Irrigation and Water Utilization and Management Department
Ministry of Agriculture, Livestock and Irrigation

Summary Report

Union of the Myanmar Republic

Verification Survey with the Private Sector for Disseminating Japanese Technologies for Micro-hydropower Generation System Project

April 2018

Japan International Cooperation Agency

Hokuriku Seiki Co., Ltd.

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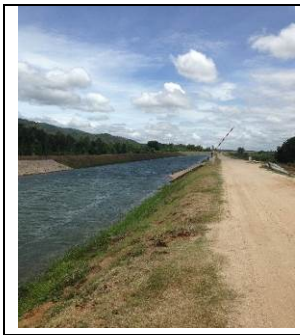			
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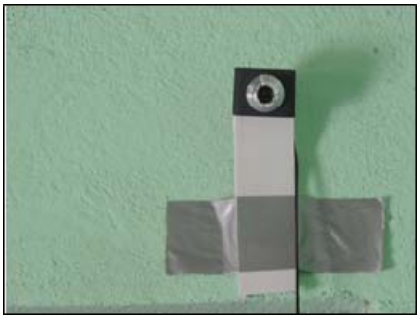

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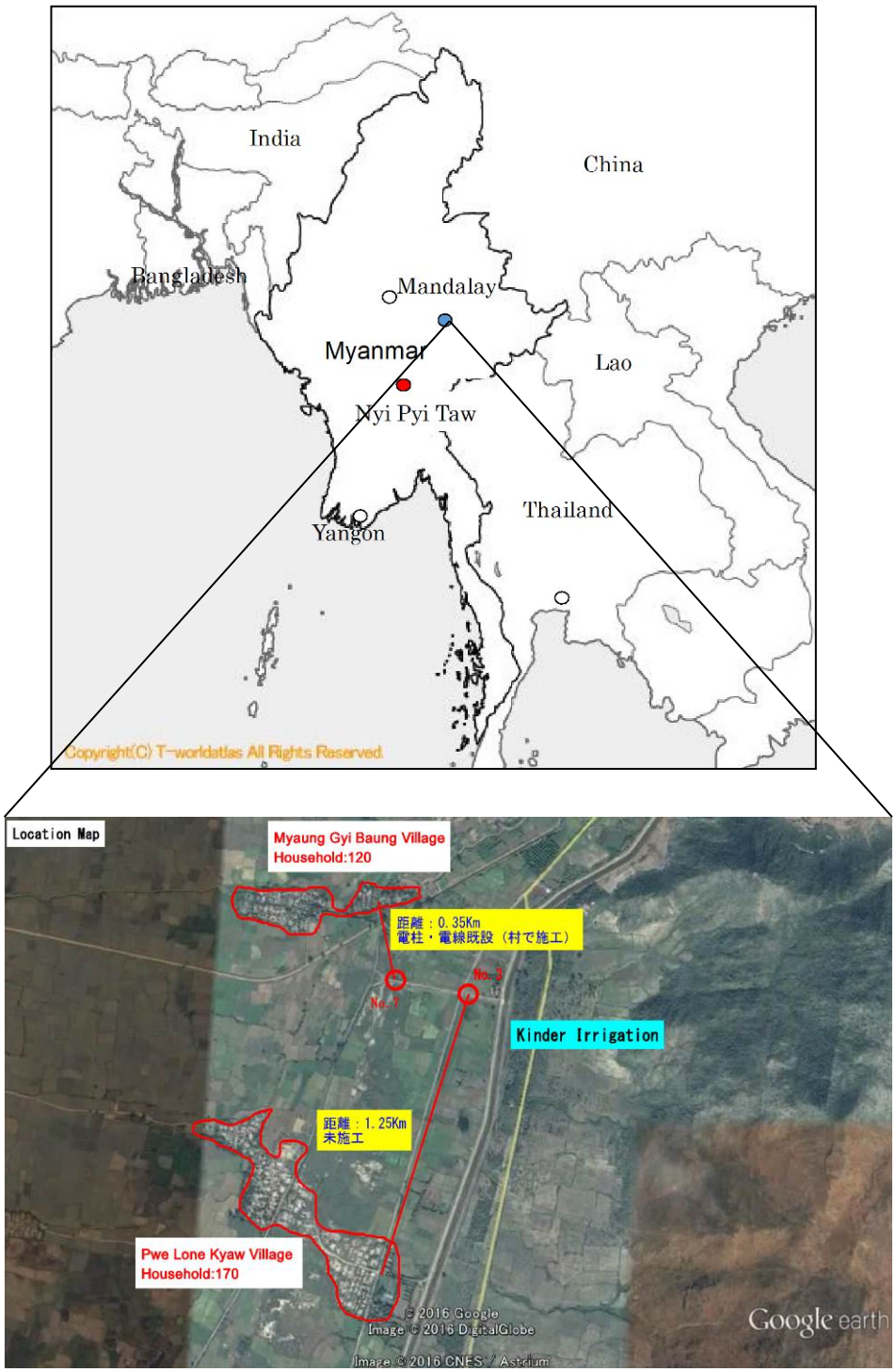


Myaung Gyi Boung Village and Pwe Lone Kyau Village in Mandalay Region

1. Project Background

A shortage of electric power is a serious issue that Myanmar has been facing. A realization of a sustainable and stable power supply is most important. Hydropower generation accounts for around 67% of the total power generation capacity at present. The electrification ratio of Myanmar is quite low, especially in rural areas. Around 2.7 million households out of 8.9 million total households (or 29% of total households) are connected to the power grid. The average electrification ratio is around 29%, however in rural areas it is mere 16%. The largest power consumption area in Myanmar is Yangon and its surrounding area, which consumes around 50% of the total power generated in Myanmar. Meanwhile the progress of electrification in rural areas is slow, especially at the village level.

The project formulation survey was carried out by Hokuriku Seiki Co., Ltd. in 2013 to formulate the project aiming at verifying and demonstrating the effectiveness of the micro hydropower generation technologies developed by Hokuriku Seiki Co., Ltd., in collaboration with the Irrigation and Water Utilization Management Department (IWUMD) – formerly the Irrigation Department or ID - of the Ministry of Agriculture, Livestock and Irrigation (MOALI). Through this project formulation survey, the needs for the provision of a micro-hydropower generation system, which can be installed at the drops/falls in irrigation channels, was confirmed.

2. Outline of the Project

2.1 Objectives of the Project

The Project is designed to verify the performance of the micro-hydropower generation system developed by Hokuriku Seiki Co., Ltd. and to contribute to the village electrification program, especially in non-electrified rural areas, in collaboration with the Irrigation and Water Utilization Management Department (IWUMD) of the Ministry of Agriculture, Livestock and Irrigation (MOALI). The objective was to localize production of the product so as to set the price of the product as low as possible in order to make such off-grid type independent power projects financially viable.

The Project envisages installing the micro-hydropower generation system at the drops/falls in the secondary irrigation channels that are controlled and managed by the IWUMD throughout Myanmar. An examination on how the improvement of living standards (or the elimination of poverty in such non-electrified rural areas) by means of village electrification schemes using the micro-hydro power generation system could be realized was undertaken. Furthermore, the process of how the dissemination of such micro-hydro power generation systems could be achieved was examined, in collaboration with the IWUMD.

2.2 Project Activities

In order to achieve the objectives of the Project, the counterpart organization for the execution of the Project was determined as the IWUMD. The direct beneficiaries of the Project are those 120 households of Myaung Gyi Boung Village and those 170 households of Pwe Lone Kyau Village, in the Mandalay Region. These two villages are located about 1 mile away from the selected drops /falls in the secondary channels of the Kinder East Irrigation System that serves the irrigation of some 42,000 hectares. The potential future beneficiaries during implementation of the Project is estimated to be around 20,000 households (equivalent to 6 – 7 million people who reside alongside the irrigation channels) to be developed by the IWUMD.

2.3 Features of the Total System

The inputs to the implementation of the Project are as follows:

Power Unit : Power Archimedes designed and developed by Hokuriku Seiki Co., Ltd.

Output ：7 kW for each drop/fall selected namely CY-3C Drop No. 3 and Drop No. 7

Dimensions : Width 1.3 m, Length 1.3 m, Height 3.2 m

Uniqueness of Power Archimedes：

① Power Archimedes is of the Vertical Axis Water Flow Type. Minimum requirement of water discharge is 0.1m^3/sec with and effective height 1.0 m for effective power generation (which other Companies cannot achieve);

② Easy installation of equipment, especially when the machine is planned to be installed at the drop /fall in the irrigation channel. No substantial volume of civil engineering works is required, thereby the system cost can be minimized;

③ Hydro-power generation unit can be designed as either a hanging type or a standing type, depending on the shape of drop/fall in the irrigation channel;

④ Installation of a hydropower generation unit needs only one day in the case of the 10kW unit

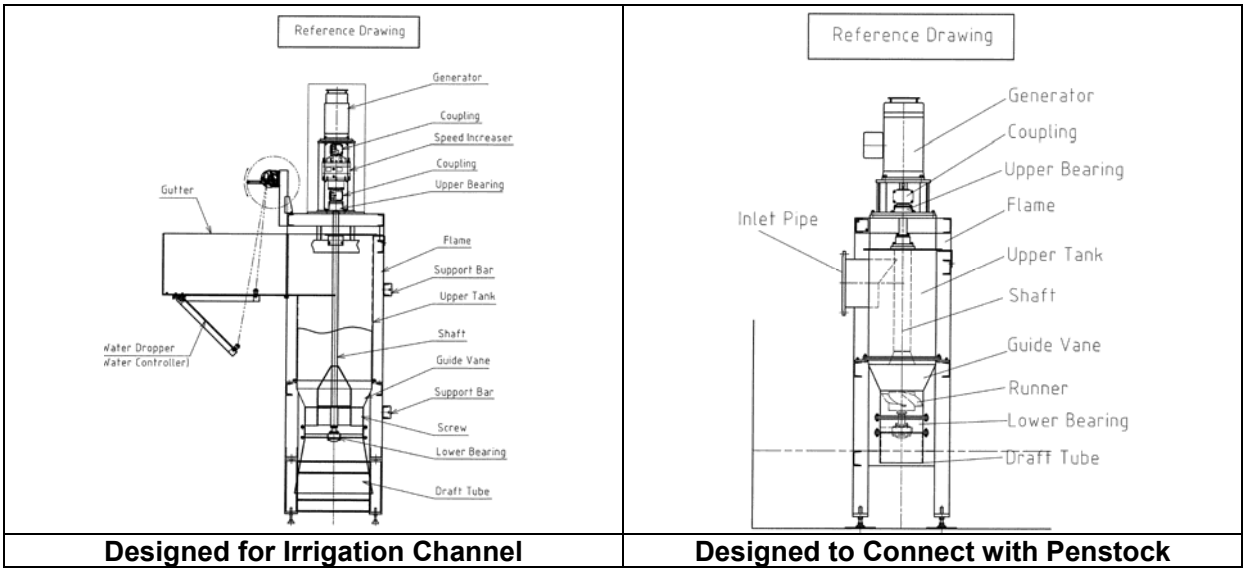
⑤ Easy maintenance is possible by equipping the controller; and

⑥ Extremely long life of the equipment (20 years) subject to the proper maintenance of the machine.

【Power Generation System】

The difference of water level at the drops/falls in the irrigation channels between the up-stream side and the down-stream side (around 1.0 – 1.5m) is sufficient to rotate the screw of hydropower generation unit. The rotation of the shaft coupled with a screw drives the power generator. The power output is determined either by water discharge volume or by effective height at the drop/fall. The power conversion factor is 0.6, which is quite high compared with similar models made by other manufacturers.

Power Archimedes can be designed to meet with technical requirement either for installing it in the irrigation channel or to connect it with the penstock. (Refer Figure-1 Typical Sections of Power Archimedes)



Designed for Irrigation Channel | **Designed to Connect with Penstock**

Figure-1 Typical Section of Power Archimedes

【Power Distribution System】

Basically the power distribution system designed is to transmit the power generated through the overhead wire to the battery charging units, located in the central area of the target village. The number of batteries rented out to the users in both villages was estimated, and subsequently 168 units were purchased. Since the water flow to the secondary channel where the hydropower generating units are installed is suspended during 2 months (December and January) each year, battery recharging is planned to be carried out in a conventional way that bring batteries for recharging to the nearest town, where the power is available from the grid power system.

In terms of the battery charger supplied, it is possible to re-charge 5 batteries of 40-70 Ah at the same time. The required period for recharging the batteries in full is around 8 hours. The power needed for re-charging around 60 units of batteries is around 2.5 kW depending on the size of batteries to be re-charged. As the required power for re-charging batteries is less than the net output power or around 7 – 10 kW, the remaining power of 4.5 – 7.5 kW can be utilized for industrial activities in the village, composing of around 300 households.

【Hydro-power Generation Units Provided for the Project】

The following photos and drawings show the outlook of the drops /falls and sections of two different types of Power Archimedes designed for installing at the respective drops/falls in the irrigation channels.

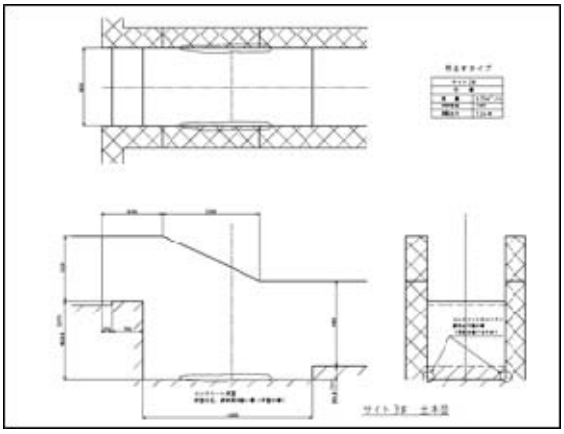


Figure-2 No.3 Drop/Fall of CY-3C Secondary Channel

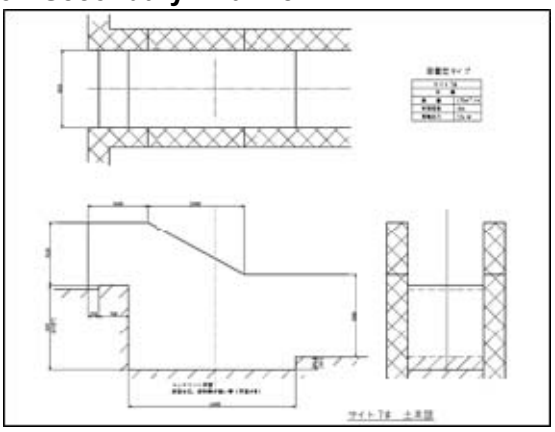


Figure-3 No.7 Drop/Fall of CY-3C Secondary Channel

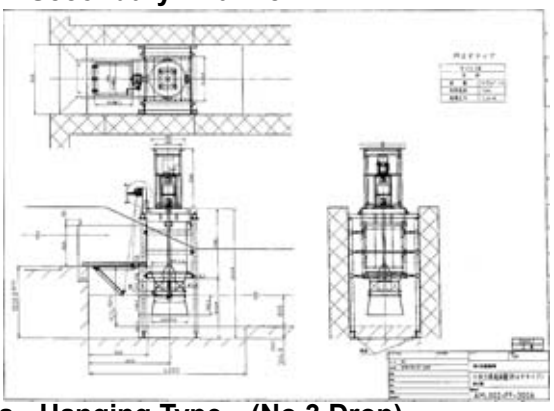


Figure-4 Installation of Power Archimedes - Hanging Type (No.3 Drop)

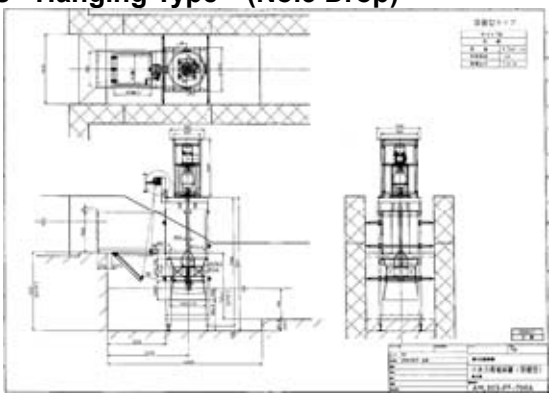


Figure-5 Installation of Power Archimedes – Standing Type (No.7 Drop)

【Total System】

Figure-6 illustrates the total power generation and distribution system in both of the target villages.

Figure-5　Features of the Total System

【Counterpart Government Agency】

The counterpart government agency of Hokuriku Seiki Co., Ltd. is the Irrigation Water Utilization Management Department (IWUMD) of the Ministry of Agriculture, Livestock and Irrigation (MOALI). The IWUMD is mandated for the plan preparation, development, maintenance of the irrigation facilities, composed of dam, water reservoir, irrigation channels and water utilization (hydropower generation) in the rural areas. The IWUMD is one of the largest government organizations and has a division specialized in the manufacture of hydropower generation units (mostly of the S-shape tubular type). In the past few years, the IWUMD has produced around 100 units of these S-shape tubular type small-hydropower generators.

Figure-6 S-shape Tubular Runner Produced in Yangon Factory of IWUMD

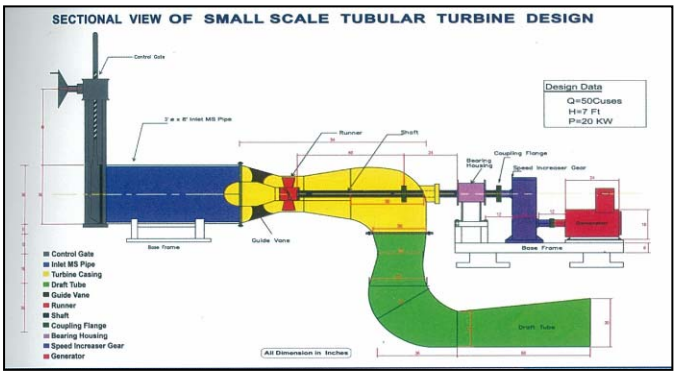


Figure-7　Typical Section of S-shape Tubular Small-hydropower Generator of IWUMD

Figure-8　View of Installation of S-shape Tubular Type Power Generation Units (20 kW)

【Target Area of Beneficiaries】

The direct beneficiaries of the Project are the populations of the two villages where the two power generation systems are provided. The number of households in the project villages is 120 in Myaung Gyi Boung Village and 170 in Pwe Lone Kyau Village. The estimated number of villages that can be electrified by small-hydropower generators is around 36,000 villages, assuming that around 83% of the total number of villages (some 43,300 villages) is not electrified as of 2017. Most of the irrigation systems are situated in the upland intensive mixed-use agricultural areas (in the Mandalay Region, Sagaing Region, Magway Region, and Bago Region) where around 22 million people reside, or some 40% of the total population of Myanmar. Thus the potential number of villages for electrification through the use of micro-hydropower generation units can be estimated at around 14,400 villages. Assuming the number of households per village is around 150, and an average number of people per household is 4, then around 8.6 million people could be potential beneficiaries of such small-hydropower generation systems installed along the irrigation systems.

2.4 Work Schedule of the Project

The work schedule and progress are shown in Figure-9 below.

2.5 Project Implementation Organization

The organization chart of the project implementing organization is as illustrated in Figure-10.

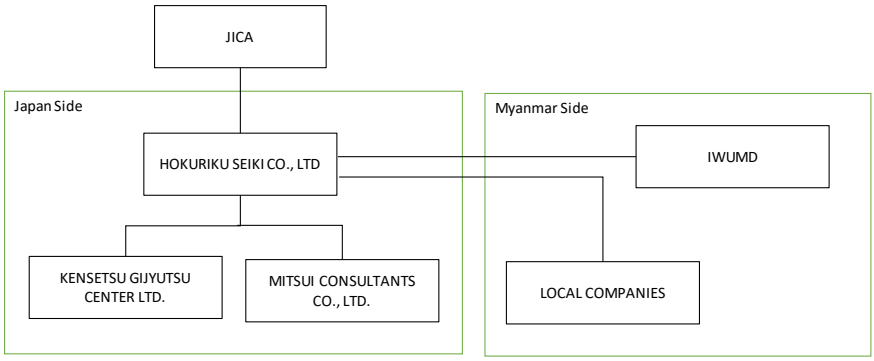


Figure-10 Project Implementation Organization

【Japan side】

Hokuriku Seiki Co., Ltd. (Manufacturer)

Kensetsu Gijyutsu Center, Ltd. (Supporting Consultants)

Mitsui Consultants Co., Ltd. (Supporting Consultants)

【Myanmar side】

Irrigation Water Utilization and Management Department of

Ministry of Agriculture, Livestock and Irrigation

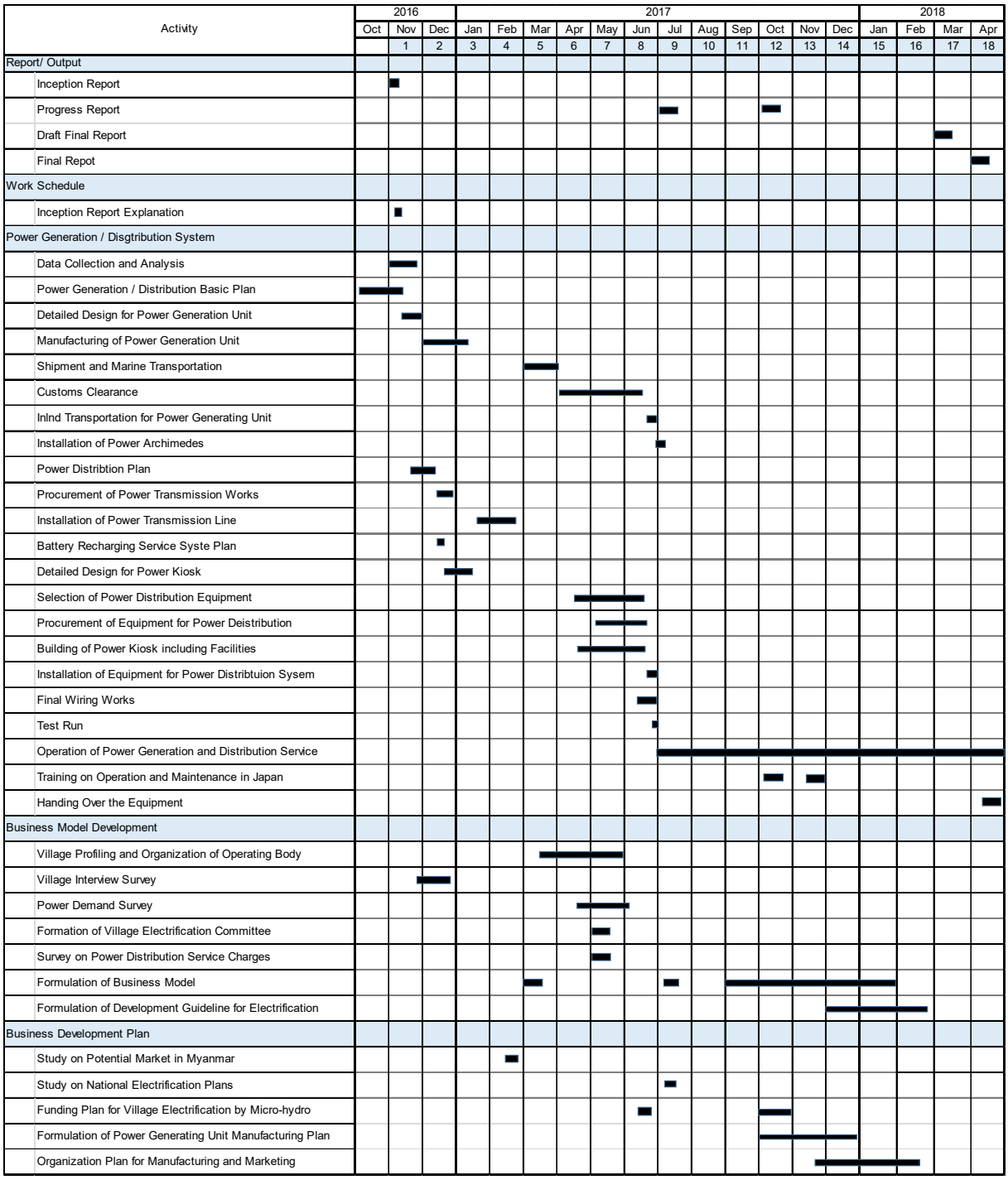


Figure-9 Work Schedule and Progress

2.6 Targets of the Project and the Activities Taken

The achievements of the targets set out for the execution of "*Verification Survey with the Private Sector for Disseminating Japanese Technologies for Micro-hydropower Generation System Project*" are measured by the achievement of the following targets.

Target-1	Power Archimedes is installed properly as designed and the power generated is transmitted to the target villages and the possibility to improving the living standards of villages is confirmed.
Target-2	The organization for the maintenance of the system in the IWUMD and for the utilization of power in the target villages is designed and formed in both villages.
Target-3	Dissemination plan of Power Archimedes is formulated.

The activities to be carried out to achieve each target are stipulated accordingly, as follows:

Actions taken for the Target-1.

Target-1	Power Archimedes is installed properly as designed and the power generated is transmitted to target villages and the possibility to improve the living standards of villages is confirmed.
1-1	Conduct village interview surveys to grasp the profile of the target villages and issues at non-electrified villages.
1-2	Collect the data needed to install the Power Archimedes and conduct the necessary engineering design, taking into account the result of analysis of such data collected that has been collected.
1-3	Design the transmission and distribution system
1-4	Install the Power Archimedes manufactured in Japan to the designated locations along the secondary irrigation channels
1-5	Operate the Power Archimedes and monitor the operational conditions to confirm a stable power supply
1-6	Confirm that the power is transmitted to the power receiving panel in a stable manner
1-7	Confirm how the power generated and transmitted is used by the villagers and how the electrification has been achieved in both quantitative and qualitative ways
1-8	Improve the Power Archimedes if any deficiency is found, through the operation of the power generation / distribution systems
1-9	Summarize the criteria and ways to install the Power Archimedes in the secondary irrigation channels.
1-10	Confirm the power generation efficiency of the Power Archimedes based on the data collected through the operations of power generation systems

Actions taken for the Target-2.

Target-2	The organization for the maintenance of the system in the IWUMD and utilization of power in the target villages is designed and formed in both villages.
2-1	Explain the outline of the Project and required activities to the IWUMD and the villagers to establish the proper organization for sustainable operation of the power generation and utilization systems.
2-2	Determine the service charge level and the way of correcting service charges with the village electrification committee and the power kiosk operation body to

	operate the system in sustainable way.
2-3	Conduct workshops in the villages to help villagers to utilize the electrical power made available to the villages.
2-4	Prepare the manuals and guidelines for the installation and maintenance of the power generation and distribution system for the IWUMD.
2-5	Receive key staff of the IWUMD in Japan for the technical knowledge transfer needed for the maintenance of the hydropower generation unit.
2-6	Establish a regular maintenance system that is to be undertaken by the IWUMD and the village electrification committee
2-7	Establish the system for battery re-charging, aimed at distribution of electrical power to the users.
2-8	Complete the operation and maintenance manuals based on the analytical results of activities carried out at this stage.

Actions taken for the Target-3.

Target-3	Dissemination plan of Power Archimedes is formulated.
3-1	Collect data and information relevant to the electrification program for the non-electrified villages by the IWUMD, using the micro or small-hydro power generation units and forecast of the potential market size in Myanmar
3-2	Study and analyze the various business risks (i.e. country risk, currency exchange risks, taxation, regulations, etc.) for the marketing of the Power Archimedes.
3-3	Sort out the issues to expand the market of the Power Archimedes in the non-electrified villages in Myanmar based on the analytical results of above studies.
3-4	Introduce the Power Archimedes through an observation tour or a seminar for government organizations to share the results and issues identified through the execution of the Project, which includes observations from project sites.
3-5	Formulate the production, marketing and location plan of the Power Archimedes

3. Achievements

Target-1	Power Archimedes is installed properly as designed and the power generated is transmitted to the target villages and the possibility to improve the living standards of village is confirmed.

1) Verification of Power Generation

The discharge volume of CY-3C is as shown in the table below.

Name of Month	Discharge (ft^3/month)	Remarks
January	-	
February	364	Ref. No. of Secondary Channel DY-3C
March	616	Rainfall in 2014
April	532	Rain Drop Days: 49 Days
May	588	Total: 30 inches
June	588	
July	532	
August	616	Average Discharge: 28 ft^3/sec
September	560	Average Discharge: 0.79 m3/sec
October	560	
November	448	
December	-	

Source: IWUMD Mitta Branch

After installation of Power Archimedes at designated locations, the output power was measured. The output power measured at the time of testing at the project site was around 7.0 kW, in accordance with the design.

2) Verification of Time Needed for the Installation of Power Archimedes at the Project Sites

The water flow in the secondary channel was stopped completely for one day before the day of the machine installation. The components and part of the machines in disassembled form arrived at the project site. The wooden crate and frame protecting the different components of the machine from damages were removed one by one, then were transferred to both positions planned as close as possible to each drop/fall selected for the installation of Power Archimedes by using a mobile crane, a 4-wheel drive truck and labourers. The Power Archimedes was assembled and the steel frames were set at the drops/falls. Then the Power Archimedes was installed by fixing it to the steel frame. In parallel with the installation of Power Archimedes, a self-standing type control panel was erected on a concrete base prepared prior to the arrival of machine at the project site. Thereafter the wire between Power Archimedes and control panel was connected. The power was generated and transmitted to the designated villages through the power transmission lines erected prior to the day of machine installation. The power transmission was measured at the receiving panel furnished in the Power Kiosk at each village and it was confirmed that the power was transmitted properly. All these works were carried out in a single day.

Target-2	The organization for the maintenance of the system in the IWUMD and utilization of power in the target villages were designed and formed in both villages.

3) Formation of Village Electrification Committee and Power Kiosk Operating Body

The Organization required for sustainable operation, maintenance and management of the total system was formulated as shown in Figure-10 by the concerned agencies and organization inside and outside of the village.

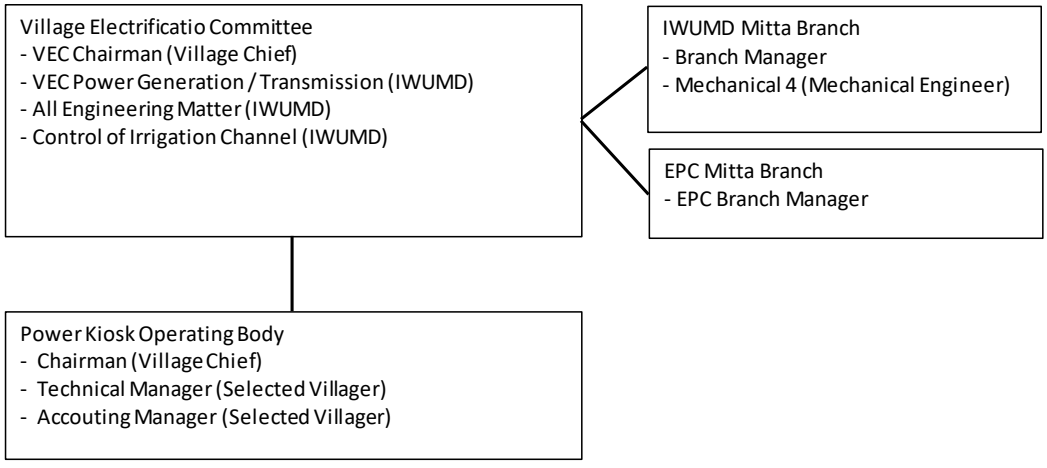


Figure-10 Village Electrification Committee Organigram

4) Maintenance of Power Archimedes and the Total System

The maintenance manuals of Power Archimedes were prepared and delivered to the office of IWUMD directly in-charge of the Project. The most important point of maintenance of Power Archimedes is the replacement of ball bearings attached to the axles of runners, once in every three years of operation. The selected mechanical engineer of IWUMD has been invited to the factory of Hokuriku Seiki Co., Ltd. and the demonstration for the replacement of the important bearings was carried out to transfer knowledge of the relevant technique.

5) Training on Regular Maintenance Activities

During the course of implementation of the project, t training on the regular maintenance activities, such as inspection and greasing of ball bearings and other moving parts was conducted at the project site. Figure-11 shows the details of training on the maintenance of machines.

Training on Greasing

Training on Greasing

Training on Greasing of Machine

Training on Greasing of Machine

On-the-Job Training for Operations

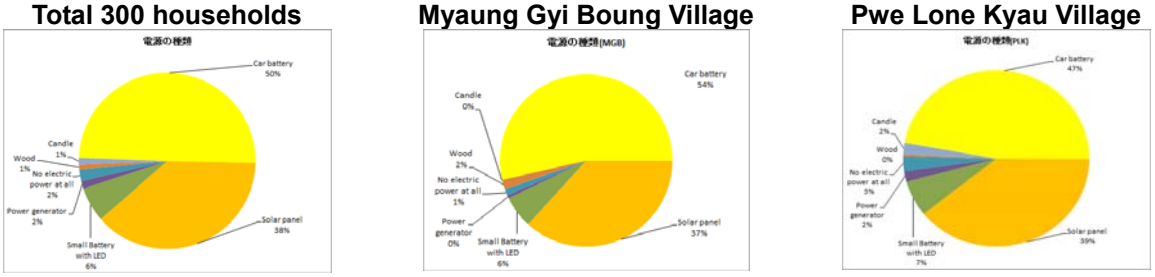
On-the-Job Training for Maintenance

Figure-11 On-the-Job Training Conducted

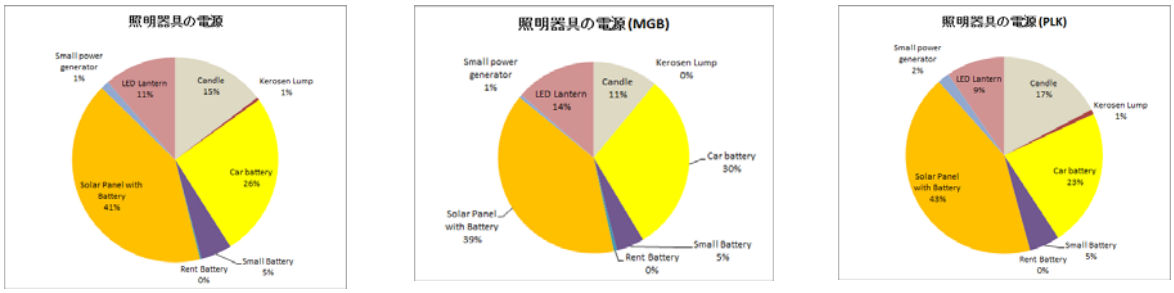
6) Present Power Source and Purpose of Using Electric Power in the Villages

The results of the village interview survey are summarized as shown in Figure-12.

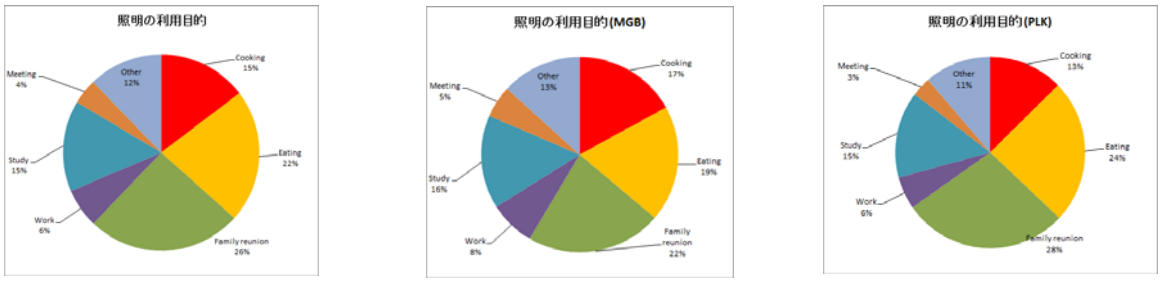
Total 300 households | **Myaung Gyi Boung Village** | **Pwe Lone Kyau Village**



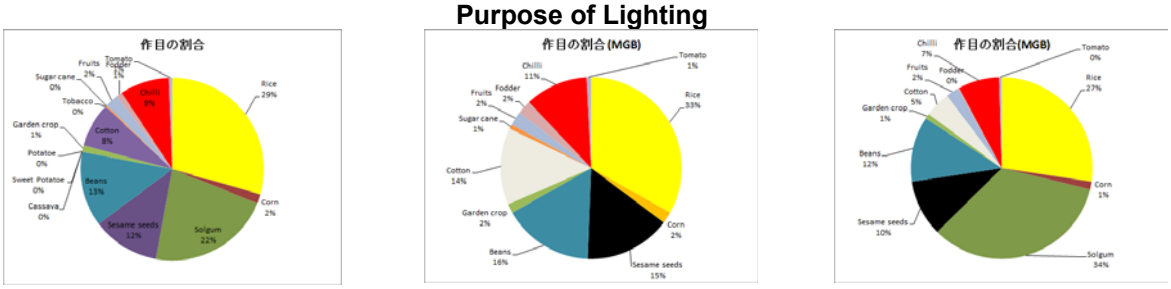
Source of Electric Power



Kind of Lighting Apparatus and Tools



Purpose of Lighting



Kinds of Crops Cultivated in the Villages

Figure-12 Results of Village Interview Survey on the Use of Electric Power in the Village

7) Average Income and Possible Expenditure for Electric Power Service

The result of interview survey in both villages shows that the average monthly household income is around US$ 111 (MMK 150,000), of which around 60% is earned by non-farming works outside of the village. Around 50% of the households have borrowed money from moneylender. . The average amount of credit per household is US$ 330 (MMK 440,000) or equaling 3 times the average monthly income. Around one third of households possess solar panels, batteries, and televisions.

8) Willingness-to-Pay for Electric Power Service

According to the results of the village interview surveys, the average monthly charge that a household is willing and possible to pay for power service is US$ 3.5 (MMK 4,600) or 5% of their monthly income. Based on this data, the monthly charge for re-charging batteries (for rental batteries is set at MMK 5,000).

9) Average Monthly Revenue of Power Kiosk

It took some months of continuous battery re-charging operations for the Power Kiosk operator to master the battery re-charging procedure and to keep the accounting book recording the sales of battery re-charging services and the expenditure needed for the proper operation of the Power Kiosk. The battery re-charging service started in August 2017, after the Power Archimedes started power generation. The accumulated revenue up to November 2017 reached around US$ 120 in the respective villages. The monthly revenue is around US$ 100 or MMK 134,000. If this rate of revenue per month should continue for ten (10) months, the annual revenue of each Power Kiosk can be estimated as US$ 1,000. Assuming the total initial capital investment cost is US$ 50,000 and required annual budget for maintenance of machine is 1% of the total initial capital investment cost, the annual budget requirement is US$ 500. Thus the revenue generated from the battery re-charging services could be sufficient to cover the expenditure for the maintenance of the machine. However, if the power generation project needs to be financially viable from a commercial point of view, the revenue generated from the sale of services for re-charging batteries is not sufficient at all.

10) Optimization of Power Generated by Power Archimedes

The average power consumed for the battery re-charging services for each village is analyzed through four months operation of the total system and was found to be around 2.5 kW. This means that there is a balance available of around 5kW. This 5kW power output can be utilized further for increased revenue of the Power Kiosk and the income of villagers or farmers. A testing of oil extraction using raw materials available locally was carried out. Both villages cultivate several crops that can be processed in the village to add value, such as sesame seed, cotton, and sunflower seed processing. The business plan for industrial activity in the village through utilizing the electric power available was vested to the villagers headed by the village chief. However no good results were obtained, due to a lack of knowledge and experience of business operations by villager themselves.

11) Small Public-Private Partnership type Business is Recommended

It is recommended to invite private business entities from the nearest rural city / township to utilize the electric power made available for small-scale rural agro-industrial businesses in places where the Power Archimedes is installed aimed at village electrification along the irrigation channels. The IWUMD will install the Power Archimedes at several drops/falls along irrigation channels properly and will lease out the machine to private business qualified entities,

selected through public bidding and ready to conduct agro-industrial business utilizing the power available at the villages. In this way, the power requirement of villagers can be met, the income of villagers will increase through sale of their farm products for processing by the private business entity and the private business entity will generate a profit. Then the IWUMD would lead and guide the villagers to attain the best outcome of power generation along irrigation channels.

Target-3	Dissemination plan of Power Archimedes is formulated.

1) The Potential Market Size of Power Archimedes

The total number of population of Myanmar is around 53.9 million, of which 35.5 million is considered as the rural population. Assuming the average number of persons per household in rural areas is 5.5; then the total number of rural household would be around 6.5 million. The average number of households in a village may be assumed as 150. Then the total number of villages in the rural area can be estimated at 43,300 villages. As the electrification ratio in the rural area is estimated at around 17% (Source: World Bank), the number of non-electrified villages is around 36,000. The intensive irrigation system is spread out in Mandalay, Sagaing, Magway and Bago regions. The total population of these regions is around 22 million or around 60% of the total rural population. Thus around 21,600 households are considered as non-electrified households. The potential users of power generated along the irrigation channels therefore can be estimated say 60% of non-electrified households or some 13,000 households in total.

2) Requirement of the IWUMD Mitta Branch

The IWUMD's Mitta Branch is responsible for the control and management of the Kinder Irrigation System and oversees the village electrification project and verification survey project of Hokuriku Seiki Co., Ltd. as the site selected for the project belonging to the Kinder East Irrigation System. The IWUMD has already acknowledged the superior performance of the Power Archimedes, and the ease of installing machines and of commissioning the total system for village electrification. Then the IWUMD Mitta Branch has suggested considering the need of village electrification by utilizing the irrigation channel of the Kinder East Irrigation System further. The actual demand of the Power Archimedes exists at around 21 drops/falls in total at DY-21, DY-23 and DY-25. The total population of three villages related to these secondary irrigation channels of the Kinder East System is estimated at around 8,500 and the number of households is around 2,000, all of which are non-electrified at present. Figure-12 shows the outlook of these secondary channels suggested by the IWUMD Mitta Branch to be considered for village electrification through use of the Power Archimedes. As all the drops/falls are standardized and similar to that of DY-3C, where the verification survey project was carried out, the power output of each drop/fall by the Power Archimedes can be estimated at some 7 kW. If

all the drops/falls are utilized for power generation, the total output can be around 150 kW, which is considerable and could be utilized for rural industrialization.

DY-21 Secondary Channel

DY-21 One of 7 Drops

DY-23 Secondary Channel

DY-23 One of 8 Drops

DY-25 Secondary Channel

DY-25 One of 6 Drops

3) Localization of the Manufacturing of Power Archimedes

The IWUMD principally agreed with the Hokuriku Seiki Co., Ltd. to manufacture the substantial part of the Power Archimedes at their factories operating at present under the supervision, and quality control management of Hokuriku Seiki Co., Ltd. The technical collaboration agreement is expected to be concluded in the future. Hokuriku Seiki Co., Ltd. has already observed the existing factories of the IWUMD and assessed that it is possible to utilize the existing building and some machine tools, however it may need to replace and to provide several other machine tools in future.

4. Business Development Plan and Perspective

4.1 Business Perspective

Depending on the agreed conditions with the IWUMD, at the beginning of the cooperation the power generator, speed increaser, screw, axle, and control panel will be manufactured

in Japan and exported to Myanmar (recipient the IWUMD). The steel frameworks and the cylinders will be manufactured locally. The proportion of localized sourced parts will increase on a step-by step basis. The duration of technical collaboration agreement is expected to be 3 years. After the experience of collaborative manufacturing activities, it is expected that a more advance collaboration agreement can l be concluded between the two parties.

4.2 Production and Sales Plan

At the beginning of the technical collaboration the average monthly production volume can be set say at five units per month. The project formulation and design will be carried out by the IWUMD, in collaboration with Hokuriku Seiki Co., Ltd. Subsequently after the initial period, the number of production units could be doubled, through increasing the amount of machine tools and labourers.