SMALL HYDRO-ELECTRICAL POWER DEVELOPMENT IN THE NORTHERN AREA, PAKISTAN

MISSION REPORT NO.2

HYDROLOGY
ELECTRO/MECHANICAL EQUIPMENT

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Sammendrag/Abstract

This report is based on the recommendations in NVE mission to Pakistan, Report 04-88. The previous report recommended the establishment of a mech./el-workshop for improved maintenance of existing powerplants in the Northern Area (NA), Pakistan. It also provided recommendations on upgrading and rehabilitation of small hydel plants, the construction of new small hydel plants and planning of medium scaled hydel plants.

This report improves the background knowledge for the planning and implementation of the workshop. It emphasizes the electro, mechanical, sediment and hydrology problems regarding the proposed programme for improvement and development of hydel plants in NA.

It also gives information on cooperation between pakistant Authorities and Norwegian consultants and finally proposes some minor changes in the SHP development programme.

Emneord/Subject Terms

Pakistan, the Northern Area
Small Hydel Plants
Maintenance
Development
Training

Ansvarlig underskrift/
Project Co-ordinator

Egil Skofterland
NORAD-Coordinator
Electricity
The source of power generation in the Northern Areas is primarily hydro. During summer, due to the high water level and strong currents accompanied by silt and mud, the electricity generator turbines are often clogged. Hence, the supply of electricity is drastically reduced. The Lodge has its own standby generator which is operated between 1700 hours to 0030 hours and 0400 hours to 0800 hours.

Hot Water
Due to the energy crisis, we are compelled to restrict the operation of water heaters. Hot water is therefore, available from 0600 hours to 0800 hours and from 1800 hours to 2100 hours. To obtain hot water, it may be necessary to run the tap for at least five minutes.
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APPENDIX 4: Sediment Problems and Sediment Excluders in the Northern Area, Pakistan

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1 EXECUTIVE SUMMARY

This report summarises the findings of a mission to Pakistan and discussions with The Ministry of Kashmir and Northern Area, Water and Power development Authority (WAPDA) and Northern Area Public Works Department (NAPWD).

The purpose of the mission was to improve NORAD's, WAPDA's and NAPWD's background knowledge on a proposed project in accordance with the Agreed Minutes of the 1988 country negotiations. The mission was required to deal with the following specific project components and subjects:

* Mech/el workshop in Gilgit
* mech/el equipment in existing plants
* Improved solutions for intake and channels
* Hydrology
* Organisational arrangements between consultants and WAPDA/NAPWD

The summary of conclusions is as follows:

* The planning, construction and training of employees for the workshop is a four year programme which includes the rehabilitation of mechanical and electrical equipment in the Kargah 5, Hassanabad 1 and Skardu 1 powerplants. The workshop is planned to be in operation with 20 employees (12 skilled) within the four year period. The whole project including the refurbishing of the three power plants has a budget of approximately NOK 40 mill. It is expected that most of the refurbishing work can be undertaken by the workshop and that machinery, tools etc for the workshop can be purchased in Pakistan or obtained second hand in Europe. NAPWD will be the responsible authority in Pakistan for this project.
To improve and increase the electricity production for Gilgit town (back up supply for the workshop) and the villages in Hunza Valley (where 25,000 people have at present only 100 kW electricity available) it is proposed to uprate the Kargah 5 and Hassanabad 2 powerplants. The uprating will also include improvements in channel, intake and sediment chamber. It is proposed that these plants are implemented so that the head between powerplants upstream and downstream is fully utilized and so that the turbine flow is similar to the existing plants downstream and upstream. Both plants will be uprated from 200 kW to approximately 1000 kW and the expected costs are approximately NOK 30 mill. The planning, concession and construction period is estimated 2.5 years. NAPWD will be the executive authority responsible for these projects.

The programme for the development of new power plants is smaller than that which was earlier considered, due to the increased uprating programme. It is proposed that Tangir and Nomal small hydro power schemes are planned for concession, but only Tangir is given priority to be implemented during the four year period. Nomal can be implemented if cost savings are achieved or if there is an extension of the project. To increase the electricity production to meet the power demand in the more populated areas it is proposed to work for the development of medium scaled power plants (10-20 MW). Besides being less costly than small scale plants these can also be a better solution environmentally. As a consequence it is proposed that a review of the Parri scheme currently being planned at WAPDA and a prefeasibility study of a low head scheme in Gilgit river are carried out. The programme for these new projects is expected to cost approximately NOK 50 mill. WAPDA is the responsible authority for the planning of all these projects.

For all projects the mission found that the hydrology expertise at WAPDA is sufficient for planning and implementation of the schemes.
2 INTRODUCTION

2.1 Background
In 1986, it was proposed that Norwegian assistance to Pakistan should include energy supply projects, with special emphasis on technical solutions where Norway has special knowledge; and Pakistan subsequently applied for support for such projects.

In two missions to Pakistan and in co-operation with the relevant Pakistan authorities, the Ministry of Kashmir and Northern Area, Pakistan Water and Power Development Authority (WAPDA) and Northern Area Public Works Department (NAPWD) projects have been identified (NVE report 04-88) which will improve and increase energy production in the Northern Area (Fig.1).
The NVE report 04-88 contained the following recommended programme:

* Construction and running of a mech/el workshop.
* Refurbishing of Hassanabad phase 1 and 2 (160/400 KW) and Skardu phase 1 (320 kW) powerplants.
* Uprating of Kargah phase 5 powerplant (200 KW to 550 kW).
* Review of plans for Parri multi purpose scheme (15 MW) and Hanzal low head scheme in Gilgit river (10 MW).

2.2 Mission on Mechanical, Electrical, Hydrology and Sediment problems.

To improve NORAD’s background knowledge and to clarify all relevant technical aspect of the proposed programme a mission was sent to Pakistan in February 1989. The mission was organised by Norwegian Water Resources and Energy Administration (NVE) and headed in Pakistan by the NORAD’s Resident Representative, Mr. Per T. Skogstad.

The other mission members were:

Mr. Torodd Jensen, Hydro Power Planner
Team Leader Technical Aspects (NVE)
Mr. Dan Lundquist, Hydrologist, (NVE)
Mr. Einar Tesaker, Hydraulics Specialist, Norwegian Hydro-dynamics Laboratories (NHL)
Mr. Oddmund Kristensen, Electrical Engineer, EB-Energy
Mr. Tore Knutsen, Mech. Engineer, Kvaerner Group

2.3 Present Hydro Electric Situation in the Northern Area.

The Northern Area consists of Gilgit, Baltistan and Diamar districts situated between longitude 62-76 degree East and latitude 34-36.5 degree North. The total area is about 69,600 square km. The population of the Northern Area was 0.65 million in 1981. The distribution of the population follows the lines of streams and rivers on the alluvial fans where water is available. The total requirement for electric power was about 78 MW, in 1988 according to NAPWD which includes domestic, commercial and industrial demand.

The mountainous terrain and major water resources makes the Northern Area suitable for hydro electric generation at small, medium and large scale production. Since the population is located in the valleys, the development efforts so far have concentrated on building small hydel stations to serve the villages. Except for powerstations situated in the same river, very few powerplants are interconnected in a grid. The existing transmission lines are built to deliver the power over short distances. They therefore normally are 11 KV leading the power to a distribution grid.

The estimate of present demand in the Northern Area is 78 MW which far exceeds what can be produced by constructing small hydro power plants, and areas presently without electricity are pressing to be able to join in. Hence the conclusion is that small hydro-electric power plants (100-5,000 kW) should be built in rural and sparsely populated areas, while medium scaled hydro-electric power plants (5,000-20,000 kW) should be built to meet the demand in heavily populated areas and town centres like Gilgit. The planning of medium scaled power plants has started. The implementation of these plants will make the construction of high voltage transmission lines more feasible, which is a necessity for the development of an interconnected grid system. An interconnected grid system which also includes the small hydro power plants will improve the quality of electric production and allow the electrification of more villages.
In the Northern Area, 75 small hydro electric power plants will be in operation in the near future (Fig 2) producing approximately 30 MW. Some of the existing 40 power plants lack proper maintenance and daily operation is difficult. The frequent occurrence of power failures and load shedding lead to increased strain for the employees of NAPWD. There are no local facilities for even the smallest maintenance work on el/mech equipment, and it is necessary to wait for weeks to get even the simplest repair work done.
3.1 Objectives of the project

The major objective of the electrification project is to contribute to socioeconomic development of the population of the area. Efforts will be made to reach the poor inhabitants of the area, although they probably will benefit only indirectly. Another important objective is to improve the technological capacity of the area. The specific project targets are as follows:

- Increase production capacity of electric power in the Northern Area and improve NAPWD’s capacity to maintain small hydro power stations.

- By construction of new power plants, supply 10,000 households with an average of 200 W each at a low price.

- Transfer knowledge of the planning and construction of small scale hydro power plants to NAPWD and WAPDA.

- Introduce new knowledge concerning tunnel techniques and assessment of the environmental effects of medium scale river power plants.

- Use inputs from Pakistan industry by engaging local entrepreneurs and engineers.

3.2 Expected results of the Project

- Establish a maintenance workshop which is able to service small power plants in the area.

- Establish maintenance routines based on the capacity of the workshop and the level of knowledge of local personnel.

- Rehabilitate three existing small hydro power stations (ranging from 100 to 400 kW capacity).
- Expand two existing small power plants (of 200 to 1000 KW capacity).

- Plan two new small power plants each of 2000 KW capacity, and construct at least one of them.

- Construct transmission lines from the new hydro power plants.

- Carry out a pre-feasibility study of a medium scale hydro power plant (15 MW) in Gilgit River at the village of Gamuch 45 km upstream from Gilgit town.

- Review the Parri multi purpose scheme currently being planned by WAPDA.

3.3 Cost estimate and project schedule.
The total cost of these projects is estimated at NOK 120 mill (at 01.07.89). An approximate phasing of expenditure is as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>NOK 5 - 10 million</td>
</tr>
<tr>
<td>1990,1991,1992</td>
<td>NOK 30 million each</td>
</tr>
<tr>
<td>1993</td>
<td>NOK 20 - 25 million</td>
</tr>
</tbody>
</table>

A project schedule and cost estimate for each activity are presented in fig 4.

3.4 Organization

NAPWD has executive responsibility for rehabilitation and expansion of existing small hydro power plants, as well as the maintenance workshop. Planning of new power plants, and operation and maintenance of power plants over 5 MW, is the responsibility of WAPDA.
Tender documents will be prepared and sent to selected Norwegian consulting firms regarding the planning and construction of new powerplants and uprating of old power plants. The workshop component and planning/refurbishment of 3 old power plants will be discussed with the most experienced Norwegian company, The Kvaerner Group. NORAD will prepare terms of reference for this as well as a time schedule and budget. Details of selected consulting firms and TOR for all projects will be sent to WAPDA and NAPWD for approval. The two Norwegian companies will enter into contracts with WAPDA and NAPWD.

Two working groups are proposed to be established as follows:

1: Workshop, refurbishment and uprating of existing plants
   Representatives from NORAD, NVE, NAPWD, consultant (uprating) and consultant (workshop). NAPWD will chair the group and the consultants will provide secretarial support.

2: Planning and construction of new plants
   Representatives from NORAD, NVE, WAPDA and the consultant. WAPDA will chair the group and the consultant will provide secretarial support.
Fig 3 Organization chart

Project agreement

NORAD
NVE/NORAD Pakistan

Ministry of Finance
Pakistan

NAPWD

Workshop
Hassanabad II
Kargah V

WAPDA

Tangir, Nomal, Parri
Gilgit river

Norwegian hydro-power manufacturer
also experienced in maintenance abroad

Pakistani manufacturers
Pakistani contractor

Norwegian hydro-power consultant firm

Pakistani and Norwegian manufacturers
Pakistani contractors

Contracts

Control/following up
<table>
<thead>
<tr>
<th>PROJECT</th>
<th>YEAR 1 1-12 mnths</th>
<th>YEAR 2 12-24 mnths</th>
<th>YEAR 3 12-24 mnths</th>
<th>YEAR 4 36-48 mnths</th>
<th>NOK MILLION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance workshop (construction, equipment, training). Revision Hassanabad I, Kargah V, Skardu I</td>
<td>20 mill</td>
<td>10 mill</td>
<td>5 mill</td>
<td>4 mill</td>
<td>39</td>
</tr>
<tr>
<td>Hassanabad II, uprating (planning, construction)</td>
<td>2 mill</td>
<td>8 mill</td>
<td>7 mill</td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>Kargah V, uprating (planning construction)</td>
<td>2 mill</td>
<td>8 mill</td>
<td></td>
<td>6 mill</td>
<td>16</td>
</tr>
<tr>
<td>Tangir, Nomal, Parri, Gilgit river (planning)</td>
<td>6 mill</td>
<td></td>
<td>2 mill</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Tangir (construction)</td>
<td></td>
<td>5 mill</td>
<td>20 mill</td>
<td>15 mill</td>
<td>40</td>
</tr>
<tr>
<td>Sum budget 1)</td>
<td>30 mill</td>
<td>33 mill</td>
<td>38 mill</td>
<td>19 mill</td>
<td>120</td>
</tr>
</tbody>
</table>

1) At the present stage Norwegian gross prices for all material are quoted in the budget. Pakistani industry can and will supply a substantial part. The construction of Nomal depends on savings made in the rest of the programme, or on the success of the project so that an expansion of the programme must be considered.

Milestones:

- Planning stage completed
- Project completed
3.5 **Conclusion on Hydro Power Projects**
For details see appendix 2.

**REHABILITATION OF OLD POWER PLANTS**
The existing electromechanical equipment in Hassanabad phase 1, Skardu phase 1 and Kargah phase 5 should be disassembled and rehabilitated at the workshop as a part of the training programme for the workers.

**EXPANSION OF TWO POWER PLANTS**
Operating in series of existing and planned powerplants, Kargah phase 5 (Fig.5) and Hassanabad phase 2 (Fig.6;A,B) should be uprated to fit to the discharge in other plants upstream and downstream. After uprating the output in these two plants will be approximately 1000 KW. The uprated Hassanabad station will give power to villages in Hunza valley which currently has access to little or no electric power. Kargah phase 5 will cover the need for power at the planned workshop. Planning and concession 1989-1990; Construction and commissioning 1990-1992.

**PLANNING AND CONSTRUCTION OF NEW POWER PLANTS**
The extension of the programmes for the existing plants will influence the budget so that only one new small scheme can be expected developed. Tangir (Fig 7) has been chosen as first priority. Tangir and Nomal (Fig 8) will be planned, but only Tangir can be expected to be in operation within the four year period. Construction of Nomal and other possible schemes may be discussed, especially if cost savings are achieved. Planning and concession 1989-1991; Construction and commissioning 1991-1993.

The work with the Parry scheme will be limited to a review of a feasibility study currently under work at WAPDA. This review shall focus on technical and environmental aspects.

The review of the Hanzal scheme shall not be carried out, but be replaced by a pre-feasibility study of the pos-
sibilities of utilizing rapids in the Gilgit river some 45 km upstream Gilgit town close to the village Hamucha. (Fig 9) This scheme has potential for a turbine installation of 10-20 MW with much lower construction cost than the Hanzal scheme. This scheme will also introduce tunnel technology, a technology which can play an important role in the future development of Pakistan (road/hydro power construction).

3.6 Mechanical/electric study conclusion

For details see appendix 3.

3.6.1 WORKSHOP- CONCLUSION

The establishment of the workshop and training of workers is the most important part of the whole project. As part of this project maintenance routines must be established based on the capacity of the workshop and the level of knowledge of local personnel. The rehabilitation of the electro/mechanical equipment in three powerstations is included in the total budget which is estimated at NOK 39 mill.

A large number of the power plants requiring assistance from the workshop are in such a bad condition that major break downs may occur any time. Even break down of the smallest unit will lead to great inconvenience for the population.

With the desperate need for repair facilities in the Northern Area, it is recommended that the workshop is constructed and put in operation in the quickest way possible.

Construction in this area is normally terminated in wintertime. By extending the construction period to the whole year, a lot of time is gained.

To save planning and design time also, we have examined the foundation and layout drawings for the diesel plant building.
Fig 5

Kargah Phase 5, 200 kW. Can be uprated to 1200 kW.

Fig 6 A

Hassanabad Phase 2. By using the old irrigation channel (right) instead of the headrace channel with rapids (left), it is possible to gain 20 m head.
Hassanabad Phase 2. The uprating will exclude the rapids in the headrace channel and therefore minimize the ice problems and add 20 m head. Construction of a sediment chamber will reduce the abrasion in the turbines.

Tangir, the planning and implementation of the hydro power plant must take into account the cultural and physical environments in the Tangir valley.
Fig 8

Nomal, downstream site for the new power plant.

Fig 9

Gilgit river at Hamucha. Proposed dam site and headrace channel for the low head tunnel scheme in Gilgit river. The estimated capacity is between 10-20 MW.
Our investigations confirm that the size is adequate, and only minor adjustments have to be made to satisfy workshop requirements. The workshop will be designed to service both mechanical and electrical needs. Tools and accessories will be as listed in Addendum 2 and under Item 1.3.3.

It is recommended that the workshop is developed gradually in 3 stages. Where stage 1 is actual for this project.

Total recommended local employment after implementation of each stage:

Stage 1: 20 people - of these 12 educated
  " 2: 30 " - ?
  " 3: 50 " - ?

The importance of the training program for local employees cannot be over-emphasized, and must be considered the key to success in having a self-sufficient unit after 3-4 years. It is anticipated that 4-6 Norwegian teachers will be required (inremittently) over a period of 3 years.

As much as possible of the repair work to be done on the existing priority projects will be performed in the workshop as part of the training program.

The budget estimates after implementing stage 3 are approximately as follows:

- Workshop construction NOK 3.000.000,-
- Mechanical tools and stock hold equipment NOK 10.000.000,-
- Electrical tools and stock hold equipment NOK 4.000.000,-
- Contingencies NOK 1.000.000,-
Salaries and social welfare cost

- Mechanical 2 Norwegians 3 years  NOK 6.000.000,-
- Electrical " "  NOK 6.000.000,-

Travelling expenses and accommodation
in Pakistan and Norway  NOK 4.000.000,-

Salaries for the Pakistan employees 3 years  NOK 2.000.000,-
Contingencies  NOK 2.000.000,-

3.6.2 Kargah, Phase 5. Refurbishment - Conclusion

Mechanical
The turbine equipment in Kargah, ph. 5 powerhouse, is in a condition where, from a technical point of view, we would recommend a complete repair/upgrading process to start as soon as possible in order to avoid unscheduled shut-downs. The extent of work should in general follow the guidelines indicated in Addendum 1, General Upgrading Procedure.

The major portion of the repair work could probably be performed as part of the training process in the planned workshop in Gilgit. Major components, however, which have to be replaced, should be manufactured by experienced turbine suppliers. Output monitoring clearly indicates that both turbines are operated at low efficiency (full gate - 70 kW. Rated value - 100 kW). New efficient runners would increase production significantly. The following cost estimate is based on cost level in Norway, 1st quarter 1989.

A. Total costs for upgrading both turbines at Kargah, Ph. 5, not including new parts:  NOK 0.5 mill.
B. Two new runners:  NOK 0.5 mill.
C. Potential upgrading of appurtenant parts, such as main inlet valve, governor, etc.  NOK 0.2 mill.
TOTAL BUDGET:  NOK 1.2 mill.
Electrical:

The control- and switchboard have to be replaced by a new board.

The generators have to be dismantled and cleaned. The bearings and brushes have to be replaced by new.

It is recommended that an air-cooling system is built for each generator.

The excitation systems have to be overhauled.

The spare 400 kVA transformer must be overhauled and tested for reuse. All cables have to be replaced.

The following cost estimate is based on cost levels in Norway.

Total cost \text{NOK 700,000,-}

3.6.3 Kargah - Phase 5. Uprating - Conclusion.

Mechanical:

The construction of new feeder canals with higher capacity for Kargah, ph. 6 and 7 projects make an expansion of the Kargah, ph. 5 powerhouse very attractive from an economical point of view.

In principle, the existing powerhouse should be extended to make room for one more unit of 1000 kW operating at a net head of 58 m.

Scope of Supply - Technical Data

- one (1) Horizontal Francis turbine, model FShzH595J
  \text{$P_r=1000$ kW, $n_r=750$ rpm, $H_r=58$ m}
- one (1) Inlet valve
- one (1) Governor
- one (1) set of appurtenances and spares normally included in the supply.
Cost Estimates - Turbine Equipment

The total budget costs ex. works for Scope of Supply as listed above: NOK 4,000,000.-

Electrical:

In addition to upgrading of the old plant a new 1 MW power plant should be built named Kargah, phase 5B equipped as follows:

Calculated production:
- Turbine: Horizontal Francis
- Guide vanes: adjustable
- Runner blades: fixed
- Turbine load: 1,020 kVA
- Speed /synchronous): 750 rpm
- Overspeed, on-cam: 1,560 rpm
- Overspeed, off-cam: 1,560 rpm

The water is led towards the power plant through a channel into a forebay and from the forebay down to the power plant through a penstock.

The turbine output can be adjusted according to water flow. The plant is regulated to frequency.

The plant should only be manually operated.

The plant can be started and run without an activated grid.

The following cost estimate is based on cost level in Norway. Total cost NOK 3,500,000.-
3.6.4 Hassanabad, Phase 1. Refurbishment - Conclusion

Mechanical:

The turbine in Hassanabad, Phase 1 Powerhouse is in very bad condition. A complete refurbishment of this turbine would be relatively expensive as many parts would have to be replaced.

What we would suggest as a solution for this power house is to replace the existing turbine with one of the units, which will be redundant when the new powerhouses under construction in the Kargah system are commissioned. The turbine has to be identical to the existing Hassanabad, Phase 1 turbine. This turbine could undergo a complete refurbishing process at the workshop while the existing turbine is continuing operation. The complete turbine unit could then be replaced.

Compared to a normal upgrading schedule, this procedure would cut the power station down-time to a minimum, provided that vital parts do not require replacement.

In this area (Hunza), where the need for electricity is enormous, short down-time is essential and will reduce the inconvenience for the consumer.

The repair procedure and budget cost for one of the redundant Kargah units would be quite similar to what has been previously described for Kargah, Phase 5 Powerhouse.

Total budget: NOK 600.000.-

Electrical:

The control- and switchboard have to be replaced by a new board.

The generator has to be dismantled and cleaned. The bearings and brushes have to be replaced by new.
The excitation system at the end of the generator has to be overhauled.

The main transformer has to be overhauled, tested and reused.

The same procedure should be applied to the small distribution transformer.

All cables have to be replaced.

The following cost estimate is based on cost levels in Norway.

Total cost \text{ NOK 550,000.}-

3.6.5 Hassanabad Phase 2, Uprating - Conclusion

Mechanical

The sand content in the water to this powerhouse is considerable. This is the major reason why the two existing cross-flow turbines frequently have to be repaired. This is not acceptable to NAPWD from an economical and operational point of view.

To remedy this situation we propose the following:

A. Reconstruction of sand trap(s) to a better design for increasing efficiency, and to the highest capacity which is acceptable from an economical point of view.

B. The two cross-flow units are replaced with one new horizontal Francis unit.
   Approximate design data according to the latest information provided by NAPWD should be:
   - Static head: 440 ft (134 m)
   - Rated flow: 32 cfs (0,9 m³/s)
The two cross-flow units could be refurbished and utilized at a new convenient site, where the water quality is much better. Under such conditions these units may operate satisfactorily.

C. We believe that a Francis turbine is likely to last much longer than the existing cross-flow turbines for the following reasons:

- The cross-flow turbines are operating in the upper head range of this turbine type. Hence, the water velocities in the turbine is relatively high.

- The proposed Francis turbine is of a design to be used up to about 400 m of head. At this head of 134 m the velocities in the turbine are substantially lower than in the existing cross-flow turbines.

- Lower silt content after improvements of the silt excluders at the headworks and with the construction of new forebay.

D. The new design data would require a new and longer penstock to be installed.

E. The intake structure must be reconstructed at a higher elevation to a design and capacity which is favorable for silt exclusion.

**Scope of Supply - Technical Data:**

- One (1) Horizontal, Francis turbin, model FShzH370E  
  \( P_r = 1000 \text{ kW}, \ n = 1000 \text{ rpm}, \ H_r = 130 \text{ m} \)

- One (1) Inlet valve

- One (1) Governor

- One (1) set of appurtenances and spares normally included in the supply
Cost Estimates - Turbine Equipment

Total budget costs ex. works for Scope of Supply as listed above: NOK 4,000,000.-

Electrical:

All electrical equipment is brand new and works perfectly.

The problem is associated with the turbine. It is proposed that the existing two units be dismantled and replaced by a new unit of 1 MW.

The following cost estimate is based on cost levels in Norway.

Total cost (budget price) NOK 3,500,000.-

3.6.6 Skardu Powerhouse, Phase 1. Refurbishing - Conclusion

Mechanical:

Although the turbines are generally worn and need upgrading they are in relatively good condition considering the time they have been in operation (commissioned 1972).

Compared to the Kargah and Hassanabad powerhouses, the water quality is much better and the silt content is small.

The output readings indicate, however, that an appreciable reduction in efficiency has occurred since 1972. At one gate opening the output was 180 kW in 1973. The corresponding output today is 140 kW. If these units shall be in operation in the foreseeable future, a complete refurbishment of mechanical equipment would be required in order to avoid unscheduled shut-downs.

Such a refurbishment process could in general be accomplished
along the guidelines listed in Addendum 1, and as described for Kargah, Phase 5 Powerhouse.

The estimated costs would be equivalent to the estimates given for Kargah, Phase 5.

A. Total costs for complete upgrading of both turbines, not including new parts: NOK 500,000.-

B. Two new runners: NOK 500,000.-

C. Possible upgrading of inlet valve, governor etc.: NOK 200,000.-

Total budget NOK 1,200,000.-

Electrical:

The control- and switchboard have to be replaced with a new board.

The two generators must be dismantled and cleaned. Bearings and brushes have to be replaced by new ones.

The excitation system at the end of each generator has to be overhauled.

The two main transformers have to be dismantled and replaced by new.

The oil circuit-breaker on 11 kV should be replaced by high voltage fuses.

The following cost estimate is based on cost levels in Norway.

Total cost NOK 1,000,000.-
3.7 Sediment problems and sediment excluders—conclusion
(Appendix 4).

- The winter flow is rather stable and carries little sediment in all rivers visited. The summer flow is much higher due to melting of snow and glaciers, with a regular diurnal variation: morning low and evening high. The sediment contents of the summer discharges are generally very high, but vary from river to river.

- The sediments have high content of feldspar and quartz particles of sizes usually considered harmful to turbines.

- Installations in the power plants visited have been adjusted to the winter discharge. During the summer period with much sediments, the rivers carry sufficient excess water for flushing of sediment traps located near the headworks. Existing supply channels, however, have little or no excess capacity.

- Flushing arrangements located between the headworks and the penstock can therefore in most cases only be used when the power plant has been shut down or is running with reduced capacity.

- Local slides and small creeks in many cases supply significant amounts of sediment along the channel, at some places even during the winter season.

- Main sediment excluders should be arranged near the headworks where there is excess water available for flushing. These should preferably be arranged such that continuous delivery of full channel capacity flow can be maintained during flushing.

- Secondary sediment excluders will usually be needed close to the forebay/penstock, or even at intervals along the channel.
1 route. Flushing of these may require temporary reduction or closure of the power production.

- It is possible to arrange parallel sediment chambers for manual or mechanical removal of deposits, always using one for the turbine discharge, while the other chamber may be drained and emptied. This method may be feasible for secondary sediment excluders where the amounts of deposits are moderate.

- For details, reference is made to Appendix 4.

3.8 Hydrology-conclusion (Appendix 5).

During the mission to Pakistan relevant data and reports were collected at WAPDA in Lahore. Informative discussions on hydrological were topics also held in Lahore with deputy director of WAPDA-HEP Abdul Rabbani Qureshi and in Gilgit with director II of WAPDA-HEP M.A.A. Nomani.

The general impression after these contacts with WAPDA is that most of the hydrological and sedimentological data necessary for the evaluation of small and medium scale hydel projects are available at WAPDA. Complementary investigations can also be performed by or through WAPDA, if necessary. There seems to be little need for transfer of knowledge in the field of hydrology, meteorology or sedimentology to WAPDA. Nevertheless it may be of future value to initiate a cooperation between WAPDA and NVE on selected hydrological topics such as hydrological modelling.

During the mission several discharge measurements were performed using the salt dilution method. These measurements can be assumed to be approximate measures of this winter’s minimum discharges.

At Tangir a suitable site for a staff gauge was examined and instructions for installation and observation were given to Sher
Dil Khan, sub-divisional officer of NAPWD at Chilas, B&R Division.

On the basis of these data from Pakistan and an analysis of river basin characteristics performed in Norway, the following conclusions are drawn regarding minimum discharges at Tangir, Kargah, Nomal, Hasanabad and at alternative sites in Gilgit River:

- For Tangir at Jaglot the minimum discharge could be expected to be in the range 3.0 - 3.5 m³/s.

- For Kargah 5, Nomal and Hasanabad the minimum discharge could be expected to be in the range 1.0 - 1.5 m³/s.

- For all the proposed schemes in Gilgit River the minimum discharge is approximately 30 m³/s.

These minimum discharges in normal years could be expected to be enough for all of the planned installations. In dry years, however, one might experience periods of water shortage at the schemes of Kargah 5, Nomal and Hasanabad. During such years one should also expect conflicts with irrigation demands. For Tangir no conflict with irrigation or water shortage of other reasons is expected for projects double the size of the proposed one.

Finally it is recommended that minimum discharges are measured for as many winter seasons as possible at the different project sites and correlated to longterm statistics for Gilgit and Hunza River. This is considered the best way of increasing the knowledge of minimum discharges relevant for dimensioning of installed capacities.
UPRATING/REFURBISHING MISSION TO PAKISTAN

TERMS OF REFERENCE

BACKGROUND

In October 1988 NORAD sent a delegation of professionals in hydro power planning and social development to Pakistan to improve NORAD's background for decisionmaking concerning studies and implementation of six specifically mentioned small hydro power projects in Northern Area. The mission which was headed by NORAD's Resident Representative to Pakistan concluded that some of the existing hydro power plants were in poor condition and that the Northern Area Public Works Department (NAPWD) acutely needed a workshop to carry out regular maintenance on el/mech equipment in the power plants. Furthermore it was concluded that four powerstations in operation should be upgraded and used as demonstrations for other plants with similar potential for improvement.

Later discussions in NORAD and the annual consultations between The Government of Pakistan and The Government of Norway have focused on this project proposal and defined it as priority one within Norwegian contribution in rural electrification programme in the Northern Area.

MISSION MEMBERS

The mission will be organised by Norwegian Water Resources and Energy Administration (NVE) and headed in Pakistan by the NORAD's Resident Representative, Mr. Per T. Skogstad. Other mission members will be:

- Mr. Torodd Jensen, Hydro Power Planner, Team Leader Technical Aspects (NVE)
- Mr. Dan Lundquist, Hydrologist, NVE
- Mr. Einar Tesaker, Hydraulics Specialist, Norwegian Hydro dynamics Laboratories (NHL)
- Mr. Oddmund Kristensen, Electrical Engineer, EB-Energy
- Mr. Tore Knutsen, Mech. Engineer, Kvaerner Group

In Norway, Mr. T. Jensen will act as responsible Team Leader on behalf of NVE.

GENERAL SCOPE OF WORK

The Mission shall clarify all relevant technical aspects and provide NORAD and WATER AND POWER DEVELOPMENT AUTHORITY (WAPDA) and NAPWD with an objective report usable for national as well as international procurement and/or tendering for capital items or consultancy services. The Mission shall furthermore deal with general project planning issues and plan for project implementation in accordance with the Agreed Minutes of the 1988 country negotiations and NORAD's general requirements.
The Missions shall work in full understanding with and with participation from WAPDA and NAPWD. The October 88 Mission Report (04-88) shall serve as general reference and guideline for the Mission.

The Mission shall during the stay in Pakistan deal with the following specific project components and subjects:

- Mech/el workshop in Gilgit
- Mech/el equipment in existing plants
- Improved solutions for intakes and channels
- Organisation between consultants and NAPWD/WAPDA
- Hydrology

REPORTING TO NORAD

The Mission shall report to NORAD in the form of an official report issued by NVE. This report shall present specific plans for progress, resource needs, budget requirements and management setups as agreed within the full team while, in Pakistan following discussions with Pakistan authorities. Furthermore, it shall include technical reporting, descriptions/specifications, Terms of Reference for further work, procurement guidelines and other technical details which may be finalized in Oslo.

The main report with conclusions and recommendations shall be submitted to NORAD within 4 weeks of the Team’s return to Oslo; technical details and documents may be submitted with some delay.

The assignment shall be carried out in accordance with the attached Description of Technical Issues.
DESCRIPTION OF TECHNICAL ISSUES

1 MECHANICAL/ELECTRICAL WORKSHOP AT GILGIT

1.1 BACKGROUND

In the Northern Area there are 40 small hydro electric power plants in operation today and another 35 are under construction. The el/mech equipment in the powerstations consist of several types of technology, and originate from different manufactures. Some plants have components of low technological quality which gives frequent breakdowns. There is no workshop available locally to repair even uncomplicated damage on parts of turbines, generators or panels. The parts are brought to Lahore for fabrication and repair. This is costly in terms of time and money, in addition to the inconvenience to the consumers facing the blackouts for extended periods, before the parts arrive from Lahore. It is therefore decided that the construction and necessary training for the operation of an el/mech workshop at Gilgit is given first priority regarding Norwegian contribution to rural electrification in the Northern Area in Pakistan.

Upon request from NVE, Kvaerner has produced a memo regarding equipment and tools in the workshop. (report no 47698).

1.2 FURTHER INVESTIGATION BY THIS MISSION

The Mission shall carry out discussions with WAPDA/NAPWD regarding:
- Equipment needed
- Construction of building
- Future workforce in the workshop
- Training of personnel

1.3 SCOPE OF WORK

1.3.1 Construction of Workshop

The site for and the construction of the workshop shall be discussed with NAPWD and WAPDA. It shall be clarified who will be responsible for the construction. Drawings, a cost estimate and time schedule for the construction shall be presented by comparing similar buildings in Gilgit.

1.3.2 Equipment in the Workshop

The equipment proposed in the memo from Kvaerner shall be discussed with NAPWD and WAPDA in order that machinery installation and operation can be handled by a departmental workforce recruited locally.
1.3.3 Workforce in the Workshop

The present requirements and their training needs for future work in the workshop shall be discussed with WAPDA and NAPWD in order to start the process of recruitment. Kvaerner/ EB shall give information on necessary background for the employees needed.

1.3.4 Running of the Workshop

The responsibilities and tasks related to the running of the workshop after construction shall be clarified. The question of involvement of Pakistani industries like PECO shall be raised and recommended upon if feasible.

1.4 REPORTING

The report shall include minutes from every meeting regarding the various items. Conclusions shall be stated. Where necessary a cost estimate and time schedule shall be presented. The report shall be finalized as a draft not later than two weeks after return to Norway.

2. EVALUATING OF MECH/EL EQUIPMENT IN EXISTING PLANTS

2.1 GENERAL AND REPORTING

Training opportunities and possible contribution from Pakistani industry shall be included in each item. The kind of work concerning each projects which can be carried out in the proposed workshop shall be described. The report shall include a cost estimate and time schedule for each item which is identified for repair work even if the work is suggested to be carried out in the Gilgit workshop. Draft reports from each project shall be completed not later than two weeks after return to Norway.

2.2 KARGAH PHASE 5

2.2.1 Background

Phase 5 powerstation includes two generating units of 200 KV each. Both are old and improved efficiency is required. The ongoing construction of a new powerstation with intake in the tailrace channel of phase 5 also includes the enlargement of the feeder channel for phase 5 to cater for twice the discharge needed for the operation of the existing turbines. Hence uprating of Kargah phase 5 seems feasible.
2.2.2 Further Investigation by This Mission.

One of the existing generating units is proposed substituted by a new and larger one. Hence all necessary improvements and equipment renewals for the uprating shall be identified on the basis of the existing situation and professional judgement.

2.2.3 Scope of work

The new unit shall be analysed for joint running with one of the old units. These two units combined must have the same max. flow as the new powerstation downstream. The type, size and output shall be given as well as comments on necessary civil works on the powerhouse. The civil works shall specially be discussed with NAPWD.

The two existing penstocks shall be investigated for corrosive attack and be analysed to cater for the enlarged discharge. If the head loss is unsatisfactory, the construction of a new penstock shall be discussed with NAPWD.

One of the two old units shall be disassembled to determine the necessary renewals for improved efficiency. Work suitable for the proposed workshop shall be described specifically.

Existing electrical equipment in and outside the powerstation shall be investigated. Recommendations shall be grouped in replacements needed from a point of view of improved operation and those strictly needed for technical functional reasons.

2.3 HASSANABAD PHASE ONE AND TWO

2.3.1 Background

Hassanabad phase 1 is 20 years old. The existing output is 160 kW. It is considered feasible to uprate the plant by enlarging its usable head and discharge. Hassanabad phase 2 is one year old. There are two units of 200 kW each. The runners in both units are already worn out by high runner speed, silty water and inappropriate materials in the runner (Kvaerner report no 47698).

2.3.2 Further Investigation by This Mission

Hassanabad phase 1 shall be investigated for uprating potentials and state of repair of existing equipment. Hassanabad phase 2 shall have its turbines investigated and a suitable replacement turbine specified including requirements for replacement of electric equipment.

2.3.3 Scope of work

The turbine /generator unit in Hassanabad phase 1 shall be disassembled and required refurbishing work shall be defined to
the degree possible.

The feasibility of uprating the plant by enlargement of head and discharge shall be evaluated. Through discussions with NAPWD the mission shall clarify whether the uprating is realistically expected in foreseeable future or not. The refurbishing of the existing unit shall have the possible uprating in mind.

The turbine units in Hassanabad phase 2 shall be disassembled. The investigation shall determine the need for a new turbine.

The new turbine and if necessary the new generator shall be described regarding size, output etc. This must be analysed with the existing penstock in mind.

Necessary civil works on the power house shall be specified and discussed with NAPWD.

Existing electric equipment shall be investigated to ensure compatibility with the new unit.

If replacement is necessary the reuse of the existing units in other suitable schemes should be discussed with NAPWD.

2.4 SKARDU PHASE 1

2.4.1 Background

The two units (320 kW each) in this powerstation have low efficiencies (less than 60%). Uprating of the plant might be feasible by constructing an intake in the tailrace channel of Skardu phase 2 which is located upstream existing intake of Skardu phase 1. Thus an increased head is obtainable for Skardu phase 1.

2.4.2 Further Investigation by This Mission

The Skardu phase 1 generating units shall be investigated for mech/el efficiency and the feasibility of uprating the plant shall be investigated.

2.4.3 Scope of work

The two units shall be disassembled and the need for refurbishing work specified.

Comments shall be given on the general adequacy of the electrical equipment.

Discussions shall be held with NAPWD in order to determine the feasibility of uprating Skardu phase 1 and give estimates of the time schedule for such an uprating.
If uprating of Skardu phase 1 is to be expected in foreseeable future, then the reuse of the existing units in other suitable schemes shall be discussed with NAPWD.

3 IMPROVED SOLUTIONS FOR INTAKES AND CHANNELS

3.1 GENERAL

The intakes and channels cause problems both during the high flow season (stones and siltation in the waterway) and during low flow season (leakages to the river). Improved knowledge of hydrology and hydraulics is therefore important. Chapter 3 gives TOR for hydraulics and chapter 5 hydrology.

For each of the sites visited a system sketch shall be made and comments shall be given so that other schemes not visited also can benefit from the information.

3.2 KARGAH PHASE 5

3.2.1 Background

This existing power plant has a new intake, silting chamber and channel designed to cater for a flow of approximately 1.6 m/s which is twice the flow needed to run Kargah phase 5. The enlargement has been carried out to fit the maximum discharge in Kargah phase 6 downstream of phase 5. A by pass arrangement has been constructed to channel the unutilized water in phase 5 to the tailrace channel of phase 5 (headrace channel for phase 6).

Kargah phase 5 can be uprated which in this context means enlargement of the forebay.

3.2.2 Further Investigation by This Mission

Investigation of the adequacy of existing intake, silting chamber and channel and the amendments necessary on existing forebay and trashrack to accommodate the new discharge.

3.2.3 Scope of work

The layout construction of intake, silting chamber and channel shall be evaluated, and if necessary, improvements shall be suggested.

The existing forebay shall be analysed to cater for a higher discharge. If enlargement is necessary dimensions and design solutions shall be given.

The existing trashrack shall be investigated and improvements suggested if necessary.
3.3 HASSANABAD PHASE 1 AND 2

3.3.1 Background

Hassanabad 1 is not in operation due to landslides in the channel area caused by the construction of an irrigation channel in the hillside upstream. The reconstruction of the channel has started.

Hassanabad 2 has problems with siltation in the waterway. A silting chamber is under construction.

The October Mission report indicates the size and nature of particles which must be expected to be carried in the water.

3.3.2 Further Investigation by this Mission

The intake, channel and forebay layout of Hassanabad 1 and Hassanabad 2 shall be investigated.

3.3.3 Scope of Work

If technically necessary, improvements to intake, channel and forebay regarding Hassanabad 1 shall be suggested. Find site and give dimension and layout for the construction of a silting basin suitable to the existing plant and the possibly uprated plant.

If necessary, suggest improvements to intake, silting chamber, feeder channel and forebay regarding Hassanabad 2 by providing sketch designs and simple construction specifications.

3.4 NOMAL HYDRO ELECTRIC POWER SCHEME

3.4.1 Background

One identified solution for the new Nomal SHP (Small Hydro Power) plant is to utilize the existing intake and channel for the small plant now in operation. Another alternative for the new Nomal SHP is to construct the plant upstream of the existing intake. The existing intake, channel and forebay needs to be improved.

3.4.2 Further Investigation by This Mission

The site upstream of the existing power plant shall be investigated. The waterway layout for the existing power plant shall be investigated for improvements.

3.4.3 Scope of work

The possibilities for constructing intake, silting chamber, channel and forebay sufficient for a 2MW plant upstream of the existing plant shall be assessed and solutions shall be sketched and described to a conceptional design level.
Suggestions for improved intake, channel and forebay solutions regarding the existing power plant shall be given.

Suggestions for the uprating of the existing waterway to accommodate the flow requirements of a 2 MW plant shall be put forward.
The technical feasibility of construction a new 2 MW plant upstream of the existing powerplant or the possibilities of uprating the existing plant shall be identified in a preliminary manner.

3.5 TANGIR SMALL HYDRO ELECTRIC POWER SCHEME

If time allows, the site for the new Tangir SHP plant should be visited and the proposed waterway for the scheme shall then be commented upon.

3.6 SKARDU PHASE 1

If time allows, the existing Skardu Phase 1 power plant should be visited and comments given on the waterway.

3.7 REPORTING

For each of the site visited a sketch solutions shall be made and description given so that other schemes not visited also can benefit from the information. All conclusions shall be supported by design calculations, references etc. The report shall be in accordance with these and a draft shall be completed not later than two weeks after return to Norway.

4 CO-OPERATION BETWEEN NORWEGIAN CONSULTANTS AND WAPDA/NAPWD

4.1 CLARIFICATION ON ORGANIZATIONAL ASPECTS.

The Mission shall seek clarification on the organizational aspects in Pakistan of the Norwegian assistance. This means in respect of the upgrading/refurbishing programme, the construction and the running of the el/mech workshop, the implementation of Tangir and Nomal SHP and the review of the plans for the Parri and Hanzal medium scaled hydroelectric power schemes.

5 HYDROLOGY AND SEDIMENTOLOGY

5.1 BACKGROUND AND PRIORITIES

The October '88 investigations (NVE-Report 04-88) approached the hydrological and sedimentological questions on a general level. Potential and experienced problems in this field were observed in the field and informed about by WAPDA and NAPWD staff. Actual data or hydrological activities were not observed or scrutinized. Hence the hydrological data base for detailed project planning still remains to be investigated.
Hydrological assessment is required for the two SHP-schemes at Nomal and Tangir as a first priority while actions towards improving the hydrological and sedimentological knowledge of the two planned medium sized hydro power plants at Hanzal and Parri shall be regarded as second priority. Detailed field work and further site visits shall be carried out only if time allows and if travelling arrangements makes it practical or possible. Data collection, storage and analysis methods used locally shall be discussed with officials so as to give the hydrologist a basis for evaluating the usefulness of existing data and the need for further work in this field.

5.2 REQUIRED INVESTIGATIONS

The October '88 delegation focused on data quality, low flow assessments, water utilization and sediment characteristics as items of particular importance. The Hydrologist shall improve on this situation through consultations with the hydrological and related services staff in Pakistan basically represented by WAPDA and NAPWD, by making field observations, by instructing NAPWD staff, by carrying out rough analyses on collected data and by defining the requirements for later running of detailed analyses and collection of additional data.

5.3 SCOPE OF WORK

In the context of above general requirements for investigations, the Hydrologist shall in particular carry out the work described below.

5.3.1 COLLECTION AND CONTROL OF EXISTING DATA

The hydrological services of WAPDA in Lahore and WAPDA/NAPWD in Gilgit and Chilas, shall be visited. Hydrological climatological and sedimentological data relevant to the project, shall be examined, collected or copied.

5.3.2 ASSESSMENT AND DATA COVERAGE AND QUALITY

Relevant drainage basins and the river gauging station at Gilgit shall be visited and assessed in relation to the findings regarding the data base and collection methods and as a means to evaluate hydrological and sedimentological homogenities in the area.

The possibility of extracting discharge data from existing small scale hydro power plants in the Northern Area shall be checked and carried out if feasible.

Proposals for further necessary quality control of available data and improvements in methods, instrumentation and manpower shall be worked out. Necessary analyses of data relevant to all projects shall be proposed.
5.3.3 COLLECTION OF NEW DATA

As the mission visits the project area during the low flow season, discharge information of value to the low flow analysis may be collected on site. The Hydrologist shall be equipped for carrying out quick spot gaugings using the salt dilution method and as time and conditions allow, he shall make measurements in Nomal, Kargah, Hassanabad and Tangir.

On Tangir River a suitable site for a much needed staff gauge was observed by the October '88 delegation. The hydrologist shall bring two sections of staff gauge plate to Pakistan and make arrangements for erecting a staff gauge while in Tangir and instruct local NAPWD staff in readings of it.

5.3.4 WATER DEMAND IN NOMAL AND TANGIR

Clarify the water rights situation and estimate the need of water for domestic use and agricultural purposes during winter and early spring in Nomal and Tangir. Estimate the total water demand (the small scale projects included) and the low flow in the critical periods.

5.3.5 HYDROLOGICAL AND SEDIMENTOLOGICAL BACKGROUND FOR THE HANZAL AND PARRI PROJECTS

The hydrological and sedimentological data base of the Hanzal and Parri projects shall be evaluated. A hydrological regionalisation and evaluation of the representativity of available data shall be carried out to the extent the data allow. The need of supplementary data relevant to these two projects shall be summarized.

5.4 REPORTING

The report shall include hydrological and sedimentological findings and conclusions and be finalized as a draft not later than two weeks after return to Norway.
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SMALL HYDRO-ELECTRIC POWER DEVELOPMENT
IN THE NORTHERN AREA, PAKISTAN

APPENDIX 2 HYDRO POWER PROJECTS

A2-1 INTRODUCTION

In March 1988 NORAD sent a delegation to Pakistan to evaluate possible Norwegian participation in rural electrification development in Pakistan. One of the conclusions was that Norway should consider to assisting Pakistan in the planning and development of small hydro power plants (SHP) in the Northern Area.

To improve NORAD’s background knowledge on technical, economical, environmental and socio cultural issues another mission was sent to Pakistan in October 1988. In co-operation with the relevant Pakistan authorities Pakistan Water and Power Development Authority (WAPDA), and Northern Area Public Works Department (NAPWD) projects were identified which will improve and increase energy production in this area which is unlikely to be connected to the main grid in the foreseeable future.(NVE-report no 04-88).

The October mission report recommended the following:

Construction and operation of a mech/el workshop.
Refurbishing of Hassanabad phase 1 and 2 (160/400 KW) and Skardu phase 1 (320 kW) powerplants.
Uprating of Kargah phase 5 powerplant (200 KW to 550 kW).
Review of plans for Parri multi purpose scheme (15 MW) and Hanzal low head scheme in Gilgit river (10 MW).

From an environmental point of view it was concluded that the programme had minor negative effects. Socio economically it was stressed that introduction of electricity has had a marked welfare effect in electrified areas, and this effect was expected
also to follow this programme. It was, however, concluded that sociocultural expertise should be included in the project to avoid cultural misunderstandings and improve the training possibilities.

The annual meeting between NORAD and Pakistan in November 1988 approved the proposals in the October Mission Report and defined the workshop as first priority in the development programme for the Northern Area.

The aim of the February 1989 mission was to improve NORAD's background knowledge regarding electro/mechanical, sediment and hydrology problems and organization aspects related to the programme.

Through discussions with WAPDA and NAPWD and after receiving new information on the different powerplants, the February mission proposed some changes in the programme.

FIG 1 LOCATION MAP OF PROPOSED PROJECTS
A2-2  FEBRUARY MISSION CONCLUSIONS ON HYDRO POWER PROJECTS

REHABILITATION OF OLD POWER PLANTS
The existing electromechanical equipment in Hassanabad phase 1, Skardu phase 1 and Kargah phase 5 should be disassembled and rehabilitated at the workshop as a part of the training programme for the workers.

EXPANSION OF TWO POWER PLANTS
Kargah phase 5 and Hassanabad phase 2 should be uprated to fit to the discharge in other existing plants upstream and downstream. After uprating the output in these two plants can be approximately 1,200 and 1,000 KW respectively. The uprated Hassanabad station will give power to villages in Hunza valley which currently has access to little or no electric power. Kargah phase 5 will cover the need for power at the planned workshop. Planning and concession 1989-1990; Construction and commissioning 1990-1992.

PLANNING AND CONSTRUCTION OF NEW POWER PLANTS
The extension of the programmes for the existing plants will affect the budget so that it is likely that only one new small scheme can be developed. Tangir has been chosen as first priority by NAPWD and the mission team. Tangir and Nomal will be planned, but only Tangir can be expected to be in operation within the four year period. Construction of Nomal and other possible schemes may be discussed, especially if cost savings are achieved. Planning and concession 1989-1991; Construction and commissioning 1991-1993.

The work with the Parry scheme should be limited to a review of a feasibility study currently under preparation at WAPDA. This review shall focus on technical and environmental aspects.

The review of the Hanzal scheme shall not be carried out, but be replaced by a pre-feasibility study of the possibilities of utilizing rapids in the Gilgit river some 45
km upstream Gilgit town close to the village Hamucha. This scheme has potential for a turbine installation of 10-20 MW with much lower construction cost than the Hanzal scheme. This scheme will also introduce tunnel technology, a technology which can play an important role in the future development of Pakistan (road/hydro power construction).

A2-3 REHABILITATION OF POWER PLANTS

A2-3.1 General

The rehabilitation programme is focused on the electro/mechanical equipment in the following power plants:

* Kargah phase 5 (200 kW)
* Hassanabad phase (160 kW)
* Skardu phase 1 (320 kW)

Necessary improvements regarding intake, sediment chamber, channel, penstock and power house are the responsibility of NAPWD; i.e all civil works.

A2-3.2 Kargah phase 5

For information on this plant see A2-4.2 and appendix 3.

A2-3.3 Hassanabad phase 1

This power plant has not been in operation for 1 1/2 years, due to the destruction of the headrace channel, caused by the construction of an irrigation channel above in the hillside. This construction is now completed and the refurbishing work on the power channel has started. There is a plan for the uprating of the powerplant by making the channel wider and longer.
Data for existing and proposed power plants at Hassanabad (For more information see appendix 3, 4 and 5):

<table>
<thead>
<tr>
<th>Name of plant</th>
<th>head discharge (m)</th>
<th>discharge (M3/s)</th>
<th>turbine units</th>
<th>type</th>
<th>output (KW)</th>
<th>commissioned year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hassanabad ph.1</td>
<td>52</td>
<td>0.50</td>
<td>1</td>
<td>Francis</td>
<td>160</td>
<td>1965</td>
</tr>
<tr>
<td>New scheme</td>
<td>67</td>
<td>0.85</td>
<td>?</td>
<td>Francis</td>
<td>450</td>
<td>?</td>
</tr>
</tbody>
</table>

A2-3.4 Skardu phase 1

Skardu ph.1 is running at approximately 60% efficiency, and the power plant needs refurbishing. After the regulation of Sadpara Lake in Sadpara watercourse (See NVE 04-88), it is probably feasible to increase the head for Skardu ph.1 by constructing a new intake at the tailrace channel of Skardu ph.2, a new headrace channel and a new power station downstream from the old existing power station. In any case, the old turbines should be refurbished. If the existing plant is uprated, these turbines could be utilized in nearby schemes. For more information on the refurbishment programme see appendix 3.

Data on existing and proposed power plant:

<table>
<thead>
<tr>
<th>Name of plant</th>
<th>head (m)</th>
<th>discharge (M3/s)</th>
<th>turbine units</th>
<th>type</th>
<th>output (KW)</th>
<th>commissioned year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skardu ph.1</td>
<td>37</td>
<td>1.47</td>
<td>2</td>
<td>Francis</td>
<td>320</td>
<td>1972</td>
</tr>
<tr>
<td>Uprated</td>
<td>76</td>
<td>2.0</td>
<td>?</td>
<td>Francis</td>
<td>1300</td>
<td>?</td>
</tr>
</tbody>
</table>
A2-4 UPRATING OF POWER PLANTS

A2-4.1 Kargah phase 5

A2-4.1.1 Present situation in the Kargah watercourse

The existing SHP in Kargah watercourse are the only hydro electric power plants which serve the capital of the area, Gilgit.

Data on existing power plants:

<table>
<thead>
<tr>
<th>Name of station</th>
<th>head (m)</th>
<th>discharge (M/s)</th>
<th>installed units</th>
<th>type</th>
<th>output (KW)</th>
<th>year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kargah phase 1</td>
<td>37</td>
<td>1.47</td>
<td>2</td>
<td>Francis</td>
<td>320</td>
<td>1965</td>
</tr>
<tr>
<td>Kargah phase 2A</td>
<td>61</td>
<td>0.57</td>
<td>2</td>
<td>Cross Flow</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>Kargah phase 2B</td>
<td>61</td>
<td>0.76</td>
<td>2</td>
<td>Cross Flow</td>
<td>324</td>
<td>1978</td>
</tr>
<tr>
<td>Kargah phase 3</td>
<td>43</td>
<td>1.20</td>
<td>3</td>
<td>Francis</td>
<td>300</td>
<td>1980</td>
</tr>
<tr>
<td>Kargah phase 4</td>
<td>43</td>
<td>1.20</td>
<td>3</td>
<td>Francis</td>
<td>300</td>
<td>1980</td>
</tr>
<tr>
<td>Kargah phase 5</td>
<td>43</td>
<td>0.79</td>
<td>2</td>
<td>Francis</td>
<td>200</td>
<td>1984</td>
</tr>
</tbody>
</table>

Firm power from these power plants varies from 50% to 70% depending on the efficiency and available water during low flow season. Hence the available power production during winter time from Kargah watercourse today is 1,12 MW.

A2-4.1.2 Information on new schemes in Kargah

The turbines in phase 1, 3 and 4 will be replaced by Chinese turbines. Phase 2 (A,B) will be replaced by a new scheme presently under construction (Phase 6), with the installation of four units of 1 MW each. Bywater (GB) will deliver the turbines. Phase 6 will utilize the head between phase 3 and 5 (Fig 2). The discharge will be approximately 1.6 M/s. The old power plants will be operated during the high flow season.
Kargah phase 6 will use the same intake as Kargah phase 5 (Fig 3). The intake for phase 5 is reconstructed and there is a plan for enlarging the headrace channel of phase 5 to cater for the necessary discharge. Because ph.5 has less capacity than ph.6 a bypass tapping construction. The existing sediment chamber will be used. The February Mission has some comments to improve the sedimentation, see appendix 4.

Fig 3  The head between tailrace water phase 7 and headrace water phase 6 should be fully utilized in Kargah phase 5. Upstream the intake of phase 5 power plant there is a new scheme
under construction with maximum output of 1 MW (Kargah Phase 7). This plant is planned with approximately the same discharge as Kargah ph. 6. It is proposed that the sediment chamber and intake solution in Kargah ph. 7 be improved (Appendix 4), hence Kargah ph. 5 should be uprated to utilize the full head between the tailrace channel of Kargah ph. 7 and the headrace channel of Kargah ph. 6. The clean water from Kargah ph. 7 will then be utilized in kargah ph. 5 and 6. The reconstructed intake for Kargah ph. 5 should be operated to serve the old refurbished turbines in Kargah ph. 5 (Refurbishment of these turbines is a part of the programme), hence Kargah ph. 5 can be operated during high flow season (May-September). This intake will also have to be a security intake for Kargah ph. 6, the most important plant in the Kargah system in the future.

The extension of Kargah ph. 5 will include the following construction work:

* Construction of an open flow channel, designed for a discharge of 1.6 M3/s, from the tailrace channel of Kargah ph. 7 to the forebay for the new Kargah ph. 5

* Construction of a new forebay and by pass channel to the head race channel of ph 6.

* Construction of a penstock and a power house, or an extension of the old house for a 1 MW Francis unit operating on approximately 60 m head.

* Installation of the necessary mechanical and electrical equipment (Turbine approximately 1 MW, transformation 11 KV)(Appendix 3).
A2-4.2 HASSANABAD phase 2

A2-4.2.1 General

Hassanabad Phases 1 and 2 provide the only source of electrical supply for the west bank of the Hunza valley, i.e. the former kingdom of Hunza.

The hydro power plants are constructed in a river where analysis of flow sediments carried out by the team shows that the possibility of turbine wear is great. When planning sedimentation chambers the accumulation of these particles must be considered. The chambers and the channel have to be constructed with this in mind. The critical factors are slow stream velocity, optimal shape of the sedimentation chamber, knowledge of size and amount of actual particles and their sedimentation rate. (Appendix 4)

A2-4.2.2 The Hassanabad ph.2 project

This is a new scheme commissioned in 1986 with two crossflow turbines manufactured in Japan. The power plant was out of order at the Missions visit because the silty water in combination with high runner speed had destroyed the runners (appendix 3).

Fig 4 gives an overall view of the project where intake, sedimentation chambers, penstock and power plants are located.

A new plant (Hassanabad ph.2B) utilizing the head from tailrace channel of Hassanabad ph 2 to the river will be constructed in near future. The turbines (Chinese) are already purchased. This scheme is planned with a maximum discharge of approximately 1 M3/s to produce 270 kW. This plant will require an enlargement of the headrace channel and the sediment chambers. Proposals for enlargement and improvements are made in appendix 4. The enlargement of the headrace channel of Hassanabad ph.2 will make it feasible to uprate the existing plant. In addition it is possible to increase the head by approximately 18 m, hence Hassanabad ph.2 could produce approximately 1,000 kW.
Fig. 4 Hassanabad ph. 2 and 2B system.

Legend

1  Intake could be improved to utilize more water from small tributaries in the flow season

2,3,4 Water channel and sediment chambers are proposed enlarged and improved to cater for 30+5 cusec, where 5 cusec is irrigation water.

5,6,7,8 Extension and enlarged penstock for increased head and flow and uprating the existing plant from 400 kW to 1,000 kW is proposed.

9,10 Penstock and powerhouse hassanabad ph. 2B

It is proposed that parts 1, 2, 3, 4, 9 and 10 are the responsibility of NAPWD concerning planning, construction and financing. Parts 5, 6, 7, 8 should be financed by NORAD and planned and constructed in close cooperation with NAPWD.
<table>
<thead>
<tr>
<th>Name of plant</th>
<th>head</th>
<th>discharge</th>
<th>turbine</th>
<th>output</th>
<th>commissioned</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m</td>
<td>M3/s</td>
<td>units</td>
<td>type</td>
<td>year</td>
</tr>
<tr>
<td>Old:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hassanabad ph.2</td>
<td>114</td>
<td>0.57</td>
<td>2</td>
<td>Cross Flow</td>
<td>400 1986</td>
</tr>
<tr>
<td>New:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hassanabad ph.2</td>
<td>132</td>
<td>0.95</td>
<td>1</td>
<td>Francis</td>
<td>1000 1992</td>
</tr>
<tr>
<td>Hassanabad ph.2B</td>
<td>45</td>
<td>0.95</td>
<td>2</td>
<td>Francis</td>
<td>270 ?</td>
</tr>
</tbody>
</table>

To reduce the wearing on the turbine runners it is proposed to replace the two existing turbines in Hassanabad ph.2 by one new larger Francis turbine. This is more cost-effective and gives a better effect than using two or more turbines (Appendix 3). The alternative to this solution is to build a new power station between the forebay and the existing power house. This solution will reduce the pressure and the wearing, but is far more costly than the solution proposed.
A2-5 PLANNING AND CONSTRUCTION OF NEW HYDRO POWER PLANTS

A2-5.1 TANGIR small hydro electric power scheme
A2-5.1.1 General
Population, cultural position and socio-cultural and environmental effects are described in the NVE report 04-88. Since this is an isolated valley with no possibilities in the near future to be connected to the main grid system, electrification of the Tangir valley with the population of approximately 25,000 persons will fully satisfy NORAD’s objectives with regard to rural electrification.

A2-5.1.2 The Tangir project
The project is located downstream of Chimari village (Fig.5) and the power plant will be close to the village Shearkh. Appendix 4 and 5 give information on sediment problems and hydrology. It is clear that the minimum discharge in the river will at least allow a 4 MW plant to be constructed if the total head is utilized.

FIG. 5
There are great boulders in the river where the intake is located, hence only a weir can be constructed for the intake. There is moraine/loose material in the headrace channel, penstock and powerplant area.

The hydro power resource in this part of the river can be utilized by constructing one power plant utilizing the total head and prepared for extension or one plant utilizing the minimum discharge in the river and the necessary head to obtain 2 MW which will cover the demand in near future. Our proposal is to construct one plant with the intake, headrace channel and forebay designed for a 4 MW plant and penstock and power house designed for a 2 MW plant. The scheme will also have to include transmission lines (33 kV) and a distribution network. This scheme is expected to cost approximately NOK 40 mill. and be commissioned 4 years after planning has started.

It should be noted that the implementation of this scheme will lead to improvement of existing roads and give a road to two villages not presently served. It can also give possibilities of improving irrigation channels in the area.

WAPDA will be the responsible authority concerning the planning of this scheme. Since the which will cost more than RS 60 mill (Approximately NOK 20 mill.) this will need concession from the Executive Committee of the National Economic Council (ECNEC). The concession period can be 6-15 months. It is at present not decided whether WAPDA or NAPWD will be the responsible authority concerning construction.
Data on the proposed scheme (Including the existing hydro power plant in the valley):

<table>
<thead>
<tr>
<th>Name</th>
<th>head</th>
<th>turbine</th>
<th>channel</th>
<th>output</th>
<th>trans-</th>
<th>distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m</td>
<td>M3/s</td>
<td>m</td>
<td>KW</td>
<td>km</td>
<td>km</td>
</tr>
<tr>
<td>TANGIR PH1</td>
<td>42</td>
<td>0.84</td>
<td>3416</td>
<td>160</td>
<td>19</td>
<td>34 (ext.)</td>
</tr>
<tr>
<td>TANGIR PH2A</td>
<td>180</td>
<td>1.5</td>
<td>3500</td>
<td>2000</td>
<td>?</td>
<td>? (plan)</td>
</tr>
<tr>
<td>TANGIR PH2B</td>
<td>180</td>
<td>1.5</td>
<td>&quot;</td>
<td>2000</td>
<td>?</td>
<td>? (plan)</td>
</tr>
</tbody>
</table>

Phase 2 B is not a part of the programme, but its future implementation will be made easier by preparing for it as part of the Phase 2 A.

A2-5.2 NOMAL hydro electric power scheme

A2-5.2.1 General
NVE report 04-88 describes the socio cultural and environmental effects. There is presently pressure on land in Nomal, and a reluctance on the part of established owners to sell land to recent settlers. The proposed hydel scheme will require the purchase of a small cultivated area as site for the powerhouse and penstock. There is also a potential conflict of interest between hydrogenerating use and irrigation use of water from the river in the low flow months of February and March, when sowing and irrigation have started but melting has not set in the Nomal river watershed. A division of these water resources must be such as to secure the irrigation interests.

The objective of the SHP project is to provide electric energy for domestic consumption and illumination of 2,000 houses, and power for small industries. About 10,000 people living in the villages Rahimabad, Jutal, Juglote and Chilmis Das will benefit from this project. A truckable road exists from Gilgit town to Nomal.
The estimated minimum flow in Nomal river is 2.0 M3/s (Appendix 5). An existing hydro electric powerplant of 108 KW is hardly sufficient to meet the power requirement of about 500 consumers. This plant utilizes a head of 33m and a flow of 522 l/s in Cross flow turbines.

In the Nomal river watercourse studies have also been carried out on a medium scale high head hydropower scheme. According to WAPDA this has not proved to be feasible. A high head scheme can also be in conflict with the environment in the catchment area.

A2-5.2.2 Nomal hydro power project
The proposed scheme utilizes the existing feeder channel to the old power plant. The channel must be enlarged to cater for approximately 2 M3/s. The existing intake and silting basin must be improved and a new forebay must be constructed upstream from the one existing in the channel (Appendix 4). A bedded pipeline can be built from the new forebay to the powerstation which can be located about 400 m downstream from the existing plant. It is roughly estimated that the head can be approximately 125 m, and with a discharge of 2 M3/s the output is estimated at 2000 KW.

The development of Nomal with necessary transmission lines will far exceed the concession limit of RS 60 mill., hence the concession procedure and local responsibility will be similar to Tangir. Because of the increased programme on uprating Kargah ph.5 and Hassanabad ph.2 there is not expected to be enough money to construct Nomal within the proposed budget of NOK 120 mill. The development of Nomal and other schemes can be financed only if there are cost savings in the proposed programme or if the programme is extended on the basis of positive experience from the implementation of the proposed projects.

If construction of the proposed Nomal scheme takes place, the existing plant can be used during high flow season. An even better alternative is to disassemble it and rebuilt it upstream
in Nomal river site close to a village where no electricity is available to day.

Data on existing and planned power plants:

<table>
<thead>
<tr>
<th>Name</th>
<th>Head Turbine discharge</th>
<th>Output</th>
<th>Transmission line</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOMAL PH1</td>
<td>33m 522 l/s (1 unit)</td>
<td>108 KW</td>
<td>11 KV (exist.)</td>
</tr>
<tr>
<td>NOMAL PH2</td>
<td>120m 2000l/s (2 units)</td>
<td>2000KW</td>
<td>11/33 KV (plan)</td>
</tr>
</tbody>
</table>

**A2-5.3 The Parri Multi Purpose scheme**

A2-5.3.1 General Medium Scaled Schemes

Present power demand at Gilgit city is 10 MW and connected load is 6 MW. The total hydel power generated is 1.12 MW. During peak load time, small diesel generators located at various places in Gilgit town are also operated. The total output of such generators is 0.5 MW. A new diesel generating station of 3 MW is constructed by WAPDA. Of the six generators installed in this power station only three are running during peak load time. The output available from this power station is 1.2 MW.

To cover the connected load of 6 MW during peak load times only 2.82 MW is available at present.

The only hydro electric power of Gilgit is produced from KARGAH watercourse. In 1989 another two SHP plants will be commissioned producing a total of 5 MW.

These new schemes will not cover the present demand of Gilgit city. There are plans for more shops, workshops (welding, car repair), street lightning, electric heating to reduce the need for firewood, electric facilities in domestic use as refrigerators, television etc. Thus the power demand in the near future is much higher than what can be covered by the implementation of small hydel plants. A greater utilization of the tributaries to
Gilgit and Hunza rivers for hydro electric generating may in some places be in conflict with wildlife or environmental conservation plans. NAPWD and WAPDA are therefore looking for a chance to construct medium scale hydro power plants in order to meet the power demand of the area.

A2-5.3.2 NORAD contribution to the Parri project

The project is described in NVE report 04-88. Currently WAPDA is working with a new plan which may also include more reservoirs in the catchment area. The scheme is a combination of irrigation and electric production. Thousands of acres (20-40,000) of dry land can be irrigated by this scheme and 10-20 MW power can be produced. WAPDA is interested in Norwegian assistance, and the mission team propose that a review of the new plans should be carried out. This review should be limited to technical and environmental aspects. The budget for this review should be limited.

A2-5.4 Hydro Electric Power Schemes in GILGIT River.

A2-5.4.1 The Hanzal Hydro Electric Power Scheme.

Hanzal is located 15 km upstream from Gilgit in Gilgit river. A shingle truckable road leads to the site. A scheme in this area producing 10-15 MW would require a large dam in the river. Due to enormous deposits of sand a large dam has not been found feasible, hence the rapids can only be utilized by small plants. Even this is costly because large quantities of water would have to be involved to yield only a few MW. It is therefore not recommended that the existing plans be reviewed.
A2-5.4.2 The Hamucha Hydro-Electric Power Scheme

The scheme is located 45 km upstream from Gilgit town in Gilgit River near Sher Qila and close to the village Hamucha (Fig 7). This scheme can give 10-20 MW power, by constructing a small dam (weir) in the river, a tunnel and an underground power plant. The power station would utilize rapids in an oxbow in the river and during wintertime this part of the river will be dried out. During summertime, however, the maximum discharge through the power plant will be much less than the flow in the river. (Appendix 5). The scheme will introduce Norwegian tunneltechnology in Pakistan and will also allow a cooperation between Norwegian experts on environmental issues and the new environmental department which is newly established in WAPDA. It is therefore recommended that the programme should include funds for a pre-feasibility study on this project.
ADDENDUM 1 TO APPENDIX 2

LIST OF MEETINGS, PERSONS MET AND SITE VISITS
List of meetings:

<table>
<thead>
<tr>
<th>date</th>
<th>time</th>
<th>meeting with / visits to</th>
</tr>
</thead>
<tbody>
<tr>
<td>07/02</td>
<td>1000-1530</td>
<td>WAPDA</td>
</tr>
<tr>
<td>08/02</td>
<td>0830-1500</td>
<td>Chief Eng.Hydel,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mr.MUHAMMAD ZAKRIA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deputy Director,Hydel,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mr.Abdul Rabbani Quresh</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deputy Director, Electrical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mr. Muhammad Ismail</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deputy Director, Civil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mr. Syed Abdallah Shah</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deputy Director, Mechanical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mr. Tanquid Hussain Usmani</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deputy Director, Hydel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mr. Abdul Rabbani Quresh</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mr. Shahid Hussain</td>
</tr>
</tbody>
</table>

During these two days in Lahore at H.E.P WAPDA, Sunny View the proposed programme in the October Mission report was discussed. Emphasis was put on equipment and training for the electro/mechanical workshop, Hydrology in Northern Area, medium scale power projects like Parri and organization related to the proposed programme. The results of the discussion are included in the conclusion.

Some members of the mission also visited PECO 08-02-89. See Appendix 3.
The proposals in the October Mission report and site visits and meeting concerning this mission were discussed. For meeting concerning the workshop see appendix 3.

09/02  Afternoon  Site visit Kargah
10/02  Morning  Site visit 3 MW diesel plant

Electric Engineer
Mr. Amin Mohammad

Mechanical Engineer
Mr. Muhammad Yaqub Khan

The group decided that the mech/el investigations should concentrate on Kargah, Hassanabad and Skardu. For the mechanical/electrical part see appendix 3.
10/02  
Afternoon/evening  
Site visit Nomal  
Sediment & hydrological work

11/02  
Morning  
Departure for Chilas (meeting)  
Superintending Engineer  
Colonel Mumir Afgal

Sub Divisional Officer  
Mechanical engineer  
Mr. Sher Dil

11/02  
Afternoon  
Site visit and hydrology measurement Tangir.

12/02  
Morning/afternoon  
Site visit Tangir  
Evening  
Return to Gilgit

13/02  
Morning  
Meeting NAPWD  
Afternoon/Evening  
Departure for Hunza, site visit  
Hassanabad ph.1 and ph.2. Meeting.  
Executive Engineer, Hunza division  
Mr. Darveshali

14/02  
Morning/afternoon  
Site visit Hassanabad phase 1.  
Hydrological/sediment investigation (collecting samples)

15/02  
Morning  
Return to Gilgit, visit Bodalas SHP  
(3*200 kW)  
Afternoon  
Meeting NAPWD.  
Chief Engineer  
Brigadier Najeeb Ullah Kahn and his staff.  
The workshop, refurbishing Hassanabad ph.1, uprating Hassanabad ph. 2 and refurbishing/uprating Kargah ph. 5 was discussed. The
information given in the meetings are included in the conclusion.

16/02 Morning Meeting NAPWD. Discussion of the need for medium scaled power plants, procedure and organization concerning the implementation of the small hydro-electric projects and the workshop.

Afternoon Site visit Kargah, hydrology/sediment.

Evening WAPDA meeting.
Director Hydro Electric Project
Engr. M.A.A. Nomani
Hydrology and information on Parri, Nomal and Tangir

17/02 Morning Site visit Gilgit River, Henzel scheme.

Afternoon Site visit Hamucha scheme
Assistant executive Engineer, Mech
Mr. Ali Ahmed Jon
Assistant Executive Engineer, Civil
Mr. Muhammad Bashir
Assistant Executive Engineer, Elec
Mr. Abdul Amir

Evening Return to Gilgit

18/02 Morning Meeting NAPWD.

NAPWD will be responsible for the workshop, the rehabilitation of power plants and the uprating of power plants. The Norwegian consultant shall cooperate with NAPWD when making the PC-1 documents for concession and the tender documents for implementation. NAPWD will provide local engineers to support the consultant. Projects with total budget between RS 20-60 mill must have concession granted by Northern Areas Council (NAC).
18/02  Afternoon/  
Evening/night  Return to Islamabad

19/02  Afternoon  Meeting with the Ministry of Kashmir and Northern Area  
The secretary  
Mr. Hussain  
Chief Engineer, NAPWD  
Brigadier Najeeb Ullah Khan  
Joint Sec. KA & NA Division  
Mr. Zafrullah Kahn  
NAPWD I.S.E Gilgit  
Lt. Col. Javed Ahmad  
Dy. Chief. KA & NA Division  
Mr. Rafiq Ahmad Chavdhary  

NORAD contribution to rural electrification in Northern Area was discussed, and information given on the projects. It was stated that the Ministry wanted new hydro-electric power plants to be a WAPDA responsibility even if the output of the plants was less than 5 MW. This responsibility should cover both planning, implementation and operation. For the moment WAPDA is only willing to take the responsibility for planning. It was concluded that the disagreement between the Ministry and WAPDA could be settled during the planning and concession period.
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**ADDENDUM**

1 - MINUTES OF Meeting, NAPWD

2 - Workshop tools, Mechanical

3 - General Upgrading Procedure, Francis turbine

4 - Workshop Organization Chart

5 - Workshop lay-out sketch

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CONCLUSIONS

WORKSHOP - CONCLUSION

A major portion of the power plants requiring assistance from the workshop is in such a bad condition that major break downs may occur any time. Even break down on the smallest unit will lead to great inconvenience for the population.

With the desperate need for repair facilities in the Northern Area, it is recommended that the workshop is being constructed and put in operation the quickest way possible.

Construction in this area is normally terminated in wintertime. By extending the construction period to the whole year, a lot of time is gained.

To save planning and design time also, we have examined the foundation and arrangement drawings for the diesel plant building.

Our investigation confirm that the size is adequate, and only minor adjustments have to be done to satisfy workshop requirements. The workshop will be designed to service both mechanical and electrical needs. Tools and accessories will basically be as listed in Addendum 2 and under Item 1.3.3.

It is recommended that the workshop is developed gradually in 3 stages as far as capacity is concerned.

Total recommended local employment after implementation of each stage:

<table>
<thead>
<tr>
<th>Stage</th>
<th>Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20 people - of these 12 educated</td>
</tr>
<tr>
<td>2</td>
<td>39</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
</tr>
</tbody>
</table>

The importance of the training program for local employees can not be over-emphasized, and must be considered the key to succeed in having a selfsufficient unit after 3-4 years. It is anticipated 4-6 Norwegian teachers (on and off) over a period of 3 years.

As much as possible of the repair work to be done on the existing priority projects will be performed in the workshop as part of the training program.
The budget estimates after implementing stage 3 are roughly as follows:

**Investment**

- Workshop construction
  - Mechanical tools and stock hold equipment
  - Electrical tools and stock hold equipment
  - Contingencies

**Salaries and social welfare cost**

- Mechanical 2 Norwegians 3 years
- Electrical

**Travelling expenses and accommodation in Pakistan and Norway**

**Salaries for the Pakistan employees 3 years**

**Contingencies**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost (NOK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workshop construction</td>
<td>3,000,000</td>
</tr>
<tr>
<td>Mechanical tools and stock hold equipment</td>
<td>10,000,000</td>
</tr>
<tr>
<td>Electrical tools and stock hold equipment</td>
<td>4,000,000</td>
</tr>
<tr>
<td>Contingencies</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Mechanical 2 Norwegians 3 years</td>
<td>6,000,000</td>
</tr>
<tr>
<td>Electrical</td>
<td>6,000,000</td>
</tr>
<tr>
<td>Travelling expenses and accommodation in Pakistan and Norway</td>
<td>4,000,000</td>
</tr>
<tr>
<td>Salaries for the Pakistan employees 3 years</td>
<td>2,000,000</td>
</tr>
<tr>
<td>Contingencies</td>
<td>2,000,000</td>
</tr>
</tbody>
</table>
KARGAH POWERHOUSE, PHASE 5 - CONCLUSION

Mechanical:

The turbine equipment in Kargah, ph. 5 powerhouse, is in a condition where we from a technical point of view, would recommend a complete repair/upgrading process to start as soon as possible in order to avoid unscheduled shut-downs. The extent of work should in general follow the guidelines indicated in Addendum 1, General Upgrading Procedure.

The major portion of the repair work could probably be performed as part of the training process in the planned workshop in Gilgit. Major components, however, which have to be replaced, should be manufactured by experienced turbine suppliers. Output monitoring clearly indicate that both turbines are operated at low efficiency (full gate - 70 kW, Rated value - 100 kW). New efficient runners would increase production significantly. The following cost estimate is based on cost level in Norway, 1st quarter 1989.

A. Total costs for upgrading both turbines at Kargah, Ph. 5, not including new parts: NOK 0.5 mill.
B. Two new runners: NOK 0.5 mill.
C. Potential upgrading of appurtenant parts, such as main inlet valve, governor, etc. NOK 0.2 mill.

TOTAL BUDGET: NOK 1.2 mill.

Electrical:

The control- and switchboard have to be replaced by a new board.

The generators have to be dismantled and cleaned.

The bearings and brushes have to be replaced by new.

An air-cooling system is recommended to build on each generator.

The excitation systems have to be overhauled and reused.

The spare 400 kVA transformer must be overhauled and tested for reuse. All cables have to be replaced.

The following cost estimate is based on cost level in Norway.

Total cost (budget price) NOK 700.000,-
EXPANSION - KARGAH POWERHOUSE, PHASE 5B - CONCLUSION

Mechanical:

The construction of new feeder canals with higher capacity for Kargah, ph. 6 and 7 projects make an expansion of the Kargah, ph. 5 powerhouse very attractive from an economical point of view.
In principal, the existing powerhouse is extended to make room for one more unit of 1000 kW operating at a net head of 58 m.

Scope of Supply - Technical Data
- one (1) Horizontal Francis turbine, model FShzH595J
  \[ P_r = 1000 \text{ kW}, \ n_r = 750 \text{ rpm}, \ H_r = 58 \text{ m} \]
- one (1) Inlet valve
- one (1) Governor
- one (1) set of appurtenances and spares normally included in the supply.

Cost Estimates - Turbine Equipment
The total budget costs ex. works for Scope of Supply as listed above: NOK 4.0 mill.

Local Supply
At this stage it is anticipated that penstock, intake structure and major civil features are the responsibility of NAPWD.

Electrical:

In addition to upgrading of the old plant there should be built a new 1 MW power plant named Kargah, phase 5B equipped as follows:

Calculated production:
Turbine: Horizontal Francis
Guide vanes: adjustable
Runner blades: fixed
Turbine load: 1 020 kVA
Speed (synchronous): 750 rpm
Overspeed, on-cam: 1 560 rpm
Overspeed, off-cam: 1 560 rpm

The water is led towards the power plant through a channel into a forbay and from the forbay down to the power plant through a penstock.

The turbine output can be adjusted according to water flow. The plant is regulated to frequency.

CON5/224
Electrical

The plant should only be manually operated.

The plant can be started and run without an activated grid.

The following cost estimate is based on cost level in Norway.
Total cost (budget price) NOK 3,500,000,-
Mechanical:

The turbine in Hassanabad, Phase 1 Powerhouse is in very bad condition. A complete refurbishment of this turbine would be relatively expensive as many parts would have to be replaced.

What we would suggest as a solution for this powerhouse is to replace the existing turbine with one of the units, which will be redundant when the new powerhouses under construction in the Kargah system is commissioned. The turbine has to be identical to the existing Hassanabad, Phase 1 turbine. This turbine could undergo a complete refurbishing process at the workshop while the existing turbine is continuing operation. The complete turbine unit could then be replaced.

Compared to a normal upgrading schedule, this procedure would cut the power station down time to a minimum, provided that vitale parts do not require replacement.

In this area (Hunza), where the need for electricity is enormous, short down time is essential and will reduce the inconvenience for the consumer.

The repair procedure and budget cost for one of the redundant Kargah units would be quite similar to what is previously described for Kargah, Phase 5 Powerhouse.

Total budget: NOK 0.6 mill.

Electrical:

The control- and switchboard have to be replaced by a new board.

The generator has to be dismantled and cleaned. The bearings and brushes have to be replaced by new.

The excitation system at the end of the generator has to be overhauled and reused.

The main transformer has to be overhauled, tested and reused.

The same procedure should be applied to the small distribution transformer.

All cables have to be replaced.

The following cost estimate is based on cost level in Norway.

Total cost (budget price): NOK 550,000,-
Mechanical:

The sand content in the water to this powerhouse is considerable. This is the major reason why the two existing cross-flow turbines frequently have to be repaired. This is not acceptable to NAPWD from an economical and operational point of view.

To remedy this situation we propose as follows:

A. Reconstruction of sand traps to a better design for increasing efficiency, and to the highest capacity which is acceptable from an economical point of view.

B. The two cross-flow units are replaced with one new horizontal Francis unit. Approximate design data according to the latest information provided by NAPWD should be:

- Static head: 440 ft (134 m)
- Rated flow: 32 cfs (0.9 m³/s)

The two cross-flow units could be refurbished and utilized at a new convenient site, where the water quality is much better. Under such conditions these units may operate satisfactorily.

C. We believe that a Francis turbine is likely to last much longer than the existing cross-flow turbines for the following reasons:

- The cross-flow turbines are operating in the upper head range of this turbine type. Hence, the water velocities in the turbine is relatively high.

- The proposed Francis turbine is a design which is used up to about 400 m of head. At this head of 134 m the velocities in the turbine is substantially lower than in the existing cross-flow turbines.

- Lower silt content after improvements of the silt excluders at the headworks and with the construction of new forebay.

D. The new design data would require a new and longer penstock to be installed.

E. The intake structure must be reconstructed at a higher elevation to a design and capacity which is favourable for silt exclusion.
Scope of Supply - Technical Data:
- One (1) Horizontal Francis turbin, model FShzH370E
  \( P_r = 1000 \text{ kW}, n_r = 1000 \text{ rpm}, H_r = 130 \text{ m} \)
- One (1) Inlet valve
- One (1) Governor
- One (1) set of appurtenances and spares normally included in the supply.

Cost Estimates - Turbine Equipment:
Total budget costs ex. works for Scope of Supply as listed above: NOK 4.0 mill.

Local Supply:
Powerhouse, penstock, hydraulic steel works and major civil features are anticipated to be supplied by local companies.

Electrical:
All electrical equipment is brand new and works perfectly.

The problem is associated with the turbine. It was decided that the existing two units have to be dismantled and replaced by a new unit of 1 MW kW.

The following cost estimate is based on cost level in Norway.
Total cost (budget price) NOK 3,500,000,-
SKARDO POWERHOUSE, PHASE 1 - CONCLUSION

Mechanical:

Although the turbines are generally worn and need an upgrading, they are in relatively good condition considering the time they have been in operation (commissioned 1972). Compared to the Kargah and Hassanabad powerhouses, the water quality is much better and the silt content is minor. The output readings indicate, however, that an appreciable reduction in efficiency has occurred since 1972. At a certain gate opening the output was 180 kW in 1973. The corresponding output today is 140 kW. If these units shall be in operation in the foreseeable future, a complete refurbishment of mechanical equipment would be required in order to avoid unscheduled shut-downs. Such a refurbishment process could in general be accomplished along the guidelines listed in Addendum 1, and as described for Kargah, Phase 5 Powerhouse.

The estimated costs would be equivalent to the estimation given for Kargah, Phase 5.

A. Total costs for complete upgrading of both turbines, not including new parts: NOK 0.5 mill.
B. Two new runners: NOK 0.5 mill.
C. Potential upgrading of inlet valve, governor etc.: NOK 0.2 mill.

Total budget: NOK 1.2 mill.

Electrical:

The control- and switchboard have to be replaced with a new board.

The two generators must be dismantled and cleaned. Bearings and brushes have to be replaced by new ones.

The excitation system at the end of each generator has to be overhauled and reused.

The two main transformers have to be dismantled and replaced by new.

The oil circuit-breaker on 11 kV should be replaced by high voltage fuses.

The following cost estimate is based on cost level in Norway.

Total cost (budget price) NOK 1.000.000,-
Alternative Installation:

Mechanical:

Upstream of Skardu Phase 1 Powerhouse, Shardu Phase 2 is located. This powerhouse has recently been extended by two extra units. As these two power stations utilize basically the same water, extra water is now easy available for increasing installation in the Phase 1 Powerhouse also.

NAPWD has already conducted initial investigation to survey the potential. These plans include a new short feeder canal from the Phase 2 tailwater to a new intake structure, and two new penstocks down to the existing powerhouse where two (2) new units are installed.

Design data for this new installation are estimated to be:

- Static head : 82 m
- Design flow (total): 2 m³/s

NAPWD prefer to have two units installed to ensure reliable electricity supply.

Equipment data:

- Two (2) Horizontal Francis turbines, model FShzH430G
  \( P_r=670 \text{ kW}, n_r=1000 \text{ rpm}, H_r=76 \text{ m} \)

- Two (2) Inlet valves

- Two (2) Governors

- Two (2) sets of appurtenant equipment and spares normally included in the supply.

Cost Estimates:

The total budget costs ex. works for equipment supply as listed above: NOK 6.0 mill.

Local Supply:

It is anticipated that penstock, intake structure and major civil features are the responsibility of NAPWD.

Electrical:

- Two new generators of 670 kW with control boards, switch equipment and main transformer.

The following cost estimate is based on cost level in Norway.

Total cost (budget price): NOK 5.5 mill.
1. WORKSHOP

1.1 Background Information

In October 1988 Norad had a mission to Pakistan for closer investigation of specifically mentioned projects (ref. report no. 4-88).

One thing which became evident to the mission was the complete lack of adequate workshop facilities in the Northern Area.

Even the simple type of repairs on turbines and generators have to be sent to Lahore.

This is to great inconvenience to both the power producer and the user, as down time is considerable and costs relatively high.

The mission proposed a workshop to be established in Gilgit to cover the needs for maintenance services to the power stations in the Northern Area.

This was also emphasized in the agreed minutes from the annual meeting between Pakistan and Norway in December 1988.

1.2 Objectives

The workshop should first of all have the ability of assisting the power stations in the Northern Area with repairs and skilled personnel assistance in order to keep the power stations running.

Secondly, it should be equipped with a minimum of tools, machinery, material stock and skilled operators to enable the workshop to perform a general upgrading of a Drees/PECO turbine as described in Addendum 1.

Production of new equipment should not be a priority.

However, during a normal upgrading process, there will always be need for making new parts to replace completely worn out parts. This will be a normal service for the workshop to provide, except some complicated parts, such as turbine runner, governor etc. which have to be purchased from experienced manufacturers.

1.3 Planning and Construction - Recommendation

1.3.1 Civil

The construction of the workshop building will be undertaken by local contractors under supervision of NAPWD (or Kvaerner Brug A/S).

The final responsibility shall be defined before the detailed planning process starts.
In reference to the meeting with NAPWD on February 5th, 1989, see Addendum 1, Minutes of Meeting, there is a good chance the workshop design could be identical to the building for the 3 MW diesel power plant recently constructed in Gilgit.

Preliminary examination of the foundation and arrangement drawings for the diesel plant confirm the building's suitability regarding physical size and lay-out.

Enclosed drawing no. 378408 is a preliminary lay-out drawing developed on the basis of the diesel plant drawings.

The floor space seems to be adequate for the capacity level planned for stage 1. However, before construction starts, the building floor space must be thoroughly evaluated with stage 2 and 3 in mind.

The complete set of construction drawings for the diesel plant must be accurately examined and adjusted where necessary.

Emphasis must be given to foundations for tool machines and overhead travelling crane.

The construction phase for a building of this size and category will according to NAPWD normally stretch over a period of 12-18 months.

By using modern technology and construction means, if this is appropriate, the construction period could be reduced substantially.

There are two major things which to a great degree will influence the date of operation for the workshop:

1. Utilizing existing construction drawings for the diesel plant to reduce design/planning time.
2. Provide the required material and equipment for using modern construction methods.

Recommendation

With the desperate need for repair facilities in the Northern Area, it is recommended that the workshop is being constructed and put in operation the quickest way possible.

A major portion of the power plants requiring assistance from the workshop is in such a bad condition that major breakdowns may occur any time. Even break down on the smallest unit will lead to great inconvenience for the population.

Construction in this area is normally terminated in wintertime. By extending the construction period to the whole year, a lot of time is gained.
1.3.2 Mechanical

In reference to the meeting held with NAPWD February 5th, 1989, the workshop should generally be equipped as listed in Addendum 2, List of Tools. This is when the workshop is operating at the intended full capacity level, i.e. after implementing Stage 3.

At Stage 1, initial start up, the List of Tools are not quite so comprehensive.

However, to assure that the workshop will have the ability to perform the required repairs and to serve the area as intended, a minimum of different machines and tools must be present.

Even the omission of minor things may have serious consequences and call the whole repair process to halt.

In other words, the workshop must have a repair/production line which in all aspects is equipped for a complete turbine upgrading process.

The capacity is more a function of employment and it is proposed to build it up in 3 stages, see item 1.4, Future Expansion.

Stage 1 is the minimum of what is considered necessary to suffice the immediate needs for assistance in the area.

The final selection of equipment is essential and will be given preference during the detailing face.

1.3.3 Electrical

The aim of the electrical workshop is to train Pakistan people to perform repair works, maintenance and small upgrading of existing and new small power plants in the Gilgit area. The workshop building should consist of an electrical area of about 100 sq.m. and an office area of 30 sq.m.

The electrical workshop should be equipped with:

Tools:
- Working desk
- Storage rack
- Small vertical boring machine
- Small welding transformer
- Saw machine with table
- 3 pcs Mitsubishi 4 WD Jeep Pajero
- 350 kVA mobile diesel-generator set
- EB Energi AS equipment list for a site workshop

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1.3.3
Cont.:  

Test equipment
- Primary injection current tester
- Secondary injection current tester
- High voltage tester 70 kV
- Oil tester 60 kV
- Frame oil filter
- High voltage phase tester
- Power indicator
- Test instrument (EB Energi AS equipment list for test engineers)
- Hand tools

Mounting equipment
- EB Energi AS equipment list for a site workshop

Store equipment
- Cable
- Copper busbar
- EB Energi AS equipment lists for a site workshop

Electrical Employees

We have emphasized the need to build up two trouble shooting groups, which should be trained in repair works, maintenance and upgrading of existing and new small power plants.

Each group should consist of the following Pakistani personnel:

- One Electrical Engineer 13 years education
- One Electrician (High voltage) 10 years education
- One Unskilled

From Norway we have planned to have:

- One Electrical Engineer 12 years education
- One Electrician (High voltage) 14 years education
1.3.4 Management

The workshop should have one leader, an Executive Engineer (EE) reporting directly to the Chief Engineer's Office in NAPWD.

The EE should be a graduate Mechanical/Electrical Engineer with a minimum of 10 years experience from small hydro operation and/or experience from an administrative position in Mechanical/Electrical workshop.

The EE should have a young Mechanical/Electrical graduate Engineer as his assistant (AEE).

To manage the budget and the cash-flow in the workshop an accountant would be required. The accountant should work closely with the EE and report periodically to the implementry agency which will report further to NORAD/ NAPWD.

It is also necessary to have the following service staff:

- 1 head clerk
- 2 upper division clerk
- 2 lower division clerks
- 2 guards
- 2 drivers
- 2 peons
- 2 sweepers

It is recommended that the administration and service staff are built up in three stages:

First stage: 1 Executive Engineer
1 Accountant
1 Head clerk
2 Guards
2 Sweepers
Total: 7 people

Second stage: Add: 1 Assistant Executive Engineer
1 Upper division clerk
1 Lower division clerk
1 Driver
1 Peon
Total: 16 people
The Executive Engineer and the Accountant should come to Norway, and together with the financing personnel in EB Energi AS, work out a 5 years budget and make a plan for the cash-flow from NORAD and NAPWD to the workshop. In the plan they have to establish for a self-financing system for the workshop after 3 years.

### 1.3.5 Cost estimate

<table>
<thead>
<tr>
<th>Investment</th>
<th>Cost (NOK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workshop construction</td>
<td>3,000,000,-</td>
</tr>
<tr>
<td>Mechanical tools and stock hold</td>
<td>10,000,000,-</td>
</tr>
<tr>
<td>equipment</td>
<td></td>
</tr>
<tr>
<td>Electrical tools and stock hold</td>
<td>4,000,000,-</td>
</tr>
<tr>
<td>equipment</td>
<td></td>
</tr>
<tr>
<td>Contingencies</td>
<td>1,000,000,-</td>
</tr>
</tbody>
</table>

### Salaries and social welfare cost

| Mechanical 2 Norwegians 3 years     | 6,000,000,-  |
| Electrical "                       | 6,000,000,-  |

### Travelling expenses and accommodation in Pakistan and Norway

| NOK 4,000,000,- |

### Salaries for the Pakistan employees 3 years

| NOK 2,000,000,- |

### Contingencies

| NOK 2,000,000,- |
1.4 Future Expansion

General

The workshop is recommended to be developed gradually in three (3) different stages where Stage 1 is the minimum initial involvement, but yet a complete operating unit, and Stage 2 and 3 are expansions if the experience with previous stages is favourable.

The time between each stage depends on how the workshop is developing, but 2-3 years seem reasonable.

The progress schedule will also be affected by the training program, and the starting skills and experience of the workforce.

For total employment, see Addendum 1, Minutes of Meeting.

1.4.1 Mechanical

The build up of employees over the three stages is recommended as follows:

Number of skilled workers:

<table>
<thead>
<tr>
<th>Category</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreman</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welding</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Machining</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Miscellaneous (sand blasting, painting, NDT, etc.)</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>TOTAL (after each expansion)</td>
<td>7</td>
<td>11</td>
<td>14</td>
</tr>
</tbody>
</table>

In addition to the skilled workforce comes the increase in administration and service staff.

For Stage 1 and partly Stage 2, the training personnel from Norway is additional and will count 2-3 people.
1.4.2 Electrical

We have decided to establish the workshop staff in three stages:

First stage: 2 Trouble shooting groups
2 Norwegians
Total 8 people

Second stage: Add 2 Trouble shooting groups
Total 14 people

Third stage: Add 2 trouble shooting groups
2 Rewinders
Total 22 people
1.5 Training of Personnel

1.5.1 Mechanical

The training of the native personnel to employ the workshop should be carried out in two phases— one theoretical and one practical. Although some of the training are executed in Norway, the major portion will take place at the workshop in Pakistan.

Training in Norway

The training should start in Norway, preferably simultaneously to the construction start of the workshop. It is assumed that two (or three) mechanical engineers, i.e. the Executive Engineer or his assistant, the mechanical foreman, and possibly one of the machine operators, should go to Norway for training at the manufacturers facilities for a period of 3-6 months.

The main topics during this training period in Norway should be:

- Theoretical classes in basic design for hydraulic equipment (turbine, governor, valve etc.)
- Workshop manufacturing processes and planning.
- Systematic maintenance planning.
- Upgrading of turbine equipment covering both engineering and manufacturing.
- Dismantling/erection of powerhouse equipment in the field.

The Norwegians allocated to the project and the training program in Norway should preferably be the same persons which later would be responsible for the training in Pakistan.

Training in Pakistan

The extent training period in Pakistan depends on what level of education and skills the workforce is in possession of.

From the initial information it is realistic to anticipate a training period of 2-3 years. It will be necessary with 2 full time mechanical engineers/teachers, one in administration and one in the workshop. In addition there might be need for specialists from time to time.
1.5.1 Cont.

Same of the topics the training program in Pakistan would cover are as follows:

- Hydraulic equipment theoretical education (basics only).
- Administration.
- Drawing, standards etc.
- Systematic maintenance.
- Workshop practical training of:
  - welders, mild steel and stainless steel
  - machine operators
  - stock administration
  - miscellaneous

Detailed program must be developed before training starts.

1.5.2 Electrical

The first stage in the plan should be to take two Electrical Engineers from Pakistan and start training in Norway.

The training group in Norway should consist of:

- Two Electrical Engineers from Pakistan
- One Electrical Engineer from Norway
- One Electrician (High-voltage) from Norway

This group should begin by visiting some small power plants in Norway, and if possible, work two weeks together with a test- and erection team on a power plant.

The second stage should be to start detailed engineering and ordering of equipment for the workshop, Kargah phase 5, Hassanabad phase 1 and Skardu phase 1. As much as possible of the equipment should be ordered from Pakistani companies like Climax and FICO.

The third stage should be to start the detailed engineering and ordering of equipment for Kargah phase 5B and Hassanabad phase 2.

When all the engineering work is finished in Norway, the whole group (4 people) will travel to Gilgit in Pakistan to build up the organisation for the workshop and go on with the repair/upgrading work for power stations.

The electrician from Norway should initially be the foreman in the el.workshop. After about 2 years the best Pakistan Engineer in the trouble shooting groups should take over as foreman.

P6.4/224
2. EXISTING POWERPLANTS - SUMMARY AND RECOMMENDATION

2.1 KARGAH POWERHOUSE, PHASE 5

2.1.1 Conclusion

Mechanical:

The turbine equipment in Kargah, ph. 5 powerhouse, is in a condition where we from a technical point of view, would recommend a complete repair/upgrading process to start as soon as possible in order to avoid unscheduled shut-downs. The extent of work should in general follow the guidelines indicated in Addendum 1, General Upgrading Procedure.

The major portion of the repair work could probably be performed as part of the training process in the planned workshop in Gilgit. Major components, however, which have to be replaced, should be manufactured by experienced turbine suppliers. Output monitoring clearly indicate that both turbines are operated at low efficiency (full gate - 70 kW. Rated value - 100 kW). New efficient runners would increase production significantly.

The following cost estimate is based on cost level in Norway, 1st quarter 1989.

A. Total costs for upgrading both turbines at Kargah, Ph. 5, not including new parts: NOK 0.5 mill.

B. Two new runners: NOK 0.5 mill.

C. Potential upgrading of appurtenant parts, such as main inlet valve, governor, etc. NOK 0.2 mill.

TOTAL BUDGET: NOK 1.2 mill.

Electrical:

The control- and switchboard have to be replaced by a new board.

The generators have to be dismantled and cleaned. The bearings and brushes have to be replaced by new.

An air-cooling system is recommended to build on each generator.

The excitation systems have to be overhauled and reused.

The spare 400 kVA transformer must be overhauled and tested for reuse. All cables have to be replaced.

In addition to the old plant a new 1 MW power plant should be built, named Kargah phase 5B. The following cost estimate is based on cost level in Norway.

Total cost (budget price) NOK 700,000,-
2.1.2 Inspection of existing mechanical equipment, February 10, 1989.

DATA:

Type and number: Two (2) identical horizontal Francis turbines
Rated output (kW): 100
" speed (r.p.m.): 1500
" head (m): 43
" flow (m³/s): 0.28 (each)
Runner discharge diameter: 305
Number of runner vanes: 15
Number of guide vanes: 10
Guide vane height, Bo (mm): 85
Inlet valve size (mm): VAG, DN300 PN10
Governor, mechanical/hydraulic: Drees, type 100 kW, belt driven
Manufacturer: Drees/PECO
Years of installation: Commissioned 1984

OBSERVATIONS

Unit in operation:

At arrival in the powerhouse, both units were being operated at about 80% gate opening. Corresponding output readings on the panelboard showed about 60 kW.
In wintertime, this is the upper limit for output in order to avoid overheating in the generator windings.
During summertime, the output has to be limited to 50 kW for the same reason.

For a short period of time, and for testing purposes only, the units were operated at full load, i.e. 100% gate opening.

The maximum output reading on the panel board was 70 kW each.

The unit output was then reduced to the corresponding 80% gate opening. In general, the turbine operated without significant noise or vibration. Some cavitation could be observed in the draft tube, but not to a degree which should cause any damage to the turbine runner or inlet bend section.

Wicket gate operating system:

Guide vanes, linkages and regulating ring are grease lubricated. There are leakage through the gaskets around some of the guide vane stems on the head cover. The guide vane stems are not going through the discharge ring, hence there is no leakage at this end of the turbine.

The bushings in the connection between guide vane arms and regulating ring is quite worn and the head cover is furnished with a Ø75 pressure relief pipe drained to atmosphere in order to prevent overpressure between head cover and runner.

Clearances in all bushings are too large.
2.1.2
Cont.:

**Shaft sealing box:** Great leakage. Drain pipe at it's capacity limit. No serious leakage around turbine shaft towards the bearing.

**Turbine shaft:** Visible part of the shaft is in relatively good condition. Some surface corrosion, mainly in the area close to the shaft sealing box.

**Turbine bearing:** The turbine bearing is a sleeve bearing with forced lubrication (shaft driven pump) and water cooling. The cooling water is fed from the spiral casing and goes through a strainer. The readings of bearing temperature is not reliable, but it seems reasonable. No serious problems have been experienced.

**Unit shut down:**

Turbine 1 (closest to the door) was shut down for closer inspection. Stopping time from rated speed, 1500 r.p.m., to standstill was about 6 min. The unit has a total of 3 bearings, 1 on the turbine and 2 in the generator.

The draft tube bend and discharge ring were dismantled.

**Runner:** The runner is of stainless steel material. No sign of damaging cavitation on runner vanes, but the complete runner clearly shows that is has been exposed to sand abrasion. On sealing surface towards the discharge ring a 1 mm deep groove has eroded. The runner has not replaceable seal ring.

**Discharge ring:** The discharge ring is of cast steel and is in fairly good condition. No areas of deep erosion. The facing surface is rusty and sand eroded, particularly around the guide vane profile and between guide vanes and runner. The bronze bushings for guide vanes are seriously worn and have suffered from lack of lubrication and sand exposure. The guide vane stem is not through-going, so there is no leakage problem because of the wear. The sealing surface towards the runner is integral with the discharge ring (not replaceable), and it is sand eroded. The clearance between runner and discharge is totally about 2-2.5 mm.
2.1.2
Cont.:

Guide vanes: The guide vanes are of cast steel and generally worn and rusty, but not to a great degree.

Draft tube: The draft tube bend and cone are in relatively good condition, even if the bend shows some wear from sand erosion.

GENERAL

Only unit 1 was dismantled for inspection. However, from information given by the operation staff and from what could be seen, unit 2 is in about the same condition as unit 1. No periodical maintenance is being performed, and the wear and tear on the equipment is increasing at an accelerating rate. Surface treatment is insufficient. Painting is peeling off, leaving the surface bare resulting in immediate corrosion attach. Inside the turbine there is little sign of painting or any surface protection.

The problems are dealt with in the order they occur. Leakage problems are very often dealt with by diverting the water away from bearings etc., and not by solving the problems permanently.

The major problem is that spares and funds for maintenance are very limited.

2.1.3 Inspection of existing electrical equipment

The powerstation includes two generator units of 125 kVA each. It was built in 1976.

DATA

Generator 2

Three-phase synchronous generator

<table>
<thead>
<tr>
<th>Manufacture</th>
<th>Siemens Pakistan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>IFA4 286-4</td>
</tr>
<tr>
<td>Rated power</td>
<td>125 kVA</td>
</tr>
<tr>
<td>Rated voltage</td>
<td>440 V AC</td>
</tr>
<tr>
<td>Rated amp.</td>
<td>164 A</td>
</tr>
<tr>
<td>Frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Power factor</td>
<td>0.8</td>
</tr>
<tr>
<td>Rated speed</td>
<td>1500 rpm</td>
</tr>
<tr>
<td>Insulation class</td>
<td>B</td>
</tr>
<tr>
<td>Enclosure</td>
<td>IP 23</td>
</tr>
</tbody>
</table>
2.1.3
Cont.

Exciter 2

Excitation : DC
Rated max voltage : 98V
Rated max current : 35.9 A

Main transformer 1

Three-phase oil insulated transformer for out-door installation.

Manufacture : Climax Pakistan
Rated power : 200 kVA
No load ratio : 11000/415 V + -
Vector group : YD 11

Spare Main transformer 1

Three-phase oil insulated transformer for out-door installation.

Manufacture : Climax Pakistan
Rated power : 400 kVA
No load ratio : 11000/415 V + -
Vector group : YD 11

There is grounds for presuming that this transformer is defect.

Disconnector 1

Three single-pole fuse switch disconnector

Manufacture : FICO Pakistan
Rated voltage : 11 kV
Rated current : up to 100 A
Operated by : Hand

Spare 11 kV metal-clad in-door switchgear 1

The cubicles are equipped with:

Circuit breaker : Oil
Operated by : Hand
Trip coils :
2.1.3
Cont.:

Over-current relay : made in UK 2,5 - 10A
A-meter : 50/5 A
V-meter : 11000 / 110 V

There are grounds for presuming that this switchgear is defect.

Control cubicles 3 panels
------------------------

Steel enclosed panel consisting of 3 cubicles and equipped for:
- switching
- measuring
- protection
- control

Circuit breaker 2
-------------------

Manufacture : Siemens
Type : 3 VBZ
Rated voltage : 500 V
Rated current : 250 A
Breaking capacity : 20 kA
Over current relay : 3VX3X 200
Over current : 140 - 200 A
Short circuit current : 20000 A

Instrument for each generator
-----------------------------

Voltmeter with selector switch
Amperemeter 3
Frequency-meter 1
kW-meter

Synchronizing
-------------

Double voltmeter
Double frequency meter
Synchronoscope

KA3.2/223
2.1.3 Cont.:

Disconnector low voltage

Manufacture : 
Rated voltage : 
Rated current : 
Operated by : 

All electrical equipments are in bad condition. The control- and switchboard have to be replaced by a new one. The excitation system for each generator has to be dismantled, overhauled and reused. Some of the other equipment in the old board could be used as spare parts in the workshop.

Upgrading recommendation:

Generator 2

The three-phase synchronous generator, has to be dismantled and cleaned. Bearings and brushes have to be replaced by new.

Each generator requires also an air-cooling system. All this work should be done in the workshop.

Excitation system

The excitation system should be overhauled in the new workshop.

Speed supervision

Initiator for speed control (mounted within the stator house)

The initiators are used for:
1 Runaway speed control
2 Speed supervision

Temperature supervision

PT 100 detectors for temperature in stator winding.
PT 100 detectors for bearing temperature
2.1.3 Cont.:

Main transformer

The three-phase oil insulated transformer for outdoor installation should be overhauled and reused.

Rated power : 400 kVA
No load ratio : 415/11 000 V + -
Rated frequency : 50 Hz
Standard : IEC 76

11 kV outdoor switch disconnector

Triple-pole switch disconnector

Rated voltage : 12 kV
Rated current : up to 100 A
Operated by : Hand

Control cubicles

Steel enclosed panel, in modular design, consisting of 2 cubicles and containing equipment for:

- switching
- measuring
- protection
- control
- alarm

Circuit breaker, 500 V, withdrawable

Rated current : 250 A
Breaking capacity :
Making capacity :
Total break-line : 30-40 ms
Zero-voltage/under voltage coil : 110 V, 50 Hz
2.1 3
Cont.:

Instruments
----------

Voltmeter with selector switch
Amperemeter with selector switch
W-meter
VAr-meter
kWh-counter
Hour-counter
Rpm-counter
Water level meter

Meter for load limiter position
Voltmeter for station supply

Converters with 0-20 mA output are used for W-meter and VAr-meter

Synchronizing
-----------

Double voltmeter
Double frequency meter
Synchronoscope

Relays
-------

Generator
--------

Definite time voltage relay

Rated voltage : 110 V
Setting range : 100-160 V
Time delay : 0,2-10 s

3-phase thermo-adjustable release
(included in circuit breaker)

KA3.5/224
2.1.3
Cont.:

Stator earth-fault relay

Rated voltage : 110 V ac
Setting range : 0,05-0,25 x Un
Time delay : 0,1-1 s

Overspeed relay

Reverse power relay

Rated current : 5 A ac
Rated voltage : 110 V ac

Limit setting relay

Isolation control relay

Station supply

The equipment for the station supply comprises:

230/400 V AC Distribution

Load-break switch, with fuses : 3 x 80 A
(For feeder cable)
Load-break switch with fuses : 3 x 63 A
(For light, etc.)
Miniature circuit breaker, 3x16 A
Miniature circuit breaker, 2x16 A

Current transformer

Current transformer, 200/5 A (400 V)
2.1.3 Cont.: Voltage transformer for control/protection

-------------------------

3-phase voltage transformer

Load : 50 VA cl. 1,0
Ratio: 400/110 V

Mimic diagram

-------------------

Mimic diagram with symbols, switches and position indicators.

Equipment not specified, but essential in a complete control system:

Auxiliary relay
Time relay
Terminals
Labels
Cable channels
Wiring
Miniature breakers, etc.

Temperature control

---------------------

Electronic monitoring unit with digital display and alarm contacts for measuring temperatures on the generator and transformers.

Measuring points (PT 100 sensors): 6

Electronic Alarm System

------------------------

consisting of:

Alphanumeric display indicator
Alphanumeric recorder
Number of alarms for the generating unit : 32

KA3.7/224
2.1.4 Expansion

Mechanical:

The construction of new feeder canals with higher capacity for Kargah, ph. 6 and 7 projects make an expansion of the Kargah, ph. 5 powerhouse very attractive from an economical point of view.

In principal, the existing powerhouse is extended to make room for one more unit of 1000 kW operating at a net head of 58 m.

Scope of Supply - Technical Data

- one (1) Horizontal Francis turbine, model FShzH595J
  \[ P_r = 1000 \text{ kW}, \ n_r = 750 \text{ rpm}, \ H_r = 58 \text{ m}\]
- one (1) Inlet valve
- one (1) Governor
- one (1) set of appurtenances and spares normally included in the supply.

Cost Estimates - Turbine Equipment

The total budget costs ex. works for Scope of Supply as listed above: NOK 4.0 mil.

Local Supply

At this stage it is anticipated that penstock, intake structure and major civil features are the responsibility of NAPWD.

Electrical:

In addition to upgrading of the old plant there should be built a new 1 MW power plant named Kargah, phase 5B equipped as follows:

<table>
<thead>
<tr>
<th>Calculated production :</th>
<th>Horizontal Francis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine</td>
<td>adjustable</td>
</tr>
<tr>
<td>Runner blades</td>
<td>fixed</td>
</tr>
<tr>
<td>Turbine load</td>
<td>1 020 kVA</td>
</tr>
<tr>
<td>Speed (synchronous)</td>
<td>750 rpm</td>
</tr>
<tr>
<td>Overspeed, on-cam</td>
<td>1 560 rpm</td>
</tr>
<tr>
<td>Overspeed, off-cam</td>
<td>1 560 rpm</td>
</tr>
</tbody>
</table>

The water is led towards the power plant through a channel into a forbay and from the forbay down to the power plant through a penstock.

The turbine output can be adjusted according to water flow. The plant is regulated to frequency.
2.1.4 - Electrical
Cont.

The plant should only be manually operated.

The plant can be started and run without an activated grid.

The following cost estimate is based on cost level in Norway.

Total cost (budget price) NOK 3,500,000,-

DATA

Generator

---

Three-phase synchronous generator, brushless design, with built-on exciter, rotating diodes, automatic voltage regulator and damper winding.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power</td>
<td>1 250 kVA</td>
</tr>
<tr>
<td>Rated voltage</td>
<td>440 V ac</td>
</tr>
<tr>
<td>Frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Power factor</td>
<td>0.8</td>
</tr>
<tr>
<td>Rated speed</td>
<td>750 rpm</td>
</tr>
<tr>
<td>Runaway speed, transient</td>
<td>1 560 rpm</td>
</tr>
<tr>
<td>Moment of inertia WR²</td>
<td>225 kgm²</td>
</tr>
<tr>
<td>Insulation</td>
<td>Micadur compact</td>
</tr>
<tr>
<td>Insulation class</td>
<td>F</td>
</tr>
<tr>
<td>Utilization class</td>
<td>B</td>
</tr>
<tr>
<td>Standards</td>
<td>IEC 34-1</td>
</tr>
<tr>
<td>Duty</td>
<td>Continuous</td>
</tr>
<tr>
<td>Enclosure</td>
<td>IP 23</td>
</tr>
<tr>
<td>Design</td>
<td>IM 1001</td>
</tr>
<tr>
<td>Terminal box</td>
<td>Upon request, can be mounted on either side of generator.</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>40°C</td>
</tr>
<tr>
<td>Max altitude above sea level</td>
<td>3000 m</td>
</tr>
<tr>
<td>Direction of rotation</td>
<td>To be determined by the turbine manufacturer.</td>
</tr>
<tr>
<td>Ventilation</td>
<td>Self ventilated</td>
</tr>
<tr>
<td>Cooling</td>
<td>IC Q1, Fresh air</td>
</tr>
<tr>
<td>Cooling air volume</td>
<td>3 m³/sec.</td>
</tr>
</tbody>
</table>

KA5.1/223
Exciter for Brushless Generator

The excitation system consists of a rotating exciter, mounted on the shaft inside the stator housing and an electronic voltage regulator, fitted to the generator top. The exciter feeds a rotating rectifier bridge.

Exciter data:

| Load | 42 kV          |
| Rated voltage | 60 V          |
| Rated current | 408 A         |
| Cos Ø | 0.96          |
| No. of poles | 16            |
| Frequency | 100 Hz        |
| Field current | 6.5 A        |
| Field resistance at 20°C | class F |
| Insulation | class B |

Rotating diode bridge mounted on generator shaft

| No. of diodes | 6 |
| Type | SW06RPN 935 |
| Diode protection | NL232831 |

Thyristor Voltage Regulator

Electronic voltage regulator for brushless generator.

| Input voltage | 400 V ac |
| Output voltage | 190 V max |
| Output current, continuously | 9 A |
| Output current, <2 min. | 16 A |
| Compounding current, short circuited | 25 A <2 s |
| Voltage adjustment range, t = 55 deg C | ±1.5 % |
| Regulation accuracy | < 15 ms |
| Paralleling voltage drop, cos Ø > 0.85 | 0-2 % adjustable |
| Response time | <15 ms |
| Frequency dep. voltage regulation | U = const for f>90 % |
| | U/f = const for f<90 % |
| Automatic voltage build-up | From the generators residual voltage |
| Recovery time Tr | <0.4 s |
| Ambient temperature | 55°C |
| Heat loss | 100 W |
Speed supervision

Initiator for speed control
mounted within the stator house)

The initiators are used for:
1 Runaway speed control
2 Speed supervision

Temperature supervision

PT 100 detectors for temperature in stator winding.
PT 100 detectors as full spare
PT 100 detectors for bearing temperature

Current and voltage transformers for excitation,
mounted on generator

Current transformer for regulation and compounding no-load side.

Ratio (with 6 sec. steps) : 1 600/5 A

Current transformer for quadr. drop adjusting no-load side

Ratio : 1 600/0,4 A

Main transformer

Three-phase oil insulated transformer for outdoor installation.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power</td>
<td>1 250 kVA</td>
</tr>
<tr>
<td>No load ratio</td>
<td>400/11 000 V ±2x2,5</td>
</tr>
<tr>
<td>Cooling</td>
<td>ONAN</td>
</tr>
<tr>
<td>Vector group</td>
<td>YNd11</td>
</tr>
<tr>
<td>Rated frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Standards</td>
<td>IEC 76</td>
</tr>
<tr>
<td>Total weight</td>
<td>4 850 kg</td>
</tr>
<tr>
<td>Oil weight</td>
<td>1 140 kg</td>
</tr>
<tr>
<td>Height</td>
<td>2 340 mm</td>
</tr>
<tr>
<td>Width</td>
<td>1 500 mm</td>
</tr>
<tr>
<td>Length</td>
<td>2 350 mm</td>
</tr>
</tbody>
</table>

Surge arrester, connected at high voltage neutral.
2.1.4
Cont.:

12 kV Outdoor switch disconnector

----------------------------------

Triple-pole switch disconnector

Rated voltage: 12 kV
Rated insulation level: 75/35 kV
Rated current: 630 A

Operated by
with built on fuses: Hand
Rated current: 63 A

Control cubicles

---------------

Steel enclosed panel, in modular design, consisting of
2 cubicles and containing equipment for:
- switching
- measuring
- protection
- control
- alarm

Circuit breaker, 500 V, withdrawable

Rated current: 1 600 A
Breaking capacity: 45 kA
Making capacity: 95 kA
Total break-line: 30-40 ms
Zero-voltage/under voltage coil: 110 V, 50 Hz

Instruments

Voltmeter with selector switch
Amperemeter with selector switch
W-meter
VAR-meter
kWh-meter
Hour-counter
Rpm-counter
Water level meter
Meter for load limiter position
Voltmeter for station supply

Converters with 0-20 mA output are used for W-meter and
VAR-meter

KA5.4/223
<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synchronizing</td>
<td></td>
<td>Double voltmeter, Double frequency meter, Synchronoscope</td>
</tr>
<tr>
<td>Definite time voltage relay</td>
<td>110 V</td>
<td>Stator earth-fault relay</td>
</tr>
<tr>
<td>Generator</td>
<td></td>
<td>3-phase thermo-adjustable release (included in circuit breaker)</td>
</tr>
<tr>
<td>Stator earth-fault relay</td>
<td>110 V</td>
<td>Overspeed relay</td>
</tr>
<tr>
<td>Reverse power relay</td>
<td>3 x 63 A</td>
<td>Limit setting relay</td>
</tr>
<tr>
<td>Rated voltage, Rated current</td>
<td>5 A</td>
<td>Overload control relay</td>
</tr>
<tr>
<td>Miniature circuit breaker, 2x16 A</td>
<td>3 x 80 A</td>
<td>3 x 63 A</td>
</tr>
<tr>
<td>Load-break switch, with fuses</td>
<td></td>
<td>Load-break switch, with fuses</td>
</tr>
<tr>
<td>(For feeder cable)</td>
<td></td>
<td>Isolation control relay</td>
</tr>
<tr>
<td>Distribution</td>
<td></td>
<td>230/400 V AC</td>
</tr>
<tr>
<td>Load-break switch, with fuses</td>
<td></td>
<td>Load-break switch, with fuses</td>
</tr>
<tr>
<td>(For light, etc.)</td>
<td></td>
<td>Limit setting relay</td>
</tr>
<tr>
<td>Miniature circuit breaker, 3x16 A</td>
<td>3 x 80 A</td>
<td>3 x 63 A</td>
</tr>
</tbody>
</table>

The equipment for the station supply comprises:

- Load-break switch, with fuses
- Miniature circuit breaker, 3x16 A
- Miniature circuit breaker, 2x16 A
- Load-break switch, with fuses (For feeder cable)
- Load-break switch, with fuses (For light, etc.)
- Distribution 230/400 V AC

KA5.5/223
2.1.4  
Cont.:  

DC Distribution

Miniature circuit breaker, 2x6 A

Current transformer

Current transformer, 1 600/5 A (400 V)

Voltage transformer for control/protection

3-phase voltage transformer

Load : 50 VA cl. 1,0  
Ratio : 400/110 V

Battery

Block battery 24 V/Lead acid

Capacity (10 hours rate) : 50 Ah  
Rated voltage : 24 V

including:
- steel support structure
- transparent plastic front and cover
- acid tester
- thermometer with parking bracket
- filler can

Dimensions (LxWxH) : 775x325x690 mm  
Weight of battery : 82 kg

Charger for parallel operation

Rated current : 6 A DC  
Voltage-input : 1 x 220 V +10/-15 %  
Frequency : 50 Hz
Voltage-output : 24 V DC  
Voltage stability : ± 1 %
Ripple : 5,8 %
Ambient temp. max. : 40°C
Protection : IP 20
Radio interference : Degree N (VDE0875)
Cooling : Air Natural
Instruments : Amperemeter and voltage meter
Control : Earth fault relay  
over-/under voltage relay

Battery fuse cubicle

KA5.6/223
Mimic diagram

Mimic diagram with symbols, switches and position indicators.

Equipment not specified, but essential in a complete control system:

Auxiliary relay
Time relays
Terminals
Labels
Cable channels
Wiring
Miniature breakers, etc.

Temperature control

Electronic monitoring unit with digital display and alarm contacts for measuring temperatures on the generator and transformers.

Measuring points (PT 100 sensors) : 6

Electronic Alarm System

consisting of:

Alphanumeric display indicator
Alphanumeric recorder
Number of alarms for the generating unit : 32

Auxiliary plant and services

Cables and mounting equipment

All cables and mounting equipment, as links between hydraulic and electrical equipment, including:

XLPE-cable 1 kV 1 x 500 mmsq Cu
XLPE-cable 12 kV 3 x 50 mmsq Cu

Sealing ends, indoor and outdoor type

Power cables 1 kV for the installation, type TXXP or similar

Signal cables 500 V for the installation, type PFSP or similar

Earthing cables connected to the existing earthing grid

Mounting equipment

KA5.7/223
2.2 HASSANABAD POWERHOUSE, PHASE 1

2.2.1 Conclusion

Mechanical:

The turbine in Hassanabad, Phase 1 Powerhouse is in very bad condition. A complete refurbishment of this turbine would be relatively expensive as many parts would have to be replaced.

What we would suggest as a solution for this powerhouse is to replace the existing turbine with one of the units, which will be redundant when the new powerhouses under construction in the Kargah system are commissioned. The turbine has to be identical to the existing Hassanabad, Phase 1 turbine. This turbine could undergo a complete refurbishing process at the workshop while the existing turbine is continuing operation. The complete turbine unit could then be replaced.

Compared to a normal upgrading schedule, this procedure would cut the power station down time to a minimum, provided that vital parts do not require replacement.

In this area (Hunza), where the need for electricity is enormous, short down time is essential and will reduce the inconvenience for the consumer.

The repair procedure and budget cost for one of the redundant Kargah units would be quite similar to what is previously described for Kargah, Phase 5 Powerhouse.

Total budget: NOK 0.6 mill.

Electrical:

The control- and switchboard have to be replaced by a new board.

The generator has to be dismantled and cleaned. The bearings and brushes have to be replaced by new.

The excitation system at the end of the generator has to be overhauled and reused.

The main transformer has to be overhauled, tested and reused.

The same procedure should be applied to the small distribution transformer.

All cables have to be replaced.

The following cost estimate is based on cost level in Norway.

Total cost (budget price): NOK 550,000,-
### Inspection of existing mechanical equipment, February 13, 1989

#### DATA

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine type</td>
<td>1 horizontal Francis turbine</td>
</tr>
<tr>
<td>Rated output</td>
<td>220 (kW)</td>
</tr>
<tr>
<td>&quot; speed</td>
<td>1500 (r.p.m.)</td>
</tr>
<tr>
<td>&quot; head</td>
<td>48 (m)</td>
</tr>
<tr>
<td>&quot; flow</td>
<td>0.57 (m^3/s)</td>
</tr>
<tr>
<td>Runner outlet diameter</td>
<td>335 (mm)</td>
</tr>
<tr>
<td>Number of runner vanes</td>
<td>9 (original Drees:15)</td>
</tr>
<tr>
<td>Number of guide vanes</td>
<td>10</td>
</tr>
<tr>
<td>Guide vane height</td>
<td>100 (mm)</td>
</tr>
<tr>
<td>Inlet valve diameter</td>
<td>DN 350, DN 10</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Drees/PECO</td>
</tr>
<tr>
<td>Year of installation</td>
<td>1965</td>
</tr>
</tbody>
</table>

#### OBSERVATIONS

**Unit in shut-down position:**

The unit design is quite similar to the Kargah 5 units, only that this one is slightly larger in dimension and generally in much worse condition.

**Wicket gate system:**

Even with the main gate valve and the wicket gates completely closed, the leakage through the valve and the gaskets around the guide vane stems on lower half of head cover was considerable. The connection between guide vane arms and the guide vane stems was in bad shape from many re-positionings. Several connections are fixed by hexagon bolts instead of tapered pins.

The bushings in link connections between arms and regulating ring are virtually worn out. It is reason to believe that the same goes for the guide vane bushings.

A lot of sand and mud have settled around on the head cover as a result of great leakage.

All main parts on head cover and regulating system are seriously corroded.

**Runner:**

The original cast steel runner from Drees lasted for 10 years without any kind of maintenance before it broke down. This runner had 15 runner vanes. The present runner is manufactured by Ghulam Muhammad & Brothers Engineering Company in Lahore and has 9 vanes which is only single curved. The vanes are welded to hub and ring, and no grinding has been done. The welds are of very bad quality. The material is unalloyed steel. See attached photos for illustration.
Shaft sealing box:
The sealing box is seriously worn and leaks heavily with a great
danger of getting water into the bearing. It is very rusty and
muddy.

Turbine shaft:
The turbine shaft is corroded in the sealing box area, otherwise
relatively clean. No painting.

Discharge ring and draft tube:
Very rusty and small leakages through main flange gasket.
Painting is peeling off in large areas.

Shut-off Valve:
The gate valve is leaking through main seals and around hand wheel
stem and flange.

Governor:
The governor is functioning relatively good without any serious
operational problems.

General:
The unit is vibrating dangerously during operation.
The runout at the turbine bearing and the flywheel is about 1 mm.
Because of the fear of breakdown, the unit speed was limited to
about 90% of rated speed.
Alignment of the shaft/coupling system should be executed as soon
as possible.

2.2.3 Inspection of existing electrical equipment

The powerstation consists of one generator unit of 200 kVA. Built in 1965.

DATA

Generator

Three-phase synchronous generator

Manufacture : AEG
Type : DGKLa 293/4
No : 458633
### 2.2.3 - Generator

Cont.:  
<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power</td>
<td>200 kVA</td>
</tr>
<tr>
<td>Rated voltage</td>
<td>400 V AC</td>
</tr>
<tr>
<td>Rated amp.</td>
<td>289 A</td>
</tr>
<tr>
<td>Frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Power factor</td>
<td>0,9/1,0</td>
</tr>
<tr>
<td>Rated speed</td>
<td>1500 rpm</td>
</tr>
<tr>
<td>Runaway speed</td>
<td>2700 rpm</td>
</tr>
<tr>
<td>Insulation class</td>
<td>B</td>
</tr>
<tr>
<td>Enclosure</td>
<td>P 21</td>
</tr>
<tr>
<td>Max. altitude above sea level</td>
<td>2440 m</td>
</tr>
<tr>
<td>Duty</td>
<td>Continuous</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>33°C</td>
</tr>
</tbody>
</table>

**Exciter**  

<table>
<thead>
<tr>
<th>Manufacture</th>
<th>AEG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>KR 60-a</td>
</tr>
<tr>
<td>Load</td>
<td>2,3 kW</td>
</tr>
<tr>
<td>Rated max voltage</td>
<td>74V</td>
</tr>
<tr>
<td>Rated max current</td>
<td>31 A</td>
</tr>
<tr>
<td>Insulation class</td>
<td>B/E</td>
</tr>
<tr>
<td>Enclosure</td>
<td>P 21</td>
</tr>
</tbody>
</table>

**Main transformer**  

Three-phase oil insulated transformer for out-door installation.

<table>
<thead>
<tr>
<th>Manufacture</th>
<th>AEG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power</td>
<td></td>
</tr>
<tr>
<td>No load ratio</td>
<td>11000/415 V + -</td>
</tr>
<tr>
<td>Vector group</td>
<td>YD 11</td>
</tr>
</tbody>
</table>

**Distribution transformer 1**  

Single-phase oil insulated transformer for out-door installation.

<table>
<thead>
<tr>
<th>Manufacture</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power</td>
<td></td>
</tr>
<tr>
<td>No load ratio</td>
<td></td>
</tr>
<tr>
<td>Vector group</td>
<td></td>
</tr>
</tbody>
</table>

**Disconnector 1**  

Three one-pole fuse switch disconnector

<table>
<thead>
<tr>
<th>Manufacture</th>
<th>FICO Pakistan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>11 kV</td>
</tr>
<tr>
<td>Rated current</td>
<td>up to 100 A</td>
</tr>
<tr>
<td>Operated by</td>
<td>Hand</td>
</tr>
</tbody>
</table>
2.2.3
Cont.:  

Spare 11 kV Circuit breaker
---------------------------------

Circuit breaker : Oil
Operated by : Hand
Trip coils :

The breaker is bypassed.

Control cubicles 3 panels
-------------------------

Steel enclosed panel consisting of 1 cubicle and equipped with:
- switching
- measuring
- protection
- control

Circuit breaker
---------------
Manufacture : AEG
Type :
Rated voltage :
Rated current :
Breaking capacity :
Over current relay :
Over current :
Short circuit current :

This breaker was bypassed, and a new contactor had been installed.

Instruments for each generator
-----------------------------

Voltmeter with selector switch
Amperemeter 3
Frequency-meter 1
W-meter

Synchronizing
--------------

Synchronizing equipment has not been installed.

All electrical equipments are in bad condition. The control- and switchboard have to be replaced by new ones. The excitation system for each generator has to be dismantled, overhauled and reused. Some of the other equipment in the old board could be used as spare parts in the workshop.
Upgrading Recommendation:

Generator

The three-phase synchronous generator has to be dismantled and cleaned. Bearings and brushes have to be replaced by new.

All this work should be done in the workshop.

Excitation system

The excitation system should be overhauled in the new workshop and reused.

Speed supervision

Initiator for speed control (mounted within the stator house)

The initiators are used for:

1. Runaway speed control
2. Speed supervision

Temperature supervision

PT 100 detectors for temperature in stator winding.

PT 100 detectors for bearing temperature

Main transformer

The three-phase oil insulated transformer for outdoor installation should be overhauled and reused.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power</td>
<td>250 kVA</td>
</tr>
<tr>
<td>No load ratio</td>
<td>415/11 000 V + -</td>
</tr>
<tr>
<td>Rated frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Standards</td>
<td>IEC 76</td>
</tr>
</tbody>
</table>

HAS4.3/224
2.2.3
Cont.:  

11 kV outdoor switch disconnector  
-------------------------------

Triple-pole switch disconnector  

Rated voltage : 12 kV  
Rated current : up to 100 A  
Operated by : Hand  

Control cubicles  
-------------

Steel enclosed panel, in modular design, consisting of 1 cubicle and containing equipment for:

- switching
- measuring
- protection
- control
- alarm

Circuit breaker, 500 V, withdrawable  

Rated current : 400 A  
Breaking capacity :  
Making capacity :  
Total break-time : 30-40 ms  
Zero-voltage/under voltage coil : 110 V, 50 Hz

Instruments  
----------

Voltmeter with selector switch  
Amperemeter with selector switch  
W-meter  
VAR-meter  
kWh-counter  
Hour-counter  
Rpm-counter  
Water level meter

Meter for load limiter position  
Voltmeter for station supply  
Converters with 0-20 mA output are used for W-meter and VAR-meter

HAS4.4./224
2.2.3
Cont.:

Synchronizing

Double voltmeter
Double frequency meter
Synchronoscope

Relays

Generator

Definite time voltage relay

Rated voltage : 110 V
Setting range : 100-160 V
Time delay : 0,2-10 s

3-phase thermo-adjustable release
(included in circuit breaker)

Stator earth-fault relay

Rated voltage : 110 V ac
Setting range : 0,05-0,25 x Un
Time delay : 0,1-1 s

Overspeed relay

Reverse power relay

Rated current : 5 A ac
Rated voltage : 110 V ac

Limit setting relay

Isolation control relay
2.2.3 Cont.:

Station supply

The equipment for the station supply comprise:

230/400 V AC Distribution

Load-break switch, with fuses : 3 x 80 A
(For feeder cable)
Load-break switch with fuses : 3 x 63 A
(For light, etc.)
Miniature circuit breaker, 3x16 A
Miniature circuit breaker, 2x16 A

Current transformer

Current transformer, 300/5 A (400 V)

Voltage transformer for control/protection

3-phase voltage transformer

Load : 50 VA cl. 1.0
Ratio : 400/110 V

Mimic diagram

Mimic diagram with symbols, switches and position indicators.

Equipment not specified, but essential in a complete control system:

Auxiliary relay
Time relay
Terminals
Labels
Cable channels
Wiring
Miniature breakers, etc.

HAS4.6/224
2.2.3 Cont.:

Temperature control

Electronic monitoring unit with digital display and alarm contacts for measuring temperatures on the generator and transformers.

Measuring points (PT 100 sensors): 6

Electronic Alarm System

consisting of:

Alphanumeric display indicator

Alphanumeric recorder

Number of alarms for the generating unit: 32
2.3 HASSANABAD POWERHOUSE, PHASE 2

2.3.1 Conclusion

Mechanical:

The sand content in the water to this powerhouse is considerable. This is the major reason why the two existing cross-flow turbines frequently have to be repaired. This is not acceptable to NAPWD from an economical and operational point of view.

To remedy this situation we propose as follows:

A. Reconstruction of sand traps to a better design for increasing efficiency, and to the highest capacity which is acceptable from an economical point of view.

B. The two cross-flow units are replaced with one new horizontal Francis unit. Approximate design data according to the latest information provided by NAPWD should be:

- Static head: 440 ft (134 m)
- Rated flow: 32 cfs (0.9 m$^3$/s)

The two cross-flow units could be refurbished and utilized at a new convenient site, where the water quality is much better. Under such conditions these units may operate satisfactorily.

C. We believe that a Francis turbine is likely to last much longer than the existing cross-flow turbines for the following reasons:

- The cross-flow turbines are operating in the upper head range of this turbine type. Hence, the water velocities in the turbine is relatively high.

- The proposed Francis turbine is a design which is used up to about 400 m of head. At this head of 134 m the velocities in the turbine is substantially lower than in the existing cross-flow turbines.

- Lower silt content after improvements of the silt excluders at the headworks and with the construction of new forebay.

D. The new design data would require a new and longer penstock to be installed.

E. The intake structure must be reconstructed at a higher elevation to a design and capacity which is favourable for silt exclusion.
2.3.1 Cont.:

Scope of Supply - Technical Data:
- One (1) Horizontal Francis turbine, model FShzH370E
  \( P_r = 1000 \text{ kW}, \ n_r = 1000 \text{ rpm}, \ H_r = 130 \text{ m} \)
- One (1) Inlet valve
- One (1) Governor
- One (1) set of appurtenances and spares normally included in the supply.

Cost Estimates - Turbine Equipment:
Total budget costs ex. works for Scope of Supply as listed above: NOK 4.0 mill.

Local Supply:
Powerhouse, penstock, hydraulic steel works and major civil features are anticipated to be supplied by local companies.

Electrical:
All electrical equipment is brand new and works perfectly.

The problem is associated with the turbine. It was decided that the existing two units have to be dismantled and replaced by a new unit of 1 MW kW.

The following cost estimate is based on cost level in Norway.
Total cost (budget price) NOK 3,500,000,-
2.3.2 Inspection of existing mechanical equipment, February 12, 1989

DATA

<table>
<thead>
<tr>
<th>Type and number</th>
<th>Two (2) horizontal crossflow turbines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated output (kW)</td>
<td>235</td>
</tr>
<tr>
<td>&quot; speed (r.p.m.)</td>
<td>1500</td>
</tr>
<tr>
<td>&quot; head (m)</td>
<td>114</td>
</tr>
<tr>
<td>&quot; flow (m³/s)</td>
<td>0.26</td>
</tr>
<tr>
<td>Number of runner vanes</td>
<td>30</td>
</tr>
<tr>
<td>Number of guide vanes</td>
<td>2</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Kubota, Japan (Shinko)</td>
</tr>
<tr>
<td>Year of installation</td>
<td>Commissioned 1986</td>
</tr>
</tbody>
</table>

BACKGROUND INFORMATION

This powerplant is exposed to very silty water. According to information from NAPWD personnel, the original runners, which are of welded construction in 18/8 CrNi stainless steel, had only been in operation for about 3 months before they practically started to fall apart. The runners had to be sent to Lahore for complete repair. Also the turbine housing and guide vanes needed extensive repair. These parts were repaired in Gilgit.

The extensive wear and the fact that the runners had to be sent to Lahore, created a serious problem for NAPWD, both economically and because of the down time of the units.

After the first experience, NAPWD operated the units basically after dark to minimize the daily hours in operation. The load is by large lights and heatings.

With this new plan of operation, they have to repair the units every 6 months.

Kubota has delivered new runners of different construction and material with the objective of longer life. The long term experience with these runners in operation is not adequate, but the indications are that they last longer than the originals.

OBSERVATIONS

At the time of arrival both units were shut down, turbine no. 1 for repair and turbine no. 2 for operational reasons.

Turbine no. 1:
The top part of the turbine housing, runner, shaft and guide vanes for turbine no. 1 were sent to a small workshop in Gilgit for repair. At the attached photos, both the original runner with 1 middle disc and the new runner with 3 middle discs are shown.
The original runner, where some of the vanes have fallen out, has been in operation for about 3 months. This runner is made of 18/8 CrNi stainless steel. According to NAPWD personnel, this runner started to develop cracks shortly after commissioning.

The new runner (with shaft) has been in operation about 6 months at an average of 8-10 hours a day.

Turbine no. 2:
The top cover was removed to inspect the runner.

This runner has been in operation for about 45 days.

Sand erosion is not serious yet, but the process has definitely started and will surely increase when summer floods start. See attached photos for illustration.
The workmanship on this runner is not good. No grinding of welds has been performed.

The turbine was assembled and started up for running tests. The operational staff was complaining that the governor was very slow to adjust speed when load was applied. The test showed that governor opening time was approximately 8-10 sec. from fully closed to fully open. The problem is more a result of low unit inertia rather than slow governor responding time. When about 80 kW was applied, the unit speed decreased about 10-12%. Maximum output readings on the panel board at 100% gate opening: 150 kW.

No indication of penstock pressure available.

GENERAL

NAPWD wants to have new equipment installed which is not so vulnerable to sand erosion. At the same time they want to optimise the available water and head giving potential installation of about 1 MW.

New data: 
\[ \text{Hst} = 440 \text{ ft} = 13 \text{ m} \]
\[ Q_r = 32 \text{ cfs} = 0.9 \text{ m}^3/\text{s} \]
2.3.3 Inspection/ of existing electrical equipment

The powerstation consists of two generators, each unit of 250 kVA, and built in 1986.

DATA

Generator 2

Three-phase synchronous generator

<table>
<thead>
<tr>
<th>Manufacture</th>
<th>SHINKO Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td></td>
</tr>
<tr>
<td>Rated power</td>
<td>250 kVA</td>
</tr>
<tr>
<td>Rated voltage</td>
<td>400/231 V</td>
</tr>
<tr>
<td>Rated amp.</td>
<td>367 A</td>
</tr>
<tr>
<td>Frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Power factor</td>
<td>0.8</td>
</tr>
<tr>
<td>Rated speed</td>
<td>1500 rpm</td>
</tr>
<tr>
<td>Insulation class</td>
<td>F</td>
</tr>
<tr>
<td>Ambient temp.</td>
<td>100°C</td>
</tr>
</tbody>
</table>

Exciter 2

<table>
<thead>
<tr>
<th>Manufacture</th>
<th>SHINKO Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>ASN-C-350</td>
</tr>
<tr>
<td>Excitation</td>
<td>AC</td>
</tr>
<tr>
<td>Rated max voltage</td>
<td>100V</td>
</tr>
<tr>
<td>Rated max current</td>
<td>62.6 A</td>
</tr>
<tr>
<td>Load</td>
<td>7.2 kW</td>
</tr>
</tbody>
</table>

Voltage regulator

<table>
<thead>
<tr>
<th>Manufacture</th>
<th>SHINKO Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>CEC 4141</td>
</tr>
<tr>
<td>No</td>
<td>G 093160501</td>
</tr>
</tbody>
</table>

Main transformer 1

Three-phase oil insulated transformer for out-door installation.

<table>
<thead>
<tr>
<th>Manufacture</th>
<th>Climax Pakistan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power</td>
<td>400 kVA</td>
</tr>
<tr>
<td>No load ratio</td>
<td>11000/400 V + -</td>
</tr>
<tr>
<td>Vector group</td>
<td>YD 11</td>
</tr>
</tbody>
</table>

HAS2.1/223
2.3.3
Cont.:

Disconnectors 1

Three one-pole fuse switch disconnectors

Manufacture: FICO Pakistan
Rated voltage: 11 kV
Rated current: up to 100 A
Operated by: Hand

Spare 11 kV metal-clad in-door switchgear 1

The cubicles are equipped with:

Circuit breaker: Air
Operated by: Hand
Trip coils:
Over current:
kWh-counter:
A-meter: 50/5 A
V-meter: 11000 / 110 V

The switchgear was new and had never been put into operation.

Control cubicles 3 panels

Steel enclosed panel consisting of 2 cubicles and equipped with:

- switching
- measuring
- protection
- control

Circuit breaker 2

Manufacture:
Type:
Rated voltage:
Rated current:
Breaking capacity:
Over current relay:
Over current:
Short circuit current:
2.3.3
Cont.:

Instrument for each generator
-----------------------------

Voltmeter with selector switch
Ampermeter 3
Frequency-meter 1
kW-meter

Synchronizing
---------

Double voltmeter
Double frequency meter
Synchronoscope

All electrical equipment is new and works perfectly.

It was decided that the two complete existing units should be dismantled and used at another site. A new unit of 1 MW should be installed in the existing power house.

New unit:

It should be installed a new 1 MW power unit for Hassanabad phase 2 equipped as follows:

Calculated production :
Turbine : Horizontal Francis
Guide vanes : adjustable
Runner blades : fixed
Turbine load : 1 010 kVA
Speed (synchronous) : 1000 rpm
Overspeed, on-cam : 1 800 rpm
Overspeed, off-cam : 1 800 rpm

The water is led towards the power plant through a channel into a forbay and from the forbay down to the power plant through a penstock.

The turbine output can be adjusted according to water flow. The plant is regulated to frequency.

The plant should only be manually operated.

The plant can be started and run without an activated grid.
**GENERATOR**

Three-phase synchronous generator, brushless design, with built-on exciter, rotating diodes, automatic voltage regulator and damper winding.

**MAIN DATA**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power</td>
<td>1 250 kVA</td>
</tr>
<tr>
<td>Rated voltage</td>
<td>400 V Ac</td>
</tr>
<tr>
<td>Frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Power factor</td>
<td>0,8</td>
</tr>
<tr>
<td>Rated speed</td>
<td>1000 rpm</td>
</tr>
<tr>
<td>Runaway speed, transient</td>
<td>1 800 rpm</td>
</tr>
<tr>
<td>Moment of inertia WR²</td>
<td></td>
</tr>
<tr>
<td>Insulation</td>
<td>Micadur compact</td>
</tr>
<tr>
<td>Insulation class</td>
<td>F</td>
</tr>
<tr>
<td>Utilization class</td>
<td>B</td>
</tr>
<tr>
<td>Standards</td>
<td>IEC 34-1</td>
</tr>
<tr>
<td>Duty</td>
<td>Continuous</td>
</tr>
<tr>
<td>Enclosure</td>
<td>IP 23</td>
</tr>
<tr>
<td>Design</td>
<td>IPM 1001</td>
</tr>
<tr>
<td>Terminal box</td>
<td>Upon request, can be mounted on either side of generator.</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>40°C</td>
</tr>
<tr>
<td>Max altitude above sea level</td>
<td>3000 m</td>
</tr>
<tr>
<td>Direction of rotation</td>
<td>To be determined by the turbine manufacturer.</td>
</tr>
<tr>
<td>Ventilation</td>
<td>Self ventilated</td>
</tr>
<tr>
<td>Cooling</td>
<td>IC 01, Fresh air</td>
</tr>
<tr>
<td>Cooling air volume</td>
<td>3 m³/sec.</td>
</tr>
</tbody>
</table>

**Exciter for Brushless Generator**

The excitation system consists of a rotating exciter, mounted on the shaft inside the stator housing and an electronic voltage regulator, fitted to the generator top. The exciter feeds a rotating rectifier bridge.

**Exciter data:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td>42 kV</td>
</tr>
<tr>
<td>Rated voltage</td>
<td>60 V</td>
</tr>
<tr>
<td>Rated current</td>
<td>408 A</td>
</tr>
<tr>
<td>Cos ø</td>
<td>0,96</td>
</tr>
<tr>
<td>No. of poles</td>
<td>12</td>
</tr>
<tr>
<td>Frequency</td>
<td>100 Hz</td>
</tr>
<tr>
<td>Field current</td>
<td>6,5 A</td>
</tr>
<tr>
<td>Field resistance at 20°C</td>
<td>class F</td>
</tr>
<tr>
<td>Insulation</td>
<td>class B</td>
</tr>
</tbody>
</table>

Rotating diode bridge mounted on generator shaft

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of diodes</td>
<td>6</td>
</tr>
<tr>
<td>Type</td>
<td>SW06RPW 935</td>
</tr>
<tr>
<td>Diode protection</td>
<td>NL232831</td>
</tr>
</tbody>
</table>
2.3.3
Cont.:  

Thyristor Voltage Regulator

Electronic voltage regulator for brushless generator.

- **Input voltage**: 400 V ac
- **Output voltage**: 190 V max
- **Output current**, continuously: 9 A
- **Compounding current**, short circuited: 25 A < 2 s
- **Voltage adjustment range**, $t = 55$ deg C: $+ - 1.5\%$
- **Regulation accuracy**: < 15 ms
- **Paralleling voltage drop**, $\cos \theta > 0.85$: 0-2% adjustable
- **Response time**: < 15 ms
- **Frequency dep. voltage regulation**: $U = \text{const for } f > 90\%$
  $U/f = \text{const for } f < 90\%$
- **Automatic voltage build-up**: From the generators residual voltage
- **Recovery time $T_r$**: < 0.4 s
- **Ambient temperature**: 55°C
- **Heat loss**: 100 W

**Speed supervision**

Initiator for speed control
(mounted within the stator house)

The initiators are used for:
1. Runaway speed control
2. Speed supervision

**Temperature supervision**

PT 100 detectors for temperature in stator winding.

PT 100 detectors as full spare
PT 100 detectors for bearing temperature

HAS2.5/224
2.3.3 Cont.: 

Current and voltage transformers for excitation, mounted on generator:

Current transformer for regulation and compounding no-load side.

Ratio (with 6 sec. steps) : 1 600/5 A

Current transformer for quadr. drop adjusting no-load side

Ratio : 1 600/0.4 A

Main transformer

Three-phase oil insulated transformer for outdoor installation.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power</td>
<td>1 250 kVA</td>
</tr>
<tr>
<td>No load ratio</td>
<td>400/11 000 V ±2x2.5</td>
</tr>
<tr>
<td>Cooling</td>
<td>ONAN</td>
</tr>
<tr>
<td>Vector group</td>
<td>YNd11</td>
</tr>
<tr>
<td>Rated frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Standards</td>
<td>IEC 76</td>
</tr>
<tr>
<td>Total weight</td>
<td>4 850 kg</td>
</tr>
<tr>
<td>Oil weight</td>
<td>1 140 kg</td>
</tr>
<tr>
<td>Height</td>
<td>2 340 mm</td>
</tr>
<tr>
<td>Width</td>
<td>1 500 mm</td>
</tr>
<tr>
<td>Length</td>
<td>2 350 mm</td>
</tr>
</tbody>
</table>

Surge arrester, connected at high voltage neutral.

12 kV Outdoor switch disconnector

Triple-pole switch disconnector

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>12 kV</td>
</tr>
<tr>
<td>Rated insulation level</td>
<td>75/35 kV</td>
</tr>
<tr>
<td>Rated current</td>
<td>630 A</td>
</tr>
</tbody>
</table>

Operated by
with built on fuses : Hand
Rated current : 63 A

HAS2.6/224
2.3.3 Cont.: Control cubicles
Steel enclosed panel, in modular design, consisting of 2 cubicles and containing equipment for:
- switching
- measuring
- protection
- control
- alarm
Circuit breaker, 500 V, withdrawable
Rated current: 1600 A
Breaking capacity: 45 kA
Making capacity: 95 kA
Total break-line: 30-40 ms
Zero-voltage/under voltage coil: 110 V, 50 Hz

Instruments
Voltmeter with selector switch
Amperemeter with selector switch
W-meter
VAr-meter
kWh-meter
Hour-counter
Rpm-counter
Water level meter
Meter for load limiter position
Voltmeter for station supply
Converters with 0-20 mA output are used for W-meter and VAr-meter

Synchronizing
Double voltmeter
Double frequency meter
Synchronoscope
2.3.3
Cont.:

Relays

Generator

---------

Definite time voltage relay

Rated voltage : 110 V
Setting range : 100-160 V
Time delay : 0,2-10 s

3-phase thermo-adjustable release
(included in circuit breaker)

Stator earth-fault relay

Rated voltage : 110 V ac
Setting range : 0,05-0,25 x Un
Time delay : 0,1-1 s

Overspeed relay

Reverse power relay

Rated current : 5 A ac
Rated voltage : 110 V ac

Limit setting relay

Isolation control relay

Station supply

The equipment for the station supply comprise:

230/400 V AC Distribution

-----------------------

Load-break switch, with fuses : 3 x 80 A
(For feeder cable)

Load-break switch with fuses : 3 x 63 A
(For light, etc.)

Miniature circuit breaker, 3x16 A
Miniature circuit breaker, 2x16 A

HAS2.8/223
2.3.3 Cont.

DC Distribution

Miniature circuit breaker, 2x6 A

Current transformer

Current transformer, 1 600/5 A (400 V)

Voltage transformer for control/protection

3-phase voltage transformer

| Load | 50 VA cl. 1.0 |
| Ratio | 400/110 V |

Battery

Block battery 24 V/Lead acid

| Capacity (10 hours rate) | 50 Ah |
| Rated voltage | 24 V |

including:
- steel support structure
- transparent plastic front and cover
- acid tester
- thermometer with parking bracket
- filler can

Dimensions (LxWxH) : 775x325x690 mm

Weight of battery : 82 kg

Charger for parallel operation

| Rated current | 6 A DC |
| Voltage-input | 1 x 220 V +10/-15 % |
| Frequency | 50 Hz |
| Voltage-output | 24 V DC |
| Voltage stability | ± 1 % |
| Rippel | 5,8 % |
| Ambient temp. max. | 40°C |
| Protection | IP 20 |
| Radio interference | Degree N (VDE0875) |
| Cooling | Air Natural |
| Instruments | Amperemeter and voltage meter |
| Control | Earth fault relay over-/under voltage relay |

Battery fuse cubicle

HAS2.9/224
Mimic diagram

Mimic diagram with symbols, switches and position indicators.

Equipment not specified, but essential in a complete control system:

Auxiliary relay
Time relays
Terminals
Labels
Cable channels
Wiring
Miniature breakers, etc.

Temperature control

Electronic monitoring unit with digital display and alarm contacts for measuring temperatures on the generator and transformers.

Measuring points (PT 100 sensors): 6

Electronic Alarm System

consisting of:

Alphanumeric display indicator
Alphanumeric recorder
Number of alarms for the generating unit: 32

AUXILIARY PLANT AND SERVICES

Cables and mounting equipment

All cables and mounting equipment, as links between hydraulic and electrical equipment, including:

XLPE-cable 1 kV 1 x 500 mmsq Cu
XLPE-cable 12 kV 3 x 50 mmsq Cu

Sealing ends, indoor and outdoor type

Power cables 1 kV for the installation, type TXXP or similar

Signal cables 500 V for the installation, type PFSP or similar

Earthing cables connected to the existing earthing grid

Mounting equipment
HAJSHANABAD, PHASE 2
2.4 SKARDU POWERHOUSE, PHASE 1

2.4.1 Conclusion

Mechanical:

Although the turbines are generally worn and need an upgrading, they are in relatively good condition considering the time they have been in operation (commissioned 1972). Compared to the Kargah and Hassanabad powerhouses, the water quality is much better and the silt content is minor. The output readings indicate, however, that an appreciable reduction in efficiency has occurred since 1972. At a certain gate opening the output was 180 kW in 1973. The corresponding output today is 140 kW. If these units shall be in operation in the foreseeable future, a complete refurbishment of mechanical equipment would be required in order to avoid unscheduled shut-downs. Such a refurbishment process could in general be accomplished along the guidelines listed in Addendum 1, and as described for Kargah, Phase 5 Powerhouse.

The estimated costs would be equivalent to the estimation given for Kargah, Phase 5.

A. Total costs for complete upgrading of both turbines, not including new parts: NOK 0.5 mill.

B. Two new runners: NOK 0.5 mill.

C. Potential upgrading of inlet valve, governor etc.: NOK 0.2 mill.

Total budget: NOK 1.2 mill.

Electrical:

The control- and switchboard have to be replaced with a new board.

The two generators must be dismantled and cleaned. Bearings and brushes have to be replaced by new ones.

The excitation system at the end of each generator has to be overhauled and reused.

The two main transformers have to be dismantled and replaced by new.

The oil circuit-breaker on 11 kV should be replaced by high voltage fuses.

The following cost estimate is based on cost level in Norway.

Total cost (budget price) NOK 1,000,000,-
2.4.1.1 Alternative Installation:

Mechanical:

Upstream of Skardu Phase 1 Powerhouse, Shardu Phase 2 is located. This powerhouse has recently been extended by two extra units. As these two power stations utilize basically the same water, extra water is now easy available for increasing installation in the Phase 1 Powerhouse also.

NAPWD has already conducted initial investigation to survey the potential. These plans include a new short feeder canal from the Phase 2 tailwater to a new intake structure, and two new penstocks down to the existing powerhouse where two (2) new units are installed.

Design data for this new installation are estimated to be:

- Static head : 82 m
- Design flow (total): 2 m³/s

NAPWD prefer to have two units installed to ensure reliable electricity supply.

Equipment data:

- Two (2) Horizontal Francis turbines, model FShzH430G
  - $P_r=670$ kW, $n_r=1000$ rpm, $H_r=76$ m
- Two (2) Inlet valves
- Two (2) Governors
- Two (2) sets of appurtenant equipment and spares normally included in the supply.

Cost Estimates:

The total budget costs ex. works for equipment supply as listed above: NOK 6.0 mill.

Local Supply:

It is anticipated that penstock, intake structure and major civil features are the responsibility of NAPWD.

Electrical:

Two new generators of 670 kW with control boards, switch equipment and main transformer.

The following cost estimate is based on cost level in Norway.

Total cost (budget price): NOK 5.5 mill.
2.4.2 **Inspection of existing mechanical equipment**, February 19, 1989

**DATA**

<table>
<thead>
<tr>
<th>Data</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine type</td>
<td>Two (2) identical horizontal Francis turbines</td>
</tr>
<tr>
<td>Rated output (kW)</td>
<td>220</td>
</tr>
<tr>
<td>&quot; speed (r.p.m.)</td>
<td>1000</td>
</tr>
<tr>
<td>&quot; head (m)</td>
<td>32.6</td>
</tr>
<tr>
<td>&quot; flow (m³/s)</td>
<td>0.826 (each)</td>
</tr>
<tr>
<td>Runner outlet diameter (mm)</td>
<td>415</td>
</tr>
<tr>
<td>Number of runner vanes</td>
<td>Original Drees (turbine 1): 9</td>
</tr>
<tr>
<td></td>
<td>Local made (turbine 2): 9</td>
</tr>
<tr>
<td>Number of guide vanes</td>
<td>10</td>
</tr>
<tr>
<td>Guide vane height (mm)</td>
<td>130</td>
</tr>
<tr>
<td>Inlet valve diameter (mm)</td>
<td>DN 450, PN 10</td>
</tr>
<tr>
<td>Governor</td>
<td>Drees, belt driven mech./hydraulic</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Drees/PECO</td>
</tr>
<tr>
<td>Year of installation</td>
<td>1972</td>
</tr>
</tbody>
</table>

**OBSERVATIONS**

**Turbine no. 1 - In operation**

Only turbine 1 was in operation because of low flow. The load readings on the panel board was 120 kW. The unit operates very quiet and without any vibration. This turbine still has the original Drees runner of cast steel, similar to the one showed on the attached photos.

**Wicket gate operating system:**

All bushings and moving connections are manually grease lubricated. Some of the wicket gate gland gaskets are leaking, causing rust attacks and water creeping along the shaft to the bearing. The painting on head cover, gland and guide vane stems is worn off, and these parts are very rusty. The head cover is furnished with a 3" pressure relief pipe connected to the draft tube.

The bushings are not extremely worn, but should be checked soon.

**Shaft sealing box:**

The sealing box is very worn, and the leakage is substantial. The drain pipe is working at full capacity, and the funnel is floating over. From time to time, the leakage from the sealing box has caused water to enter the bearing oil sump with subsequent bearing break down.
2.4.2
Cont.:

Turbine shaft:
Visible parts of the turbine shaft seem to be in good condition with most of the painting still there.

Turbine bearing:
The turbine bearing is not causing any problem as long as the water is kept from entering the oil sump.

Draft tube:
The draft tube bend and the draft tube are in fairly good condition. The bend is provided with a small air inlet valve for air admission to the draft tube during operation.

Turbine no. 2 - Shut down

This turbine was not in operation. The draft tube hand cover was removed for inspection of the runner discharge. This runner is a copy of the original one, and are made locally in Pakistan. While the original one is a one piece casting, this one is of welded construction, and the material is unalloyed plate steel. The weld quality and general workmanship is not good.

According to the operational personnel, the leakages on turbine no. 2 are about the same as on turbine no. 1. This indicates that both turbines are in about the same condition.

The main inlet valve is leaking at a rate of about 6-10 l/min.

GENERAL

Of the powerstations with old Drees/PECO turbine (Kargah, ph. 5, Hassanabad, ph. 1 and Skardu, ph. 1), this one is in best condition. There are clear indications that attempts on maintenance and repair have been a priority issue. However, both turbines are worn and operates with low efficiency and need a general overhaul.

According to NAPWD information the panel board readings at full load are 140 kW for each unit. In 1973 the same output was 180 kW. Both units have a setting of 1-1.3 m above tailwater level (from turbine shaft centerline).

NAPWD has complete plans for uprating this powerhouse with two new units of approximately 700 kW each.
2.4.3 *Inspection of existing electrical equipment*

The power station consists of two generator units of 200 kVA each built in 1973.

**DATA**

**Generator two**

---

**Three-phase synchronous generator**

<table>
<thead>
<tr>
<th>Manufacture</th>
<th>AEG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>295/6</td>
</tr>
<tr>
<td>Rated power</td>
<td>200 kVA</td>
</tr>
<tr>
<td>Rated voltage</td>
<td>400 V AC</td>
</tr>
<tr>
<td>Rated amp.</td>
<td>288 A</td>
</tr>
<tr>
<td>Frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Power factor</td>
<td>0.9-1</td>
</tr>
<tr>
<td>Rated speed</td>
<td>1000 rpm</td>
</tr>
<tr>
<td>Insulation class</td>
<td></td>
</tr>
<tr>
<td>Enclosure</td>
<td></td>
</tr>
</tbody>
</table>

**Exciter 2**

---

<table>
<thead>
<tr>
<th>Excitation</th>
<th>DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated max voltage</td>
<td>68V</td>
</tr>
<tr>
<td>Rated max current</td>
<td>46 A</td>
</tr>
</tbody>
</table>

**Main transformer 2**

---

Three-phase oil insulated transformer for out-door installation.

<table>
<thead>
<tr>
<th>Manufacture</th>
<th>Climax Pakistan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power</td>
<td></td>
</tr>
<tr>
<td>No load ratio</td>
<td>11000/415 V + - 10%</td>
</tr>
<tr>
<td>Vector group</td>
<td>YD 11</td>
</tr>
</tbody>
</table>

**Circuit-breaker 2**

---

Three single-pole oil circuit-breaker

<table>
<thead>
<tr>
<th>Manufacture</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>11 kV</td>
</tr>
<tr>
<td>Rated current</td>
<td>Hand</td>
</tr>
</tbody>
</table>
2.4.3
Cont.:

Spase 11 kV Metal clad in-door switchgear one

The cubicles are equipped with:

- Circuit breaker: Oil
- Operated by: Hand
- Trip coils:
- Over current relay: made in UK 2,5 - 10A
- A-meter: 50/5 A
- V-meter: 11000 / 110 V

Control cubicles 3 panels

Steel enclosed panel consisting of 3 cubicles and equipped for:

- switching
- measuring
- protection
- control

Circuit breaker two

<table>
<thead>
<tr>
<th>Manufacture</th>
<th>AEG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td></td>
</tr>
<tr>
<td>Rated voltage</td>
<td>500 V</td>
</tr>
<tr>
<td>Rated current</td>
<td>250 A</td>
</tr>
<tr>
<td>Breaking capacity</td>
<td></td>
</tr>
<tr>
<td>Over current relay</td>
<td></td>
</tr>
<tr>
<td>Over current</td>
<td></td>
</tr>
<tr>
<td>Short circuit current</td>
<td></td>
</tr>
</tbody>
</table>

Instrument for each generator

Voltmeter with selector switch
Amperemeter 3
Frequency-meter 1
kW-meter
kWh-counter

Synchronizing

Double voltmeter
Double frequency meter
Synchronoscope

SK4/224
2.4.3
Cont.:

Disconnectors low voltage

Manufacture:
Rated voltage:
Rated current:
Operated by:

All electrical equipments are in a bad condition. The control- and switchboard have to be replaced by a new one. The excitation system for each generator has to be dismantled, overhauled and reuse. Some of the other equipment in the existing board could be used as spare parts in workshop.

Upgrading Recommendation:

Generator 2

The three-phase synchronous generator, has to be dismantled and cleaned. Bearings and brushes brushes have to be replaced by new.

Each generator needs also an air-cooling system. All this work should be done in the workshop.

Excitation system

The excitation system should be overhauled in the new workshop.

Speed supervision

Initiator for speed control (mounted within the stator house)

The initiators are used for:
1. Runaway speed control
2. Speed supervision

Temperature supervision

PT 100 detectors for temperature in stator winding.
PT 100 detectors for bearing temperature
2.4.3
Cont.: Main transformer

The three-phase oil insulated transformer for outdoor installation, should be overhauled and reused.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power</td>
<td>400 kVA</td>
</tr>
<tr>
<td>No load ratio</td>
<td>415/11 000 V + -</td>
</tr>
<tr>
<td>Rated frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Standard</td>
<td>IEC 76</td>
</tr>
</tbody>
</table>

11 kV outdoor switch disconnector

Triple-pole switch disconnector

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>12 kV</td>
</tr>
<tr>
<td>Rated current</td>
<td>up to 100 A</td>
</tr>
<tr>
<td>Operated by</td>
<td>Hand</td>
</tr>
</tbody>
</table>

Control cubicles

Steel enclosed panel, in modular design, consisting of 3 cubicles and containing equipment for:

- switching
- measuring
- protection
- control
- alarm

Circuit breaker, 500 V, withdrawable

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated current</td>
<td>250 A</td>
</tr>
<tr>
<td>Breaking capacity</td>
<td></td>
</tr>
<tr>
<td>Making capacity</td>
<td></td>
</tr>
<tr>
<td>Total break-line</td>
<td>30-40 ms</td>
</tr>
<tr>
<td>Zero-voltage/under voltage coil</td>
<td>110 V, 50 Hz</td>
</tr>
</tbody>
</table>
2.4.3 Cont.:

Instruments
---------

Voltmeter with selector switch

Amperemeter with selector switch

W-meter

VAR-meter

kWh-counter

Hour-counter

Rpm-counter

Water level meter

Meter for load limiter position

Voltmeter for station supply

Converters with 0-20 mA output are used for W-meter and VAR-meter

Synchronizing
---------

Double voltmeter

Double frequency meter

Synchronoscope

Relays

Generator
---------

Definite time voltage relay

Rated voltage : 110 V
Setting range : 100-160 V
Time delay : 0,2-10 s

3-phase thermo-adjustable release
(included in circuit breaker)

SK7/224
2.4.3 - Generator
Cont.

Stator earth-fault relay

- Rated voltage: 110 V ac
- Setting range: 0,05-0,25 x Un
- Time delay: 0,1-1 s

Overspeed relay

Reverse power relay

- Rated current: 5 A ac
- Rated voltage: 110 V ac

Limit setting relay

Isolation control relay

Station supply

The equipment for the station supply comprise:

230/400 V AC Distribution
-----------------------------

Load-break switch, with fuses: 3 x 80 A
(For feeder cable)
Load-break switch with fuses: 3 x 63 A
(For light, etc.)
Miniature circuit breaker, 3x16 A
Miniature circuit breaker, 2x16 A

Current transformer
---------------------

Current transformer, 200/5 A (400 V)

SK8/224
2.4.3 Cont.

Voltage transformer for control/protection

3-phase voltage transformer

| Load | 50 VA cl. 1,0 |
| Ratio | 400/110 V |

Mimic diagram

Mimic diagram with symbols, switches and position indicators.

Equipment not specified, but essential in a complete control system:

- Auxiliary relay
- Time relay
- Terminals
- Labels
- Cable channels
- Wiring
- Miniature breakers, etc.

Temperature control

Electronic monitoring unit with digital display and alarm contacts for measuring temperatures on the generator and transformers.

Measuring points (PT 100 sensors): 6

Electronic Alarm System

consisting of:

- Alphanumeric display indicator
- Alphanumeric recorder

Number of alarms for the generating unit: 32
MINUTES OF MEETING

Meeting at: Northern Area Public Works Department's (NAPWD) Office in Gilgit, February 11th, 1989.
Lt. Col. Rashid's office, 09.00 - 17.00.

Subject: Maintenance workshop in Gilgit.

Purpose: To service all power plants under supervision of NAPWD in Northern Areas.

Participants:
- Superintending engineer, Construction & Works, Chief Engineer's office, Lt. Col. Rashid Ahmad.
- Executive Engineer, Water & Power Division, Gilgit, Mr. Suleman Wali Khan.
- Executive Engineer, Electric/Mechanical, Chief Eng. Office, Mr. Mohammad Nabi.
- Mr. Muhammad Yagub Khan, Mech. Eng., In charge of the 3 MW diesel plant.
- Mr. Abdul Amir, El. Eng., Water & Power Division, Gilgit.
- Oddmund Kristensen, El. Eng., Norad
- Tore Knutsen, Mech. Eng., Norad

The topics of this meeting was primarily to go through and elaborate the preliminary views presented by Kvaerner Brug A/S in the report No. 47698, and a proposal presented in the meeting by EB Energi A/S about the electrical part.
NAPWD's reaction and comments to these ideas was one of the major objectives for this meeting.
The meeting was organized in four sessions: one civil - one mechanical - one electrical and one session discussing the professional requirements and number of people to be employed.
MINUTES OF MEETING
cont.:

1. CIVIL

Construction of building

It was proposed that the building for the 3 MW diesel plant should be evaluated on the basis of making the workshop building exactly identical to the diesel plant building.

NAPWD agreed, and mentioned that they could obtain complete set of drawings from WAPDA. This would save considerable time in the planning period.

It was also agreed that it was necessary to have a 15 tons overhead travelling crane in the workshop (same as in diesel building) in case NAPWD should overhaul one of the diesel units.

Provided that the diesel power plant building is found suitable, one set of lay-out drawings should be provided. NAPWD agreed that the mech./el. contractor from Norway should be responsible for the plan arrangement of the building, i.e. location of machines, stores, offices etc.

In principle, NAPWD will accept full responsibility for construction of the building, i.e. sign contract with the successful civil contractor and supervise the construction together with one (civil) engineer from Norway. Pre-qualification, bidding and Award of Contract will take minimum 3 months after receipt of detailed design drawings and specifications for the building.

The construction period, anticipating a building identical to the diesel plant, will be 12 - 18 months.

If tool machines arrive before the building is ready, they will have to be stored outdoor. No indoor storage area is available in Gilgit today.

2. MECHANICAL

Based on the preliminary list of tools attached, each item was discussed and made comments to as follows:

Item 1: NAPWD suggests one complete gas welding stand in addition to the stationary welding transformer, TIG equipment and combustion engine operated welding machine.

Item 2: Preferably, the rolling machine should have a capacity of 15 mm steel plate.
MINUTES OF MEETING
cont.:

Item 3. No comments.

Item 4: NAPWD agrees that this machine probably could be a little smaller. To be decided by us.

Item 5: No comment.

Item 6: This bench lathe (the largest) should be specified keeping in mind the possibility of machining the crank shafts for the diesel engines in the 3 MW diesel power plant. Max. weight of items to be machined: about 2 tons.

Item 7. No comments.

Item 8: To be specified during detailed layout/design process.

Item 9: To be specified during detailed layout/design process.

Item 10: No comments. Final size to be specified during detailed layout/design process.

Item 11: No comments. Type and final size to be specified during detailed layout/design process.

Item 12: No comments.

Item 13: No comments.

Item 14: No comments.

Item 15: No comments. Type and capacity to be specified during detailed layout/design process.

Item 16: No comments. Type, capacity and cabinet to be finalized during detailed layout/design process.

Item 17: No comments.

Item 18: No comments.

Item 19: Final size and capacity to be specified during detailed layout/design process.
MINUTES OF MEETING
cont.:

Item 20: The overhead travelling crane should have a nominal lifting capacity of 15 tons.

Item 21: NAPWD thinks one of these lifting devices is enough. Final number to be specified during detailed layout/design process.

Item 22: No comments.

Item 23: NAPWD suggests a total of 6 (six) 10 tons jacks.

Item 24: No comments. Final list to be developed during detailed layout/design process.

Item 25: NAPWD is of the opinion that only surface testing is required, (no X-ray or ultrasonic equipment).

Item 26: No comments. Final list of tools to be developed during detailed layout/design work.

Item 27: No comments. Final list of tools to be developed during detailed layout/design work.

In addition to the above list the following items were discussed.

1. One complete set of castings equipment for applying new babbit lining in sleeve bearings are essential.

2. NAPWD requests in stock some "good quality materials", meaning materials which is not easily obtainable in Pakistan. NAPWD to develop list for evaluation by NORAD.

3. The need for a vehicle equipped as a "mobile workshop" was discussed thoroughly. Finally NAPWD came to the conclusion that this was not required nor practical having the present access road conditions in mind.

4. One heavy duty shaping machine is required.

5. Alignment and static balancing equipment should be included.

6. Basic carpenting tools should also be included.

7. NAPWD would also like to have complete equipment and accessories for a small gray iron casting facility.
3. ELECTRICAL

The electrical session started with EB Energi A/S making a presentation of the main equipment and tools that normally are available in their site workshops.

Test equipment

- Primary injection current tester
- Secondary injection current tester
- High voltage tester 70 kV
- Oil tester 60 kV
- Frame oil filter
- High voltage phase tester
- Power indicator
- Test instrument (EB Energi equipment lists for test engineers)
- Hand tools (EB Energi equipment lists for test engineers)

Tools in workshop:

- Vertical boring machine (small)
- Welding transformer (small)
- Saw machine with table
- EB Energi's equipment lists for a site workshop

Mounting equipment:

- EB Energi's equipment lists for a site workshop.

Store equipment:

- Cable
- Copper bus
- EB Energi's equipment list for site workshop.

NAPWD agreed that they would need these main tools, but they claimed that in addition to this, it would be necessary to have facilities for rewinding of generators and transformers up to 630 kVA.
4. PERSONNEL

To operate a workshop as the one proposed at a level of operation which meets the anticipated demand of services in Northern Areas, it will require a certain number of personnel in the different positions. The exact number depends on what level of education and skills the workforce is in possession of and what capacity (delivery time) is required.

NAPWD's opinion of what the future service demand will be was a major issue in the discussions. The availability of skilled personnel in Pakistan and their employment in Gilgit is another important issue which has to be clarified.

ADMINISTRATION AND SERVICE STAFF FOR THE WORKSHOP

We emphasized that the workshop should have one responsible leader, an Executive Engineer (EE), reporting directly to the Chief Engineer's office at NAPWD.

The EE should be a degree Mechanical/Electrical Engineer with a minimum of 15 years of education and experience from small hydro operation and/or experience from administrative positions in a mechanical/electrical workshop.

We further emphasized that it would be required with an accountant in order to manage the budget and cash-flow in the company. The accountant should work closely with the EE, and report to Norad periodically.

It will also be necessary to have one or two skilled secretaries to assist the EE and the accountant.

NAPWD agreed that it is necessary for the workshop to have its own accountant and administration reporting to the Chief Engineer's office. They also suggested that the EE would need an assistant Executive Engineer (AEE) (a young Electrical/Mechanical degree engineer).

NAPWD agreed that it would be necessary to have one technical leader (foreman) on both mechanical and electrical side, each with one assistant.

According to NAPWD, Pakistani companies require a minimum of general service staff, which in this case will be:
- 1 head clerk
- 2 upper division clerks
- 2 lower division clerks
- 2 guards
- 2 drivers
- 2 peons
- 2 sweepers
MINUTES OF MEETING

ELECTRICAL EMPLOYEES IN THE WORKSHOP

We proposed that it would be necessary to build up some trouble-shooting groups, who could be trained in maintenance on the electrical side of small hydro power plants. Each group should also be trained to do design work for modification.

The leader of each group should be trained in Norway for about 6 to 12 months.

Each group should consist of:

- One Electrical Engineer 13 years education
- One Electrician (H-voltage) 10 years education
- One unskilled assistant

When the workshop is completed, we proposed to send one Electrical Engineer and one Electrician (H-voltage) from Norway to continue the training in Pakistan for a period of up to 3 years.

We also proposed that it would be convenient to have one storeman in the electrical store.

NAPWD agreed about this trouble-shooting groups, and they requested a total of 6 groups, where each educated man should have one unskilled worker as assistant. In addition they wanted to have workers for rewinding of generators and transformers up to 630 kVA.

MECHANICAL EMPLOYEES IN THE WORKSHOP

Based on the discussions in session 2, Mechanical, the required mechanical staff should be as follows:

1 foreman (experienced diploma engineer, 13 years education)
3 welders where at least one is stainless steel welder)
2 operators for rolling machine, cutting machine and miscellaneous tools
2 operators for bench lathes and vertical turning lathe
1 operator for the milling machine
1 operator for sand blasting and painting equipment
2 persons for operation of the heating own and casting equipment
1 carpenter
1 storage administrator

At least 2 of the above mentioned persons should be qualified of operating the overhead travelling crane.

NA7/223
MINUTES OF MEETING
cont.:

TOTAL EMPLOYMENT

Based on the preceding assumptions regarding structure and capacity, we arrived at the following suggestion to total employment.

Administration: 5 people
Service: 13 people
Electrical: 18 people
Mechanical: 14 people
TOTAL: 50 people

This is what is considered a minimum of all time employment. The actual employment should according to NAPWD, be about 50% higher to compensate for leave of sickness, resignations etc.

In addition to the degree and diploma engineers, the workforce should have a minimum of 10 years basic schooling, and it would be a great advantage if some of the trainees already had same experience in mechanical and/or electrical work.

In addition to the practical training of workshop employees, NAPWD also wants similar training of the power station operation staff. NAPWD also suggests a 4-5 months theoretical training course for the management.

After approval and go ahead for the program, NAPWD anticipate about 3 months to come up with the key persons to be employed in the workshop.

Persons going to Norway for training, would prefer to live in a house and care for themselves and not stay in hotels.

................................. .................................
Tore Knutsen            Oddmund Kristensen
Mech. Engineer         El. Engineer

TKn/go
89.04.06
NA8/223
## WORKSHOP IN NORTHERN PAKISTAN

### WORKSHOP EQUIPMENT - LIST OF TOOLS

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<td>Radial boring machine, swing radius 1500</td>
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<td>9</td>
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<td>Pedestal steel cutting saw</td>
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<td>Milling machine 1000 x 1000 x 1000</td>
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<td>Overhead travelling crane</td>
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<td>Measuring tools, lifting device etc.</td>
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<td>25</td>
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<td>NDT-testing equipment</td>
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<tr>
<td>26</td>
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<td>Miscellaneous hand tools</td>
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<tr>
<td>27</td>
<td>1</td>
<td>Miscellaneous machine tools for the different machines</td>
</tr>
</tbody>
</table>
ADDENDUM 3

GENERAL UPGRADING PROCEDURE - FRANCIS TURBINE

A complete upgrading/repair job of a typical horizontal Francis turbine similar to the 100 kW Drees/Peco turbines could be accomplished along the following guidelines.

1. **Work prior to dismantling**

   Before the dismantling process commence, the following operations should be done:
   
   - Necessary measurements and match-marking of existing parts related to each other and to embedded parts must be carried out carefully.
   
   - Load rejection tests at 1/4 - 1/2 - 3/4 and full load.
   
   - Recording of general data/observations during operation.

2. **Cleaning and sand blasting**

   After dismantling and transport to the cleaning area of the workshop, all turbine parts should be steamed to remove greas and oil. Non-machined surfaces should be sand blasted with subsequent priming. Machined surfaces must be protected before sand blasting.

3. **General Inspection**

   All parts should be thoroughly inspected with the view to uncover potential cracks and determine state of wear.

4. **Spiral Casing**

   If possible, the spiral casing should be dismantled and brought to the workshop (if not embedded) for cleaning and painting inside and outside to a dry film thickness of 280-300 my. The machined surfaces should be cleaned and checked for undulation and carefully machined if necessary.

5. **Turbine Runner**

   If runner material is weldable, all cracks (if any) and damages caused by cavitation and/or erosion should be repaired by welding and grinding. The remaining surfaces of runner and vanes should be ground and polished to smoothness according to normal practice.

   All seal surfaces should be machined and the runner statically balanced before it is mounted on the turbine shaft (if appropriate) for alignment and run-out tests.

   If the runner is furnished with replaceable seal rings, new rings should be produced and installed depending on the extent of wear.
6. **Turbine Shaft**

The shaft should be softly machined and/or ground all over to remove any rust that may have settled. The matching surfaces between turbine shaft/generator shaft and turbine shaft/runner should not be touched unless absolute necessary. The shaft should be thoroughly inspected for cracks.

If bearing surface on the turbine shaft require machining, it usually also requires the bearing to be completely overhauled.

7. **Shaft Sealing Box**

The sealing ring or metal casting should be replaced with new ones which is accurately fitted to the corresponding surface on the shaft or runner hub.

8. **Turbine Covers**

Provided weldable material, worn out areas should be refilled and repaired by welding and grinding.

Facing surfaces and flanges should be machined carefully. If the covers are furnished with replaceable facing plates, new ones should be installed if required.

Old bushings should be checked against the guide vane stem. If the clearance is too large, new bushings should be installed.

Alternatively, old bushings could be machined and selflubricating bushings installed inside the old ones. This would, however, require the guide vane stem to be of stainless steel or at least covered by stainless steel.

The support (bearing) for the regulating ring (head cover) should be machined and, if appropriate, rebuilt to self-lubricating bearings.

Sealing rings against runner should be replaced with new ones which are accurately fitted to the corresponding surface on the newly machined runner.

If the covers do not have replaceable seal rings, necessary design adjustment should be executed in order to install replaceable seal rings.

9. **Regulating mechanism**

Bushings in all connections between lever arms, guide vanes and regulating ring should be thoroughly inspected and if necessary replaced with new bronze or self-lubricated bushings.

In case of self-lubricated bushings, the trunnions have to be of stainless steel.

P2/224
10. Guide vanes

Provided the material is weldable, any damages should be repaired by welding and grinding (blade). The stems are machined to fit the new bushings. If self-lubricating bushings are installed, the guide vane stems have to be metal-sprayed with stainless steel if the material is mild steel.

The blade surfaces against facing surfaces on covers should be carefully machined to clean and fresh metal surface only.

The individual sealing between the guide vanes should be carefully fitted during workshop assembly.

11. Draft tube cone and bend

These parts should be cleaned, sand blasted and painted inside and outside where appropriate.

If the inlet of the draft tube bend has cavitation damages, these should be repaired prior to painting by welding and grinding if the material is of a weldable quality.

12. Flywheel

The flywheel should be thoroughly checked for run-outs and unbalance.

Final test should be performed with flywheel and shaft assembled.

13. Workshop Assembly - Turbine

All parts should be assembled as far as practical in the workshop, and seal clearances and all parts should be checked to make sure they fit as planned.

14. Turbine Inlet Valve

If the valve is leaking, the penstock should be drained and the valve brought to the workshop for inspection and repair of sealing surfaces and change of gaskets and other packings.

The valve should be completely assembled in the workshop and pressure tested.

Prior to installation, the valve should be painted inside and outside.
15. Miscellaneous Equipment

In addition to the main turbine components described above, a general turbine upgrading often involves appurtenances which also need upgrading and repair.

These appurtenances may be quite different from powerhouse to powerhouse, and a repair procedure for these components is not very practical to describe in general.

The repair procedure would best be decided after collecting specific data and information for these components.

This would include governors, electrical components, instruments, etc.

April 7, 1989

Tore Knutsen
Subject: Visit to Pakistan Engineering Co. Ltd. (PECO), Badami Bagh Works, Lahore February 8th, 1989 at 09.00 - 12.00.

Participants: Mr. Birgees Asghar - General Manager, Badami Bagh Works.
Mr. Rana Abdul Wahid - General Manager, Mntg. Tech.
Mr. Ali Ahmad - Manager, Quality Assurance
Mr. Torodd Jensen - NORAD
Mr. Einar Tesaker - NORAD
Mr. Oddmund Kristensen - NORAD
Mr. Tore Knutsen - NORAD

General

PECO is a state owned mechanical workshop with a total of 5500 employees. The Badami Bagh Works, located in center Lahore and which we visited, has about 2500 employees. The Kot Lakhpat Works, just outside Lahore, employs about 2000 people.

The Company was planned and built by the Germans in the late 1940's and started out as a privat enterprise producing basically German goods on license agreements (MWM diesel engines etc.). To manufacture according to DIN Standards is therefore routine at PECO. They prefer to have drawings and specifications in English.

The workshop in general, including production tools and machinery is comparable to a typical mechanical workshop in the 1950's and 60's in Norway.

Major departments such as the foundry, machinery and assembly is dominating. Welding capacity of mild steel is relatively good, but stainless steel technology is not available. PECO does not have stainless steel welders employed at present.

The company has a training center for training/education of skilled workers. The normal training period for steel workers (welding, grinding etc.) and for operators of lathes and milling machines is 1-2 years.

In principle, PECO is interested in cooperation regarding personnel training to the Gilgit Workshop. The minimum level of basic education for the trainees should be ten years schooling. Preferably the trainees should have some previous knowledge about mechanical work.

All tool machinery were completely manual, and a big portion of the machinery were old, and some of it quite worn. The foundry was going through a period of build up and quality improvement. A new furnace was under construction. List of tool machinery were not available, and capacity limits were not confirmed.

However, of what could be observed, PECO will not have any capacity problems as far as weight and dimensions are concerned regarding the equipment for this project.

PE1/223
MINUTES OF MEETING
cont.:

Products

Some of PECO'S main products are:
- textile machines
- concrete mixers
- centrifugal pumps
- diesel engines
- tool machines
- penstocks
- intake- and draft tube gates
- steel structures for transmission lines
- various cast and welded steel products (flywheel etc.)

The product range of tool machines are mainly:
- bench lathes, max. center height: 335 mm
  max. center length: 2500 mm
- vertical drilling machines, max. drilling capacity: 50 mm
- shaping machines, max. 460 mm stroke length
- hack sawing machine, max. 160 mm stroke length
- small milling machines, max. capacity not confirmed

Other products which may be of interest in regard to this project are:
- overhead travelling crane, max. 25 tons.
- steel beams and canals, max. 180 mm height.

Hydro turbine background

In the early 1970's, West-Germany and Pakistan agree on a developing program for electrification of Northern Areas. This resulted in a government agreement for the delivery of 50 nos. 100 kW Francis units (Drees) and 50 nos. 50 kW cross-flow units (Ossberger) to be implemented in the Northern Areas.

PECO worked with Drees as a sub-contractor, and delivered everything except turbine runner, spiral casing, guide vanes and governor.

Ossberger cooperated with Climax of Pakistan.

For unknow reasons the program was discontinued after about 30-35 nos. of each type of units were delivered.

It was mentioned that PECO also had delivered a number of Drees-turbines completely manufactured in Pakistan. This was not easy to get confirmed though.

Today, PECO is not manufacturing turbines, but they are a big supplier of steel structures for the hydro-electric business, such as penstocks, gates, steel supports for transmission lines and transformers etc.

March 16, 1989

Tore Knutsen

TKn/go
PE2/223
A D D E N D U M 7

MINUTES OF MEETING 22.2.89

PEL
(Pakistan Electron Limited, Lahore)

Mr. S.M. Usmani  General Manager Production
Mr. N.A. Siddiqi   General Manager Production-Switchgear
Mr. Tore Knutsen  Mech. Eng. Kvaerner A/S
Mr. Oddmund Kristensen  E1. Eng. EB Energi AS

PEL is an electrical company.

They are about 1000 employees and a staff of about 250.

They are producing:
- Distribution transformers up to 630 kVA
- 11 kV metal clad switchgear
- Distribution boards
- Power transformers up to 5 MVA
- Motor control center
- Low voltage switchgear
- Refrigerators
- Air conditioners

PEL/224
ADDENDUM 8

MINUTES OF MEETING 23.2.89

CLIMAX
(The Climax Engineering Co. Ltd. Gujranwala)

Mr. Javed Iqbal Bhutto Manager Eng. Mech.
Mr. Mansoor-Ul-Haq Manager Engineering Design
Mr. Tore Knutsen Mech. Eng. Kværner A/S
Mr. Oddmund Kristensen El. Eng. EB Energi AS

CLIMAX is an electrical company, private owned, with about 1000 employees.

They are producing:
- Distribution transformers up to 630 kVA
- Power transformers up to 5000 kVA
- kWh-meters
- Motors up to 100 Hp
- Air conditioners
- Current measuring transformers
- Voltage measuring transformers
- Complete small hydro power generating units 50-125 kW
MINUTES OF MEETING 23.2.89

F I C O

(Faizi Industries Limited Gujranwala)

Mr. M.A. Hamid Faizi  Executive Director
Mr. Zia-ul-Hameed  B.Sc. Eng. (Elects.)
Mr. Tore Knutsen  Mech. Eng. Kværner A/S
Mr. Oddmund Kristensen  El.Eng. EB Energi AS

FICO is an electrical private owned company.
They are producing:
- 11 kV Switchgears with oil circuit breakers
- Control panels
- LV switch boards
- LV fuses switch
- HV fuses switch
- Motor control centres
- Motor starters
- Miniature circuit breakers

FICO/224
## IMPLEMENTATION OF PROJECTS IN THE NORTHERN AREA, PAKISTAN

### Project Schedule

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<thead>
<tr>
<th>ACTIVITY</th>
<th>1st. Year</th>
<th>2nd. Year</th>
<th>3rd. Year</th>
<th>4th. Year</th>
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| 1. AWARD OF CONTRACT  
- workshop | 1 - 12 | | | |
| 2. PLANNING AND CONSTRUCTION OF WORKSHOP | | | | |
| 3. PURCHASING, DELIVERY AND INSTALLATION OF WORKSHOP MACHINES | | | | |
| 4. NAPWD TRAINING IN NORWAY | | | | |
| 5. WORKSHOP SUPERVISION AND TRAINING OF WORKSHOP PERSONNEL IN PAKISTAN | | | | |
| 6. HASSANABAD 1 (1 unit)  
- refurbishment  
- runner fabrication  
- erection/commissioning | | | | |

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Kværner Brug A/S

ADDENDUM 10

A3-109
### Project Schedule

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<tr>
<th>ACTIVITY</th>
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APPENDIX 4. SEDIMENT PROBLEMS AND SEDIMENT EXCLUDERS

A4.1. SUMMARY

The power plants visited have the following features in common:

- The Winter flow is rather stable and carries little sediment, as it originates mainly from groundwater seepage.

- The Summer flow is much higher and is mainly caused by melting of snow and glaciers, varying with temperature and cloudiness, and with a regular diurnal variation: morning low and evening high. The sediment contents of the Summer discharges are generally very high, but vary from river to river according to source.

- The sediments have high content of feldspar and quartz particles of sizes usually considered harmful to turbines.

- Installations in the powerplants have been adjusted to the Winter discharge, such that during the Summer period with much sediment, the rivers carry sufficient excess water for flushing and other facilities connected to the headworks.

- The lower parts of existing supply channels have little or no capacity in excess of the design discharge of the power plants. Flushing facilities located between the headworks and the penstock can therefore in most cases only be used when the power plant has been shut down or is running with reduced capacity.

- There is in many cases a significant supply of sediments along the supply channel, caused by local landslides and small creeks entering the channel. This may be of significance also during the Winter season.

The following general guidelines for the arrangement of sediment traps and sediment excluders follow as a consequence:

- The main sediment excluders should be arranged near the headworks where there is excess water available for flushing. These should
preferably be arranged such that continuous delivery of full channel capacity flow can be maintained during flushing.

- Secondary sediment excluders will usually be needed close to the forebay/penstock, or even at intervals along the channel route. Flushing of these may require temporary reduction or closure of the power production. The design should aim at economic water budgetting by use of minimum flushing water during periods of full demand on the power output.

- It is possible to plan sediment chambers for manual or mechanical removal of deposits by arranging two parallel sediment chambers and always using one for the full throughflow of turbine discharge. The chamber unused at any time may than be drained and emptied. This method may be useful for secondary sediment excluders where the amounts of deposit are moderate, but will usually not be feasible for the main excluders, where deposition may amount to hundreds of tons a day.

The situations have been reviewed for six plants visited during the mission. A short summary of the results/conclusions is found below. More details will be found in the following chapters:

Kharga, phase 7.

- This is a new powerplant under construction. Recommended facilities have been adjusted to match already completed work.

- It is suggested that a sediment excluder at the headworks be doubled in length and given modified in- and outlets.

- Unless a parallel sediment trap is constructed, the production must be closed during flushing.

- A secondary sediment trap has been proposed near the forebay/penstock, unless most of the canal can be covered.

- Some possibilities exist for dynamic separation of bed load from the canal inlet.
Kharga, phase 5

- The old powerplant will be combined with a new phase 6. Total discharge through the present intake and canal will be increased to 70 cf/s.

- It is proposed to connect the tailrace of Kharga 7 with the headrace of Kharga 6 which will give sediment-free water. The intermediate head may be used for an extra installation Kharga 5B.

- The old intake to Kharga 5 must be retained for use when Kharga 7 is closed in order to give water to Kharga phase 6. An improved sediment excluder must therefore be constructed downstream of the old intake, of similar design and capacity as that proposed for Kharga 7.

- The existing Kharga 5 plant may be retained for use when there is enough extra water in the river to run the plant parallel to Kharga 7/5B/6.

Hassanabad, phase I

- The old plant is in very poor condition due to rock slides. There is a very large sediment load. There are plans for upgrading by local authorities.

- Combined repair and improvement of the existing sediment trap have been proposed, including a dividing wall to make a double trap for alternating use, such that the powerplant can be operated continuously.

- A secondary sediment trap near the forebay and/or covering of the parts of the canal most threatened by landslides are recommended.

Hassanabad, phase II

- The existing plant has great sediment problems, both turbine wear and silting in the canal. The sediment excluders are insufficient.
- A new sediment excluder with two parallel chambers is proposed near the existing excluder.

- Extensive covering of the canal is needed to reduce lateral intrusion of sediments.

- A secondary sediment trap near the penstock area may be combined with extension of penstock and canal to gain extra head.

Nomal

- This is another plant with great sediment problems, unused head and discharge potential, and insufficient sediment excluder.

- The proposal to increase the used discharge from 25 cf/s to 80 cf/s requires increased canal dimensions and efficient sediment excluders.

- A site for a new two-chamber sediment excluder has been found near the headworks.

- A secondary sediment excluder should be planned near the (new) forebay for added safety.

- It is necessary to rearrange the intake of the canal due to increased canal discharge. The proposed arrangement should be further checked during flood discharge.

Tangir

- The existing plant is not included in the upgrading proposal.

- A new 180 m head plant has been investigated for development in two phases: 50 cf/s and 140 cf/s.

- The new canal should be constructed for 140 cf/s from start.
- The terrain is too steep for the arrangement of an efficient sediment excluder near the headworks, but a gravel trap has been proposed in connection with the intake.

- The main sediment excluder may be placed in the lower part of the canal. It has been proposed to arrange a two-chamber excluder for phase I, with capacity $2 \times 70 \text{ cf/s}$, utilizing the fact that the canal can carry up to $140 \text{ cf/s}$ also during phase I.

- Experience during phase I will show if a new parallel $140 \text{ cf/s}$ capacity excluder will be needed for phase II, or whether interrupted supply during flushing may be acceptable.
A4.2. PRINCIPLES FOR SEDIMENT EXCLUDERS

Methods for removal of sediments from flowing water may be divided into three groups:

a) Deposition by reducing the flow velocity and turbulence.
b) Separation by dynamic methods.
c) Chemical methods.

Only a) and b) are of interest here.

Deposition is obtained in sand traps or settling basins. The simple principle is to reduce the bottom shear stress and the turbulence below the limits where sediment transport can be sustained. It is also necessary to provide enough time for the settling of suspended particles while in the trap, and enough volume to store trapped material until it can be removed.

Removal can be done by hand or mechanical equipment, or by flushing through special outlets.

Dynamic separation methods use the different densities of water and sediments to divert and drain sediment particles away from the main flow of water. Centrifuges and cyclones are widely used for industrial purposes. For power plant purposes, it is possible to use the centrifugal effect to direct bed sediments towards the inner bank of a horizontal curve or to the center of a cylindrical basin with rotating flow. The concentrated sediments may then be removed by moderate use of water, or utility discharge with reduced sediment content may be diverted from the outer bank or circumference.

A special case of dynamic separation may occur at the point of diversion of the canal from the river. By choosing the diversion point where the streamlines are curving away from the intake, a significant reduction of bed-load intrusion to the canal may be obtained. Where there is no natural curvature, artificial guide walls or jetties may be constructed in order to obtain this effect. Fig 2.1 shows examples. In swift rivers, where even gravel and small cobbles may be suspended during floods, the effect of such methods may be somewhat limited.
SEDIMENT EXCLUDING GUIDE VANES (a) AND GUIDE WALLS (b)(c)(d) IN FRONT OF THE CANAL HEADWORKS. REF A3
A4.3. SEDIMENT CONDITIONS AT THE VISITED SITES

3.1 GENERAL INFORMATION

The visit occurred during a period with near minimum discharge in all rivers, and consequently little or no sediment transport could be observed. The head race canals carried clear, apparently sediment-free water except at Hassanabad I and II, where very fine suspended sediments made the water non-transparent, even at shallow depths.

Water samples to determine sediment concentrations were considered useless under these conditions, as quite different conditions prevail during the Summer season.

Sediment concentration data for flood conditions are to our knowledge non-existent for the visited rivers. Some data from Hunza and Gilgit rivers were provided by WAPDA in Lahore. These show concentrations up to 2% by weight in Hunza river, however, with very great variations from sample to sample.

Judging from local information, observations of soil conditions at the head works and deposits in the canals, as well as reports and observations of worn turbines, our tentative impression is that all visited sites require efficient silt excluders. The expected volume rate of transport seems much larger at Hassanabad than at Kharga, Nomal and Tangir.

In order to get more precise information it is recommended to take samples of suspended sediment concentration during the coming Summer season at all the sites visited during the mission. Sampling should be made as close as possible to the existing or proposed canal entrances preferably for very high and "typical" Summer flows.
3.2 INFORMATION FROM SAND SAMPLES

Two series of sand samples have been analysed for mineral contents. The first series is reported in ref (A1) and is based on counting of particles under microscope. The second series from the visit 6-20 Febr. is based on XRD - analysis, and is reported as an addendum to this Appendix (p. A4.30-40).

A comparison of the two series is given for some minerals below.

Contents of quartz and feldspar in sand samples, per cent.

<table>
<thead>
<tr>
<th>Site</th>
<th>Series</th>
<th>Quartz</th>
<th>Feldspar Mono-plagio</th>
<th>Sum</th>
<th>Size fraction (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hassanabad Series 1</td>
<td>67</td>
<td>16</td>
<td>83</td>
<td>0.75-0.125</td>
<td></td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>18</td>
<td>85</td>
<td>0.125-0.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>61</td>
<td>21</td>
<td>81</td>
<td>&gt; 0.25</td>
<td></td>
</tr>
<tr>
<td>Hassanabad Series 2</td>
<td>7</td>
<td>17</td>
<td>42</td>
<td>0.075-0.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>20</td>
<td>40</td>
<td>0.25-0.5</td>
<td></td>
</tr>
<tr>
<td>Tangir Series 1</td>
<td>42</td>
<td>27</td>
<td>69</td>
<td>0.075-0.125</td>
<td></td>
</tr>
<tr>
<td></td>
<td>38</td>
<td>35</td>
<td>73</td>
<td>0.175-0.75</td>
<td></td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>39</td>
<td>79</td>
<td>&gt; 0.25</td>
<td></td>
</tr>
<tr>
<td>Tangir Series 2</td>
<td>19</td>
<td>0</td>
<td>62</td>
<td>0.25-0.50</td>
<td></td>
</tr>
<tr>
<td>Kharga Series 2</td>
<td>15</td>
<td>0</td>
<td>61</td>
<td>0.075-0.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>8</td>
<td>62</td>
<td>0.25-0.50</td>
<td></td>
</tr>
<tr>
<td>Nomal Series 2</td>
<td>17</td>
<td>0</td>
<td>59</td>
<td>0.25-0.50</td>
<td></td>
</tr>
</tbody>
</table>

The two series differ greatly in the amounts of quartz. The sums of quartz and feldspar show good consistency, however, within the variation that must be expected from different local sampling sites.

The variation in quartz contents most likely originates from problems in distinguishing quartz and plagioclase feldspar particles in the microscope. Since both minerals are considered dangerous to turbines,
the difference may not be very significant. In conclusion, the samples indicate that 65 to 85 per cent of the sediments are minerals known to be harmful to turbines.

However, if the difference in hardness between quartz (7) and feldspar (6) is enough to qualify or disqualify a certain turbine material as finishing, the results may well be important for the projects.
A4.4 RECOMMENDATIONS FOR SEDIMENT EXCLUDERS

4.1 KHARGA, PHASE 7

This powerplant is under construction,

Design data: discharge 68 cf/s = 1.94 m³/s
  canal width 5' = 1.5 m
  slope ~ 1:300 in main part.

The design includes a silt trap near the intake site, width 20', length 60', depth 3.5' below the canal bed, top of wall about 5' above the canal bed. The silt trap was designed with a sloping bed ~ 1:25 and a sideways flushing gate at the lower end. The in- and outlet to the canal was designed without tapering and with 90° corners. Photo no .1-.2. The silt basin walls had been reinforced but not yet cast due to cold weather. It was therefore still possible to propose some improvements of the basin without much need to demolish completed parts.

Based on calculations see addendum p A4.41-46 it was concluded that the 60' x 20' basin might be modified to serve for trapping of particles coarser than 0.3 mm and a greater part of particles down to 0.2 mm as well.

The modifications included:

- expansion of the inlet from canal to basin until full width (20') at the entrance
- making the top of the basin walls horizontal allowing for minimum slope through the basin
- construction of an overflow weir of full width (20') at the outlet
- arranging a control gate and a side spillway placed upstream of the expanded section, for adjustment of discharge through the basin.
In order to trap most of the 0.2 mm particles as well as a significant part of particles between 0.1 and 0.2 mm, a basin of double length would be required.

This extension of the basin from 60' length to 120' length is recommended. It was found sufficient in this particular case to use the same bed level for this extended part (lower 60') of the basin as already prepared for the canal, but increase the width of the basin to 20'.

A drawing of the extended version of the basin was delivered to the local authorities for possible action.

This drawing is shown in Fig. 4.1.

No information was found about actual silt concentration in the Kharga water during various discharge situations. It will therefore be mere guesswork to estimate how frequently the basin will need flushing.

The proposed basin has a useful volume for deposits of 12600 cf = 360 m$^3$ i.e enough for 500 tons of dry weight of deposits. The through-flow in one day is $68 \cdot 3600 \cdot 24 = 5.8$ mill cf = 165000 m$^3$.

For flushing once a day this permits maximum deposition of 3000 p.p.m, which may result from a total load of about 5000 p.p.m.

Such concentrations may occur during short periods, but usually less sediment load is expected. It is therefore anticipated that the basin will need flushing after some days of operation during peak floods.

Partial removal of deposits close to the flushing gates may be obtained during operation of the power station, as long as there is excess water available for flushing. To remove the greater part of the deposits, it is necessary to drain the basin during flushing, which means that all supply to the power plant will be closed during the flushing period.
KHARGA '7. SILT EXCLUDER. PROPOSED DIMENSIONS

Fig. 4.1.

Top weir to top wall ~ 0.75m (2.5')
Top basin wall (horizontal water surface (approx.)

Basin floor at channel level

Basin floor as under construction

Side view

Overflow weir

Flush sluices

Plan

18.0 m (60')

Spillway extension

Basin under construction

Entrance

0 5 10 m

K. Feb. 1989
E. Zarker

Fig. 4.1. Sediment Excluder for Kharga Phase 7
Experience and increasing power demand may call for later arrangement of a parallel siltation basin and special flushing facilities for instance by similar principles as described below for Hassanabad I/II. At the moment our concern is more about sediments entering downstream of the siltation basin from slides or small tributaries. It is also unavoidable that some harmful sediments will pass the sediment chamber during operation of flushing gates etc., and be transported to the forebay and turbines.

Slides and tributary inflow may be prevented by covering of the canal. Some parts of the canal are already prepared for covering. It may be good economy to cover larger parts of the canal by a roof.

Unless all significant lateral sources of sediments can be avoided, there will still be need for a secondary sifting basin near the forebay.

It is recommended to use the same basic layout and dimensions for this basin as shown in Fig. 4.1. At this location, however, all flushing will have to be made on the expence of power production, since there is no capacity for excess water in the canal. It seems therefore wise to construct the bottom of the basin with sideways's slope towards the flushing gates for more efficient flushing. A sloping bottom is also convenient for later inclusion of more sofisticated flushing facilities if such should prove feasible.

The intake location for Kharga 7 is at a very turbulent part of the river and it is therefore uncertain whether any practical arrangement may be found in order to reduce intrusion of bed load sediments. At the site visit, a possible short jetty on the opposite side of the river was indicated. Photo no. 3 shows the river bed looking upstream along the canal. There is a rock outcrop where the jetty may be based. It is necessary to observe the flow conditions during high discharge for a realistic assessment of the possibilities.
KHARGA

1.1

.2

.3
Design data: discharge during visit 28 \( \text{cf/s} = 0.8 \text{ m}^3/\text{s} \)
- canal width 5' = 1.25 m
- max canal depth 2.5' = 0.68 m
- slope ~ 1:250 (varying)

The intake is located in a steep and almost straight part of the river with large boulders, photo no. 4. A short threshold dam has been constructed to control the water level at minimum discharge. The dam has an opening meant for stop logs or a slide gate, intended to be removed when needed for high discharges. The opening was now temporarily closed by a rock wall typical for traditional local rock masonry. It was explained that the rock wall would yield during rising discharge, and had to be rebuilt every fall.

The arrangement may well be efficient for preventing coarse particles to enter the canal.

A stilling basin, 15' wide 60' long is located shortly below the intake, photo no. 5. The canal entered and left the basin asymmetrically, near opposite corners. Some gravel and sand was found trapped in the two remaining corners, but the flow velocity through the chamber was generally too high for settling of finer particles.

No details were given about flushing practice. It is clear that only a small part of the sediments entering the canal can be removed by the stilling basin.

New plans for Kharga phase 6 will utilize the same intake, but raise the discharge to 70 \( \text{cf/s} = 2.00 \text{ m}^3/\text{s} \). This is very close to the discharge of Kharga 7. A silting basin of similar size and design as described for Kharga 7 should therefore be sufficient. Site for such a structure may be found immediately downstream of the existing basin.

An elegant solution may be obtained by directly connecting the tailrace of Kharga 7 and the headworks of Kharga 6. With efficient silt removal from Kharga phase 7, this will ensure the same good sediment conditions for Kharga 6, whenever Kharga 7 is operating.
For use when Kharga 7 is out of operation (repair, flushing), the existing intake should be retained, and it is therefore necessary also in this case to install a new sediment trap in the existing canal. It is envisaged that Kharga 5 may still be operated parallel to the Kharga (7 + 6) system whenever the discharge is sufficient in the river. The improved sediment trap will benefit also this operation.

The head difference between the Kharga 7 tailrace and the Kharga 6 headworks may be used for a new installation, Kharga 5B, otherwise the energy must be killed by special arrangements in the connecting channel. Details should be left to the consultant.
4.3 HASSANABAD I

Data: discharge 23 cf/s = 0.65 m³/s
   canal size: 6' wide 4' deep
   canal length 1.5 km
   slope upper part - 1:200    lower part 1:300

This plant was in a very dilapidated condition during the visit. In the station the turbine runners and the bearings were badly worn and the generator was running at too low frequency. The canal and settling basin were both partly damaged by rockfall said to have come from construction of a new irrigation canal. The new canal was now completed, and plans for reconstruction of the power plant were under discussion.

The lower part of the canal was concrete lined and partly covered by concrete slabs, but many cover plates were broken, photo no .6. The middle part was open, and less threatened by slides, photo no .7. Irregular cross sections and slope caused local deposition of sand and gravel. A temporary silting trap had been arranged, photo no .8.

The damaged sediment basin is shown on photos no .9-.10. It is 35 m long, 12 m wide and 3 m deep. Entrance and outlet have the width of the adjoining canals, with no expansion or rounded corners, as can be seen on the photos. Two flushing gates were arranged along the side facing the river, photo no .9. A by-pass canal, showing on photo no .10 was arranged for water supply to the power plant during flushing. It was presently in permanent use while the basin was broken.

The basin was half full of sediments. We were told that the situation now was about as resulting from an ordinary flushing, but some sand had obviously also been flushed through the broken wall. An ordinary flushing was said to take 4 hours, even with assistance of 4 men with showels. During the flood season, the basin might fill in two days.

Filled to 2 m average depth, the sediment volume will be 840 m³ i.e. about 1200 tons dry weight. Residual sediments after flushing may reduce this to 1000 tons per filling. Two days of 0.65 m³/s totals 112 000 m³ of throughflow i.e. average silting 1000/0.112 ppm = 9000
ppm. This might indicate that total concentrations up to 15000 ppm occur during floods. Incidentally this figure corresponds with maximum figures for concentrations in Hunza river reported by WAPDA.

In order to avoid closure of the power plant or using bypassed water with full sediment load while flushing, the Executing Engineer suggested to divide the existing basin into **two parallel chambers**, for alternating use. This principle is the only safe method to handle such sediment quantities as found in Hassanabad river. Possible details were discussed in general terms at site. It was suggested to improve the in-and outlets in order to reduce local velocities and turbulence, using principles already discussed for Kharga 7.

Fig. 4.2 shows a proposal based on the existing basin. By using a full width overflow weir, the weir level can be raised as compared to the existing narrow outlet. This will increase the efficiency of the basin, and also its effective volume.

The design Fig. 4.2 may easily be compared with Fig. 4.1 and the calculations in p. 42-46 for Kharga 7. Since the size of each chamber after division is almost equal to the sediment chamber of Kharga 7, but the present power plant capacity in Hassanabad I is only 23 cf/s as against 68 cf/s in Kharga 7, there is no need for detailed calculations to conclude that it will remove a major part of particles down to 0.1 mm size if satisfactory inflow conditions can be obtained.

The flushing frequency will be nearly doubled with the new design, but since flushing can now be done without affecting the power production, daily flushing in the flood season should be acceptable.

The Executing Engineer indicated a possible upgrading of the canal and powerplant to 50 cf/s. The redesigned sediment chamber Fig 4.2 may work well also for this discharge, but the frequency of flushing may be increased to near twice a day in the flood season.

The only way to reduce the flushing frequency is to increase the volume available for deposits. This is most easily achieved by increasing the length of the chambers, for example to 50-70 m. Experience will show if this is necessary.
It should be mentioned that various designs for more or less continuous flushing exist, some including automatized operation. None are so far dependable for operation without supervision when the sediment load is as large as in this case.

If completely new sediment traps are to be made, however, it is possible to reduce the flushing time by giving the bottom a sideways slope creating a ditch along the flushing gates.

The intake area to Hassanabad I lies on very unstable ground. It seems unrealistic to construct permanent intake structures. The present practice of reconstructing guiding rock dams before every low water period seems most realistic.

The intake is located in an inner curve of the river. Photo no. 4. This is unfavourable because too large proportions of bed-load may enter the canal. No other useful intake location was found upstream within reasonable distance.

A more suitable intake site may be found slightly downstream of the present intake, most likely at too low level as long as the existing sediment basin shall be used. If was also argued that location at the outer bank tends to give more seasonal damage because the currents are strongest there during floods. Only strong, permanent structures can probably resist such forces.

The sediment basin Fig 4.2 may not need any supplement if the lower parts of the canal be protected against lateral inflow of slide material etc. If this is unavoidable, a single secondary sediment basin should be constructed as close to the forebay or the covered part of the canal as possible. This basin will need the same dimensions as each chamber on Fig. 2 for proper settling of the sediments. The amount of settled material will be much less, however, and it seems therefore acceptable to close the powerplant during flushing when occasionally needed.
4.4 HASSANABAD II

<table>
<thead>
<tr>
<th>Project data: discharge powerplant</th>
<th>= 18 cf/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ irrigation</td>
<td>= 5 cf/s</td>
</tr>
<tr>
<td>present canal discharge</td>
<td>= 23 cf/s 0.66 m³/s</td>
</tr>
<tr>
<td>proposed discharge</td>
<td>= 32 cf/s 0.91 m³/s</td>
</tr>
<tr>
<td>may be increased to</td>
<td>= 50 cf/s 1.43 m³/s</td>
</tr>
<tr>
<td>canal width</td>
<td>~ 8' = 2.4 m</td>
</tr>
<tr>
<td>canal length</td>
<td>4 km</td>
</tr>
</tbody>
</table>

The plant has two turbines with parallel penstocks.

Like Hassanabad I, the sand problem is very prominent. Present facilities for sand exclusion are quite inadequate, consisting of:

- one gravel trap, 110' long 8' wide, depth unknown, shown on photo no. 12.

- 7 stilling ponds along the canal arranged by slight widening of the canal cross section and local reduction of slope, each supplied with a flushing gate. Photo no. 13.

During the visit, the discharge was only 12 - 15 cf/s, but velocities in the stilling ponds were around 1 ft/s, indicating 1.5 ft/s during full operation.

Flushing practice was reported as follows: Once a day each stilling pond is being flushed one by one, starting with the lower one, ending with the gravel trap. This takes about two hours to complete, then another two hours are needed to fill the canal again. Total break in power production is 4 hours.

Even this practice could not hinder severe silting of the canal and extensive wearing of turbines.

Direct inflow from the river is the main source of sediments. The characteristics of the river have been discussed in the previous chapter. The canal headworks for Hassanabad II are located on very
unstable ground. A glacier some km upstream of the headworks feeds very turbid water even in the dry season. A tributary from the west side delivers clear water in the dry season, but is then only sufficient for an irrigation and water supply canal. During floods, the excess water from this tributary carries less sediments than the main river. Attempts to conduct the excess tributary flow into the power canal has been made, with some success.

In Photo no. 14 this "Summer channel" lies to the right with the main river intake coming from left. The gravel trap is barely visible in the center of the picture.

There are in addition several sources of sediments along the canal, Photo no. 15-16. Only small sections of the canal have been covered against slides and tributaries, Photo no. 17.

A programme for reduction of the sediment problem in the power plant may include:

a. A main sediment excluder near the headworks designed for continuous delivery of water to the canal.

b. A secondary sediment excluder near the forebay.

c. Covers on sections of the canal where slides or heavy inflow of melt water contribute significantly to the sediment load. (Alternative to extensive covering is to improve the existing local stilling basins. But operation of these will inevitably cause water loss and reduced power production).

c. Improvement of the Summer channel shown on Photo no. 14 for more effective collection of tributary flow.

The main sediment excluder a) may be located near the existing gravel trap. It is recommended to use similar design principles as described for Hassanabad I, Fig. 4.2. Since this will be a completely new structure, some improvements compared to Fig. 4.2 may be introduced:
- The basin floor may be given a transversal slope towards the flushing gates.

- The flushing conduits crossing one chamber may favourably be placed underneath the floor of this chamber.

- The width of the trap may be adjusted according to the design discharge. If 35 cf/s is chosen as maximum canal discharge, 4 m net width of each chamber will be sufficient, as against 5.75 m for 50 cf/s in Fig. 2.

For the secondary sediment excluder b), only one chamber is needed, since there will be less sediments to cater for and no excess water for flushing during full production. Whenever there is surplus water available because of reduced power production, partial flushing may be arranged by careful operation of the flushing gates.

A possible location of the secondary sediment trap may be found where the present canal turns into the steep headrace channel. The consultant will have to solve this in connection with utilization of the extra head available between this point and the existing forebay. Photo no. 17.

It is necessary to investigate the Summer channel d) further before further details can be proposed. An inspection during flood conditions may be recommended.
4.5 Nomal

Existing powerplant: min discharge = 25 cf/s = 0.7 m³/s
   canal width = 2.2 m
   canal depth = 0.9 m
   canal slope varying 1:400-1:250

Minimum river discharge 60-80 cf/s = 1.7-2.3 m³/s
Possible redesigned power plant discharge 80 cf/s.

This powerplant has serious problems with turbine wear. Like at Hassanabad II there is also available extra head, now dissipated in a steep ladder channel connecting the feeder canal and the forebay. There is also a possibility to increase the head downstream from the power house.

There exists a small gravel excluder near the canal intake, but quite inadequate even for the small discharge of today. Photo no. 18.

Proposal to increase the powerplant installation for 80 cf/s discharge will require increased canal dimensiones and efficient sediment excluders.

A proper site for the main sediment excluder exists just downstream of the existing gravel trap, photo no. 19. It is possible to construct a trap of similar design, depth and length as proposed for Hassanabad II, but with increased chamber width to cater for additional discharge. By proportional reasoning, the net width for 80 cf/s should be 9.2 m in each chamber. This is a rather wide area to flush towards one side only. If is therefore suggested to construct each chamber with central drains along a V-shaped bottom as shown on Fig. 4.3.

Little is known about the sediment concentration in Nomal river, but it is assumed to be less than for the Hassanabad case. The flushing of the trap may therefore be less frequent then at Hassanabad.

A secondary one-chamber sediment excluder may be needed near the tailrace also for this plant. The canal route is less exposed to slides than those previously described, such that if the main excluder works
efficiently, flushing of the secondary one should be required infrequently or be performed as frequent small flushings when excess water may be available.

The secondary excluder should conveniently be constructed in connection with new structures for utilizing the extra head available, above the present forebay.

The intake site for the present canal, photo no .20, will not be suitable for the increased discharge after reconstruction of the plant. It may give a better solution to cut a canal through the low threshold to the right of the rock outcrop shown in the middle of photo no .20. The canal intake will then be located under the present bridge. Also in this case it is advisable to observe the flow conditions during high discharges before the final design.
Fig. 4.3
4.6 TANGIR

The Tangir site differ from the other visited sites, since the old power plant is not included in or directly connected to the new plans under investigation.

The old 160 kW plant has little potential for upgrading and can hardly bear the expenses of new intake facilities to exclude the sediment load.

Sites for a new plant have been found in a very steep part of the river downstream of the old plant. The proposed intake site is shown on Photo no. 21. The supply canal will follow an existing irrigation canal, photo no. 22, supplying the village Shearkh, but continue further downstream until a head of about 180 m is obtained.

The terrain is very steep, but according to local information, slides are rather rare on this side of the river. There are few sites where sediment excluders may be located. It is therefore proposed to locate the main sediment excluder in the lower part of the canal past Shearkh, where a suitable site may be found. The plant is proposed for discharges of up to 140 cf/s (4 m³/s) with a first phase of 50 cf/s (1.4 m³/s). The canal and sediment excluders should be constructed for 140 cf/s. Tentatively, canal dimensions have been estimated to 1.7 x 1.7 m, slope 1:500. This has to be checked by the consultant. The steep hillslope makes it convenient to use a rather deep and narrow canal with proper concrete lining to avoid leaking.

The proposed phase I (50 cf/s) makes it possible to construct two parallel sediment chambers in the lower part of the canal along the same principles as described for Hassanabad and Nomal. The 140 cf/s capacity canal will allow for more than double discharge during phase I such that continuous delivery to the power plant will be possible during flushing. The width of each chamber should be chosen such that both chambers together later may form the sediment basin for 140 cf/s. Each chamber should therefore have a width sufficient for 140/2 = 70 cf/s i.e. about 8 m wide. A similar sluicing arrangement as for Nomal (Fig. 4.2 and 4.3) is recommended. Experience during operation of phase I will tell whether it will be required to construct an
additional parallel 140 cf/s capacity chamber for phase II in order to allow for continuous operation during sediment removal (mechanical), or whether reduced production may be accepted while flushing one by one the two phase I chambers.

In any case the site of the phase I sediment excluder should be chosen such that a possible doubling for phase II can be arranged later. It may be arranged side by side with the first chamber, or one after the other with by-pass channels for alternating use.

The location of the main sediment trap at the lower end of the canal incurs that the sediment load has to be carried along the whole canal if not deposited in the canal. During phase I, 2 x 50 cf/s (i.e. 2.85 m³/s) in a 1.7 m wide canal of slope 1:500 will be able to transport at least 8 mm size particles. Coarser particles will deposit near the intake.

In order to avoid deposition in the canal it is recommended to:

- construct a gravel trap with flushing sluices near the intake
- maintain constant (or increasing) slope along the canal.

The gravel trap should be slightly wider than the canal, and have sufficient volume for deposits. Suggested dimensions are:

- width 2-2.5 m
- length 15-20 m
- depth 1.5-2 m below the canal bed.

3-4 bottom sluices should be installed along the side facing the river, for efficient sluicing. The accurate design and location of the gravel trap have to be decided after thorough investigation of the ground conditions, and the actual bed load transport during floods.

The intake (photo no. 21) may be arranged as a concrete threshold diagonally across the river near the big rocks in the center of the photo, to be connected directly to the outside canal wall. The threshold should have a low section near the canal entrance for diversion of the bed-load transport during floods. Reference is made to the
existing threshold for the intake to Kharga phase 5. This low section may be closed by stop logs during low discharge since it is dubious whether any mechanical sluice structure will survive the flood conditions.

A4.5. REFERENCES


Prosjektnr.: 604678  
Mineralogisk XRD-analyse av prøve merket: *Nomal 0.25 - 0.50*  
Vårt J.nr.: 890232

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Med hilsen  
S. Bergstøl
ANALYSERAPPORT
for

**Norsk hydroteknisk laboratorium, Sintef Avd.**

Værts J. nr.: 890233

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Med hilsen

S. Brynild

Trondheim, den 10/3-89
**ANALYSERAPPORT**

*for*

Nors**h** hydroteknisk **Laboratorium** Sintef Avd. 60

Trondheim, den 10/3 - 89

Prosjektnr.: 604678
Mineralogisk XRD-analyse av prøve merket: Tangir 0.25 - 0.50

Vårt J.nr.: 890235

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Med hilsen

S. Børstøf
**ANALYSERAPPORT**

for

Norsk hydroteknisk laboratorium, sintef av

\[\text{Prosjektnr.: 604678}\]

Mineralogisk XRD-analyse av prøve merket: **Hassanabad II, 0.025 - 0.2**

Vårt J.nr.: **890234**

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Med hilsen

S. Bøeptof
ANALYSERAPPORT

for

Norske hydroteknisk laboratorium Sintef Avd. 60

Prosjektnr.: 60 4678
Mineralogisk XRD-analyse av prøve merket: Khanga, fraksjon 0,25-0,50

Vårt J.nr.: 890230

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Med hilsen

S. Bergfjord
ANALYSERAPPORT for

Norsk hydroteknisk laboratorium, Sintef Avd

Prosjektnr.: 604678
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Vårt J.nr.: 890231

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Trondheim, den 10/3 - 89

Med hilsen
S. Bergstol
KORNFORDELINGSANALYSE

Grain size analysis
OPPDRAG NR.: 362053.00/89020
MATERIALE: SAND
PROVEMERKING: KHARGA
LABORANT: FD
DATO: 1989.03.08.

SINTEF Avd Bergteknikk
KORNFORDELINGSANALYSE
Grain size analysis

OPPDAG NR.: 362053.00/89020
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PROVEMERKING: HASSANABAD..............................
LABORANT: FD............................ DATO: 1989.03.08.
KORNFORDELINGSANALYSE

Grain size analysis

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SINTEF Avd Bergteknikk
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Grain size analysis

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PROVEMERKING: TANGIR ...................................................
LABORANT: FD .......................... DATO: 1989.03.08.

SINTEF Avd Bergteknikk
APPENDIX
DESLITING BASINS FOR
KHARGA 7 / KHARGA 5

PREPARED AT SITE

KHARGA 7. DESLITING BASIN.

ALT. 1. USE THE BASIN UNDER CONSTRUCTION WITH THE FOLLOWING MODIFICATIONS:

- MAKE TOP OF SIDE WALLS HORIZONTAL AT LEVEL 5' ABOVE LEVEL OF INCOMING CHANNEL

- MAKE FUNNEL SHAPED APPROACH CHANNEL TAPERED 1:8 TO FULL WIDTH OF BASIN

- MAKE FULL WIDTH OVERFLOW WEIR AT DOWNSTREAM END, ABOUT 2.5' BELOW TOP OF SIDE WALL.

CALCULATIONS:

GIVEN: DISCHARGE 68 cfs
       WIDTH 20'
       LENGTH 60'

1. FLOW DEPTH OVER WEIR \( \Delta h \)

\[
Q = 1.71 \cdot (\Delta h)^{3/2} \quad \text{m}^3/\text{sec}
\]

\[
Q = 68/20 = 3.4 \text{ cfs} = 0.31 \text{ m}^3/\text{m}
\]

\[
\Delta h = (0.31 / 1.71)^{2/3} = 0.32 \text{ m} = 1.05'
\]

2. FREEBOARD AT WEIR = 2.5' - 1.05' = 1.45' 04

3. ASSUME EFFECTIVE FLOW DEPTH \( \sim 3' \) MINIMUM

MAX VELOCITY IN BASIN \( 68/(20 \cdot 3) = 1.1 \text{ H/S} \)

FOR EMPTY BASIN THE VELOCITY WILL BE LESS

MIN TIME FOR PASSAGE 60/11 = 55 sec.

<table>
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<th>PARTICLE DIAMETER (MM)</th>
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<th>SETTLING TIME (SEC)</th>
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<td>0.3</td>
<td>0.1</td>
<td>5.5</td>
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<tr>
<td>0.2</td>
<td>0.05</td>
<td>2.8</td>
</tr>
<tr>
<td>0.1</td>
<td>0.017</td>
<td>0.94</td>
</tr>
<tr>
<td>0.05</td>
<td>0.004</td>
<td>0.23</td>
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</table>
4. Flow Velocity Near Weir

\[ V_w = \frac{68\,(1.05)}{2.0} = 32 \text{ ft/sec} \]

\[ V_w^2 / 2g = \frac{3.2^2}{2 \times 32} = 0.16 \text{ ft/sec} \text{ velocity head} \]

5. Flow Lines Near Weir

\[ \begin{align*}
& \text{VERTICAL COMPONENT} \\
& 1.05 \left( \frac{1}{17} \right) = 0.15 > 0.067 \text{ ft/sec} \\
& \text{CONCLUSION ACT 1} \\
\text{Particles with diameter 0.2 mm will sink at least to a level} \ 2.8 - 1.1 = 1.7 \text{ ft below the weir before reaching the suction area near the weir.} \\
\text{The vertical upward component may still be large enough near the weir to drag some of these particles over the weir.} \\
\text{The basin Act 1 is therefore not sufficient for removal of all particles of 0.2 mm diameter.} \\
\text{Particles of 0.2 mm diameter entering the basin near the channel bed or in mid stream will most likely be deposited in the basin.} \\
\text{The basin will retain most particles of 0.3 mm diameter or coarser.} \\
\text{Particles finer than 0.1 mm diameter will be little affected by the basin.} \end{align*} \]
COMMENTS TO ALT 2

THE LENGTH IS DOUBLE OF ALT 1

EFFECTIVE FLOW DEPTH MAY STILL BE 3'

PASSING TIME (MINIMUM) = 55 .2 = 110 sec

SETTLING IN 110 sec (ft)

- 0.3 mm particle (ft)
- 0.2 " 
- 0.1 " 
- 0.05 "

CONCLUSIONS, ALT 2

SAFE SETTLING OF MOST PARTICLES 0.2 mm OR COARSER

IMPROVED SETTLING OF PARTICLES 0.1 mm BUT MOST OF THIS FRACTION OR FINER WILL STILL PASS THE BASIN.

THE SITUATION AT KHARGA 5 IS SIMILAR TO KHARGA 7

THE EXISTING SEDIMENT BASIN IS INADEQUATE
THE SAME DESIGN OF BASIN MAY BE APPLIED FOR BOTH SCHEMES.

ALTERNATIVELY, THE TAILWATER OF KHARGA 7 MAY BE CHANNELLED DIRECTLY TO KHARGA 5 THEREBY AVOIDING NEW SEDIMENT LOAD TO ENTER FROM THE RIVER.

IT MAY IN THIS CASE BE CONVENIENT TO RETAIN THE PRESENT INTAKE FOR KHARGA 5 AS AUXILIARY INTAKE TO BE USED WHEN FLUSHING OF KHARGA 7 BASSIN IS CARRIED OUT.
CONTENTS

1. INTRODUCTION 3
2. DATA COLLECTED FROM WAPDA 3
3. MEASURED MINIMUM DISCHARGES 5
4. ANALYSIS OF RIVER BASINS 7
5. ANALYSIS OF DISCHARGES 7
6. CONCLUSIONS 8
1. Introduction

During the mission to Pakistan relevant data and reports were collected at WAPDA in Lahore. Informative discussions on hydrological topics also were held in Lahore with deputy director of WAPDA-HEP Abdul Rabbani Qureshi and in Gilgit with director WAPDA-HEP M. A. A. Nomani.

In the field several discharge measurements were performed using the salt dilution method. These measurements can be assumed to be approximate measures of this winter’s minimum discharges.

At Tangir a suitable site for a staff gauge was examined and instructions for installation and observation were given to Sher Dil Khan, sub-divisional officer of NAPWD at Chilas, B&R Division.

On the basis of these data from Pakistan and an analysis of river basin characteristics performed in Norway, conclusions are drawn regarding minimum discharges at Tangir, Kargah, Nomal, Hasanabad and at alternative sites in Gilgit River.

Figure 1.1 is a map of the area showing the locations of different sites and river basins.

2. Data collected from WAPDA

In the Gilgit-area WAPDA has three permanent discharge stations in operation, one in Gilgit River at Alam Bridge (26.260 km²), one in Gilgit River at Gilgit (12.142 km²) and one in Hunza River at Dainyor Bridge (13.208 km²). The station at Gilgit was established in 1960 and the other two in 1966. Data from these stations are published in "Annual report of river and climatological data of West Pakistan; Vol.1 River discharge, sediment and quality data", and copies of 11-14 years of data for each station were collected at WAPDA.

At these stations discharges are usually measured 20-30 times a year using current meter measurements at 0.2 and 0.8 of the total depth. With the same frequency depth-integrated sediment samples are collected using a D-49 sampler and surface water samples are collected for chemical analysis. All the stations have rating-curves that are revised at least once a year if necessary.

Sediment concentrations at these sites typically vary between 10 and 5.000 PPM by weight at Gilgit, between 10 and 15.000 at Dainyor Bridge and between 10 and 10.000 at Alam Bridge.

Table 2.1 gives a summary of the main features from the discharge
data sets collected. Data for years which were not collected will be sent to Norway by WAPDA.

Table 2.1. Characteristic discharges (m3/s) for WAPDA stations. (Values within brackets give specific discharge in l/s km2.)

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<td>Number of years</td>
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<td>14</td>
<td>11</td>
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<td>Basin area (km2)</td>
<td>26.260</td>
<td>12.142</td>
<td>13.208</td>
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<td>- minimum</td>
<td>513 (19.5)</td>
<td>258 (21.2)</td>
<td>266 (20.1)</td>
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<tr>
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<td>672 (25.6)</td>
<td>287 (23.6)</td>
<td>379 (28.7)</td>
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<td>365 (30.1)</td>
<td>490 (37.1)</td>
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<td>40 (3.3)</td>
<td>28 (2.1)</td>
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<td>95 (3.6)</td>
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<td>37 (2.8)</td>
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<td>131 (5.0)</td>
<td>57 (4.7)</td>
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<td>- maximum</td>
<td>3.993 (152)</td>
<td>2.362 (195)</td>
<td>2.467 (187)</td>
</tr>
</tbody>
</table>

Several interesting reports were also studied at WAPDA. The most relevant one was "Low flow analysis of small streams in Northern Area" prepared by WAPDA in 1973-74. The report gives data from measurements of minimum discharges during one winter season for 87 streams in Northern Areas. This report is considered most essential when evaluating the hydel schemes for NORAD contributions. Measured discharges and expected minimum flows with a probability of exceedance of 85% are given for relevant sites in table 2.2.

Table 2.2. Minimum discharges measured by WAPDA in 1973-74.

<table>
<thead>
<tr>
<th>Site</th>
<th>Date of Disch.</th>
<th>Expected observ. (m3/s)</th>
<th>Expected min. flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tangir River at Jaglot</td>
<td>03.01.74</td>
<td>3.46</td>
<td>3.4</td>
</tr>
<tr>
<td>Kargah power house diversion channel at head, total dis.</td>
<td>10.03.74</td>
<td>1.12</td>
<td></td>
</tr>
<tr>
<td>Nalter Nallah at Nalter</td>
<td>29.12.73</td>
<td>2.21</td>
<td></td>
</tr>
<tr>
<td>Nalter Nallah at Nomal village</td>
<td>07.03.74</td>
<td>2.26</td>
<td>2.3</td>
</tr>
</tbody>
</table>

The report also contains discharge-duration curves for the discharge stations in the Gilgit and Hunza rivers. These are shown graphically in figure 2.1.
Another relevant report was the "Naltar Hydro Power Project; Conceptual Report" from 1983. This gives a broad description of the general patterns of meteorological, hydrological, geological and ecological parameters in the area. Some of the meteorological data from this report are summarized in table 2.3. Also included in the table are calculated mean monthly values from the discharge station at Gilgit for the period 1960-71. A comparison of the water balance elements is made in figure 2.2.

Table 2.3. Hydrometeorological characteristics at Gilgit.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
<td></td>
<td></td>
<td>(mm)</td>
<td>(mm)</td>
<td>(m3/s)</td>
<td>(m3/s)</td>
</tr>
<tr>
<td>January</td>
<td>-3.1</td>
<td>9.0</td>
<td>62</td>
<td>5.5</td>
<td>66.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>0.3</td>
<td>12.1</td>
<td>63</td>
<td>7.1</td>
<td>57.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>5.2</td>
<td>18.0</td>
<td>81</td>
<td>12.6</td>
<td>51.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>9.6</td>
<td>23.9</td>
<td>84</td>
<td>23.1</td>
<td>61.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>11.9</td>
<td>27.7</td>
<td>89</td>
<td>27.4</td>
<td>181.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>16.1</td>
<td>34.8</td>
<td>82</td>
<td>5.2</td>
<td>743.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July</td>
<td>18.9</td>
<td>36.3</td>
<td>93</td>
<td>14.4</td>
<td>945.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>August</td>
<td>17.9</td>
<td>35.4</td>
<td>95</td>
<td>16.6</td>
<td>717.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>September</td>
<td>12.4</td>
<td>31.6</td>
<td>79</td>
<td>6.8</td>
<td>359.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>October</td>
<td>6.4</td>
<td>25.3</td>
<td>73</td>
<td>6.4</td>
<td>150.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>0.4</td>
<td>17.7</td>
<td>61</td>
<td>1.2</td>
<td>95.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>-2.5</td>
<td>10.9</td>
<td>62</td>
<td>2.4</td>
<td>74.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>7.8</td>
<td>23.5</td>
<td>924</td>
<td>128.7</td>
<td>292.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Measured minimum discharges

A total of 12 discharge measurements using the salt dilution method were performed during the mission. The results of these are presented in table 3.1 where 5 measurements characterized as having uncertain or bad quality have been excluded. Where two measurements on opposite banks of the stream have been performed the average of these also has been calculated.

The measurements usually confirmed visual estimates made by local personnel.

At Tangir, NAPWD staff demonstrated a hydraulic discharge measurement performed in a straightened reach of Tangir River, 8 m long, 8 m wide and 1 m deep. By measuring the surface velocity at different distances from the banks with use of floating objects, the discharge was estimated to 8.4 m3/s after 10% reduction because of lower velocities below the surface. This measurement is in acceptable agreement with the salt dilution measurements performed in Tangir River (see table 3.1).
Table 3.1. Measured minimum discharges in February 1989.
(Measured close to proposed intake sites.)

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Water temp. (°C)</th>
<th>Elec. cond. (mS/cm)</th>
<th>Measured discharge (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nomal Nallah</td>
<td>10.02.89</td>
<td>3.8</td>
<td>123</td>
<td>4.45</td>
</tr>
<tr>
<td>Tangir River</td>
<td>12.02.89</td>
<td>5.4</td>
<td>71</td>
<td>12.35</td>
</tr>
<tr>
<td>Tangir River</td>
<td>12.02.89</td>
<td>5.7</td>
<td>71</td>
<td>9.38</td>
</tr>
<tr>
<td>- Tangir average</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hasanabad Nallah</td>
<td>14.02.89</td>
<td>0.4</td>
<td>152</td>
<td>1.77</td>
</tr>
<tr>
<td>Hasanabad Nallah</td>
<td>14.02.89</td>
<td>0.5</td>
<td>152</td>
<td>2.25</td>
</tr>
<tr>
<td>- Hasanabad average</td>
<td></td>
<td></td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td>Kargah Nallah</td>
<td>16.02.89</td>
<td>2.4</td>
<td>55</td>
<td>1.63</td>
</tr>
<tr>
<td>Kargah Nallah</td>
<td>16.02.89</td>
<td>2.4</td>
<td>54</td>
<td>1.65</td>
</tr>
<tr>
<td>- Kargah average</td>
<td></td>
<td></td>
<td></td>
<td>1.6</td>
</tr>
</tbody>
</table>

4. Analysis of river basins

The river basins of the three discharge stations in the area and four hydel stations proposed to be built, updated or refurbished have been analysed according to basin area and elevation characteristics. The analysis has been performed on maps with the scale of 1:500,000 for the larger basins and 1:250,000 for the smaller basins. The results of the analysis are presented in Table 4.1 and Figure 4.1.

Table 4.1. Analysis of river basins.

<table>
<thead>
<tr>
<th>River basin</th>
<th>Area (km²)</th>
<th>Elevation median (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Gilgit River at Alam Bridge</td>
<td>26.205</td>
<td>14.000</td>
</tr>
<tr>
<td>(2) Gilgit River at Gilgit</td>
<td>12.161</td>
<td>13.000</td>
</tr>
<tr>
<td>(3) Hunza River at Dainyor Bridge</td>
<td>13.039</td>
<td>15.000</td>
</tr>
<tr>
<td>(4) Tangir River at Indus</td>
<td>988</td>
<td>9.000</td>
</tr>
<tr>
<td>(5) Hasanabad Nallah at Hunza R.</td>
<td>334</td>
<td>15.000</td>
</tr>
<tr>
<td>(6) Nomal Nallah at Hunza R.</td>
<td>288</td>
<td>13.000</td>
</tr>
<tr>
<td>(7) Kargah Nallah at Gilgit R.</td>
<td>519</td>
<td>13.000</td>
</tr>
<tr>
<td>(8) Kargah Nallah at Kargah 5</td>
<td>257</td>
<td>13.000</td>
</tr>
</tbody>
</table>

It should be noted that, in spite of the rather crude scale of the maps used, the measured basin areas for the three discharge stations only deviate slightly from the values published by WAPDA.
5. Analysis of discharges

On the basis of the river basin analysis and the data collected from WAPDA, the following general conclusions can be made with regard to the discharge stations in the larger basins:

Mean annual discharge is in the range 20-30 l/s km²
Mean annual 1-day flood is in the range 100-150 l/s km²
Mean annual 1-day lowflow is in the range 3-4 l/s km²
Minimum annual 1-day lowflow is in the range 2-3 l/s km²

There seems to be a tendency towards higher mean annual discharges and flood discharges and lesser lowflows in the eastern part of the area which can be explained by the higher median elevation. In the western part of the area, like in Tangir, one should however expect higher mean annual discharges because of the monsoon effects.

Special attention has to be drawn to the fact that the meteorological stations situated in the main valleys record mean annual precipitation values of 130-150 mm while mean annual discharge values of the WAPDA stations correspond to 700-900 mm. This can be explained by the high mean elevations of these basins (see table 2.3 and 4.1).

In spite of these rather crude values for comparatively large basins, they have been scaled according to basin area as an alternative method for calculating minimum discharges for some of the relevant smaller basins. The results are given in table 5.1. In this table are also given estimated total water demand for the proposed hydro power schemes and existing irrigation channels.

Table 5.1. Estimates of minimum discharges (m³/s) using different methods and sources.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(km²) 1973-74</td>
<td>1989</td>
<td></td>
</tr>
<tr>
<td>Tangir</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- at Indus River</td>
<td>988</td>
<td>-</td>
<td>3.0</td>
</tr>
<tr>
<td>- at Jaglot</td>
<td>824</td>
<td>3.4</td>
<td>10.9</td>
</tr>
<tr>
<td>Kargah</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- at Gilgit River</td>
<td>519</td>
<td>1.1</td>
<td>1.6</td>
</tr>
<tr>
<td>- at Kargah 5</td>
<td>257</td>
<td>-</td>
<td>0.8</td>
</tr>
<tr>
<td>Nomal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- at Hunza River</td>
<td>288</td>
<td>2.3</td>
<td>4.4</td>
</tr>
<tr>
<td>Hasanabad</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- at Hunza River</td>
<td>334</td>
<td>-</td>
<td>2.0</td>
</tr>
<tr>
<td>Gilgit River</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- at Gilgit</td>
<td>12.142</td>
<td>-</td>
<td>36.4</td>
</tr>
<tr>
<td>- at Henzel</td>
<td>11.517</td>
<td>-</td>
<td>34.6</td>
</tr>
<tr>
<td>- upstream Sher Qila (at oxbow)</td>
<td>10.874</td>
<td>-</td>
<td>32.6</td>
</tr>
<tr>
<td>- upstream Bubur (at bridge)</td>
<td>10.128</td>
<td>-</td>
<td>30.4</td>
</tr>
</tbody>
</table>
The following comments can be made on the table:

- The calculated value of 2.5 m³/s for Tangir at Jaglot is probably too low because the effect of the monsoon is much stronger at Tangir than at Gilgit. The minimum discharge could be expected to be in the range 3.0-3.5 m³/s.

- The minimum discharges at the schemes of Kargah 5, Nomal and Hasanabad could be expected to be in the range 1.0-1.5 m³/s.

- The minimum discharge for all the proposed schemes in Gilgit River is approximately 30 m³/s.

As a comparison to the runoff statistics for large basins, a series of 33 individual discharge measurements in Nomal Nallah at Nomal Village (288 km²) during the period June 1983 to February 1984 can be used. The largest measured discharge in this period was 28.5 m³/s (100 l/s km²) and the smallest was 2.3 m³/s (8.0 l/s km²). These data indicate an annual flood of approximately average size and an annual lowflow value twice the average size when compared to the values calculated by scaling of runoff data from the larger river basins.

Another comparison with measured discharges from some other small basins (20-150 km²) in the area, published in the lowflow report by from WAPDA, shows large variations in specific lowflows (2-6 l/s km²) between different basins during the same winter season. This indicates that other factors than basin area and altitude, like geology, soil types and glaciers, also may play an important role in determining the lowflow characteristics of basins in the area.

These examples show, that at least during the winter seasons of 1973-1974 and 1983-84, the minimum discharges in some of the small basins were significantly larger than indicated by the values calculated by scaling minimum discharges of Gilgit and Hunza River.

6. Conclusions

Most of the hydrological and sedimentological data necessary for the evaluation of small and medium scale hydel projects are available at WAPDA. Complementary investigations can also be performed by or through WAPDA, if necessary. There seems to be little need for transfer of knowledge in the field of hydrology, meteorology or sedimentology to WAPDA. Nevertheless it may be of future value to initiate a cooperation between WAPDA and NVE on selected hydrological topics such as hydrological modelling.

According to a preliminary analysis of available hydrological data the minimum discharges for all of the proposed hydel projects in normal years could be expected to be enough for the planned installations. In dry years, however, one might experience periods of water shortage at the schemes of Kargah 5, Nomal and Hasanabad. During such years one should also expect conflicts with irrigation demands.
For Tangir no conflict with irrigation or water shortage of other reasons is expected for projects the double size of the proposed one. At Tangir the irrigation potential of 1 m3/s was estimated to be approximately 7 km2 of cultivated land.

Finally it is recomended that minimum discharges are measured for as many winter seasons as possible at the different project sites and correlated to longterm statistics for Gilgit and Hunza River. This is considered the best way of increasing the knowledge of minimum discharges relevant for dimensioning of installed capacities.
Figure 1.1. Map of the Gilgit and Hunza River basins.

Figure 2.1. Discharge-duration curves of discharge stations.
Figure 2.2.
Water balance elements measured/calculated at Gilgit.

Figure 4.1.
Hypsometric curves of river basins.
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