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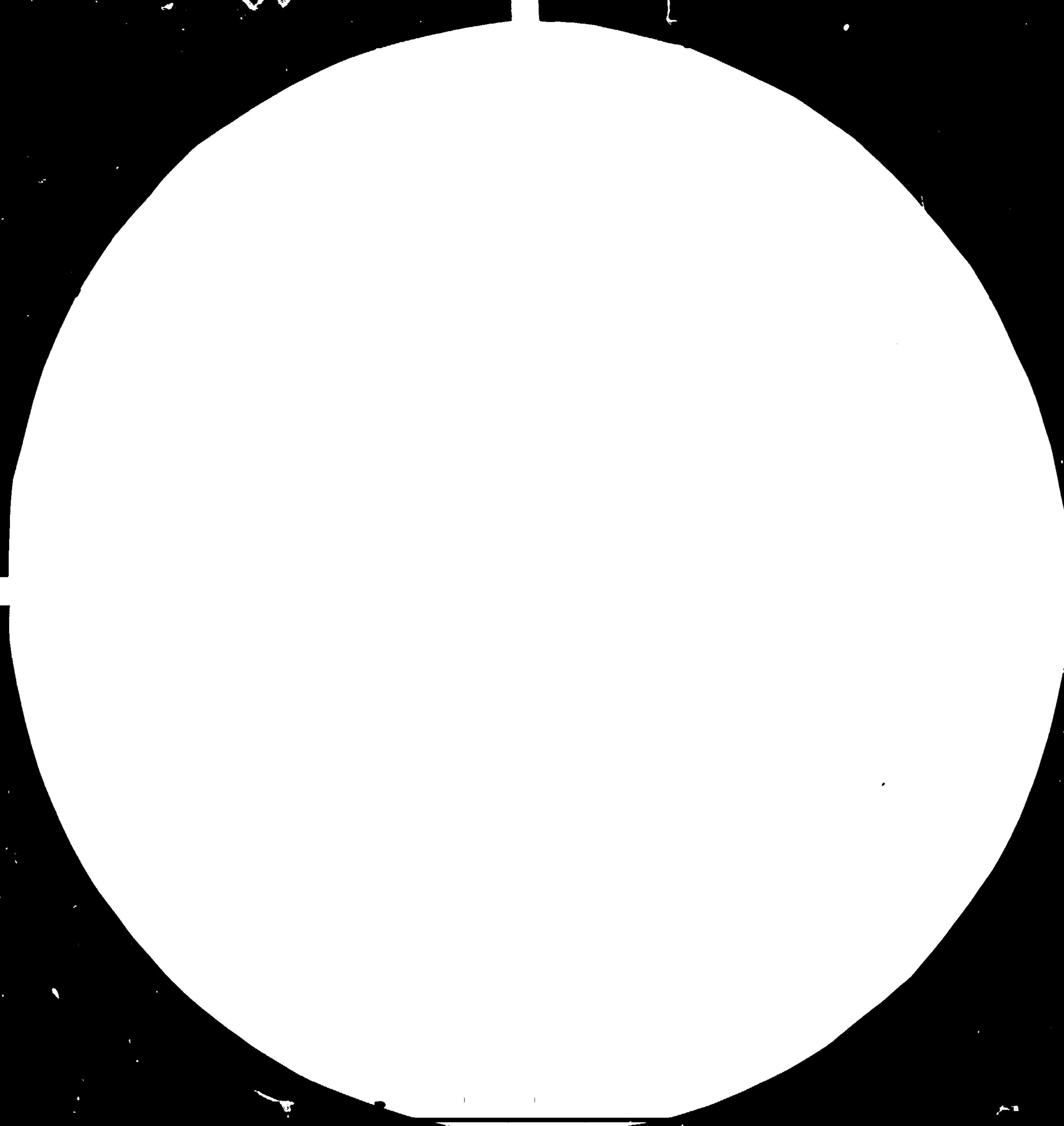

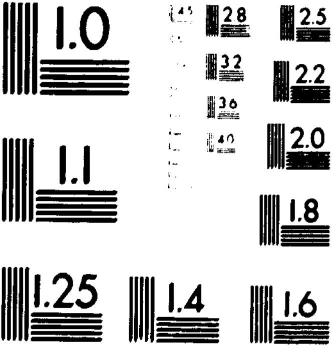
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Distr.
LIMITED

ID/WG.433/14
30 January 1985

ENGLISH

United Nations Industrial Development Organization

ESCAP Regional Energy Development Programme (REDP)
Regional Network for Small Hydropower (RN-SHP)

Technical Advisory Group (TAG)
First Meeting

Hangzhou, China, 11 - 13 December 1984

# POTENTIAL CO-OPERATIVE RESEARCH AND DEVELOPMENT PROJECTS*

Agenda item 5(b)

**Prepared by**

Interim Co-ordinator of the
Regional Network for Small Hydropower

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TABLE OF CONTENTS

## A. Design Manual*

A textbook suitable for experienced graduate engineers without specialist knowledge of hydro power is suggested.

It would cover all aspects of design including:

- Pre-Feasibility Studies
- Feasibility Studies
- Hydrology and Water Management
- Scheme Optimisation
- Dams and Weirs
- Intakes
- Gates + Stoplogs
- Canals
- Penstocks
- Surge Chambers
- Surge Analysis
- Water Hammer
- Turbines
- Governors
- Relief Valve
- Generators
- Auxiliary Systems
- Control + Supervisory Systems
- Protection and Switchgear
- Powerhouse Layout + Design
- Transformers
- Switchyards
- Transmission
- Operation

The manual would include sample computer programs (based on programs already developed) covering:

- quick estimates of cost (for pre-feasibility studies)
- simulation of scheme operation
- intake design
- gate design
- penstock design
- water hammer
- surge chamber design
- head losses
- turbine costs, characteristics and dimensions
- generator costs, characteristics and dimensions

Model specifications and drawings covering all aspects of the design process would also be provided.

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* Outline prepared by Leyland, Watson and Noble, Auckland, New Zealand. (Mention of firm names and commercial products does not imply the endorsement of the United Nations).

B. Guidelines/Criteria in the Efficient and Economical Design of the following structures and areas*:

I. Geology

- structural design and requirement to areas prone to landslide and tremors/ erosion

- sub-surface exploration - Dam location, headrace, penstock etc.

II. Hydrology

- application of computers in hydrological data gathering

- assessment of hydrological data requirements

- probability/correlation method

- hydrological investigations and investigations related to hydraulic structure and hydraulics.

III. Diversion Dam Arrangement

- criteria for Run off River arrangement, daily regulation storage

- choice of type of dam or weirs

- criteria for using gates at specific type of dam

- design of dam/weir for peaking improvement of availability factor

- Dam stability and Seepage

IV. Intake Gates/Scour Gate

- Type/Design of gate for efficient and easy operation (Manual)

- Electronically operated Gate controlled at the Power Plant

- Desilting arrangement and sediment transport
- Corrosion protection

V. Headrace/Water Conveying System

- Criteria for open canal system, the use of concrete canal, fiberglass or steel pipe

- Criteria for tunnelling

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* Prepared by NEA (National Electrification Administration), Manila, Philippines.

- Design of the canal to minimize losses, and seepage and improve stability

- economic route of conveying system

- Erosion protection and drainage design

VI. Forebay/Surge Tank

- Criteria for the selection of forebay or SurgeTank

- Materials to be used in surge tank
  Fiberglass - steel
- Desilting arrangement at Forebay and Volume of water to be stored

VII. Penstock

a. Materials to be used

b. Drainage design of Penstock

c. Erosion protection/Soil Stability

d. Effective and Efficient Penstock Transport

e. Use of Expansion joints

f. Corrosion protection

g. Penstock design with provision for flushing

h. Penstock testing

  - X - ray test - welding

  - Hydrostatic test

  - Ultrasonic test

VIII. Electro Mechanical Equipment

- Type of generators for multiple installation of units in an area

- Type of turbine for a given design head

IX. PowerHouse

- Standardization of powerhouse design

- Development of indigenous materials available in the locality.

## C. Optimum design systems for small hydro-power Project: A research project proposal - Summary*

### Background

Small hydro-power projects constitute an important part of Nepal's regional and local infrastructural development projects. IDS proposes to develop, for the use of Small Hydel Development Board (SHDB) and other potential users in His Majesty's Government, package of rational design standards for such projects to improve technical and economic efficiency in design and construction. IDS has already developed 15 different computer programmes for SHDB. This proposal seeks to continue the research work to its full completion.

At the moment, each mini hydro plant must be individually designed as each site is unique and has its own peculiar problems. Each design requires a large team consisting of a geologist, a hydrologist, a soil scientist, a mechanical engineer, an electrical engineer as well as a civil engineer. This has proved a handicap because there are few engineers with experience in this field. Even if engineers and specialists were available, their efficiency is constrained because there are no good reference books. Even a team of experienced engineers cannot satisfactorily carry out the task of rational site selection with optimum design of various structures in the absence of design standardization systems. This is possible only when thousands of factors relevant for designing various parts of the scheme are taken into account simultaneously to produce an optimum design. The innumerable factors can be properly evaluated only through a computerized system which utilizes advanced dynamic theories of optimization.

### Justification

In the absence of optimum standards, the design system, as present, is influenced by subjective factors. The quality and cost of design as well as that of construction varies from person to person or from one designer to another. The cost per kilowatt of small hydro-power has varied widely from Rs. 25,000 to Rs. 130,000 in Nepal as reported in a study made by the Water and Energy Commission. The present lack of national standards and

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* Submitted by the Small Hydel Development Board of Nepal (SHDB/Nepal).

norms for design also critically affects site selection and inhibits quality control in design and construction. The development of a design standardization system is therefore necessary to effect cost uniformity, cost reduction, savings in skilled manpower, rational site selection and to better enforce quality control.

Objective and scope of work

The primary objective of the proposed research is to improve the technical and economic efficiency of small hydro-power development projects in Nepal by developing a computer based design system. The initial phase of the research work will build upon the separate computer programmes already prepared by IDS for SHDB to develop an integrated package of optimal design programmes. After this computerized system is set up, the following documentation will be prepared.

(i) an Operational Guide for the use of SHDB and other concerned HMG personnel engaged in the design of small hydro-power projects. It will describe in detail how to operate and use the computerized design systems.

(ii) a Design Manual which will provide all information on the theoretical aspects of optimizing design systems for small hydro-power projects and the empirical formula utilizing the hydrological and other relevant data of Nepal on a region-wise basis.

(iii) a Manual of Design Rationalization which will include thousands of typical, rational design standards, ready for instant use, covering all types of hydrological and geological factors involved in any zone of Nepal. With this manual, it will not be necessary to have access to a computer or to the package of computer programmes to utilize the optimal results of the design systems.

Manpower and staffing

The research study will require a rather big team of skilled personnel including hydro-power experts (34 man-months), geologists (12 m/m), hydrologists (14 m/m), soil scientists (16 m/m), economists (12 m/m), and electro-mechanical experts (6 m/m). The Senior Systems Analyst (40 m/m) at IDS will be the key person guiding and coordinating the research. The research work itself will be carried out by IDS experts and consultants. It is also proposed that His Majesty's Government make arrangement for deputation of appropriate senior experts (on a part-time basis) to IDS to ensure full consideration of the Government's view and requirements during the research work. This arrangement will also facilitate transfer of design skills and tools in this field to the Government.

Budget

The estimated total budget for this research project is Rs.17.78 lakhs for the three year period.

Project benefits

The most immediate benefit of this research will be the savings in the cost of design and construction of small hydro-power projects. It will provide considerable savings of scarce technical manpower and project time; and also improve technical efficiency by facilitating rational site selection and quality control. Substantial indirect benefits will also be obtained. The computerized designs will be based on the maximum use of locally available building materials and labour intensive methods. There will also be some spillover benefits. It is estimated that about 40% of the computer programmes can be directly used by the Department of Electricity for the design of medium and large-scale hydro-power projects.

The savings in the cost of construction alone will far exceed the initial investment in this project. Under the least optimistic outcome of a 15% reduction in construction costs, the net benefits of the project will be Rs. 2.8 crores within five years even if only two small hydro-power projects are designed and constructed every year.

## D. Mechanical water-actuated governor*

### Speed Governor

To be able to keep the turbine speed within tolerable limits, independent on the (varying) load connected, a governing system is required.

The method generally applied is flow-control, where the volume of water (discharge) through the turbine is adjusted to match the turbine power with the actual load. This, in turn, guarantees that voltage and frequency of the electric supply remains within a specified range.

Such type of speed-control is provided by SHDB's mechanical/hydraulic governor which uses water as a working medium. The working pressure (used to open the turbine) is supplied by the head of the installation, whereas a spring serves to close the turbine-valve.

### Main Components

The device consists of the following main parts:

- flyball assembly (centrifugal pendulum)
- throttle / control valve system
- servo-cylinder / closing spring
- water supply line (pipe, tank, filters)

A schematical overview is given in fig. 1. (page 9)

### Brief Description of Main Components

a) Flyball Assembly

The centrifugal pendulum is directly mounted on the turbine shaft and serves as a tachometer. The flyball mass will shift a pushrod against a spring depending on turbine speed. Thus, for each turbine speed (within $\pm$ 10% of rated speed) there is a respective position of the flyball pushrod.

This position may be altered by varying the pretension of the flyball assembly spring. This is used for the adjustment of the nominal speed when the governor is tuned initially.

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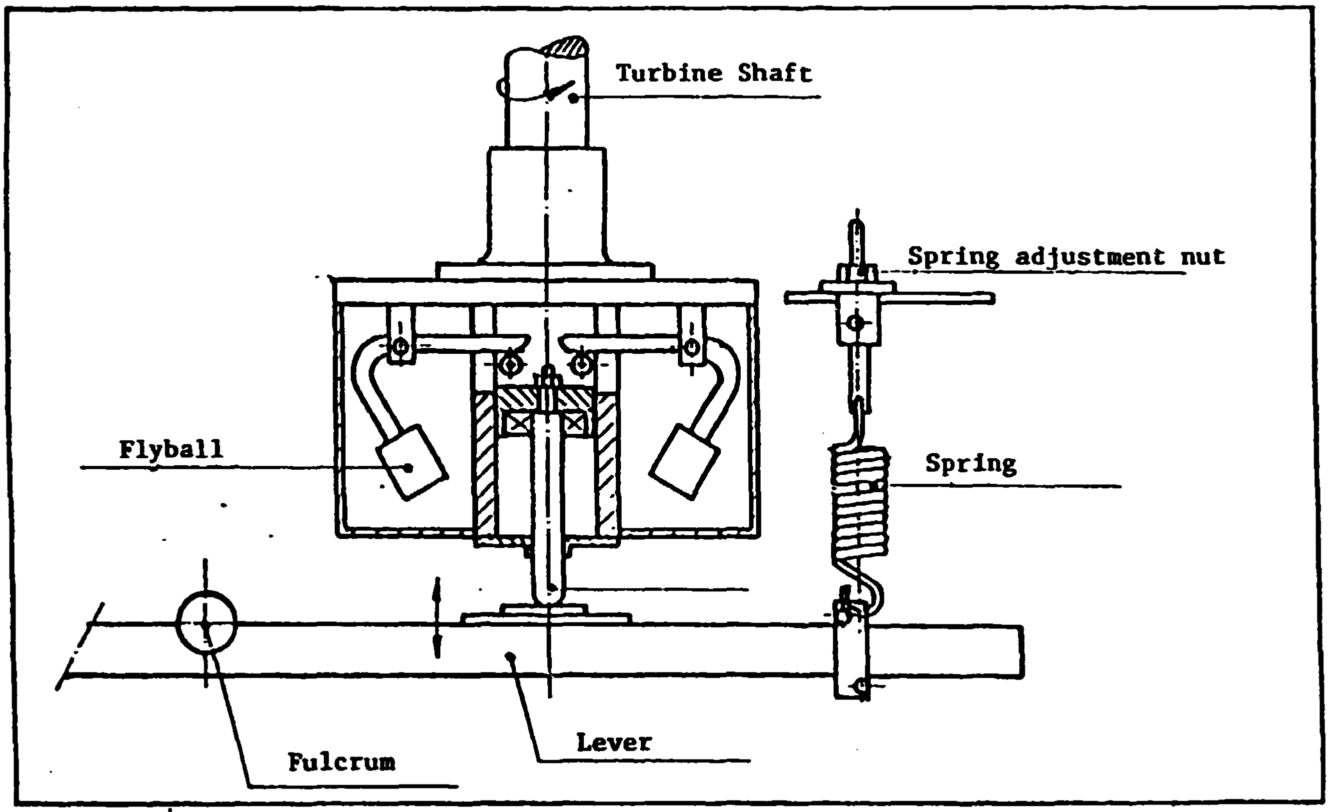
* Prepared by BYS, Nepal.

Figure 1: Schematic of Flyball Assembly

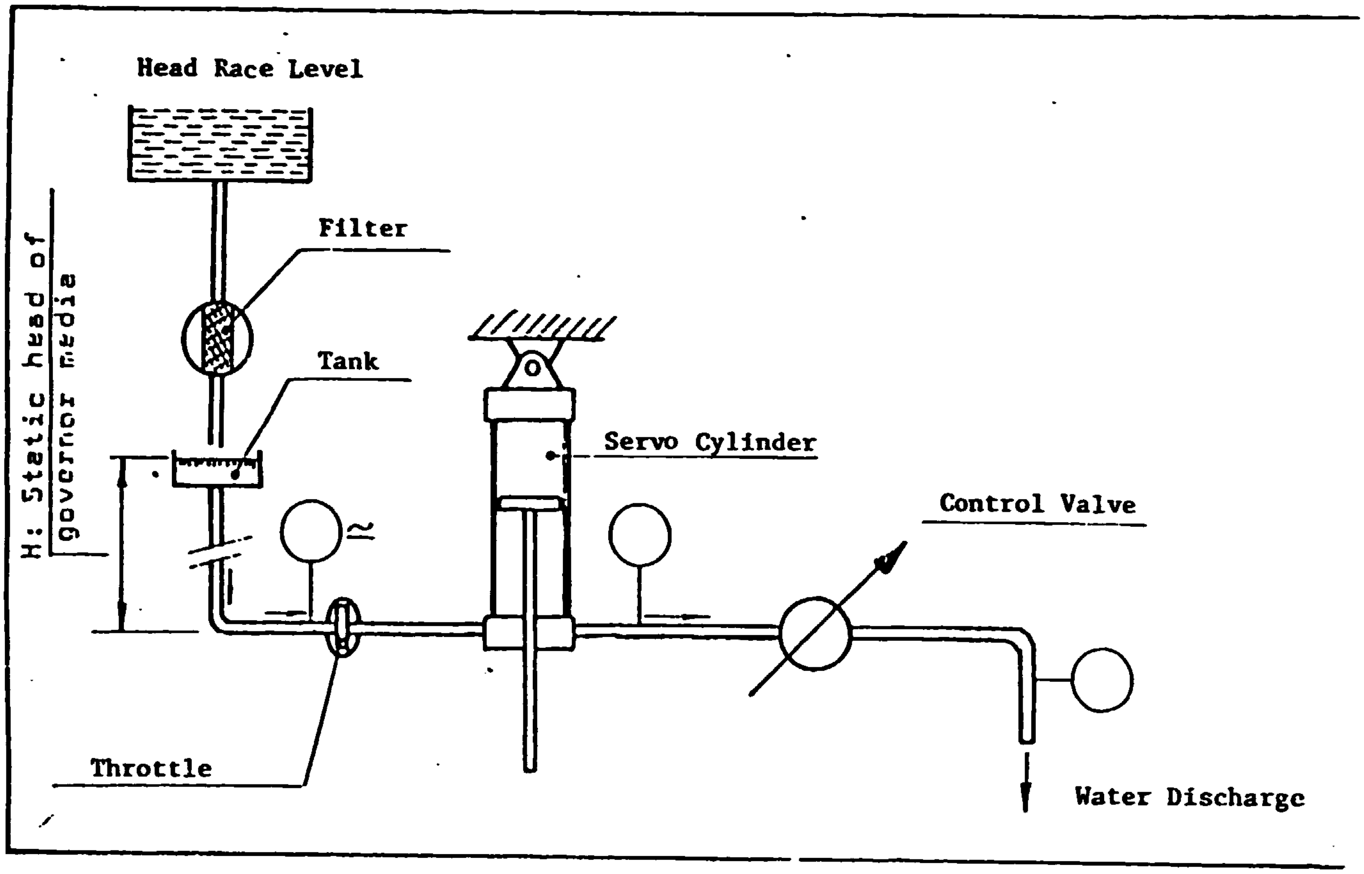



b) Throttle / Control Valve System

The principal function of these components is to vary the water pressure in the servo-cylinder as required by varying load condition of the turbine. Water, under the static head of the installation, is brought in a separate pipe to the governor; it passes first through the throttle and is discharged into the turbine pit through the control-valve. Between throttle and control-valve, the hydraulic cylinder is connected to the system as indicated in fig. 2. (page 10).

The pressure $P_1$ may be varied by varying the discharge area $A_1$ in the control-valve. The shape of the control-valve piston is designed such that the characteristic of $P_1/P_o$ over the stroke of the control-valve is linear. If the control-valve piston is connected via a lever-linkage to the flyball/pushrod it is possible to get a speed and load defined pressure $P_1$, acting on the servo-cylinder.

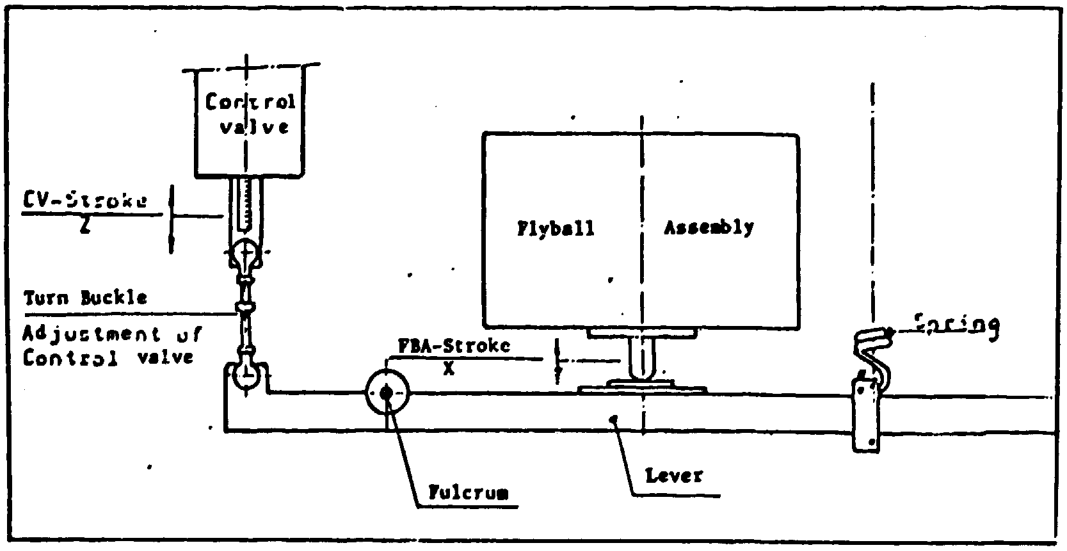
Figure 2: Schematic of Throttle / Control-Valve System




c) Lever-Linkage

The lever, as indicated in fig.3, serves to transmit the reaction of the flyball assembly to the control-valve piston when the turbine speed changes. The flyball spring is attached to the same lever, to counteract the flyball effect. The arrangement shown in fig.3 serves to adjust the position of the control-valve piston in relation to the flyball pushrod position. The adjustment is necessary for the governor tuning.

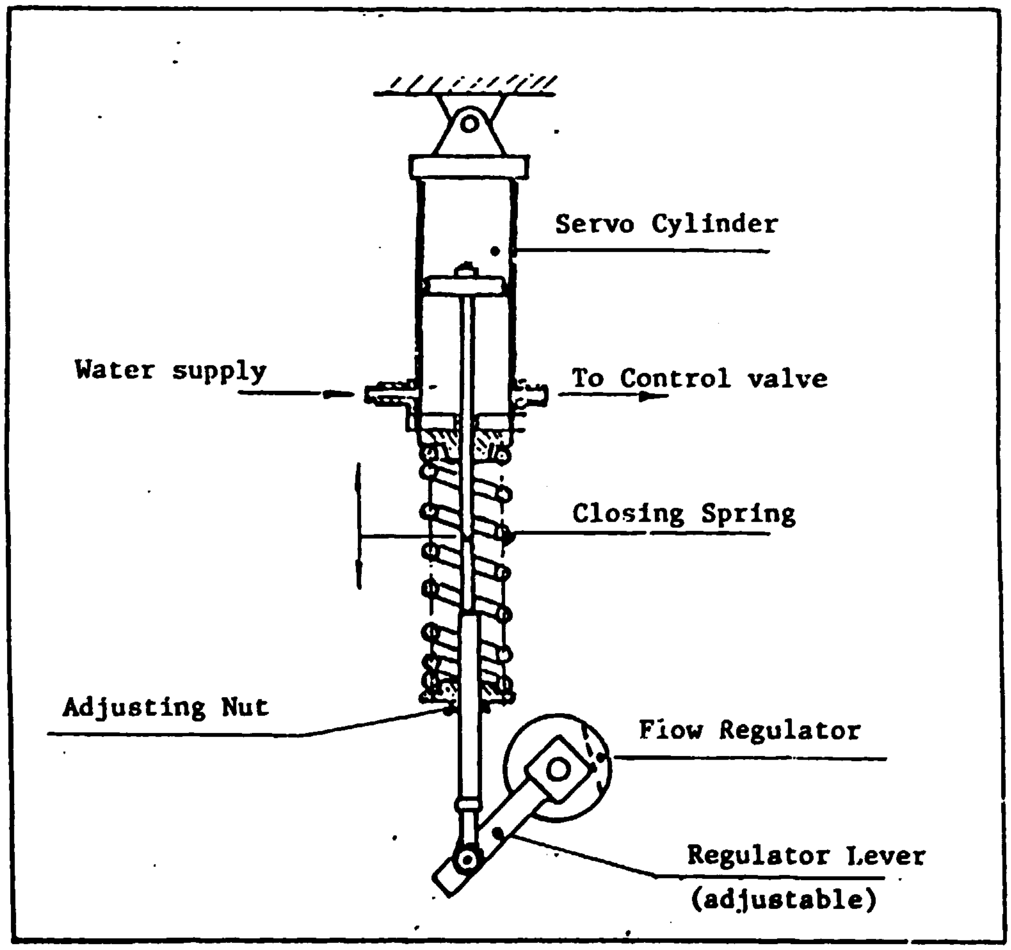
Figure 3: Schematic of Lever Linkage



d) Servo-Cylinder / Closing-Spring

This is the actual power component of the governor that moves the turbine-regulator as commanded by the flyball assembly. Hydraulic forces act in the direction of opening the turbine gate only, while forces required for closing are supplied by a helical compression spring. In the static state, as long as no load and therefore no speed changes occur, hydraulic forces in the cylinder and spring forces are in balance, keeping the turbine gate in a speed (load) defined position. It is necessary to be able to adjust the stroke of the servo piston and the pretension of the spring, when tuning the governor. The corresponding arrangements are shown in fig.4.

Figure 4: Schematic of Servo-Cylinder / Closing Spring Arrangement



e) <u>Water Supply Line</u>

The water supply line consists of four elements:

- supply pipe (2 inch GI pipe)
- filter
- supply tank
- several valves (standard, 2 inch)

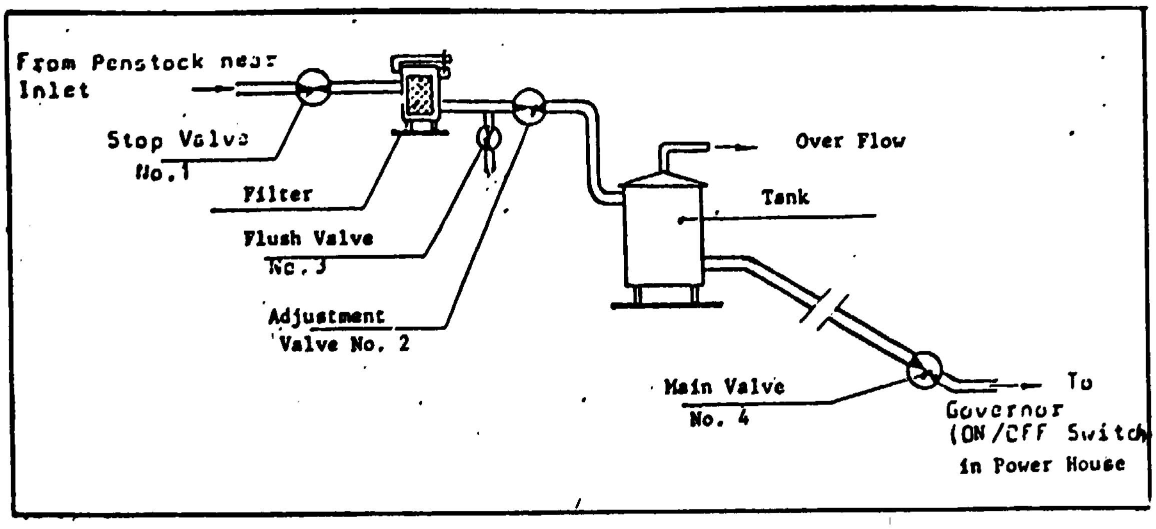
The water is taken from the penstock near the inlet. To avoid abrasing or jamming of the control valve, it is absolutely necessary to filter the water that is used in the governor. A simple basket strainer type of filter serves for that purpose, the basket consisting of very finemeshed nylon - gauze. Filter pressure required is between 2 and 3 metres.

The filtered water is collected in a tank of approx. 100 lt volume from where a 2 inch GI pipe brings the water to the governor. The tank provides an almost constant level and hence static pressure to the governor, which makes the governing characteristic independent of the water lever in the forebay and prevents shock waves that may occur in the penstock from adversely affecting the governor's performance.

Several valves are incorporated, having the following purposes:

- No.1, Stop Valve: to clean the filter, and
- No.2, Flush Valve: flush the line
- No.3, Adjustment Valve: to adjust the discharge so that a small over flow results (and to clean/flush the filter)
- No.4, Main Valve: to start and stop the turbine (only valve to be operated to run the plant)

Figure 5: Schematic of Governor Supply Line



E. High head crossflow turbine (BYS, Nepal)

Schnitt A-A

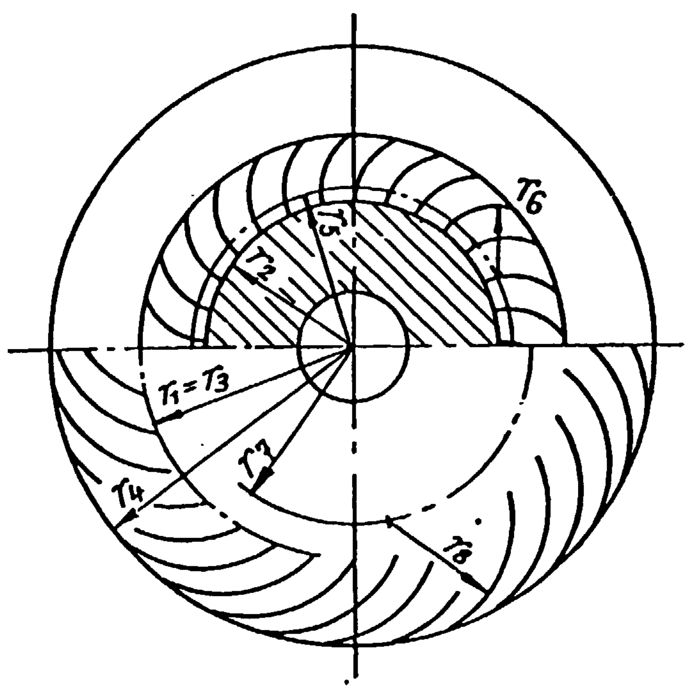



Fig. 1

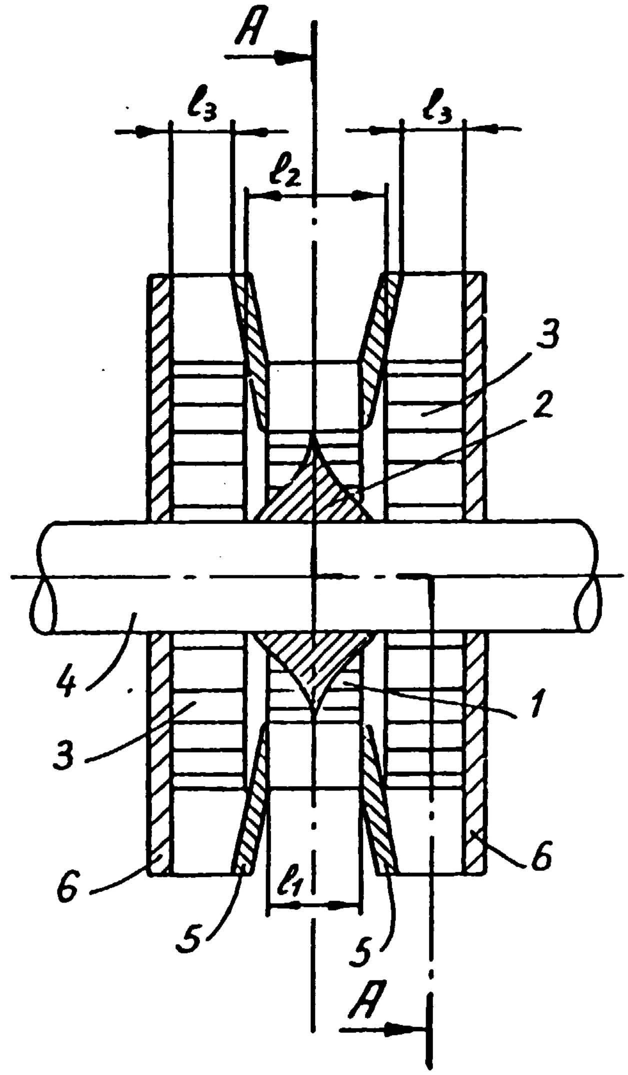



Fig. 2