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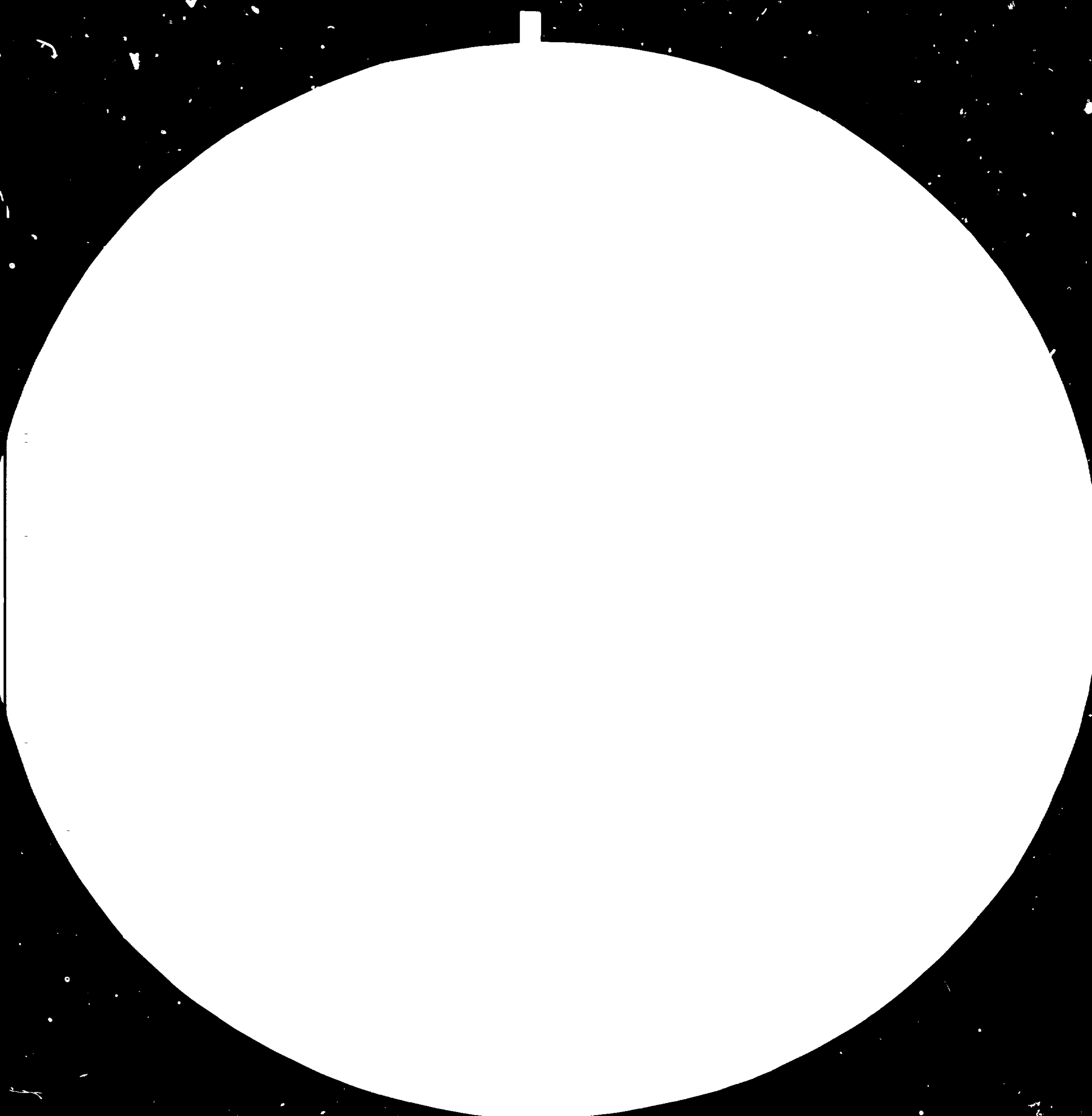

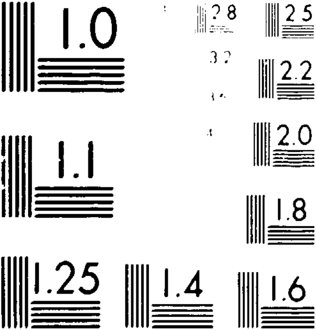
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THE ROLE OF HYDRO POWER IN RURAL DEVELOPMENT*

by

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ELECTRIFICATION AND DEVELOPMENT

One of the most easily tapped energy resources in Nepal is hydro-power, and one obvious use of hydro-power is to generate electricity. However, while it is certainly true that electrification can act as a spur to development and provide necessary input for it to happen, electrification of itself is not development. Development in a society where electricity is available is related to the use, rather than to the provision of electricity. It is therefore necessary that, where electrification is being undertaken as a spur for development, thought and planning should be given to the uses to which the electricity will be put. And this must be done first of all in terms of the development needs of the community.

Development Needs in Nepal

Nepal, in its efforts to make up for many years of under-development, is developing on a wide front. Broadly all development can be classed under four headings: health, education, energy and food. Nepal is developing in all these areas; however electrification can only make substantial contributions to the last two of these, namely energy and food. We will therefore briefly examine the needs in these areas, and consider how electrification can be used to meet them.

1. Energy Needs

It is a proverb that 'Nepal's riches are her forests'. Unfortunately that proverb has largely lost its truth, as the forest in more and more places is cut back to provide fodder for animals and fuel for cooking. As the forest cover recedes, the land is eroded, and many hillsides that once were fertile are now barren. Though His Majesty's Government of Nepal has a reforestation programme, there are many years of neglect to make up for, and as much as possible should be done to save forests from further destruction. Because of the destruction of so much of the forest, there is an increasing energy shortage in Nepal, and one that is much more serious than those which have faced western nations in recent years. This is because the shortage affects the most basic need there is, that for food. Granted food too is short; but if what food there is cannot be cooked, then one is little better off for having it. Fortunately the shortage at present does not affect everybody; however year by year an increasing number of Nepali people are feeling its effects and are being forced to look for alternative sources of fuel.

There are four main possible alternatives to firewood as a cooking fuel; gobar (cow dung), gobar gas (or bio-gas), kerosene, and electricity. Gobar although used fairly widely, is unsatisfactory in that it deprives the land of much needed fertilizer. In this respect gobar gas is much more satisfactory, in that the sludge which comes out of the plant as waste has as much fertilizer value as the gobar which is used to feed the plant. However such plants are too expensive for most Nepalis, and while their development should certainly be encouraged, other energy sources are also needed. Kerosene also is too expensive for most people, and in any case it must be imported, and therefore costs the country precious foreign exchange. Electricity is also too expensive in most places to be used for cooking.

2. Food Needs

As with energy, the food supply situation in Nepal varies very much from place to place. Some places have surpluses, while others suffer shortages. Often it is the people who live high up in the hills who go hungry, while those who live the valley are able to grow enough or more than enough to meet their needs.

There are three basic approaches to meeting the food needs of those who do not have enough. One is to raise the productivity of the land, another is redistribution of land, and the other is to develop suitable small scale industries that will provide a cash income to the people in the hills to enable them to buy enough food to make up their shortages (providing that the overall food supply situation in the country is adequate).

How Can Electrification Meet These Needs?

Energy

Though it is perfectly possible to use electricity as a cooking fuel, it is in fact hardly used at all, even in those rural areas where electricity is available. As has been said, this is because it is too expensive for people to use. Furthermore, in most small-scale hydropower projects the actual cost of the energy is usually calculated to be rather higher than the normal selling price of Rs.0.50 per kWh.

There are, however, two factors in the high actual cost of energy which give rise to hopes that the costs need not be so high. The first is that many schemes expect to have a very low maximum load for the first years when the interest payments on the loan will be high. The second is that, even when the load builds up to a reasonable level, the load factor is expected to be very low - in other words the average power produced will be much lower than the peak power. In the case of purely domestic loads, it would be expected t have a peak load for 3 to 4 hours in the evenings, and for the other 20 hours in the day very little power is consumed. In such cases the load factor (average power/peak power) could be as low as 0.2. The capital cost of the plant, and hence the costs of the energy, have to be based, not on the amount of energy produced, but on the peak power demand. To give an example, take a project with an installed capacity of 30 kW, where the load factor is 0.2. The total power that could be generated in a day if the plant operates continuously would be 720 kWh. However if the peak demand is 30 kW, because of the poor load factor, the amount of power produced will only be 144 kWh. In making up the pricing structure, a certain amount must be recovered per day. Suppose this amount is Rs.100. If only 144 kWh is generated, then the cost per kWh will be Rs.0.69. However if the plant was able to operate at full capacity, then the charge could be reduced to Rs.0.14 per kWh. If electricity is used for cooking with normal cookers, the situation is not improved, but rather worsened. Further, at peak times when people were preparing their meals, there would be only enough power available for only a very limited number of families. For instance, suppose that a family is able to cook a meal on a 1 kW cooker then a 30 kW installation would only provide enough power for 30 families to cook on. Nor is pondage an answer to this problem, as the capital costs are increased in proportion to the installed capacity, and there is the extra expense of building a pondage basin.

The only way in which the price of electrical energy in such schemes could be reduced is by improving the load factor to as near unity as possible. In other words the load should be as steady as possible. Nepal is not alone in facing this problem, but it is more acute than in most other c untries because it is shown up more sharply by hydro-power than by fossil fuel generated power, where the energy costs depend, to some extent, on the actual amount of energy consumed. But there are other countries where hydro-power is the major source of electrical energy, notably Norway, where over 90% of the electrical energy is generated by water power. There they have been able to develop very cheap electrical energy through encouraging the consumption of electricity at a high load factor. One aspect of this has been the development of a 'heat storage' cooker, to use a low energy input through a large part of the day.

The 'heat storage' cooker, as developed in Norway, has a low wattage element which is used to heat up a block of cast iron. This block is insulated, and gradually stores up the heat produced by the element. The heat is stored up slowly throughout the day and night, and is then available for cooking when required. While cooking the heat is removed at a high rate; and it is replenished at a slow rate in time for the next meal. As it stands, the cooker needs some modification before it will be suited to the needs of Nepal, and work needs to be done on this to find the most suitable materials and means of construction. (An outline design is shown in Fig. 1.) If, however, the development is successful, then it could result in a much higher load factor than is common, and therefore in much cheaper electrical energy. The example mentioned above gives some idea of the factor that could be involved, but should not be taken to represent actual costs. These will vary from place to place, and in any case are very dependent on the repayment period and interest rate of loans. Preliminary studies have suggested that an element in the range of 100 watts to 300 watts should be adequate, and part of the aim of development should be to make this as low as practicable. It is estimated that the size would be comparable with the 'chula' (wood stove) used in Nepali homes.

It should be noted that the development of the storage cooker in Norway was associated with a tariff structure that was deliberately designed to encourage consumption of electricity at a high load factor. A storage cooker will inevitably have a higher cost than a normal cooker, but should be much cheaper to run if the tariff is right. The tariff structure adopted in Norway was a 'subscribed demand' tariff: in this the consumer buys a certain number of watts at a fixed annual charge, and is then free to use that level of power for as long as he wishes. Obviously the longer he uses electricity for, the cheaper it becomes for him; conversely, given a certain total daily energy requirement, it is cheaper for him to plan to spread his power requirements through the day, so that his load is steady. In this way he can buy as few watts as possible, and so make the cost to him a minimum. This tariff structure does away with the need for a kWh meter. Instead, a current limiter is installed in the consumer's house, which disconnects him should he try to draw too much power. This function could be performed by a miniature circuit breaker, which would then also replace the main fuse.

Food

There are a number of ways in which electrification can contribute to the food supply of a community:

1. Land Conservation

   If electricity is used for cooking, as outlined above, then it will ease the pressure on the forests and so reduce the erosion which is reducing the area of land available for agriculture.

2. Fertilizer Manufacture

   The first process developed to 'fix' nitrogen from the air so that it could be used as a fertilizer used an electric arc process. While this has been superseded in industrialized nations, it could well be appropriate for a country like Nepal, where the transport costs on fertilizer are high and where electricity could be available in remote regions. At present a plant is being developed that would use about 3 kW and which would produce fertilizer in liquid form. While this is not suitable for every place, there are many places in which it could be fed into water used for irrigation, and so increase the crop yields.

3. Agro-Based Industry

   As previously mentioned, one way of increasing the food supply to a community is by developing small scale industries that will provide a cash income with which extra food can be purchased. While this is attractive as a theory, it needs careful planning to ensure that the cash generated does reach those who need it, and one must also watch against harmful social consequences attendant upon the change from subsistence to a cash economy. One thing that militates against such developments is the lack of infra-structure. One way in which electrification can help here is by providing the power for ropeways.

4. Lift Irrigation

   While the benefits of pump-lift irrigation are obvious, it is not always economically feasible, particularly where moderate pumping heads are involved. Even where it is feasible, much less expense will be involved if it can be arranged that the pumps are driven by turbines directly, rather than by electric motors. Nevertheless, where the conditions permit, the use of pump lift irrigation can substantially increase the yield of an area.

Conclusions

The generation of electricity from water power is a well established technology. While there are areas that need development, particularly the matter of speed control of turbines, it should not be too great a problem to generate hydro-electricity on a small scale for a reasonable cost. On the other hand the use of electricity to meet the basic needs of a developing country is an area that is largely unexplored. There are ways in which electrification can be not just a luxury item, as has been suggested above. But much work is needed to turn these ideas into practical hardware that can contribute, not only on paper but in reality, to the needs of the rural communities.

Hydel - How Small is Beautiful?

It is generally assumed that the costs of energy decrease as the size of individual generating installations become larger and larger. However in a country like Nepal, with a largely rural community spread out over rugged terrain, this is by no means always the case, and careful consideration should be given to choosing plants of the right size for each scheme under consideration.

Factors Affecting the Size

In planning a hydro-electric installation, the following factors should be taken into consideration when deciding upon the best size for a particular scheme.

1. Civil Works

As hydro-electric plants increase in size, not only do the civil works increase in size correspondingly, but they also increase in complexity. In industrialized countries this is not too much of a worry, as the organizations and infra-structures exist to cope with this complexity. Furthermore the skilled labour necessary for such undertakings is available. However in Nepal these conditions do not obtain: all large schemes have to be undertaken by large foreign funded organizations: furthermore the nature of the country makes the undertaking of large civil engineering works arduous and expensive. Heavy equipment cannot easily be transported and jobs which are routine in other settings become laden with problems and difficulties.

But perhaps the most important consideration is the question of labour. His Majesty's Government of Nepal, in their Rural Electrification Development Programme, as in other development programmes, are emphasizing peoples participation as one of the means of implementing this programme. This has several benefits in Nepal: one is that if there is genuine participation, then there is much more a feeling of community involvement and ownership in such projects. Another important benefit is that if the people who are to benefit by a development scheme contribute their own labour voluntarily then a significant portion of the cash cost of a scheme can be saved. This is particularly beneficial in a society where cash is used very little, and provides a means for people to pay in kind for development work when they do not have the resources to pay in cash. However, if such development is to really involve participation of the whole community, then it is important that the community is involved not only in construction of the scheme, but also in ownership, such as through a cooperative. If they have contributed to the value of a scheme through their own labour, then it is only just that they should be given the responsibility of ownership.

If a hydro-electric plant is to become a people's project in a manner outlined above, then it is evident that it must be possible for the people to contribute their labour, not just in an ancillary role, but by providing the main workforce necessary for the construction of the scheme; and this will only be possible if the bulk of the work can be done by unskilled labour. In many large schemes sophisticated techniques are used and outside skilled labour has to be employed.

2. Transmission

Because of the population distribution of Nepal, with very few large centres of population, a large hydro-electric scheme inevitably involves transmission of electric power. In the case of this power being supplied to a few large population centres the expense of the transmission line is often justified. However where the load is provided by rural communities, whose use of electricity will, at least initially, be at a very low level, the cost of transmission can become extremely large, and be more than the cost of providing a small scheme providing power to a smaller community. For schemes of the order of 50 kW the cost of transmission can equal the whole of the civil work and equipment costs if the transmission line is more than a few kilometers.

3. Distribution

In many cases the economics of a rural electrification project will hinge upon the distribution costs. In the case of a compact bazar these will not be too expensive; however, for villages which are very spread out it may turn out that the cost of distributing the power round the village from a central point becomes prohibitive.

It is therefore important that the distribution networks be looked at critically, with a view to finding the most economical ways of proceding in particular situations. There should be room for flexibility in such matters as the choice of voltages for transmission and distribution, and the experience of other countries should be drawn on when planning systems. Australia, for instance, has had considerable experience in setting up distribution systems in sparsely populated rural areas, and this experience could be used where appropriate in planning in other countries.

4. Operation

The operating costs of hydro-electric projects do not increase linearly with size, but, at least at the small end, in a series of steps. For the very smallest of plants ('Pico-hydel') an employed operater would not be needed. For a larger project, if the turbine is used to drive other machinery besides a generator (e.g. milling machinery) the operating costs, as well as construction costs can be shared. From 5 kW up to 15 or 20 kW one operator would be sufficient, with an alarm to indicate a malfunction in off-duty hours, and perhaps automatically shut the plant down. As the whole installation increases in size and complexity, so the staff needed to operate it will become larger, with managers and so on.

5. Integration

If various development schemes are planned and executed in isolation then development is likely to be haphazard, and unnecessarily expensive. This is particularly the case with rural electrification programmes, as it is not electrification in itself that improves the conditions of living, but the uses to which the energy is put. It is therefore vital that due consideration should be given to this matter at the planning stage, and that the electrification should be planned with other specific well thought out development projects in mind. Furthermore, if at all possible, these projects should be implemented at the same time as the electrification projects so that benefits are obtained from the electrification as soon as possible.

In a narrower sense, the generation of electricity should be integrated with other projects, so that the most efficient use is made of the water resources. For instance, the canals could be used for irrigation, or mechanical power at the powerhouse could be used for other purposes besides electrical generation.

6. Load

A rural electrification programme should not be planned without some consideration of the load that is likely to be needed by the community. If a plant is very likely to be under-utilized for the first years of its life, when the interest charges for the loan are highest, it may well be wise to build a smaller plant at first; if the load does build up to the extent that extra capacity is required, larger plants can be put in and the original equipment sold to another site to help pay for the larger plant. This policy also makes sense in terms of making the available financial resources benefit as many communities as possible. If smaller plants are at first installed, then more communities will receive electricity, and when the time comes to enlarge these schemes then second-hand equipment will be available to put in places where it would not be economical to provide new equipment.

Classes of Hydro-Electric Project

When the above factors have been taken into consideration, a project can be planned in one of the following brackets.

a) Pico-hydel - Below 5 kW

As has been pointed out above many Nepali villages are spread out, and the distribution of electric power can be very expensive. For such villages, are where suitable water resources are available, a cheaper solution than the conventional type of scheme may be to provide a number of 'pico-hydel' units generating about 1 kW each. These could utilize small water flows at medium heads, and the work involved in making the canal could all be done with known skills. The penstock could in many cases be made from High Density Polyethylene water pipe, and very little would be required in the way of a 'power house'.

Suitable hardware could be a small cross-flow or other type of turbine coupled to a motor car alternator. This could generate between 600 W and 1.2 kW at 24 V d.c., and has the advantage that no speed control would be required for the turbine. A solid state voltage regulator would keep the output voltage steady over a wide range of speeds. This power would be adequate to supply 5 to 10 houses with lighting, and if a storage cooker is available (see paper entitled "Electrification and Development") energy for cooking as well. The low voltage, while severely limiting the possibility of transmission, would mean that units could be operated by these who benefit from it without the dangers associated with higher voltages. On the other hand, an associated danger may be that familiarity with these low voltages could breed contempt for higher voltages which could follow at a later stage.

A suitable unit for such applications is currently under development at Butwal. It is particularly intended for providing electric lighting for turbine powered mills, but is capable of much wider application.

b) Mini-micro-hydel - 5 to 100 kW.

Projects in this range would use alternators generating 230/415 V a.c. and usually involve transmission over at least a short distance. Most of the civil works will be able to be done by local labour, but some cement and other building materials would be needed for the penstock intake and foundations, and also for the powerhouse. Because of the generator, speed control of the turbine becomes necessary, and conventional means of doing this are expensive. It is hoped that more appropriate methods will be developed. It is also necessary to employ operating and maintenance staff. At the lower end of this size range transmission is only economical over fairly short distances, but as the size increases the use of transformers and higher voltages can be considered.

c) Micro-hydel - 100 kW and Over

This scale of project will generally be outside the range in which village communities can participate. If the power is intended for rural communities, as opposed to a large population centre, then the transmission costs will generally form a major part of the cost of the whole project. In construction a sizeable contingent of outside skilled labour will be required and the project will need an operating and management staff. In some cases the plant may initially be operated far short of its capacity.

Conclusions

Since circumstances vary so much from one place to another, and development of rural electrification is at such an early stage in Nepal, it is too soon to lay down guidelines to decide on the correct scale for projects in specific localities. Rather, at each location, the different approaches should all be considered, and selection made on the basis of what will best fit the needs of the community.

DEVELOPMENT OF A VILLAGE - MAJUWA'S FIRST CHAPTER

by Bob Yoder

In 1967, while trekking from Dorpatan to Butwal, I remember sitting in a tea shop along the Bari Gad River in Gulmi District of the Lumbini Zone. The reason I remember this, of the many tea shops on that trail, was due to the new "American" bridge. The bridge had been erected by USAID in 1965. It struck me how this was a natural center where the trail along the Bari Gad River was crossed by the trail from the district center in Tamghas, on top of the ridge to the South, to Rupakot and Shantipur on the Hugdi River to the North. The Bari Gad is a large river and like most of the large rivers in Nepal, it is uesless for power and irrigation by village means. On the other hand, the Hudgi River, a steep smaller stream, is used extensively, especially for irrigation.

After the new bridge was built, Majuwa, at the confluence of the Hugdi and Bari Gad Rivers, grew rapidly from a tea shop to a small bazar. It is located on a large, well irrigated phant (large area), with easy access to the village on nearby hills. This provided a good location for a modern oil, flour, and rice mill.

The majority of the cooking oil in Nepal is pressed from mustard seeds. This was traditionally done by a heavy timber, rotated in a hollowed out log or stone, to crush and press the seeds. A modern machine can extract 50% more oil from these seeds and it is worth a four-day walk one way to a modern mill to get it pressed. Flour can be ground at home by a homemade hand flour mill, but it is heavy work and very time consuming. There are many small vertical axis water powered flour mills operating in the country, but they have a very poor efficiency and operate very slowly. Rice can also be hulled at home but it also requires a lot of time and labour. In the planting and harvest season, all labour is required in the fields. It is usual to stockpile hulled rice, flour and oil so that all the women, whose job it is to do this work, will be free to work in the fields. When rice is hulled at home, it is not uncommon for women to rise at 4:00 a.m. or earlier, and I have seen them work until after midnight to get the rice hulled. A mill can do in twelve minutes what two women do in twelve hours. It is true that there are long period of underemployment in the hills, but not for women. Much more critical is a tremendous shortage of labour before and after planting. Yields are greatly reduced by planting late, not weeding properly, not getting manure spread on the fields, and then the heartbreaking loss of a hailstorm hitting ripe grain before it could be harvested because of labour shortage.

Typically, a modern mill is powered by a 16-22 h.p. single cylinder low speed engine that runs on crude oil. All of the fuel, as well as lubricating oil, is imported into Nepal and usually requires hard currency for purchase. In the case of Majuwa, all of this fuel must be carried 2-1/2 days on porters back from the nearest road in Tansen. One strong porter can carry 5 days worth of fuel! For eight hours of operating on the average, 20 liters of fuel and 1 liter of lubricating oil are required. This represents a cost of over Rs.100/- for one day of operating, just for fuel and oil, including transport.

In 1971, two people together set up a diesel engine operated mill in Majuwa. After a few years of operating the diesel mill together, the partnership was dissolved and the second man sold out to the first. The second later became and still is Pradhan Pancha, elected leader of a local area called a panchayat, just across the bridge from Majuwa.

In 1975 a request came from the diesel mill owner to the Small Turbine and Mill Installation Project, under the United Mission to Nepal's Development and Consulting Services (DCS), to survey the possibility of his mill being run by a "Butwal Engineering Works" (BEW, also under the United Mission to Nepal) made water turbine. The site that he had chosen used an existing irrigation canal and was very close to his present diesel mill. This was not as suitable as a site some 200 meters up the canal and it was suggested that he move to the better location. Even though he owned the land, this site did not appeal to him and, since his diesel mill was still running, he did not respond to the quotation for a water powered installation given to him.

In the meantime, a BEW tradesman, who was related to the former second partner, also looked at the location and convinced the former second partner, and the "Back to the Village" (the political party in Nepal) chairman of the district, together purchase the land and install a water powered mill. Through a third party, the land was purchased and an order placed with DCS for the mill. But the diesel mill owner came to know of the scheme just before the 6-month grace period for land transactions was up and managed to get the transaction stopped. So again our survey crew was called to measure a new location on the opposite side of the Hugdi Khola about 200 meters up from the Majuwa village. A suitable site was located and on 15 March 1978 the installation was completed and test run.

This water turbine delivers 13 h.p. and is coupled directly through belts to the milling machines. Even though this is a few horsepower less than the diesel engine installed in Majuwa, the milling output is higher since the turbine can be run continuously at full output as compared to continuous operation of the diesel at about 60% load. The total cost for installing the water powered mill in this case was almost exactly that of a diesel mill at today's costs. Operating costs, however, are much, much lower since water is the power source and only a few rupees worth of grease are used in a month. Since there are only two moving parts, there is much less mechanical maintenance required on a water turbine than a diesel engine. Some maintenance needs to continually be done on the water canal, but that uses existing resources and technology of the area.

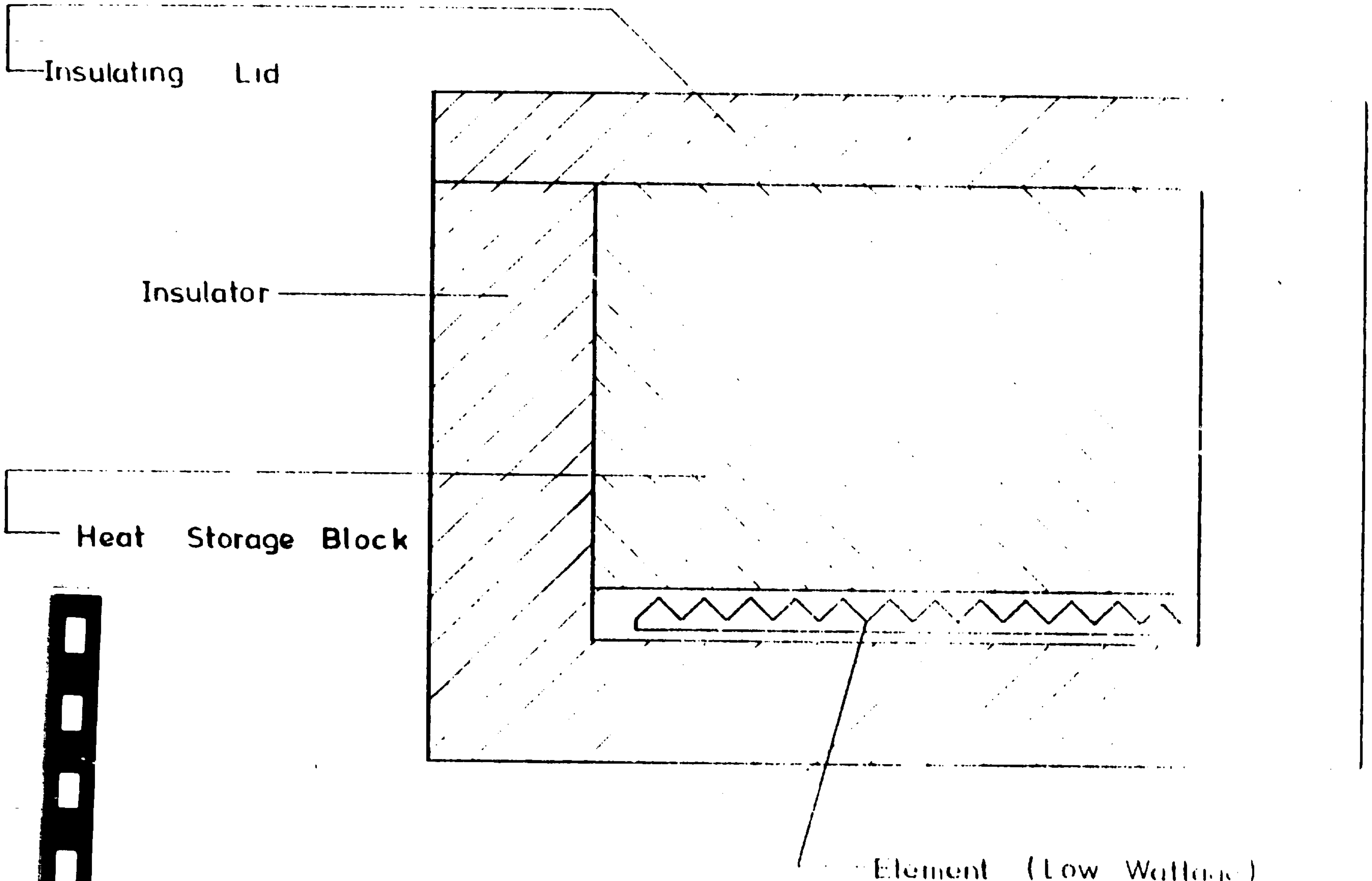
A week ago, we visited the mill to follow up on any problems that may have developed in the first 2-1_2 months of operation. Minor problems were corrected and a number of design changes were noted. In addition to the owner three people operate the mill: the main "driver", his helper, and a lady to cook for all of them. Now in the busy season, when it runs day and night, they live in the mill. When we got there, it had not been shut off for 40 hours.

The customers were very happy, not just because they had an opportunity to socialize and loaf for 10-15 hours while they waited, singing and dancing, etc., but because the payment was now considerably less than it had been with the diesel mill. Oil expelling was in full swing, with Rs.1/- per pathi of mustard seed being charged, instead of the former Rs. 1.75 in the diesel mill. Wheat was also cheaper by 33% and rice hulling by 38%. To observe the owner relating to the customers, keeping order in the long time waiting their turn, collecting his pay, and at the same time operating the mill, was worth the whole journey. His money bag hung above the oil expeller and it was obvious from its bulge that he was prospering.

The diesel mill has not operated since the water mill opened. The diesel owner has now come to us, begging for a water turbine: he still hasn't put his money down for an order, but we expect he will soon. The area will easily support two mills and it will be interesting to see what the new milling rates will be. A good return on investment should be expected by the owner, but such competition from mills just across the stream from each other should keep the rate fair. The farmers will benefit with the reduced rates, less waiting time and better reliability, since if one machine would be broken, the second at least may be running. What can be more discouraging than carrying a heavy bag of wheat 4-8 hours to discover that the mill is broken?

Milling is the first chapter in the development of Majuwa. I think the second will be written about: electrification (a rough survey of Majuwa village showed a present requirement of 100 forty watt light bulbs, just 4 kW), soap making from chiuri oil, a small workshop for repair of the equipment being used, etc. It may take 5 or 10 years for this to develop, but then, it is 13 years since the "new bridge" was built, and before that there was only a tea shop.

(1 pathi = 4 liters)



Heat Storage Cooker