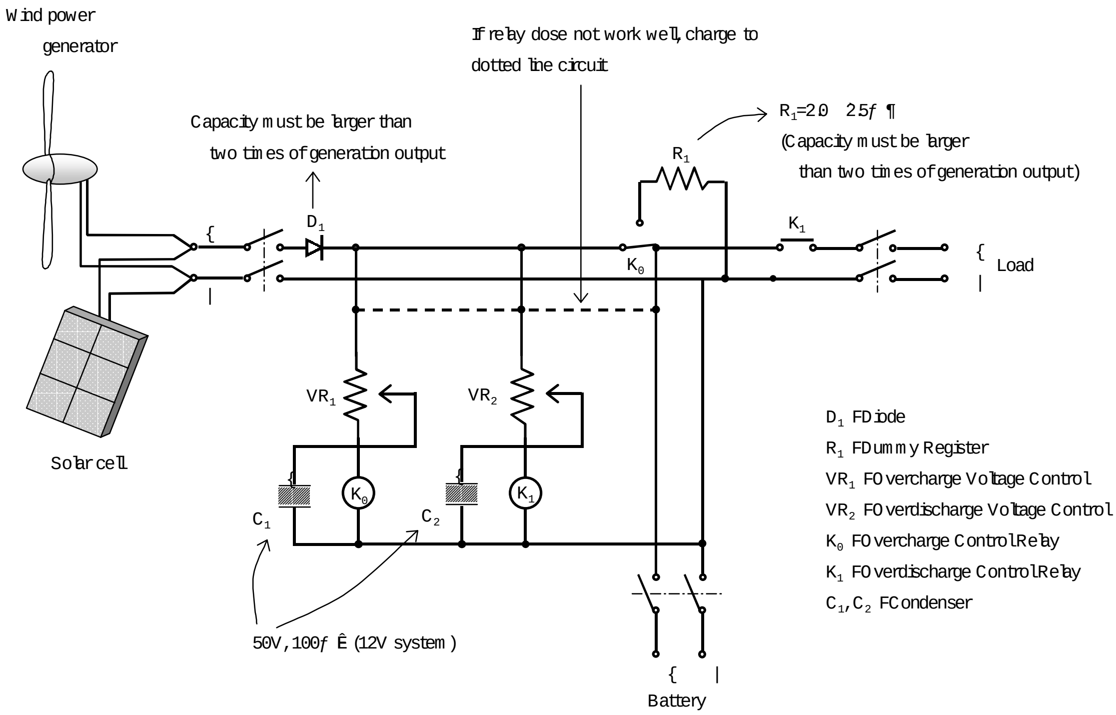

Fig.15 Control Circuit of Wind and Solar Hybrid System

increasing ratio of 5. A slip ring through which to take out the electric power generated in photovoltaic modules is mounted on the top of the WISH type windmill. Moreover, as shown on Fig.17, a Savonius type windmill without photovoltaic module on its buckets was also installed at the symmetrical position to the support. [(3),(4),(5)]

The generation output by wind powered generators and photovoltaic module was charged into 12V storage battery. At the same time, generated output by the wind powered generator and photovoltaic module is calculated through the operation of electric power unit. Figure 18 shows a cumulative daily output data in the second half of June 1995 in Ashikaga. The generated output by the Savonius wind rotors with and without photovoltaic modules are nearly the same values. However, the total generated output by WISH type windmill is nearly twice as large as the Savonius type wind rotor without photovoltaic module. Thus, the effectiveness of the WISH type power system is confirmed. After several years operation of the WISH type power system in the field, this system could acquire the stable energy from wind and solar energy through the year. Moreover, since this system is simple and robust, it is recommended to install as a small power source in the developing communities.

3.6 Solar Cookers

Solar cookers utilize the direct sunlight to cook foods. There are three main categories in solar cookers, i.e. reflecting condenser type, heat box type, and panel type. Regardless of the types, solar cookers do not need any fuels as firewood. Reflecting condenser type solar cookers are mainly used in China and adjacent countries like Tibet and Nepal. The total number of the cookers used in such areas differ with the reports, but probably is more than two hundred thousand. Heat box type solar cookers are popular in the districts where the sun elevation is large as some areas in India and Africa. In India, more than five hundred thousand solar cookers are in use and fifty thousand are sold every year. Back packers prefer panel type solar cookers because most of them are foldable. Also as they are easy to build at a low price, the panel type solar cookers are often used to relieve refugees.

About 2 billion people, over one third of world population, have daily dependence on firewood as a source of their cooking and heating energy and 1.5 billion of them are suffering from daily shortage of firewood. They live in the tropics, in the most favorable areas for solar energy utilization. 80% of firewood consumption in the developing countries is used for cooking which results in 20,000 - 25,000 km2 annual loss of tropical forests. (10% of the entire loss.) UNISEF assumes that 36% of this could be realistically replaceable by solar cookers. Wood savings would be 246 Mtons annually, worth $20 billion. Potential market of the solar cookers is some 200 M units, $18 billion. With assumed average cooker lifetime of 10 years the size of the market would be 20 M units, $1.8 billion.

Besides the saving of firewood, solar cookers can alleviate the burden of labor for women in developing countries. They spend several hours a day to collect

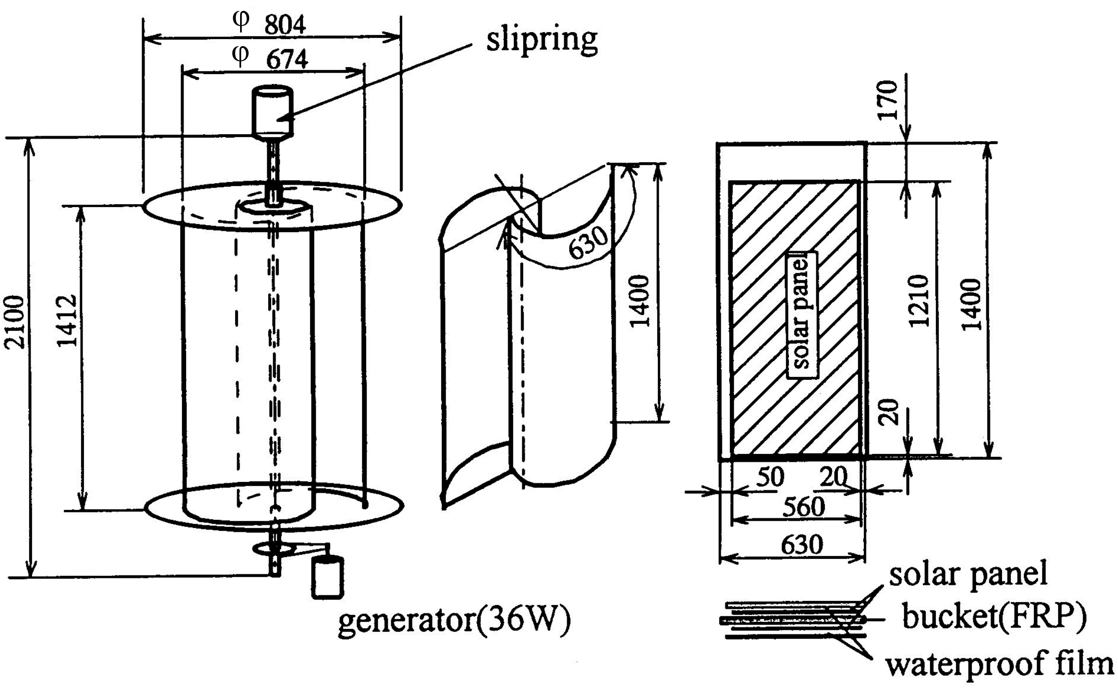

Fig.16 The schematic diagram of the WISH type Savonius windmill

Fig.17 External appearance of the experimental windmill

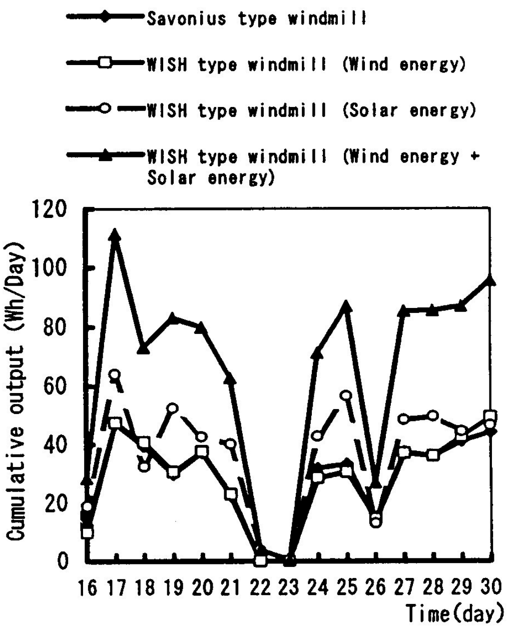

Fig.18 A cumulative daily output data in the second half of June 1995

firewood in average. Additionally, their lungs are damaged by soot and smoke due to the poor ventilation when they cook inside the houses.

Solar cooker usage also promotes another important health aspects. According to WHO diseases that are spread through contaminated water cause 80% of illnesses in the world. Heating water to pasteurization temperature 62.8^o destroys disease organisms. This temperature is easily achievable with any solar cookers. Acute respiratory infections (ARI) are the cause of death for 1/3 of the about 15 million children under 5 years of age that die in the world each year.

Opinions have been in quite accord that the box type solar cookers are not for the use in Japan. However, the heat-box type solar cookers excel the other types in versatility and ease of use, and if high-performance heat box for the use in Japan is successfully designed, many countries at middle latitudes will also receive the benefits of solar cooking. But by our modification, we now have several heat-box type solar cookers that can cook food even in winter in Japan. Actually, the booster mirror can most effectively reflect the light into the heat box when the sun elevation is 75 degrees which is about the elevation in summer in Japan. The heat box type solar cookers are now mainly used in the area where the sun elevation is high and where people prefer the boiled food. A conventional heat box type solar cooker is simply a well heat-insulated box with a glass lid and a supplementary reflector called booster mirror.

The solar cookers for Japan should not be expensive because we only have less than 200 fine days a year on which we can use solar cookers. Additionally, most Japanese would not use solar cookers if they need too frequent adjustment outside. The followings are features of our latest improved heat-box type solar-cooker.

1. No need of adjustment of orientation or angle of booster mirrors in six hours.
2. It can boil a liter of water within three hours in winter of Japan.
3. Once the temperature reaches 100 degree, it can keep it above 80 degrees for two hours.
4. If you adjust the orientation of the mirror frequently, its performance doubles.
5. When the booster mirror is folded, its dimension is as compact as 60cm x 60cm x 20cm.

Even with such performance as this, Japanese housewives would not prefer solar cookers to cook daily food. In the city areas in Japan, the percentage of people who have a place where we can get sunshine all day is quite low even for homeowners. Furthermore, the average number of days on which we have sunshine more than 6 hours is about 160 to 180 where the gas or electricity bill in Japan is relatively cheap. However, solar cooker will be a good option as a leisure tool and as a teaching material of clean energy education for children. This year, through two activities with elementary school students in “Wind and Sun Square” in AIT, we are in possession of actual proof of effectiveness of solar cookers as teaching materials.

3.7 Biomass Gasified Generation System

The gasification of biomass is mainly classified into two groups based on the process of gasification. One adopts microorganisms or anaerobic fermentation, and the

Fig. 19 Various heat box type solar cookers.

Fig. 21 Exhibition room for solar cookers.

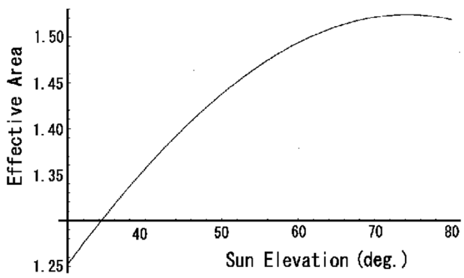

Fig. 20 Effect of the booster mirror vs. sun elevation.

Fig. 22 Our latest heat-box type solar

Fig. 23 Solar cookers in clean energy education at A.I.T

other, thermal cracking. The reaction of the latter proceeds more rapidly than the former, so it can occur through the gasification of woods and chaffs.

The authors conducted a research and development of the gasification by thermal cracking. Woods, woodchips, wood pellets made from pressed chaffs, rice straw, bagasse (fiber residue from the milling of sugar cane) are derived from agriculture.

Thermal cracking starts to occur when the temperature of woods is increased. Gas whose main components are some hydrocarbon, tar and char are then created. When the temperature exceeds around 300℃, wood can continue to burn its own and char is broken down into CO, CO_2 and H_2 gases.

In an actual utilization of wood based biomass, one of the problems was tar creation. Tar, which is the aggregate of polymers of a kind of hydrocarbon, changes to liquid with high viscosity and adhesion. Particularly, when it sticks to pistons of engine, it adheres and ignition failure causes. Thus, until now, washing equipment was used for the section between the gasifier and the engine. However, the other problems of increased facility cost and decreased synthetic efficiency are caused. Another problem was quantity of flammable gases. The chemical reactions of char gasification are complicated. The reaction speed depends on the temperature of the gasifier, quality and quantity of the fuel, and quantity and passage time of the air. It is necessary to optimize these conditions to get a higher quantity of flammable gases. Therefore, the problem up to now has been how to eliminate tar at low cost, and how to get more flammable gases.

In 2000, one of the authors Nemoto and Mr. Erdene from Mongolia conducted an experiment to solve the above-mentioned problems and to optimize the ventilation of the gasifier. Through the experiments, it was found that the tar creation became less and the quantity of flammable gases increased by adopting a downward ventilation system.

An appearance and sectional view of a small- scale gasifier are shown in Figs. 24 and 25 respectively, which was manufactured by Mr. Erdene, a Mongolian researcher at A.I.T in 2000. Since many of the Mongolian people are nomads and often change their location throughout the year, there are very limited electricity networks in Mongolia. On the other hand, because of dry climate, dried dung from livestock can be easily obtained for fuel. Mr. Erdene studied the use of dried dung as a fuel for nomads using the gasifier and developed it based on the results of the research. Similarly, the technique of biomass gasification is fairly useful and can be suited to the climate, topography and lifestyle of the country.

3.8 Water Hammer Pump

Water hammer pumps or hydraulic ram pumps are simple water pumping devices that are powered by falling water. There is no necessity to use such pumping devices in advanced countries where we can utilize electricity wherever we want. However, there is still strong needs for water hammer pumps in developing countries.

Fig.24 A Gasifier for Mongolian nomads

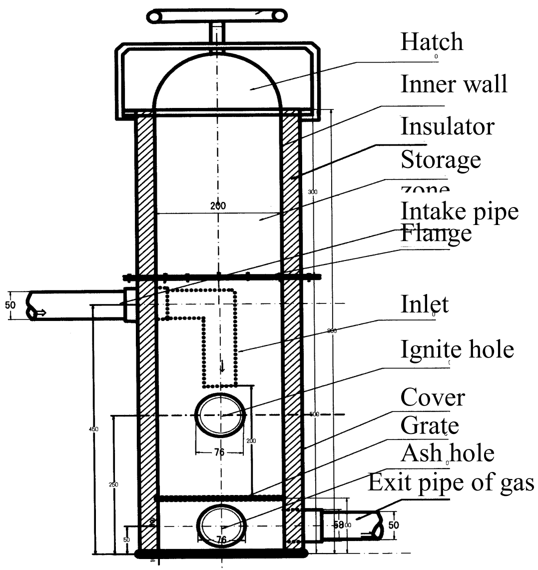

Fig.25 Sectional area of the gasifier

The pump works by using the energy of a large amount of water falling a small height to lift a small amount of that water to a much greater height. In this way, water from a spring or stream in a valley can be pumped to a village or irrigation scheme on a hillside. Wherever a fall of water can be obtained, the hydraulic ram pump can be used a comparatively cheap, simple and reliable means of raising water to considerable heights.

The power required to raise water is proportional to the water's flow rate (q) multiplied by the height (h) through which it is lifted (in a ram pump qxh). Similarly, the power available from falling water is proportional to its flow rate (Q) multiplied by the distance dropped (H): (QxH). A water hammer pump works by transferring the power of a falling drive flow to a rising delivery flow.

Thus, the input power is proportional to drive flow (Q) x drive head (H), and output power is proportional to delivery flow (q) x delivery head (h). In a real system, considering the efficiency (η), delivery flow rate is as follows.

Delivery flow (q) = QHη / h

The hydraulic pump system can only lift a fraction of the flow that drives it. This ratio of delivery head to drive head (h/H) is typically in the range 5 to 25.

Figure 26 shows a sectional view of simplified water hammer pump, which you can make in local machine shops in developing countries. All these parts are consist of water supply works Figure 27 shows a system layout of water hammer pumping. The same designed pumps were manufactured at local machine shops in Egypt and installed there under the guidance of one of the author T. Dei in the late 1990's. Figure 28 shows a demonstrative operation of the simplified water hammer pump designed by T. Dei at Ashikaga Institute of Technology.

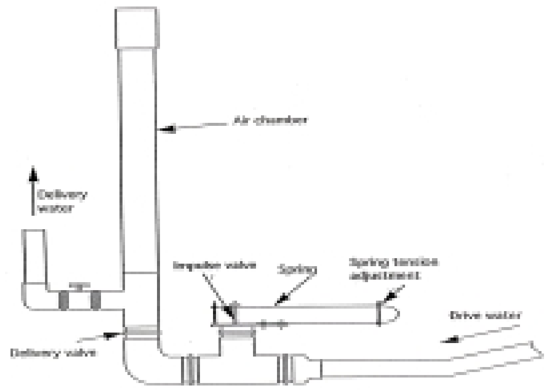

Fig.26 Simplified Water Hummer Pump

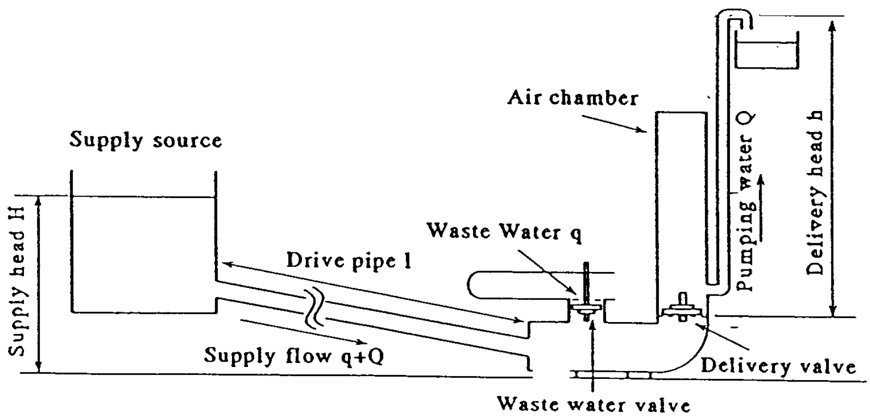

Fig. 27 A System Layout of Water hammer pump

4. DEMONSTRATION PROJECT OF ASHIKAGA INSTITUTE OF TECHNOLOGY

Recently, the global environmental problems became more and more a serious matter of concern among people in the world and AIT also has been devising some practical measures on enlightenment and dissemination of natural energy utilization. This June, we extended "Wind and Sun Square" locating near our campus expecting the following three roles. The first role of the square is an outside experimental field to learn how to make use of the natural energy. The second one is a theme park to enlighten and educate on the environmental problems. And the third one is a workshop to acquire appropriate technologies for supporting developing countries. The total area of the square is 12,000 m^2 and it consists of four sub-themes, i.e. wind, sun, water, and wood. In the square as shown in Fig. 29, the all-inclusive small-scale wind turbines, solar panels, scooping pumps, and other devices utilizing the natural energy are on display. In the site, we have a biotope pond as natural ecosystem, a deck made of lumbers from thinning out as an outside classroom, and the natural energy mini museum as exhibition hall. On the first floor of the two-story museum as shown in Fig.30, various micro-scale wind turbines, models of windmills, and other goods about “wind” are displayed. The second floor is dedicated to solar cookers and each type of representative solar cookers in the world including Chinese reflecting type, Indian heat box type, and American panel type solar cooker for back-packers, etc. are displayed. This square has been the observation site for the visitors from developing countries by the program in the agricultural machine course in Tsukuba International Center of JICA, Asian Rural Institute, New Energy Foundation, etc. since its establishment for six years. We also have been assisting introduction of wind-powered pump systems to Indonesia and Peru as an activity to transfer technology to developing countries applying the measures we worked out in this square.

Fig. 28 Water Hammer Pump in Operation

5. CONCLUSION

In order for technology transferred from developed nations to developing countries to prove useful and be actually “appropriate technology”, local needs must be measured, appropriate technology must be applied, maintenance and repair methods for the hardware must be taught, and human resources developed. Established modern technology of the one-size fits all style can be transferred with the hardware and manuals alone. Since “appropriate technology” has numerous variations in the applicability to the locality and demand, it is almost impossible to establish it as a systematic field of study. Even in Japan, it is imperative to have facilities where “appropriate technology” can be studies and implemented in earnest in order to conduct effective international contributions and technological cooperation in the future.

Finally, even though it may be seen a roundabout method, the electrification of areas in developing countries without access to electricity will bring about voluntary reductions infertility and should contribute to

Fig. 29 Natural Energy Square at A.I.T

Fig. 30 Exhibition hall of the Museum

limiting population growth. This is because electrification will make it easier to obtain entertainment and information through television and radio and increase knowledge of health and sanitary matters. Its educational effects will increase sanitary conditions and reduce infant mortality thereby reducing the necessary birth rates. The authors believe that renewable energy based generation system or hybrid system thereof are the most effective.

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