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The Study on Introduction of Renewable Energies in Rural Areas in Myanmar

Final Report

Volume 6 Supporting Report

Appendices to Manuals

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MYANMA ELECTRIC POWER ENTERPRISE
MINISTRY OF ELECTRIC POWER
UNION OF MYANMAR

THE STUDY ON INTRODUCTION OF RENEWABLE ENERGIES IN RURAL AREAS IN MYANMAR

FINAL REPORT

VOLUME 6 SUPPORTING REPORT

APPENDICES TO MANUALS FOR SUSTAINABLE SMALL HYDROS

SEPTEMBER 2003

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.
INSTITUTE OF ENERGY ECONOMICS, JAPAN

THE STUDY ON INTRODUCTION OF RENEWABLE ENERGIES
IN RURAL AREAS IN MYANMAR

Final Report
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Part 6-1 Appendix 1

Form of Equipment Inventory (Sample)

GENERATING EQUIPMENTS OF HYDROPOWER STATION

MEPE _____ Power Station Type: _____ Location: _____

River System	River Name	Lake Name	Catchment Area	Design Discharge	Location of Main Intakes

Location of Tributary Intakes	Location of Outfall (Tailrace Outlet)			
		Max.	Firm	Firm Peak
	Intake WL (m)			
	Outfall WL (m)			

Items	Max.	Firm	Firm Peak	Special	Supplement	Supplement Peak
Effective head						
Design discharge						
Theoretical output						
Installed capacity						

Dam	Name	Dam	Dam	Dam	Dam
	Type				
	Crest length				
	Height	m (F.B. m)	m (F.B. m)	m (F.B. m)	m (F.B. m)
	Dam volume (earth, conc.)				
	Foundation width				
	Type of gated weir				
	Dimension & nos. of above				
	Hoisting equipment				
	Dim. of sand flushing gate				
	Hoisting equip. of above				
	Outline of navigation lock				
	Outline of fishway				
	Other auxiliary equip.				
	Inflow design flood				

Intake	Outline of structure		Reservoir/ Regulating Pond	Gross capacity (mcm)
				Effective capacity (mcm)
				Drawdown (max.))
				Surface area (at FSL)
Desander	Outline of structure			Auxiliary facility
	Way of deposition & flushing			Way of utilization

Headrace									
	Total length								
	Type	Tunnel	Pressure T.	Conduit	Open Channel	Waterway Bridge	Pipe Bridge	Sluice	
	Length								
	Sand flushing facility								
	Excess water spillway								

Head Tank/Surge Tank	Outline of structure		Turbine	Manufacturing No.
	Excess water spillway			Type
	Discharge control facility			Model
	Excess water channel			Plate output (kW)
	Type of surge tank			Design discharge (m^3/s)
				Revolution speed (rpm)
				Runaway speed (rpm)

Penstock						
	Material &way of jointing				Efficiency	at Load %
	Penstock	Main	Length			%
			Nos. of lanes			%
			Internal dia. & thickness	Upper		%
				Lower		Material of runner vanes
		Branch	Length			Type of thrust bearing
			Nos. of lanes		nos.	Units for operation
			Int. dia. & thick.			Units for standby
		Total weight				Type of governor
		Pressure test result				Manufacturer
		Security device				Date of manufacturing
		Control valve				
		Manufacturer			Discharge measuring facility	
		Date of manufacturing				
	Blocks & supports			Draft Tube	Type	
					Drafting head	

Tailrace			Power Station		
	Outline of structure			Nos. of buildings	
	Length			Nos. of floor	
	Slope			Structure	
				Total floor area	
				Foundation area	

Other water rights					
	Rafting	Irrigation	Fishway		
				Works Supervisor	Works Contractor

Date of Project Approval	Date of Construction Approval	Date of Construction Start	Date of Commissioning	Approval Date of Water Right	Expiry Date of Water Right		Construc-tion Costs	Budget at Application for Approval	Budget for Construction	Actual Costs

Waterway (intakes, main waterways, branches, waterway bridges, pipe bridges, tailrace, etc.)								Notes
Name & No.	Length	Accumulated Length	Sectional Dimensions	Water Depth	Thickness of Lining	Channel Slope	Remarks	

Penstock (fill in for different diameter and pipe thickness.)										Locations of anchor blocks and security devices are to be noted below:
Name	Length	Accumulated Length	Static Head	Material	Internal Diameter	Pipe Thickness	Longitudinal Joints	Circumferenti al Joints	Remarks	

Typical Sections of Waterways

Conceptual Layout of Waterways

Hydropower	Filing No.				

Name	Power Station	Owner		Towns nearby	
Location				Date of provisional approval for use	
Power grid		River system/River		Date of approval for use	

	Approved Output (kW)	Discharge (m^3/s)	Effective Head (m)	Theoretical Output (kW)	Combined Efficiency of Turbine-Generator (%)
Max.					
Firm					
Special					
Firm Peak					
Supplement					
Supplement Peak					

Civil Structures							
	Reservoir/Regulating pond	Effective capacity	m^3	Drawdown	m	Type & height of weir	m
	Headrace	Type		Length	m		
	Type of head tank		Length of penstock, nos. of lanes, and nos. of branches			m, lanes, branches	
	Type & length of tailrace		m	Others			

Turbines						
	Unit No.					
	Type					
	Model					
	Rated output (max.)	(kW) kW	(kW) kW	(kW) kW	(kW) kW	
	Rated discharge	(m^3/s) m^3/s	(m^3/s) m^3/s	(m^3/s) m^3/s	(m^3/s) m^3/s	
	Rated head	(m) m	(m) m	(m) m	(m) m	
	Revolution speed	(rpm) rpm	(rpm) rpm	(rpm) rpm	(rpm) rpm	
	Runaway speed	m-kW	m-kW	m-kW	m-kW	
	Guaranteed max. efficiency	(kW) %	(kW) %	(kW) %	(kW) %	
	Guaranteed ratio of pressure change	%	%	%	%	
	Guaranteed ratio of speed change	%	%	%	%	
	Manufacturer					
	Date of manufacturing					
	nos. of units: Units for operation					
	nos. of units: Units for standby					
	Runner: Material					
	Runner: nos. of vanes					
	Packing					
	Material of liner					
	Guide-vane: Material					
	Guide-vane: nos. of vanes					
	Guide-vane: Operation method					
	Guide-vane: Locking device					
	Draft tube: Type & drafting head	m	m	m	m	
	Draft tube: Air pipe					
	Main Valve: Type					
	Main Valve: Operation method					
	Operation method of Pressure Regulator					
	Governor: Type					
	Governor: Rated oil pressure	- kg/cm^2	- kg/cm^2	- kg/cm^2	- kg/cm^2	
	Governor: Driving method of pendulum					
	Governor: Motor for governor					
	Governor: Capacity of servomotor					
	Governor: Closing time	sec	sec	sec	sec	
	Governor: Ratio of Speed Regulation (adjustable range)	- %	- %	- %	- %	
	Governor: Manufacturer					
	Pressure Oil Unit: Type of supply & nos.					
	Pressure Oil Unit: Receivers of oil supply					
	Pressure Oil Unit: Rated oil pressure range	- kg/cm^2	- kg/cm^2	- kg/cm^2	- kg/cm^2	
	Pressure Oil Unit: **Allowance at stopping pressure**	- kg/cm^2	- kg/cm^2	- kg/cm^2	- kg/cm^2	
	Pressure Oil Unit: Effective capacity of Pressure Oil Tank	l	l	l	l	
	Pressure Oil Unit: Pressure Oil Pump for operation	HP	HP	HP	HP	
	Pressure Oil Unit: Pressure Oil Pump for standby	HP	HP	HP	HP	
	Remarks					

Items Approved and Serious Accidents

Turbines	Lubricant Oil	Upper/Lower tank capacity	U	l	L	l	U	l	L	l	U	l	L	l	U	l	L	l
		Oil volume to stop turbine																
		Operation method of oil pump																
	Shaft Bearing	Type																
		Model																
		Oling and cooling methods																
	Break	Place of application																
		Operation method																
		Revolution speed for operation																
Generators	Unit No.																	
	Type																	
	Model																	
	Rated output			kVA				kVA				kVA				kVA		
	Rated power factor			%				%				%				%		
	Rated voltage			V				V				V				V		
	Frequency			Hz				Hz				Hz				Hz		
	Revolution speed			rpm				rpm				rpm				rpm		
	Ratio of short-circuit																	
	Synchronious impedance																	
	Ratio of voltage change			%				%				%				%		
	Flywheel effect			m-kW				m-kW				m-kW				m-kW		
	Allowable over-speed		%		min.		%		min.		%		min.		%		min.	
	Cooling method																	
	Coils	Type of insulation	S:		R:		S:		R:		S:		R:		S:		R:	
		Teperature measurement method	S:		R:		S:		R:		S:		R:		S:		R:	
	Coupling method with turbine																	
	Fire extinguisher for generator																	
	Manufacturer																	
	Date of manufacturing																	
	nos. of units	Units for operation																
		Units for standby																
	Grounding n.p.	Type & nos.																
		Capacity																
	Remarks																	
Excitor		Type of supply & nos.																
		Rated output		kW				kW				kW				kW		
		Rated voltage		V				V				V				V		
		Coupling method																
		Manufacturer																
		Date of manufacturing																
	Rated output & voltage of sub-excitor		kW		V		kW		V		kW		V		kW		V	
Transformers	Purpose																	
	Bank No.																	
	Model																	
	nos. of phase			phase				phase				phase				phase		
	Frequency			Hz				Hz				Hz				Hz		
	Capacity	Primary		kVA				kVA				kVA				kVA		
		Secondary		kVA				kVA				kVA				kVA		
		Tertiary		kVA				kVA				kVA				kVA		
	Voltage	Primary		V				V				V				V		
		Secondary		V				V				V				V		
		Tertiary		V				V				V				V		
	Impedance voltage			%				%				%				%		
	Type of cooling																	
	nos. of tap changer																	
	Method of cable connection																	
	Type of bushing																	
	Volume of insulation oil			l				l				l				l		
	Type of coil insulation																	
	Measuring device of coil temperature																	
	Measuring device of oil temperature																	

Layout of Machines and Equipments

Power Station – General Plan

Single Line Diagram

Power Station - 3

Transformers (continued)	Particulars	Type of Nitrogen seal												
		Design of insulation												
		Others												
	Manufacturer													
	Date of manufacturing													
	nos. of units	Units for operation												
		Units for standby												
	Grounding n.p.	Type & nos.												
		Capacity												
	Remarks													
Switching Equipments	Circuit breaker													
	Type & model													
	Rated voltage			V			V			V				V
	Rated current			A			A			A				A
	Rated shutdown capacity			kVA			kVA			kVA				kVA
	Conditions for functioning													
	Operation method	O:	C:		O:	C:		O:	C:		O:	C:		
	Time for opening/closing	O:	C:		O:	C:		O:	C:		O:	C:		
	Operating pressure or voltage			kg/m^2 (V)			kg/m^2 (V)			kg/m^2 (V)				kg/m^2 (V)
	Method of desparking													
	Type of bushing													
	Capacity & nos. of air tank	l	nos.		l	nos.		l	nos.		l	nos.		
	Air volume for operation			l										
	nos. of switching equipments			nos.			nos.			nos.				nos.
	Manufacturer													
	Date of manufacturing													
	Remarks													

Type, capacity, etc. of other main equipments									
Operation Control	Type of control & nos. of operator				Control station & cable				
	Load Dispatching Center to get instructions				Possible Watt-less power				kVar
	Adjusting equipments of voltage and power factor				Fast responding excitor				
	Automatic synchronizer				Load adjuster				
	Measuring facility for turbine efficiency				Manufacturer of Distribution Panel				
	Communications for maintenance & security								
	Method of maintenance & repairing								
	Particulars								
	Station Power: Type & capacity			kVA			kVA		kVA
	Station Power: Circuit voltage			V			V		V
	Station Power: Area of supply								
	Station Power: Battery capacity & charger								
	Station Power: Spare power source				Connection line				
	Remarks								
Protection Devices	Lightening: Circuit & nos.		nos.			nos.			nos.
	Lightening: Type & model								
	Lightening: Limit voltage			kV			kV		kV
	Lightening: Manufacturer								
	Lightening: Date of manufacturing								
	Protection Relay: Emergency stop								
	Protection Relay: Rapid stop								
	Protection Relay: No load, No excitation								
	Protection Relay: Normal stop								
	Protection Relay: Warning								
	Protection Relay: Particulars								
	Remarks								
Buildings	Structure & floor area			m^2	Installation method of turbine-generator				
	Fire distinguisher				Intake facility for cooling water				
	Remarks								

Appendix 2 Sample of Safety Rule

To introduce 'Safety Rule' as a sample, the Safety and Health Regulations for Work[*1] is provided below through translation from Japanese to English:

Part 1 Rule of General Application

Chapter1 General Rule

(Joint Venture)

Article 1…… 'Omitted from translation'

Chapter 2 Management System of Safety and Health

Section 1 General Safety and Health Supervisor

(Appointment of General Safety and Health Supervisor)

Article 2…… 'Omitted from translation'

(Deputy Supervisor of General Safety and Health)

Article 3…… 'Omitted from translation'

Note: *1: Source from: 'Safety and Health Regulation for Work, Japan', having been issued in 1998 by the Central Association for Prevention of Industrial Accident' under the editorship of the safety and health department of ministry of labor.

Section 2 Safety Supervisor

(Appointment of Safety Supervisor)

Article 4 The appointment of safety supervisor based on the provisions of Clause 1 of Article 11 in the Law shall be implemented by the following numbers:

(1) The appointment shall be carried out within 14 days since occurrence of the event to select the safety supervisor.

(2) The safety supervisor shall be appointed exclusively to the business establishment. However, in the case when the safety supervisors more than 2 persons are appointed and some of them are corresponding to the persons defined in the third number of the next Article, the appointment of safety supervisor from one of them is not necessary to be exclusive to the business establishment.

(3) 'Omitted from translation'

(4) 'Omitted from translation'

(Qualification of Safety Supervisor)

Article 5……'Omitted from translation'

(Safety Supervisor's Patrol and Admission of Power and Authority)

Article 6 The supervisor shall patrol work sections, etc. and in the case when there are fears of risks in facilities, work methods, etc. he shall take necessary measures for prevention of the risk.

2. The employer shall admit the supervisor to the power and authority relevant to conduct the measures for assurance of safety.

Part 2 Safety Standards

Chapter 1 Prevention of Risks by Machinery

Section 1 General Standards

(Prevention of Risks by Motor, Rotation Axis, etc.)

Article 101 The employer shall provide covers, enclosures, sleeves, crossover bridges, etc. for the machinery portions where are fears of endangering the worker, like a motor, a rotary shaft, a gear, a pulley, a belt, etc. of machinery.

2. In respect of stoppers incidental to a rotation axis, a gear, a pulley, a flywheel, etc. of machinery, the employer shall use the stoppers with embedded head type or he shall provide coverage, in the case of use of the stoppers with not embedded head type.

3. The employer shall not use the protruding stopper at the belt joints.

4. The employer shall use a handrail higher than 90 cm for the crossover bridges specified in Clause 1 of this Article.

5. The worker shall use the crossover bridge in the case of its provision.

(Prevention of Risks by Disconnection of Belts)

Article 102 The employer shall provide enclosures with the space below the belt which is set above passages or working areas and in which the distance between pulleys is more than 3 m, its width is more than 15 cm and its speed is more than 10 m/s.

(Device of Power Cutoff)

Article 103 The employer shall provide devices of power cutoff such as a switch, a clutch, belt shifter, etc. with each machine. However, this specification is not applicable for the machine which consists of a continuous crew of machine and has a shared device of power cutoff, and also does not need man-powered feeding and taking out of raw material on the process.

2. In the case when the machine specified in the preceding clause is prepared for a cutting process, a drawing process, a press process, stamping, bending process or squeezing process, the employer shall provide such a device of power cutoff as specified in the preceding clause with the place where the employee is able to operate it without getting away from his working place.

3. With regard to such a device of power cutoff as specified in Clause 1, it shall be a device which is easy to be operated and also has no fears of a sudden start due to contacts, vibrations, etc.

Section 8 Revolution Body with High-Speed

(Risk Prevention during Rotation Test)

Article 149 In the case when the employer carry out the rotation test for the revolution body with high-speed (which is such a revolution body as the baskets of turbine rotors and centrifugal machines, etc. and has a peripheral velocity more than 25 m/sec and which is herein under this section designated as a revolution body), he shall carry out the rotation test in the place where is segregated by the exclusive firm buildings or the firm barriers, etc. for prevention of the risks which may be caused by failures of the revolution body with high-speed. However, this specification is not applicable for the rotation test of the revolution body with high-speed other than specified in the next article and in which the preventive measures like provision of firm coverage over the test facilities are adopted for the risks which may be caused by failures of the revolution body with high-speed.

(Nondestructive Test of Rotary Shaft)

Article 150 The employer shall confirm that there are no defects which may have a fear of causing failures with an advance nondestructive test of the rotary shaft which is subject to material properties, shapes, etc., in the case when the employer carries out the rotation test for the revolution body with high-speed (which is limited to the revolution body of which rotary shaft is more than 1 ton and also of which peripheral velocity is more than

120 m/s).

(Implementation Method of Rotation Test)

Article 150-2 In the case when the employer carries out the rotation test to such a revolution body with high-speed as stipulated in the preceding article, he shall adopt such a measure as remote control, which has not a fear of putting the worker who carry out the respective work of controlling, measuring, etc. at risk due to failures of the said revolution body with high-speed.

Chapter 5 Prevention of Risks by Electricity

Section 1 Electromechanical Appliance

(Enclosure of Electromechanical Appliance, etc.)

Article 329 In respect of the charging portion of electromechanical appliance (excluding a heating element of electric heating appliance, an electrode portion of resistance welding machine, etc. such as forced to be exposed), and also the electromechanical appliance, depending on the purpose of their usage, where is a fear of electrical shock by a touch (inclusive of the touch through an electric conductor herein under this chapter) or an approach by the worker during their working or their passing, the employer shall provide enclosure or insulating coverage for the purpose of prevention of electrical shock. However, the above mentioned coverage is not applicable for electromechanical appliance to be installed at the areas blocked out like panel rooms, transformer rooms, etc. , where the employer forbids to enter to the persons other than assigned to handling of such electrical tasks as specified in the fourth number of Article 36 (herein under defined as 'the person in charge of handling electrical tasks') or at the areas segregated like the places such as on electrical poles, towers, etc. where the person except 'the person in charge of handling electrical tasks' will not approach possibly.

(Guard of Handled Lamp)

Article 330 1.The employer shall outfit a guard with the handled lamp connecting with trailing electric lines, the aerial pendant lamp connecting with temporary wires or trailing electric lines, etc. in order for prevention of the electrical shock risks due to touch on the cap and the risks of lamp bulb damages.

2. With regard to the guard mentioned above, the employer shall be responsible for conformity of the guard to the following:

(1) Those lamps shall have such a structure as not to lay easily a hand on the exposures of caps.

(2) The materials shall be selected from the materials which are hard for being damaged

or deformed.

(Holder of Welding Electrode, etc.)

Article 331 With regard to the holder of welding electrode, etc. for the use of arc welding, etc. (exclusive of automatic welding), the employer shall not use welding electrodes if they do not fulfill with the specifications stipulated in the C9302: 'Holder of welding electrode' of 'Japanese Industrial Standards (JIS)' or they do not have insulating effectiveness and heat-resistance which are equivalent to or more than the specifications.

(Automatic Prevention Device of Electric Shock for Alternating Arc Welder)

Article 332 The employer shall use an automatic prevention device of electric shock for alternating arc welder in the case of implementation of the alternating arc welding work, etc. (except automatic welding) at the remarkably narrow places enclosed by electric conductors like ships with a double bottom or the inside of peak tank or drum or dome of boilers, or at the places where are fears of the workers' contacts to grounding stuffs with high electric conductivities like steel-frames in the locations higher than 2 m which may endanger workers by their falls.

(Prevention of Electrical Shock by Electrical Leak)

Article 333 In respect to equipment or apparatus having electric motors (herein under called as 'electric-powered equipment') of either a portable type or a transportable type having the ground voltage more than 150 volts, or electric motors of either a portable type or a transportable type which is used in the places saturated with liquid such as water having a high electric conductivity and another places on a steel plate, a steel-frame, a machine platen, etc. such as have a high electric conductivity, the employer shall connect the cable way with an interrupting device which conforms to the rating of the said cable way with a high sensitivity and surely goes on for the preventive measures of electric shock.

In the case when the employer is hard to take a measure specified in the preceding

clause, he shall use the electric-powered equipment after earthing of metal portions such as a metal outer frame, a metal casing, etc. of electric-powered equipment according to the following connection ways of earthing:

(1) The connection with earthing poles shall be as follows by either (i) or (ii):

(i) The connection with earthing poles by use of traveling wires with a center core as an own ground wire and also one by use of the connection apparatus with an end terminal as the own earthing end terminal.

(ii) The connection with earthing poles by use of grounding wires attached to traveling wires and one by use of the end terminal of earthing provided in the places near power points of the said electric-powered equipment.

(2) In the case of application of the method stipulated above in (i), the employer shall take a preventive measure for the combined application of both grounding wires and electric wires to connect with the cable way, and also one for the combined application of grounding end terminals and the end terminals to connect with the cable wa.

(3) The earthing poles shall be surely connected with earth by such a measure of their sufficient burying in earth.

(Exclusion of Application)

Article 334 The provisions of the preceding article shall not be applicable for any electric-powered equipment which are fulfilled with the provisions of the following numbers:

(1) The electric-powered equipment which is used in connection with the cable way with the nongrounding system (which is limited to only the cable way where the secondary voltage of such an insulated transformer as provided with the power source side is less than 300 V and also where the load side of the relevant insulated transformer is nongrounded).

(2) The electric-powered equipment which is used on the insulated table.

(3) The electric-powered equipment with double insulation structure which is warranted in accordance with the provisions of Electrical Appliance and Material Control Law (, i.e. 234th number of the law issued in the year of 1961).

(Illumination for Handling Part of Electromechanical Appliance)

Article 335 The employer shall keep the illumination necessary for handling parts of electromechanical appliances during their handling, to prevent the risk of electrical shock or the risks which may be caused by wrong handling.

Section 2 Wiring and Trailing Electrical Cable

(Insulating Coating of Wiring, etc.)

Article 336… 'Omitted from translation'

(Insulation or Armoring of Trailing Electric Cable, etc.)

Article 337… 'Omitted from translation'

(Temporary Wiring, etc.)

Article 338… 'Omitted from translation'

Section 3 Power Outage Work

(Measure for Implementing Power Outage Work)

Article 339… 'Omitted from translation'

(Circuit Opening of Disconnector, etc.)

Article 340… 'Omitted from translation'

Section 4 Work of Hot Line and Work Near Hot Line

(Work of High-Voltage Hot Line)

Article 341… 'Omitted from translation'

(Work near High-Voltage Hot Line)

Article 342… 'Omitted from translation'

(Wearing of Protection Guard for Insulation, etc.)

Article 343… 'Omitted from translation'

(Work of Extra High-Voltage Hot Line)

Article 344… 'Omitted from translation'

(Work near Extra High-Voltage Hot Line)

Article 345… 'Omitted from translation'

(Work of Low-Voltage Hot Line)

Article 346…'Omitted from translation'

(Work near Low-Voltage Hot Line)

Article 347… 'Omitted from translation'

(Protection Equipment of Insulation, etc.)

Article 348… 'Omitted from translation'

(Protection of Electrical Shock in The Case of Construction of Work Piece)

Article 349… 'Omitted from translation'

Section 5 Supervision

(Work Control in The Case of Implementation of Electrical Works, etc.)

Article 350… 'Omitted from translation'

(Periodical Self-imposed Test for Protection Equipment of Insulation, etc.)

Article 351… 'Omitted from translation'

(Pre-operational Test of Electromechanical Appliance, etc.)

Article 352… 'Omitted from translation'

(Inspection for Enclosure of Electromechanical Appliance, etc.)

Article 353… 'Omitted from translation'

Section 6 Miscellaneous

(Exclusion of Application)

Article 354…'Omitted from translation'

Appendix 3

Guidelines for OJT

OJT (on-the-job training) is training program of skills of actual work after participating a company or organization as a practical experience.

The problems on instruction of subordinates are various and wide-ranging, but some points are common many fields. It is categorized in the following five points; 1) attitude of tackling with works, 2) personal characteristics and ability, 3) communication with other persons, 4) process of work, and 5) behaviour on ordinal work. Subjects on practice of OJT are broad and deep. The problem about acquiring knowledge and skills, main issue of OJT, is rather small in OJT practice.

Examples of act for OJT practice in various training theme is introduced below, which are only a part of know-how and are not obliged. In practice, they may not be sufficient on the workplaces and other methods should be considered with deeper communication. However it will be a reference of practical OJT.

Table 1 OJT Practice based on encouraging theme

Problem	Countermeasure
1 Attitude of tackling with works	
Not saying any opinion from trainee side	▪ Arrange a place for light conversation about 5 minutes in every morning.
Working based on only imagination	▪ Let him/her reconfirm work flow. ▪ Check diligently by direct boss.
Lack of analysis and problem solving method	▪ Teach know-how at first, and make let him/her be interested in the work during skill up process.
Little attitude for improving works	▪ Define the limit of work and make him/her try quick process ▪ Advise for job rationalization ▪ Make him/her recognize the importance in personal meeting. ▪ Let him/her participate self-training course in another department or tour training in another organization and arouse willingness ▪ Charge him/her on presentation of self training.
Weak flexibility for new task	▪ Talk enough about detail of work and make him/her understand its purpose and importance ▪ Define the work that is possible for him/her or impossible ▪ Make him/her understand that the work was handed to him/her considering his/her skill and experience

Negative attitude for instruction of subordinates	▪ Let him/her be a chairman of meeting of whole members including his/her subordinates
Limiting range of work by himself	▪ Make him/her perform inexperienced job with support and evaluate him. ▪ Emphasis that his/her cooperation is needed. ▪ Boldly charge him/her such jobs that has 20%~30% larger load than the capacity than he/she regards as it is his/her ability
Performing only what is ordered to do so.	▪ Praise when he/she expends his/her work and performs application work from his/her side. ▪ Have a discussion for recognition of his/her role, make him/her be conscious about work, and broaden his/her viewpoint. ▪ Tell him/her about overview of the work ▪ Give him/her a work of which aim is possible to be realized ▪ Arrange support from other staffs. ▪ Let him/her attend maker's lecture course and learn. ▪ Let him/her study examples of troubles
Little drive for unknown task	▪ Boss becomes the first to do and show. ▪ Make a team with a expert of the field and let him/her work
Neither trying to help others nor learning other than his/her job	▪ Persuade him/her to understand that the work will be finished after all department work is finished. ▪ Make him/her experience another department task after changing position.
Corner cutting on work	▪ Confirm with check box table.
No interest and willingness in work	▪ Try to make him/her feel achievement during work with easy theme ▪ Praise no matter how small the achievement is. ▪ Let him/her have some theme and send him/her to users. ▪ Let him/her do high level work ▪ Speak well of him/her every time when his/her work is finished ▪ Change department. ▪ Grasp the progress of work and give him/her next work. ▪ Explain the importance of the task. ▪ Advise from colleague and boss, and come off from his/her color. ▪ Give him/her enough opportunity of presentation ▪ Broaden personal communication. ▪

No utterance of self assertion	▪ Let him/her submit regular report such as daily and weekly report. Let him/her write his/her point of view in easy style. ▪ Increase the opportunity of presentation.
Being no confidence	▪ Praise of him/her on good profile. ▪ Completely leave the work to him/her even small thing. ▪ Let him/her do more work and make him/her realize the achievement, not as a supporter but as a main person in charge. ▪ Let him/her in two persons and praise him/her as three person's job.
Not being good at self appeal	▪ Let him/her explain the contents of his/her work in department meeting. ▪ Charge him/her a chairman of reporting meeting. ▪ Let him/her make 3 minutes speech.
No self-awareness as a leader	▪ Let him/her educate his/her subordinate. ▪ Increase opportunity of being authorized as proxy. ▪ Have opportunity of discussion.
Lack of awareness of common sense as social worker	▪ Let him/her attend education training. ▪ Educate him.
Need to recognize the importance of deskwork	▪ Let him/her find three "un" (unnecessary, unreasonable, and unevenness) by summarizing field work.
2 Problem of personal character	
Irresponsible utterance	■ Make him/her understand the effect of utterance and his/her position in the organisation. ■ Confirm the detail of the utterance and background ■ Consult with direct middle manager ■ Know ordinal complaint ■ Have an opportunity to talk
Insufficient responsibility and positive attitude	■ Do not make him/her leave things to his/her leader. ■ Have enough communication and grasp the problem. ■ Discuss about the importance of work as such intensively as man-to-man. ■ Let him/her feel his/her presence to others. ■ Let him/her aware of future responsibility by proposing idea and cooperation and instruction of techniques to his/her colleagues and boss. ■ Check the progress of work and advise him/her regularly.

	■ Express appreciation when the work is accomplished. ■ Look again the allocation of work. ■ Discuss on concrete example.
Not finishing to the end	■ Let him/her make schedule table. ■ Follow him/her on defined day once a week. with follow table
Selfish attitude	■ Instruct him/her so that he/she listens to others. ■ Make him/her realize the other's idea by having debate meeting about his/her report and so on. ■ Let him/her guide his/her junior.
Too much self-confident	■ Make him/her experience of another workplace and difficult work. ■ Make friendship privately and advise him/her about problem that he/she is inherent. ■ Follow the result, clear the next implementation plan, and let everyone know in everyday meeting.
Too much work on his/her hands	■ Let him/her analyze the time of his/her daily work pattern
Taking defiant attitude when advised	■ Listen carefully the feeling why he/she becomes defiant. ■ Do not advise with emotion.
Capricious attitude	■ Confirm the progress of work. ■ Let him/her check the finishing, report, and have an opportunity of self-examination ■ Think the way of work together. ■ Let him/her search his/her conscience by his/her character diagnosis
Lack of confidence	■ Praise him/her on even small result. ■ Advise him/her to talk loud.
Much fear of failure	■ Clear the problem and tell the countermeasure. ■ Let him/her look for questions on work and tackle positively. ■ Let him/her try to ask directions from boss about question.
Being unapproachable	■ Arrange common topic, including other topics than work.
Being disliked by the same sex	■ Let him/her have experiences of planning and operation of event ■ Let him/her make plans such as party including other boss
Lack of modesty	■ Advise and follow in a manner that is suitable to him ■ Make relationship of mutual trust.

3 Insufficient communication with surrounding people	
Not reporting independently	■ Set man-to-man conversation opportunity with manager. ■ Set opportunity of his/her self advertise such as weekly report, monthly report, and appointing him/her chairperson of meeting
Late reporting	■ Let him/her report the feeling of works every evening.
Few information, reporting, and asking advice	■ Remind him/her reporting, information, and asking advice in casual manner. ■ Define contents to be reported ■ Arrange time for communication consciously using meeting hours ■ Talk about standard of reporting.
Not reporting with data	■ Study with boss tighter when he/she does not know how to report. ■ Make him/her understand that output of reporting and document is the most important task, let him/her arrange them frequently, and check them each time and make him/her learn.
Inappropriate way to talk by time, place, and occasion	■ The boss should ask cooperation for colleagues to advice him/her whenever it happens.
Leaving unknown alone, process it by his/her own discretion, and reach to dead end	■ Arrange manual of basic manner to make up for insufficient experience and knowledge. ■ Work together. ■ Make him/her analyze his/her failure by himself. ■ Adjust amount of task.
Not understanding tasks properly	■ Let him/her have experiences of former and later process of the task and make him/her understand the flow of work.
Lack of cooperativeness	■ Have an opportunity to talk, and consult with direct manager. ■ Let him/her work to understand situations and intensions of other people. ■ Let him/her do such tasks that need team work. ■ Make him/her understand that organizations do not work with one person.
Selfish attitude	■ Contact him/her with sympathy, sometimes praise him/her and sometimes show cold attitude.
Lack of communication ability	■ Let him/her instruct a freshman. ■ Let him/her attend internal meeting and report. ■ Let him/her host a meeting. (Change his/her standpoint from being asked to ask)

4 Problem of making process of works	
Working without plan and schedule	■ Make him/her arrange the work and schedule. ■ Make breakdowns to detailed schedule such as weekly schedule. ■ Follow the breakdown. ■ Follow in detail to a table of pending problems and deadline.
Learning rules and know-how of work	■ Let him/her learn Quality Control method. ■ Instruct him/her to have a habit to ask consultation.
Slow work	■ Analyze a cause such as planning, process, and program. ■ Check how much he/she understands the contents of the work. ■ Clean a schedule of work implementation and follow. ■ Ask him/her the reason of slow work. ■ Let him/her perform time management.
Not following deadline	■ Make him/her understand background and importance of deadline. ■ Train him/her to complete in simple way.
Process only easy task and not doing difficult work	■ Order him/her with identifying priority. ■ Write down on a black board about the task so that he/she can see well
Need secure knowledge about work	■ Educate with manual about organization and its work. ■ Hold a training course.
Insufficient self education	■ Make an opportunity of presentation and ask direction to middle manager. ■ Let him/her participate internal presentation and lecture. ■ Let him/her hold an internal study meeting.
Insufficient cover for mistake and trouble	■ Let him/her study example of accident record. ■ Implement training about handling equipment. ■ Let him/her try always to have one interval so that not to be in panic whenever trouble.
5. Problem of ordinary working attitude	
Little confidence from subordinates	■ Instruct him/her for proper words and way of ordering.
Too much private talk in working hours	■ Advise privately not only to him/her but also to others.. ■ Let him/her understand the regulation of workplace.
Insufficient self management both	■ Arrange time for organizing staffs for one hour. ■ Prepare such small desk that can not put much stuffs on.

in office and home	
Many late-coming and absence	■ Let him/her obey the regulation of organization. ■ Educate the importance of rules. ■ Explain the importance of absence well. ■ Hold a hearing if he/she has complaint about work, and shift his/her position and according to circumstances.
Many complaints and excuses without work performance	■ Recognize the roles and contents of order. ■ Talk each other and find cause of the complaint. ■ Let him/her suggest the solution from his/her side and ask for consult with relating department ■ Hold a meeting, hear the complaint concretely, catch the complaint as a problem, and discuss about countermeasure.
Not properly dressed	■ Instruct to obey the moral as a social worker.

Appendix 4 Method on Operation of Hydraulic Turbine for Achievement of 'High Efficiency Operation'

1. High Efficiency Operation

The 'High efficiency operation' is defined as the operation of hydraulic turbines to obtain the maximum output through a reasonable distribution of discharge to each hydraulic turbine depending on their characteristics, which has its own characteristics.

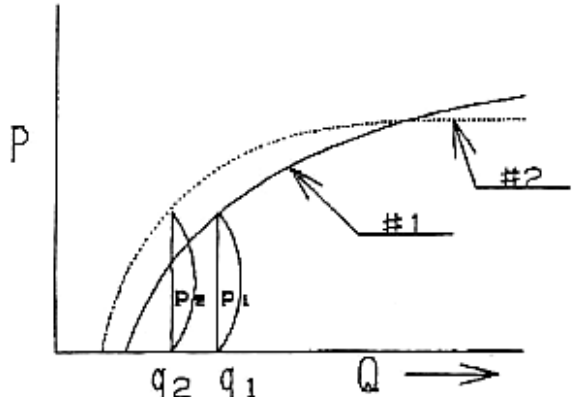


Figure A1.4.1 Characteristic Curves for 2 Units Installation of Hydraulic Turbines

Each characteristic of two (2) units of hydraulic turbines is shown in Figure 1 in which discharge is along the x-axis and power output is along the y-axis for easy calculations of efficiency, while in order to present efficiency of hydraulic turbines, power output is generally along the x-axis and discharge (or efficiency) is also generally along the y-axis.

(1) Conditions to Distribute Discharge for Achievement of Maximum Power Output

By reference to Figure 1, the characteristics of hydraulic turbines are approximately presented as follows:

$$p_1 = A_1 q_1^2 + B_1 q_1 + C_1 \quad (1)$$

$$p_2 = A_2 q_2^2 + B_2 q_2 + C_2 \quad (2)$$

$$Q = q_1 + q_2 \quad (3)$$

$$P = P_1 + P_2 \quad (4)$$

Where, suffixes of 1 and 2 are respectively given for both No.1 and No.2 units of

hydraulic turbines.

As is defined, the 'High efficiency operation' is to maximize P: power output through a reasonable distribution of Q: discharge given.

From Eq. (3)

$$q_2 = Q - q_1 \qquad (5)$$

Substituting Eq. (5) to Eq. (2),

$$p_2 = A_2(Q-q_1)^2+B_2(Q-q_1)+C_2$$
$$= A_2Q^2 - 2A_2Qq_1 + A_2q_1^2 + B_2Q - B_2q_1 + C_2 \qquad (6)$$

Adding Eq. (1) to Eq. (6) to obtain P (= p1 + p2) and putting P into order,

$$P = (A_1 + A_2)q_1^2 + (B_1 - B_2 - 2A_2Q)q_1 + A_2Q^2+B_2Q+C_1+ C_2 \qquad (7)$$

To maximize P, it is required to differentiate Eq. (7) by q_1, achieve the equation expressed in q_1 and Q, and let the equation equal to 0 as shown below.

$$\frac{dp}{dq_1} = 2(A_1+A_2)q_1+(B_1-B_2)-2A_2Q = 0$$

$$(\because d(A_2Q^2 + B_2Q + C_1 + C_2) / dq_1 = 0)$$

$$q_1 = \frac{2A_2Q}{2(A_1+A_2)} + \frac{B_2-B_1}{2(A_1+A_2)}$$

$$= \frac{A_2Q}{A_1+A_2} + \frac{B_2-B_1}{2(A_1+A_2)} \quad \cdots\cdots\cdots\cdots (8)$$

Eq. (8) means the condition of discharge distribution.

On the other hand, q_2 is presented as follows in reference to Eq. (8):

$$q_2 = Q - q_1 = \frac{2(A_1 + A_2)Q - 2A_2Q - B_2+B_1}{2(A_1+A_2)}$$

$$= \frac{A_1Q}{A_1+A_2} + \frac{B_1-B_2}{2(A_1+A_2)} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (9)$$

Substituting Eq. (8) to Eq. (1),

$$p_1 = A_1\left(\frac{2A_2Q + (B_2-B_1)}{2(A_1+A_2)}\right)^2 + B_1\left(\frac{2A_2Q+(B_2-B_1)}{2(A_1+A_2)}\right)+C_1$$

$$= \frac{4A_2^2Q^2A_2 + 4A_2A_1Q(B_2-B_1) + (B_2-B_1)^2A_1}{4(A_1+A_2)^2} + \frac{2B_1A_2Q + (B_2-B_1)B_1}{2(A_1+A_2)} + C_1$$

Similarly, computing P expressed in q_2, differentiating P by q_2 in order to eventually achieve the equation expressed in q_2 and Q, and let the equation equal 0,

$$p_2 = \frac{4A_2^2Q^2A_2 + 4A_1QA_2(B_1-B_2) + (B_1-B_2)^2A_2}{4(A_1+A_2)^2} + \frac{2B_2A_1Q + (B_1-B_2)B_1}{2(A_1+A_2)} + C_2$$

Accordingly, P (= $p_1 + p_2$) is presented as follows:

$$p_1+p_1 = \frac{A_2^2A_1Q^2 + A_1^2A_2Q_2}{(A_1+A_2)^2} + \frac{(A_1+A_2)(B_1-B_2)^2}{4(A_1+A_2)^2} + \frac{B_1A_2Q + B_2A_1Q}{A_1+A_2} + C_1 + C_2$$

$$= \frac{A_1A_2Q^2 + (B_1A_2+B_2A_1)Q + \left(\frac{B_1-B_2}{2}\right)^2 + (C_1-C_2)(A_1+A_2)}{A_1+A_2} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(10)$$

(2) Case Study of Hydraulic Turbine Units Having Equal Characteristics

In the case when characteristics of two (2) units are equal, let $A_1$and A_2, B_1 and B_2, and C_1 and C_2 equal respectively,

$A_1=A_2=A$, $B_1=B_2=B$ and $C_1=C_2=C$

Accordingly,.

$$q_1 = \frac{AQ}{(A+A)} + \frac{B-B}{2(A+A)} = \frac{Q}{2} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(11)$$

Similarly,

$$q_2 = \frac{AQ}{(A+A)} + \frac{B-B}{2(A+A)} = \frac{Q}{2} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(12)$$

Such Eq. (11) and Eq. (12) means that the maximum P: power output is achievable in distribution of discharge equal to each hydraulic turbine unit.

Further, P is presented as follows:

$$P = \frac{A}{2}Q^2 + BQ + 2C \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(13)$$

2. Computation Method of Characteristic Curves

Efficiency (or discharge) characteristics of hydraulic turbines: q is presented by p: power output as follows:

$P = Aq^2 + Bq + C$

Such constants of A, B and C are generally determined by use of Least Square Method. However, it is said that the $\Sigma\Delta$ method so called gives easy calculations and approximate quadratic curves of p and it is explained as follows:

[$\Sigma\Delta$ Method]:

Data of p and q are to be adopted for 6 points with almost equal distance.

P	P_1	P_2	P_3	P_4	P_5	P_6
q	q_1	q_2	q_3	q_4	q_5	q_6

$P_1 = Aq_1^2 + Bq_1 + C$ (1)

$P_2 = Aq_2^2 + Bq_2 + C$ (2)

$P_3 = Aq_3^2 + Bq_3 + C$ (3)

$P_4 = Aq_4^2 + Bq_4 + C$ (4)

$P_5 = Aq_5^2 + Bq_5 + C$ (5)

$P_6 = Aq_6^2 + Bq_6 + C$ (6)

Adding Eq. (1) to Eq.(2),

$P_1+P_2 = A(q_1^2+q_2^2)+B(q_1+q_2)+2C$ (7)

Adding Eq. (3) to Eq.(4),

$P_3 + P_4= A(q_3^2+q_4^2)+B(q_3+q_4)+2C$ (8)

Adding Eq. (5) to Eq.(6),

$P_5+P_6 = A(q_5^2+q_6^2)+B(q_5+q_6)+2C$ (9)

The constants of A, B and C are obtained by solving these simultaneous equations of Eqs. (7), (8) and (9).

Deducting Eq. (8) from Eq. (7),

$(P_1+P_2)-(P_3+P_4) = A(q_1^2+q_2^2-q_3^2-q_4^2)+B(q_1+q_2-q_3-q_4)$

Deducting Eq. (9) from Eq. (8),

$$(P_3+P_4)-(P_5+P_6) = A(q_3^2+q_4^2-q_5^2-q_6^2)+B(q_3+q_4-q_5-q_6)$$

Accordingly,

$$A = \frac{(P_1+P_2-P_3-P_4)(q_3+q_4-q_1-q_6)-(P_3+P_4-P_5-P_6)(q_1+q_2-q_3-q_4)}{(q_1^2+q_2^2-q_3^2-q_4^2)(q_3+q_4-q_1-q_6)-(q_3^2+q_4^2-q_5^2-q_6^2)(q_1+q_2-q_3-q_4)}$$

The constant of B is achievable by substituting A to Eq. (10) and C is achievable by substituting A and B to an equation among Eq. (7) to Eq. (9).

Appendix 5 Operating Principle and Structure of Speed Governor with Mechanical Type for Hydraulic Turbine

1. General

The hydraulic turbine continues to rotate with a constant speed of rotation as long as the output of hydraulic turbine and the size of load are equal to each other. The decrease of load increases its unbalance with the output of hydraulic turbine. Subsequently, the speed of rotation of the hydraulic turbine starts to increase and the hydraulic turbine output starts to decrease. Such increase of the speed of rotation continues till achieving a balance between the hydraulic turbine output and the load.

To fulfill such requirement, the turbine is desirable to be always operated under a constant speed of rotation and the mechanical type speed governor is prepared so as to attain a mechanism possible to automatically control the speed of rotation.

All of speed detection and automatic control of the speed are carried out by mechanical mechanism. Figure 1 is an illustration to explain the typical structure of the speed governor with mechanical type.

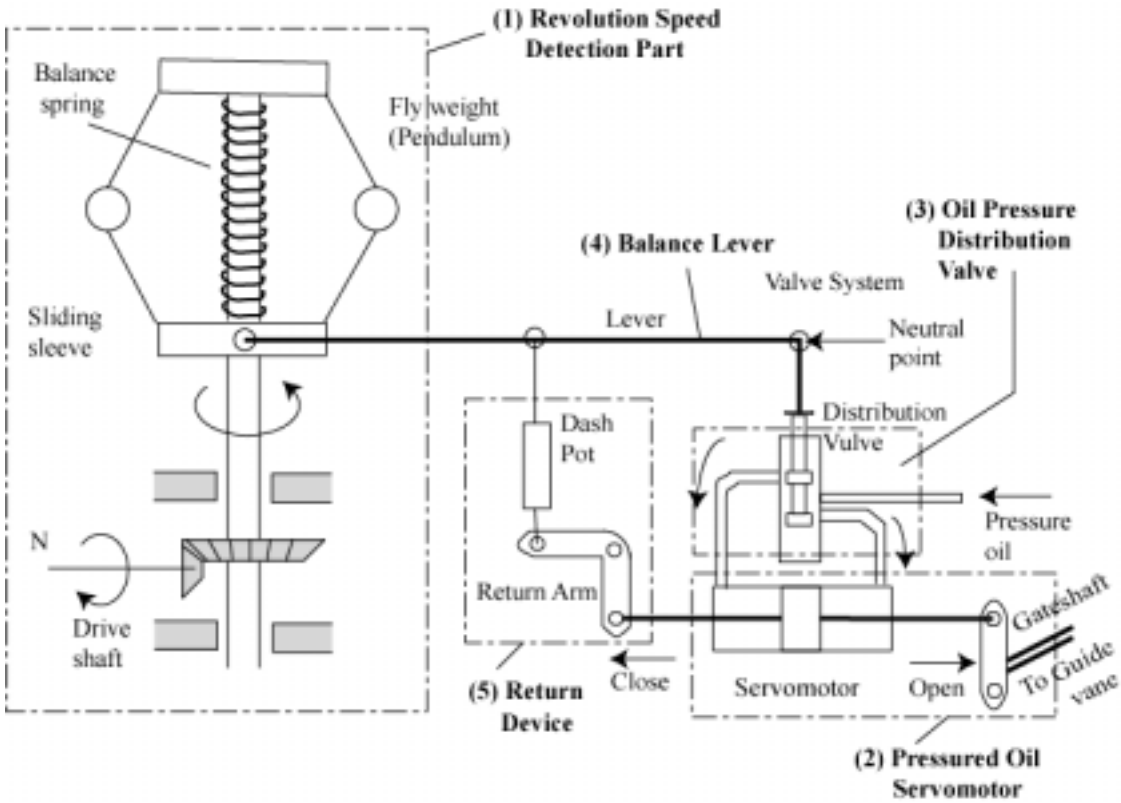


Figure 1 Main Structure of Governor

2. Role of Main Units

(1) Unit for Detection of Speed of Rotation

As shown in Figures 1 and 3, the unit for detection of speed of rotation consists of:

(i) a vertical shaft which revolves in proportion to the revolution speed of hydraulic turbine;

(ii) a pendulum which rotates with the shaft;

(iii) a spring which balances with the centrifugal force of pendulum; and

(iv) a sliding sleeve which moves in the same direction of up/down of the pendulum.

Figure 2 shows the detailed structure of the sliding sleeve.

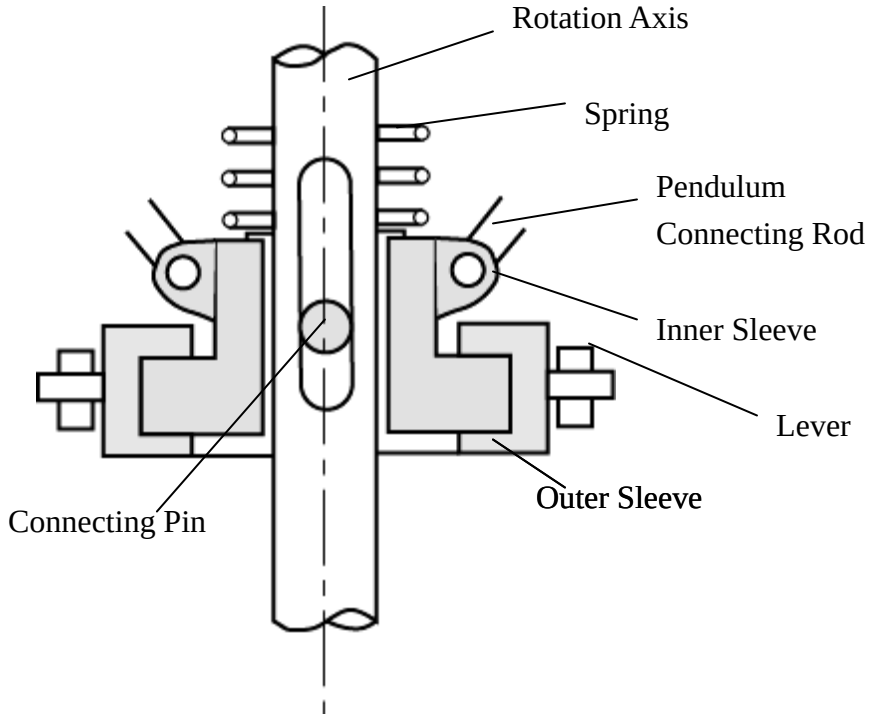


Figure 2 Detailed Structure of Sliding Sleeve

As shown in Figure 2, the sliding sleeve includes an inner sleeve and an outer sleeve. The inner sleeve rotates simultaneously with the shaft as it is connected directly to the shaft through a connecting pin. The outer sleeve is attached to the inner sleeve so as to cover the outer side of rotating plate in the inner sleeve. The outer sleeve is fixed by a lever. Consequently the outer sleeve stands still, having a sliding surface with the rotating plate.

The both pendulums are connected with the inner sleeve by the respective connecting rod, which forms a link mechanism as shown in Figure A5.1. When the shaft rotates, the inner sleeve, the link mechanism and the pendulums rotate together and simultaneously with the shaft.

Consequently, a centrifugal force out from the center of shaft to the outside works on a pendulum which forms such a shape of link mechanism as illustrated in red lines in Figure 3. The inner sleeve moves upward, compressing the spring. The inner sleeve rises up to the point at which the centrifugal force of pendulum and the reaction from the spring are balanced. By this motion of the inner sleeve, the outer sleeve and the lever are also pulled up.

Speed of rotation is related to the centrifugal force, while the centrifugal force is related to the spring deformation. Therefore, it becomes possible to detect the speed of rotation at any location of the sliding sleeve.

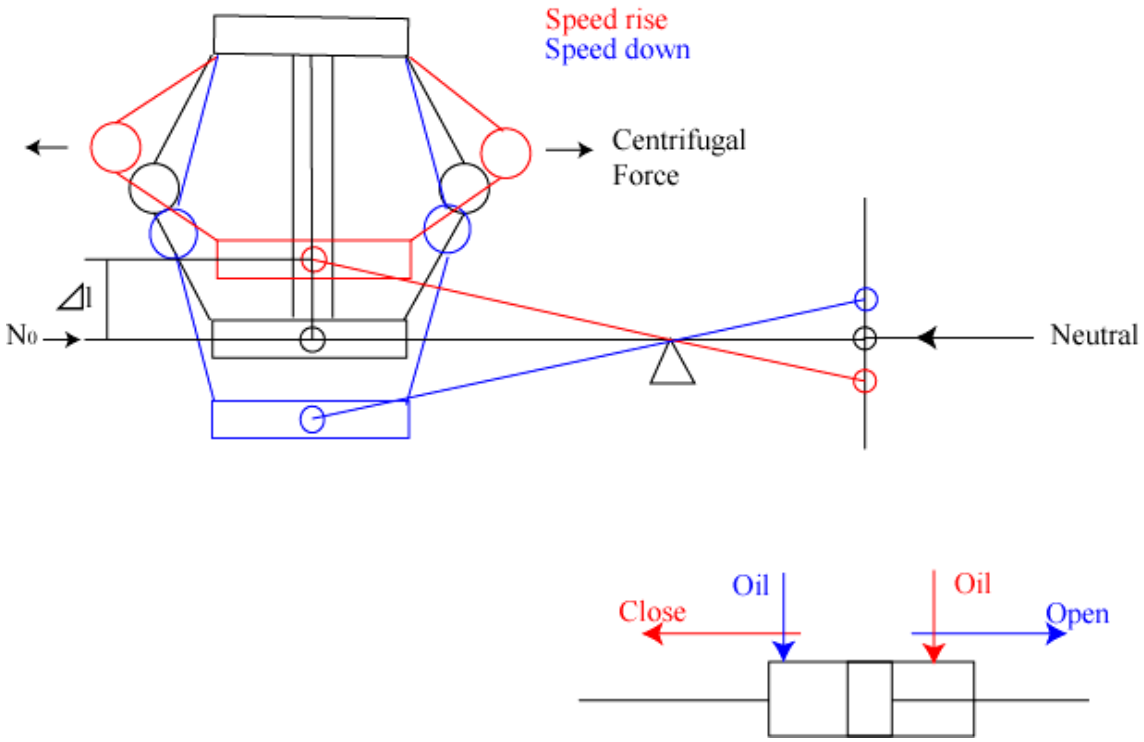


Figure 3 Link Mechanism

(2) Oil Pressure Servomotor

Since a considerable large power is required to drive the guide vane of hydraulic turbine, the oil pressure servomotor is applied for the mechanical governor to operate the guide vane.

The direction of the piston movement provided by the servomotor depends on the direction of the oil pressure as to whether the oil pressure is supplied from the right side or the left side of the servomotor piston.

The piston shown in Figure 1 has such a structure so that to move to the right and opens the guide vanes in the case when the oil pressure is supplied from the left side. On the other hand, the piston moves to the left and closes the guide vanes in the case when the oil pressure is given from the right side.

(3) Distribution Valve of Oil Pressure

Figure 4 (a) and (b) shows the mechanism of oil pressure distributing valve. Figure 4 (a) illustrates the situation where the piston valve is at the neutral point and the oil pressure is interrupted by both the upper and the lower flanges of the piston valve so that the oil pressure is not able to flow to neither the open side nor the close side. Such a location of the piston valve is called the “neutral point”.

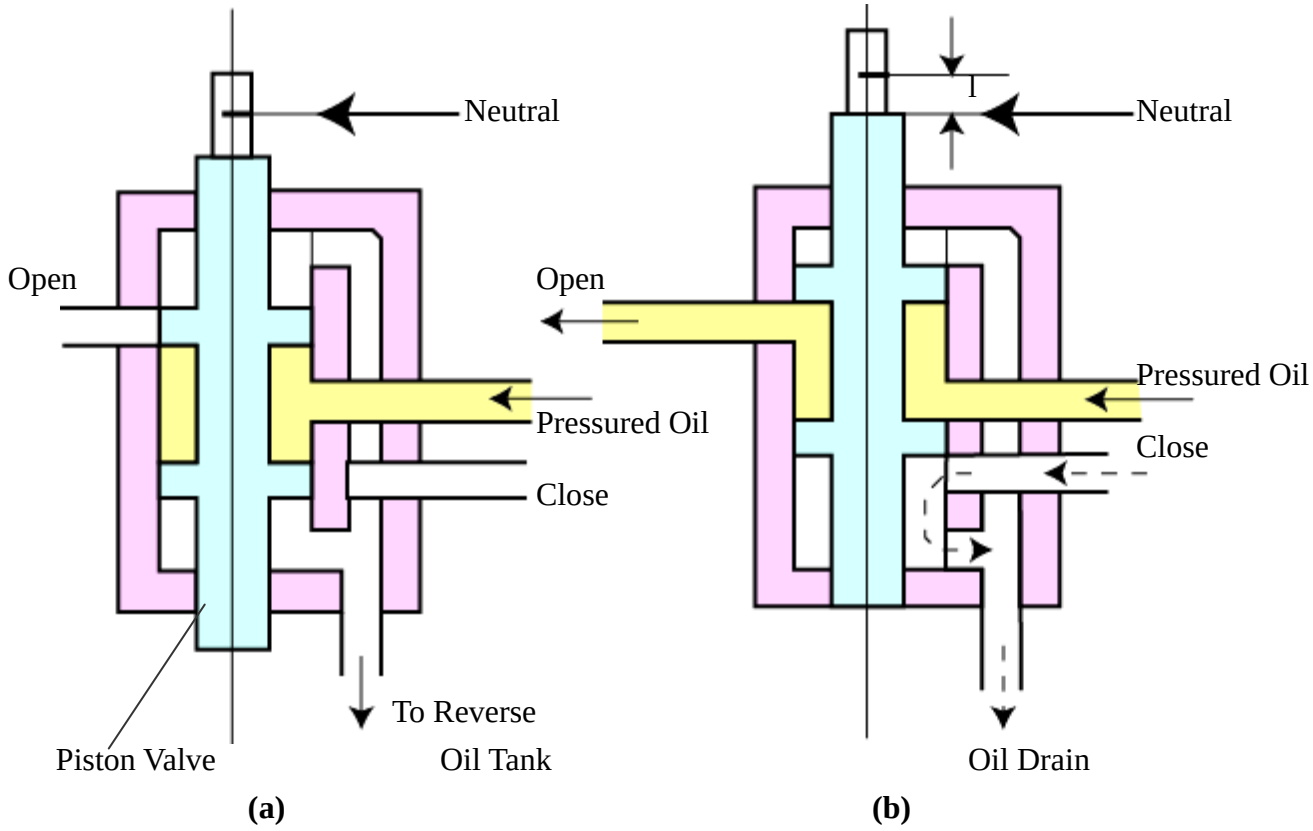


Figure 4 Mechanism of Oil Pressure Distributing Valve

On the other hand, Figure 4 (b) illustrates the situation where the piston valve goes up from the neutral point and the oil pressure flows to the open side to drive the servomotor toward the open side of guide vanes. At this moment, the scavenge oil of the servomotor flows from the close side and is sent to the reserve oil tank (a sump tank).

In addition, when the piston valve goes down from the neutral point, the pressure oil flows to the close side and the scavenge oil of the servomotor flows from the open side, which is sent to the reverse oil tank (a sump tank).

(4) Balance Lever

Balance Lever is equipped with Sliding Sleeve and Piston Valve of Distribution Valves on both sides, and provides a balance in motion as the center point becomes a fulcrum.

(5) Return Mechanism

It is a mechanism of transmitting the motion of the Servomotor to the fulcrum of the Balance Lever. It acts as restoring the motion of Distribution Valve.

3. Primitive Speed Control

Figure 3 shows the concept of the most primitive speed control unit. It transmits up-down displacement of Sliding Sleeve of Speed Detecting Part to Distribution Valve through Balance Lever, closes or opens the Servomotor corresponding to the change of revolution speed, and fixes the rotation.

In the Figure 3, when speed of rotation increases over Standard Speed N_0, Sliding Sleeve rises, and Piston Valve goes down. Then oil pressure works toward "Close" direction of Servomotor and starts to close the guide vane. By closing the guide vane, turbine output decreases, speed of rotation drops, Sliding Sleeve goes down, and Piston Valve rises up through Balance Lever.

When the speed of rotation becomes equal to the Standard Speed N_0, Piston Valve also moves back to a Neutral Point, and the closing of Servomotor is stops.

When the load fluctuation from the initial Standard Speed N_0 is small and the fluctuation is slow, it is enough to control the speed by such mechanism. But when the load fluctuation is large and the speed change is fast, Servomotor is too much closed by the delay of flow velocity change in Penstock against the change of the guide vane opening, a delay of the speed of rotation change by GD^2 of turbine and load, and so forth.

Consequently, when the Distribution Valve once reaches the Neutral Point and Servomotor stops, it is already tightly closed. Then, the speed of rotation decreases less than N_0, and the Distribution Valve rises higher than the Neutral Point, the Servomotor opens, speed of rotation increases, and the whole mechanism continues to move up and down repeatedly. Such phenomenon is called "Racing". If Racing lasts long, function of governor may be lost.

4. The Governor Speed Control with Return Mechanism

In the concept of primitive speed control, there is no effect on return of Distribution Valve until the control effect by governor appears as the change of turbine speed of rotation, and time delay of speed control happens, which causes racing. To prevent this, a mechanism is added to quicken return of Distribution Valve by transmitting displacement of Servomotor to the

fulcrum of the Balance Lever as shown in Figure 5. This mechanism is called “Return Mechanism”.

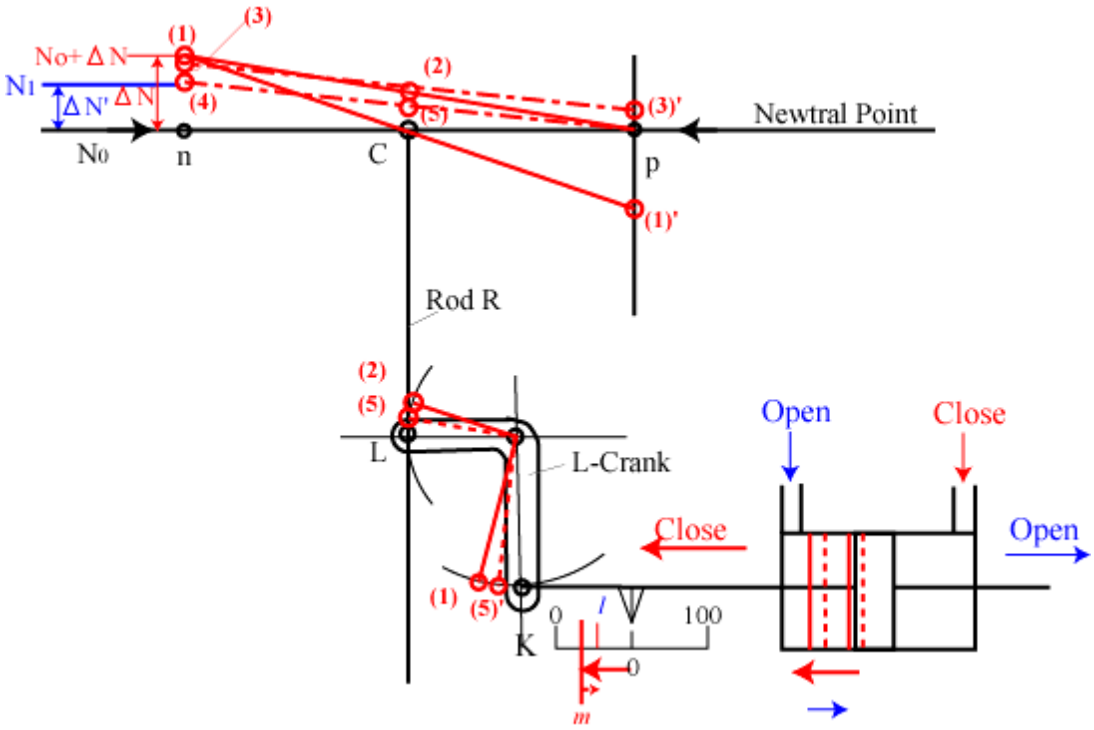


Figure 5 Return Mechanism

In Figure 5, when the load suddenly decreases and speed of rotation increases by ⊿N, Sliding Sleeve rises up to position (1), and the Balance Lever lowers the Distribution Valve from Neutral Point to position (1)' with “C” as the center between (1) and (1)'. Thus, pressured oil enters from the right side of the Servomotor. The Servomotor Piston starts to move to “Close” direction.

This movement shifts bottom edge of “K” of L-crank to the left, and simultaneously pushes and rises up “L” at the edge of the vertical arm of L-crank. “L” and “C” are connected by the rod “R” and upward motion of “L” directly pushes up “C”. The Balance Lever works so that to push and return “P” upward from position (1)' with position (1) being the center. Through this mechanism, lift of the distribution valve gradually decreases, the amount of pressured oil starts to decrease, and therefore the motion of Servomotor becomes slower. When the opening is closed up to “m”, “C” of the Balance Lever reaches position (2) and “P” becomes the Neutral Point, and accordingly the Servomotor motion stops.

At this moment, as the motion of Servomotor is quick and the time is short, the change in ⊿N becomes small. When the Servomotor is closed at “m”, turbine output decreases and the speed of rotation slows down. Then, Sliding Sleeve gradually falls from position (1) down to position (3) and the Balance Lever takes the position (3)~(2)~(3)' and pushes up the Distribution Valve from the Neutral Point to position (3)'. Accordingly, Servomotor Piston

shifts to “Open” position under oil pressure. At this time, the speed reduction of speed of rotation is very slow by the effect of GD^2. Since movement of Servomotor is fast enough to follow the speed change, the Servomotor opens simultaneously with the decrease in the speed of rotation.

By the increase of turbine opening, speed, the speed of rotation becomes slower and slower. Balance Lever slowly goes down keeping its slope in the position (3)~(2)~(3)'. When position (3)' reaches position “P”, the Servomotor stops and Balance Lever is fixed at position (4)~(5)~(P). The change is very slow and it would not overpass. Assuming that the turbine closes at position (l) to the stroke center “O”, the turbine gets its balance by allowing the degrease of the output to be the same as load reduction with increasing speed of rotation by ⊿N.

The speed of rotation at this moment becomes N_1, which is higher than N_0 by ⊿N'. This is from the effect of adding a return device, which is called “Control Offset”.

In a general control system, it is called Negative Feedback to return the amount corresponds to a response (here, servomotor opening) to input side (here, supporting point of balancing lever) against input (here, revolution speed change) such as this return mechanism. This is an important factor in stability of the control system. An Offset remains, which is particular in the structure principal and weak point in this system. Figure 6 shows the relationship between input change and response.

As for turbine governor, Speed Drop stands at the percentage of Δn and Offset of input corresponds to the total response of servomotor (total stroke of full-Open to full-Close) against standard speed of rotation N.

Figure 6 shows a simple return mechanism. Speed Drop that is needed for stable control is between 10 % and 20 %.

This is equivalent to the governor in Figure 5, that if it corresponds to 100 % load change, the response characteristics would be stable at the speed of rotation of 52.5 Hz with no load and 47.5 Hz with full load when Speed Drop is 10 % and it is adjusted at rated frequency of 50 Hz with 50 % load in automatic operation

Thus, to obtain rated speed with random load, it needs additional adjustment mechanism. Figure 7 shows the mechanism. In Figure 5, simple rod “R” connects a crank and Balance Lever. In Figure 7, Turn Buckle mechanism is attached in middle of the rod to adjust the replacement of the length between bottom of the rod “L” and top of the rod “C” by $\pm \Delta l$. This part is called 65P.

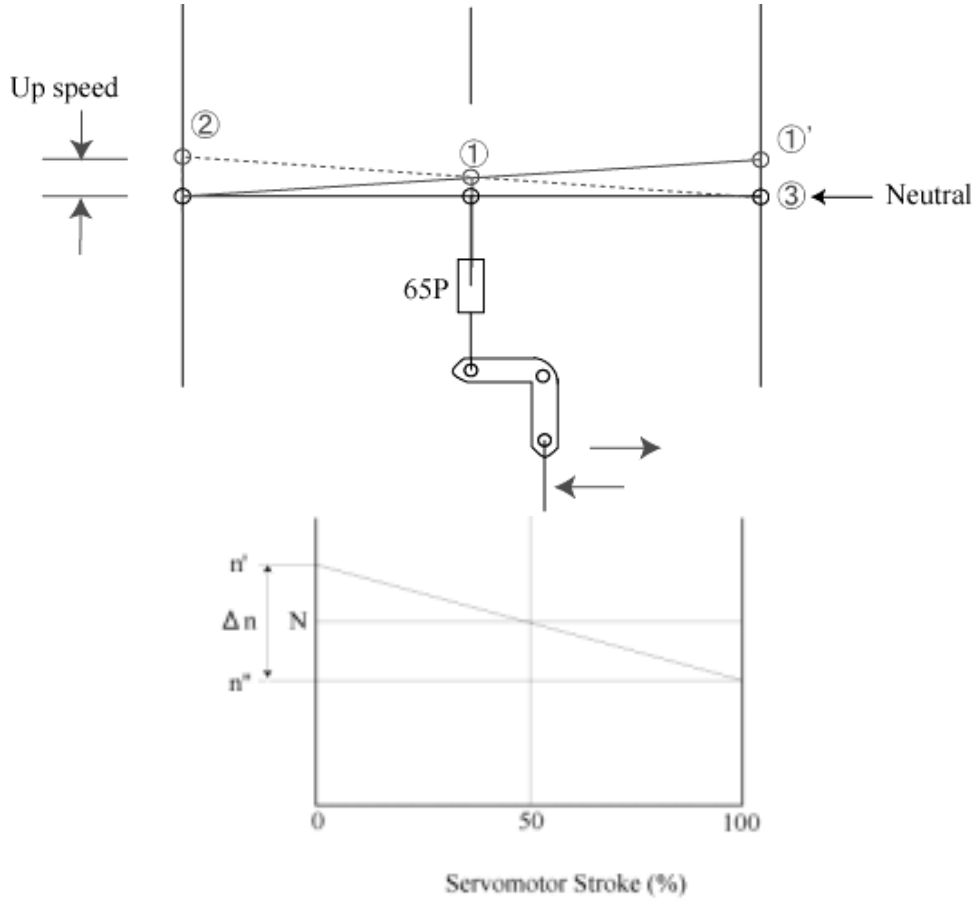


Figure 6 Speed Adjustment of Return Device

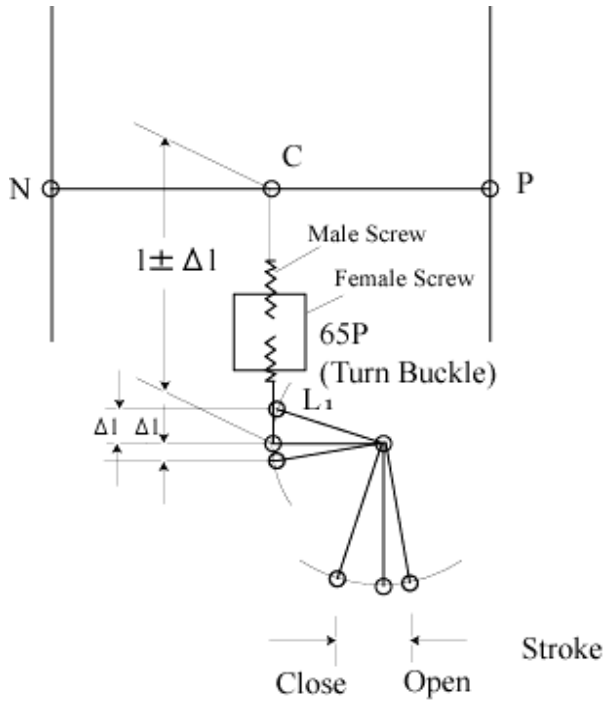


Figure 7 Control Mechanism of Return Device

When speed of rotation keeps at the rated speed, sliding sleeve should keep at position "N" and distribution valve is at neutral point "P". At this moment, the supporting point of return mechanism must be "C". In the mechanism shown in Figure 7, when return position of crank "L" is changed by load, the difference between "L" and "C" can be adjusted by 65P. Accordingly, position N-C-P is kept horizontal against random position of L and it can be operated at rated speed of rotation. Speed of 65P is adjusted by turning the outside screw of Turn Buckle and speed adjustment unit manually by hand or mechanically through a motor.

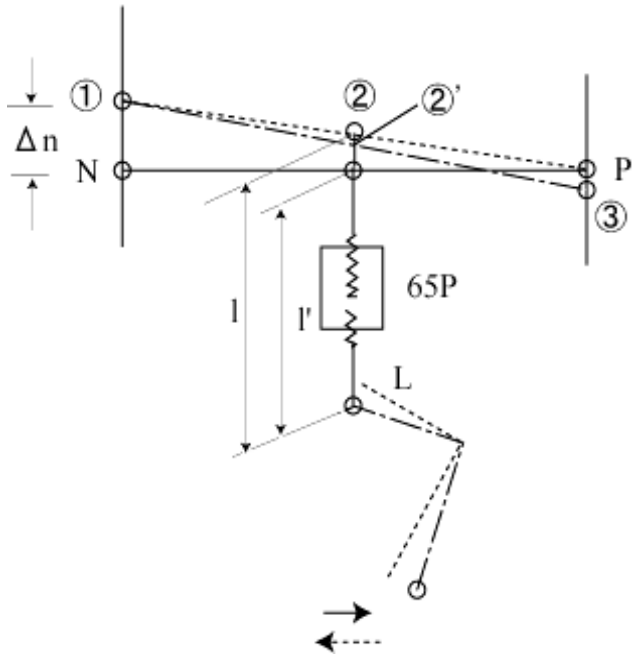


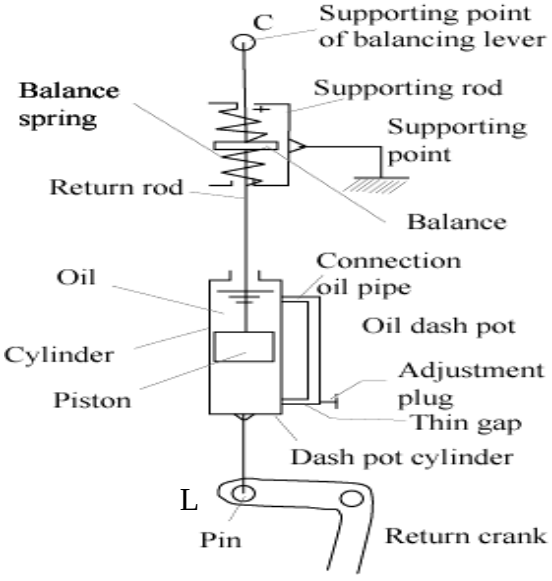
Figure 8 shows a method to adjust rated speed when load decreases and rotation becomes stable leaving Offset Δn to be adjusted by the governor action. After being stable, when the rod length decreases from "1" through the operation of 65P, the Balancing Lever at position ①-②-P changes to position ①-②'-③. Then, turbine output is decreased to some extent transitionally, position ① moves down, and position ③ soon returns to position "P". Again, by continuing the operation of 65P and repeating this effect, the speed of rotation degreases to the rated speed *N*. At this moment, position ② drops to "C" through the operation of 65P and the rod length "*l*" will be *l*'.

Figure 8 Adjustment of When Load Decrease

Thus, the speed increase by Δn can be adjusted to reach the rated speed *N*.

Strictly speaking, at this time, turbine output of the governor will be a little smaller than the output before adjustment. This value is from rotation characteristics of total control system such as revolution speed characteristics of load and turbine generator efficiency. This is generally as small as negligible.

4. Double Return Mechanism



Double return mechanism is a modification to decrease the Offset of the governor with return mechanism and improve stability.

Figure 9 shows Elastic Return Mechanism, one of elements of double return mechanism.

(1) Elastic Return Mechanism

This mechanism is to give elasticity of rod length "C" and "L" by the Dash Pot between the Return Rod of balance lever supporting point and Return Crank Pin. The weight of the Balance Lever loaded at "C" is supported indirectly by the Balance Spring inside supporting frame in the middle of the rod.

Figure 9 Elastic Return Mechanism

When force lifts rod at a regular point of supporting frame, it compresses upper spring and lifts "C" point, and when the rod is brought down, lower spring is compressed and "C" point can be lowered.

When no force is working on the rod, "C" is at the regular position as long as the supporting point does not move.

Lower point of the rod is connected to "L" of Return Crank trough Dash Pot. Piston of Dash Pot is connected to the bottom of rod and the cylinder of Dash Pot is connected to "L" point by a pin.

It is needed to transport the oil in upper and lower pistons while displacing the Dash Pot piston. For this purpose, there is a thin gap in the Connection Oil pipe that upper and lower oil move, which makes the oil hard to pass through it. The oil can not move rapidly, and the oil in the piston also can not move suddenly. Speed of the movement can be modified to some extent by adjusting the gap by a plug. Figure 10-(1) and (2) shows the return mechanism when the speed is adjusted.

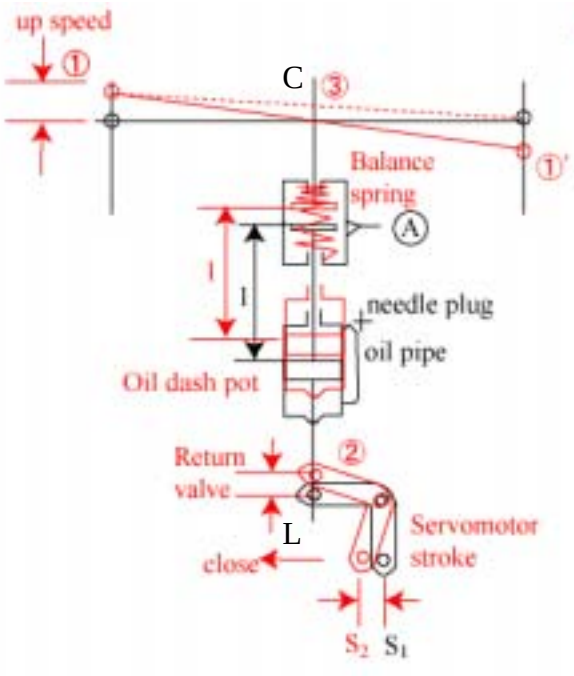


Figure 10-(1)

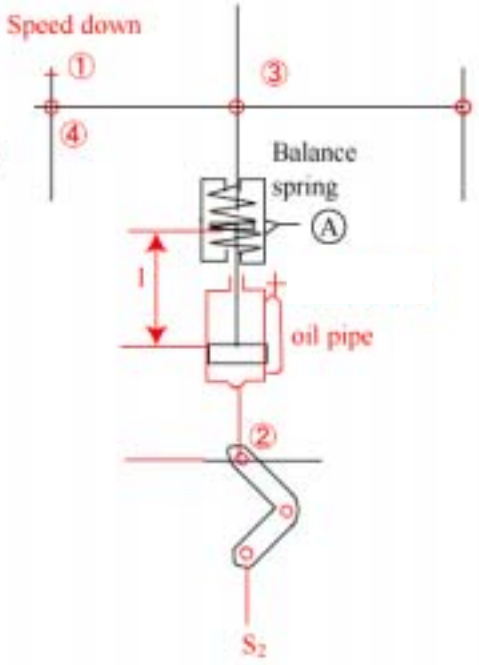


Figure 10-(2)

In Figure 10, Sliding Sleeve moves to position ①, Distribution Valve comes to position ①', and servomotor displaces from "S_1" to the closing direction "S_2". By this movement, "L" moves to position ②, and lifts the Dash Pot cylinder by Δl. This movement is much faster than the piston speed in the Dash Pot. Accordingly, the piston goes up by $\Delta /$ with the cylinder, and the rod compresses the Balance Spring and lifts "C". The mechanism is shown in Figure 10-(1) with a red line.

When "C" moves to position ③ and the Distribution Valve returns to the Neutral Point, closing operation of servomotor stops, and therefore servomotor stops at position "S_2".

By this movement of the servomotor, rotation decreases, and the sliding sleeve moves lower slowly to the position of rated speed from position ①.

At this moment, the force that compresses down the piston works by the reaction of compressed upper Balance Spring in the return mechanism. The oil at the bottom of cylinder is displaced up in the piston through the connecting point. Then, the piston goes down slowly and position ③ drops toward "C".

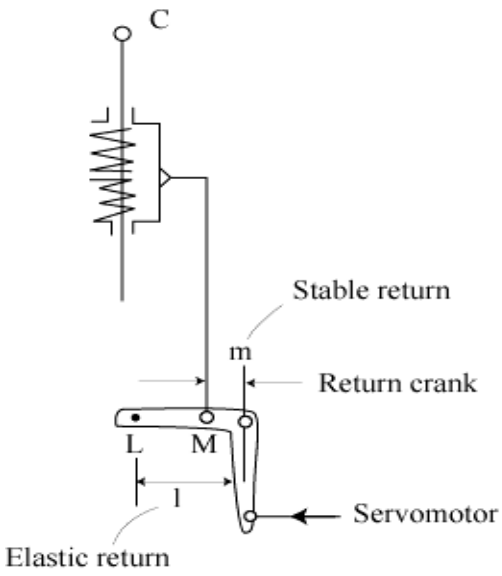
When the speed of rotation drops and the speed of the Dash Pot Piston drops almost the same, the rotation converges to N with no movement of the Neutral Point of Distribution Valve. The Balance Spring returns the position that balances up and down, and servomotor stops at "S_2".

This is the way to stabilize the speed of rotation, which is increased by load degrease up to the rated speed of rotation by degreasing turbine output through the servomotor opening and closing, and regaining the load balance. This mechanism is shown in Figure 10-(2).

Actually, the speed of rotation does not change in the same time with the Dash Pot time without adjustment. It is judged by gradual adjustment of servomotor position from the condition shown in Figure 10-(1) to become stable as in the condition shown in Figure 10-(2). The movement is controlled by the speed of the Dash Pot, and it is very slow.

In case of isolated transmission, this mechanism enables operation with constant rated speed against load change.

(2) Stable Return Mechanism



When the generator is connected and operated in parallel inside the grid, it is needed to determine a response of the turbine generator according to the frequency and the speed of rotation change of the grid. In order to add this characteristic, stable return mechanism is needed. This characteristic corresponds to Control Offset of governor with return mechanism as was described in above chapter.

By examining the modification of Balance Spring of Elastic Return device in Figure 9 into the mechanism of connecting the Return Crank and removing the Dash Pot, the return from servomotor is obtained.

Figure 11 Stable Return

In this case, no special force works on the rod. Thus, “C” point receives the return of Return Crank point “M” while the Balance Spring keeps balance constantly. This movement has the same Offset as the governor in the former chapter.

Required Offset is very small in the grid operation. Return is also small, less than 1/3 of the Elastic Return as shown in Figure 11.

Accordingly, the mechanism during isolated operation can not ensure stability only by return given to Stable Return mechanism required in the grid operation.

(3) Movement of Double Return Mechanism

Double return mechanism is equipped with both Stable Return mechanism and Elastic Return mechanism. Speed stability in the transition period and required response from grid during parallel operation is obtained by the simultaneous operation of this mechanism.

Figure 12-(1) shows the movement when Double Return governor is in grid parallel operation.

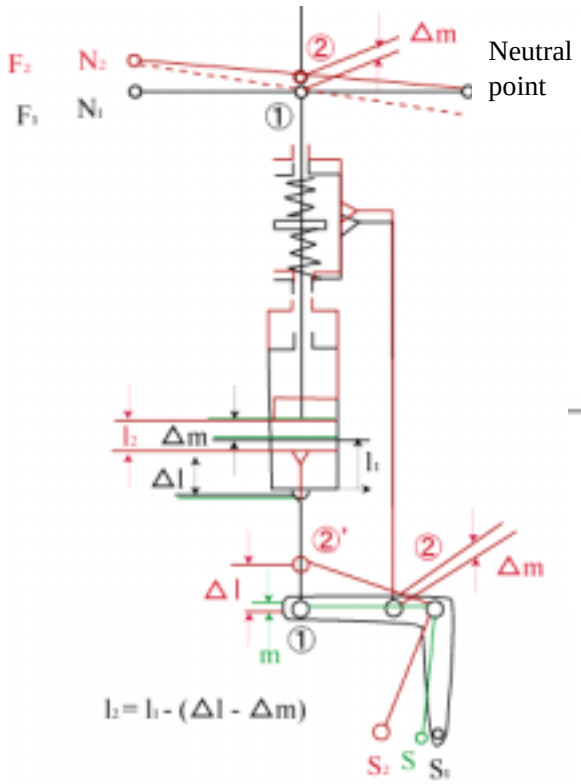


Figure 12-(1)

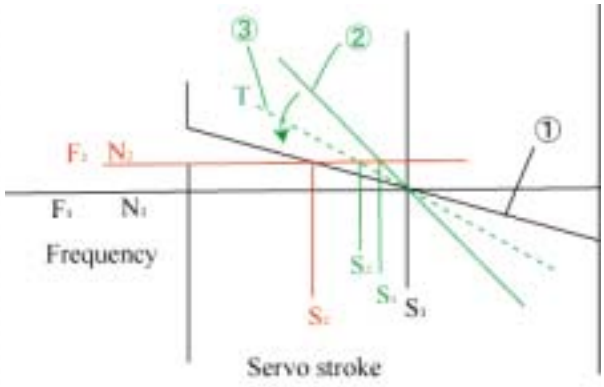


Figure 12-(2)

At first, the machine is operating when the Servomotor opening is at “S_1” position with grid frequency F_1. When the grid frequency become F_2, the location of Sliding Sleeve of the governor is displaced from “N1” to “N2”. Accordingly, the Servomotor moves from “S1” to “S2” until the Stable Return reaches Δm.

Turbine output decreases by this servomotor closing movement. This output change is very small compared to the grid capacity. Frequency of grid changes a little, staying at F_2. The new operation condition is illustrated with red lines in Figure 12-(1).

Examining the change in details, when Servomotor moves from "S2" to "S2", the Servomotor stops when Elastic Return becomes Δm through the change of F_1 to F_2.

The Stable Return at this time is very small. Upper balance spring is compressed at this moment.

Consequently, if the piston starts to move down, Elastic Return Δm starts to degrease, Balance Lever starts to drop from Neutral Point with "N_2" as a center, and the Servomotor starts closing.

This decrease is processed with a balance of piston drop and Servomotor closing operation, and continues slowly at the same speed as piston drop until the Stable Return reaches Δm.

In sum, a turbine generator with this governor has a slow response of return determined by Stable Return at the same speed as the Dash Pot time according to grid frequency change

Figure 12-(2) shows this response characteristic. The relationship of movement change and Servomotor stroke is almost linear. Stable Return is shown as position ①, of which slope is called Permanent Speed Drop. Position ② is the Elastic Return and the slop is called Transitional Speed Drop.

Examining the above explanation example in Figure 12-(2), Speed Drop is like ③ at Servomotor Stroke S" when Servomotor stopping at S' according to the first Transitional Speed Drop is on the way of moving toward "S_2" according to the piston drop.

In another point of view, Transitional Speed Drop changes to Permanent Speed Drop in time *T*. This *T* is called Return Time Constant. When a governor with Double Return mechanism is in isolated operation and Permanent Speed Adjustment has a certain value, frequency deflection takes place according to Permanent Speed Drop.

Generally it is adjusted to the rated speed by 65P. For powerhouses that have few parallel connection with the grid, "M" position should be adjusted so that the Permanent Speed Drop, that is, Stable Return Δm becomes 0.

Conclusions

The most basic structure of the mechanical oil pressure type governor was illustrated above. Actual governor has many types of speed detection, distribution valve structure, and return mechanism, as a result of being developed for a long time by many engineers. The principle is similar to the above illustration. On the conditions that well acquainted above, it would be possible to understand different structure of the governors assuming the structure of each part.

Appendix 6 Maker's Manual of Chinese Governor (Sample)

(Originally, this document was a hand-written manual of the governor installed in the Zi Chaung Power Station by Chinese Manufacturer.)

INTRODUCTION

Governor TT is a kind of super compact speed governor which is applied for the adjustment of hydroelectric generator group (mixed flow or axis flow propeller with fixed oars). The volumes of relayer are 300, 600, 1000 Nm. The following will explain to you the main points, system principle and operating way.

THE FORM OF GOVERNOR

1. Auto-adjustment

(1) Flying pendulum and pilot valve,

(2) Buffer.

(3) Steady rotary difference unit,

(4) The transmission lever's fit of the feed back unit,

(5) The main press valve,

(6) The relayer

2. The control unit,

(1) Unit of speed-adjust,

(2) The unit of unfold Limit,

(3) Operating unit by hand

3. Oil Pressure Fit

(1) The returning tank, pressure oil tank unit the middle oil tank,

(2) Screw pump and the pressure signal for control,

(3) Air valve, safety valve,

(4) Stop valve

4. Protective installation

(1) Speed-adjust unit and the switch of the operating restriction unit,

(2) The magneto electric valve for stopping,

(3) The pressure signal of oil pressure installation is low pressure,

5. Supervision instruments and etc…

(1) Speed-adjust unit, the unit of steady rotation difference, and the direction watch of the opening restriction unit,

(2) Pressure watch,

(3) Oil filter, oil pipe, circuit, and etc

1. THE MAIN CHARACTERISTICS OF THE GOVERNOR

1. The governor is consistent governor, the relayer and the oil pressure installation consist of the whole body, so as to transport and fix up easily.
2. Considering the need of fix. The governor is suitable to the upright and downright in structure, change the fix-direction of the pressure valve and the awl, it is suitable to the switch direction
3. The governor can be easily auto-adjusted and all sorts of requirement of the control of the far distance, and arranged operating unit by hand, to start, transport, and stop
4. Flying pendulum motor uses sensing motor, the power source is supplied by magnetic engine or bus of the engine. If the engine gives off the electric pressure of more than 400V, at the time it can be supplied by special transformer.
5. When flying pendulum loses power source and under other urgent conditions, at the time must stop electric magnetic valve and the relayer, shut off the water supply instrument immediately.
6. The operation power source of the governor may be 220V, 110 V, 48 V direct crurrent or 220 V alternating current.
7. The oil pressure instrument uses a screw pump, the running way of the oil pump is unconinued.
8. The oil pressure instrument is according to the auto-oil control of the oil tank can not only keep the normal oil position of the pressure oil tank under working condition, but also even if the user hasn't air compressor, it still can charge air from the pressure oil tank.

2. SOME EXPLANATIONS ON VARIOUS INSTRUMENTS OF THE GOVERNOR

(See system diagram 3T-003)

That shows the position of various instruments of the system diagram is equal to the calm transportation of the governor under auto-adjust and the ways of the oil pump that is oiling.

When water turbogenerator runs calmly and keep cirtaion speed-turn, the motor one at the same time. Lead flying pendulum 2 in the same speed. At the time heavy block 3 produces centrifugal force is

balanced to the force of spring 5. The turning sleeve leading valve keep certain middle position of plug 8. The force produced from the upper part oil pressure of assist relayer 26 (including the weighty of piston) is balanced to the force of main press valve piston 25, and makes the relayer piston 44 is in a certain condition of the parts that is loaded.

(1) The working process of the governors of a single governor and including change of the parts that is loaded:

When the load of parts reduces, the power cupboard produced by water turbine and moment of force of resistance of the motor lose the balance, the left power cupboard speed the parts, at the same time let valve motor of motor bus transformer supply electricity, the speed of flying pendulum motor one increase. The turn speed of flying pendulum 2 increases too. The centrifugal force of heavy block 3 increases in a certain way., and the spring is also compressed. The turning sleeve 7 moves upward along plug 8. That passing through the upper oil pressure of the assist relayer piston 25 moves upward. The pressure oil of the oil pressure instrument is connected with the relayer is left part through the window of the main pressing valve. Under the oil pressure the relayer piston 44 drives the water instrument of water turbine and moves to the closed direction, and reduce flow of the water turbine and reduce the motive power cabinet of the water turbine, The rotational speed reduces.

As main press valve piston 25 moves upward, this makes the leading valve plug 8 move upward through lever 29. 11 and connection rod 12, bring part returning of the press valve and leading valve.

As the realyer piston 44 moves to the closed direction, spring 39 press the rolling wheel 41 heavily on returning taper and make connecting rod 4- move upward. The frame 55 clockwise according to rotor 55 by starting point, and thus produce the following matter:

1. To make buffer produce certain matter

When the screw nut 61 on the adjust screw 59 is certainly eccentric to the rotor 54,the connecting pole 65 moves upward. The main piston 23 of buffer moves downward through lever 14. As the oil under the piston can not give off immediately from the flow-hole of plug pin 21. The pressure inside buffer increases, force elastic force inside spring 19 of the piston 22 of buffer move upward, to let plug pin 8 of the leading valve move upward through lever 11 and lever 13. Thus counteract some effects produced by rotational sleeve 1 of flying pendulum movement when rotational speed changes. The piston 22 is under some effects of inside spring 19 resume gradually forwards middle position according to some conditions when the leading piston 3 stops, and force oil under piston gives off little by little through flow-hole. As the process of adjustment is not periodic, thus process explained above of the buffer will repeat several times, till the piston 22 stay for a time to a certain middle position.

Adjust-handgrip 18 and adjust screw 14 can adjust wantonly constant Td of buffer time during

the scope of 3-129.

The position of screw nut 61 be changed by adjust screw 59, and the scope of 0-100 % arrange constant bt wantonly.

2. The feedback via the unit of steady rotation difference

The feedback via the constant of steady rotation difference be adjusted zero or 1%-2% when the single machine is operating. When the feedback via the constant of steady rotation, difference is zero, the screw 58 is not eccentric to certain axle 54. The adjustment at the time is not different.

When adopting adjustment that it is different, the screw nut 58 is eccentric to certain axle 54. When the relayer piston moves towards the closed direction, link lever 60 moves upward. To let plug pin 8 of leading valve moves upward through lever 13 and lever 11. Therefore when the adjusting process ends, the position of plug pin 8 and rotational sleeve 7 will be higher than adjustment. At the same time the unit keep higher rotational speed and operate firmly. Change the position of screw nut 58 through screw 58 be adjusted, this mainly according to the requirement of power system. And adjust the feedback via the constant bp of steady rotation difference wantonly between 0-8%.

Soft feedbacks via buffer, the hard feedbacks via the unit of steady rotation difference (adjust when it is different) and leading pressure valve - Partly feedback things pledge the adjust -quality of adjustment system.

Adjusting when it is not different, the adjust-process ends. The piston 22 of buffer, piston 25 of leading pressure vale and plug pin 8 of lading valve resume to original certain middle position except plug pin 8 is higher than the original certain piston. When the relayer piston ends the adjust process, this stabilize to twist behind, certain position of unit load

3. To let limited plug pin 33 produce contain things, the process will be explained

next.

When the load of motor increases, the rotational speed of unit descend. The adjust process of governor is on contrary explained above.

(2) The unit of steady rotation difference and adjust mechanism of rotational speed.

1. When the unit is operation, the require unit to establish certain rotational speed, according to the load quantity that is made by unit and requirement of adjustment when it is different, This is one of the aims of the unit of steady rotation difference. The unit merge into power system change and cause the change of frequency. At the same time distribute load again according to the constant valve of steady rotation difference of all units. The certain rotational speed's difference of units when it is empty and full load, is adjust-difference-valve of units. This is not different with consistent of steady rotation

difference. The adjust-difference-valve of units is smaller than the constant of steady rotation difference.

When constant of steady rotation difference is zero, and after the end of adjust process, screw nut 66 and leading valve plug pin 8 produce certain movement. When the relayer piston is from open and close, the rotational speed quantity of movement of screw nut 66 is decided by arrangement valve of constant of steady rotation difference, This valve on frame 55 is indicated by pointing needle.

2. The requirement of rotational speed adjust unit is:

To make unit turn speed when the single machine is operating and used to change the load of the unit that is had when putting into power system and operating side by side.

Rotational adjust unit is operated by hand wheel 77 through decelerometer 85 or is controlled in a far distance by miniate 56, and can reach the aim of changing unit's rotational speed of change the load. Speed change can be adjusted wantonly the scope of -15% and +10 %, and the adjust constant valve is indicated by pointing needle 90.

If screw nut 66 moves downward, plug pin 8 moves downward according to certain position of turning sleeve 7 through lever 13 and lever11, and lead main pressure valve piston 25 moves upward. The leading water unit moves toward the closed direction at the same time. When the signal machine is operating, and load does not change on the external world, lead the rotational speed of unit reduce. The valve of power system (that is unit rotational speed) does not keep change when putting into large power system and operating side by side. Thus according to the movement quantity of screw nut 66 and reduce the load of constant of steady rotation difference that is arranged.

If screw nut 66 moves upward, thus let the rotational speed of unit raise higher or the load increase.

(3) Operating restriction unit:

The requirement of operating restriction is :

a. To limit open level of unit or during the scope of strength that is required.

b. The unit of oil pressure by hand-adjust

c. Start and stop.

Limited open level can be arranged any other position on unloaded open level. According to strength limited of unit, operating requirement is decided by flow quantity. When the leading water unit is smaller than limited open level, the control of load is decided by leading valve plug pin 8 and rotation sleeve 7 to some certain position. If practical open measure is equal to limit, then the leading water unit can not start any longer. The strength of unit can not increase any more.

The requirement principle is the following explained. Opening restriction unit is operated by hand wheel 78 through decelerometer, or controlled by miniate motor 84 through far distance, and thus make screw nut 71 move along screw 70 up and down. To let limited plug pin 33 move to certain bush 34 through lever 69 connecting lever 64 and lever 31 and changes all the requirement of limited open measure. When screw nut 71 moves downward, plug pin 33 moves downward, too. When the relayrer towards starting direction, bush 34 and the upper part of relayer piston 36 is stopped up through smaller process of relayer. This explains that limited open measure reduces, otherwise the open measure increase. The arrangement valve of open limited is indicated by pointing needle 89 (red needle).

When the relayer piston 44 moves, frame 55 moves around turning axle 54. The scope of movement , that is the practical scope of leading water unit is indicated by pointing needle 91 (Black needle).

When black needle and red needle coincide the practical open measure of leading water unit is equal to limited open measure. If continue to open the measure of leading water unit, this time must let pressure oil into upper part of relayer. The main pressure valve piston 25 moves downward. At the time middle valve tray of limited plug pin 33 stops up middle oil exit on bush. The pressure oil of middle part from leading valve 6 can not come into the upper part of relayer. No matter to reduce rotational speed of unit or operating unit of rotational speed, at this time can not open the measure of leading water unit. At this time make upper oil pressure of relayer increase and lead main pressure valve piston 25 move downward. To let limited plug pin 33 move downward through lever 31, and middle valve tray of plug pin moves downward, let middle oil exit is communicated with oil that is given off. This time upper part of relayer gives off oil, and main pressure calve piston 25 will increase again.

When the main pressure valve piston moves downward, and relayer moves towards started direction, frame 55 rotates opposite direction around turning axle 54. And through ling lever 69, lever 68, link lever 64, and lever 31 let limited plug pin 33 moves downward. That is to say, under conditions of practical open measure of leading water unit and coincidence of limited open measure, the open measure can not increase , therefore can limit open measure.

(4) The unit's start, stop and change of hand-adjust auto-adjust

The unit can be adjusted by auto-adjust or hand-adjust by oil pressure. The governor's units must be in condition preparation before starting:

i. The relayer's switchs must be all shut off. The open measure pointing needle 91 (black needle) of leading water unit and pointing needle 89 (red needle) of opening restriction are at zero position at the same time.

ii. The pointing needle of adjustment of rotational speed is on position of rotational

speed that is stinted, or the position that is indicated of auto return circuit that required.

iii. The oil meter of oil pressure unit is indicated the scope of working oil pressure. The surface of oil in pressure oil pot is normal.

iv. Load valve 108 all start. The oil pressure of control cabinet indicated by auto return circuit that required.

v. Open locking plug of self-operating unit, and handwheel 49 moves to the right, The handle 46 is on position of auto-adjust.

vi. Magnet electric valve for stopping machine is on normal operating position of unit.

If conditions above possessed, then get ready for starting.

(1) Using opening restriction unit to start auto-unit:

Let cock 35 that is self-adjust and auto adjust on auto position. The main pressure valve and relayer piston 25,26 are the most upper position under condition of pressure oil. The upper oil exit of main pressure valve all open. Because turning sleeve 7 is situated on lowest position, the middle valve tray of opening restriction plug pin 33 stops up the middle oil exit of bush 34. The pressure oil is put into down oil position of middle valve tray of opening restriction plug pin 33 through the upper part of cock 35 of filter 63 from upper hole of leading valve. The starting miniate motor 84 turns towards opening direction. Screw 70 can rotate after reducing speed. This time screw nut 71 of opening restriction be put up slowly, and opening restriction plug pin 33 be put up through lever 68, link lever 63 and lever 31. And middle hole of sleeve be opened in middle valve tray, pressure oil of leading valve 6 is come into upper parts of relayer piston 26. This time main pressure valve piston 25 moves downward. When turning down hole of sleeve 24 main pressure valve, pressure oil is come into starting position of relayer (the right part of system diagram). The relayer piston 44 moves from all switched position to opened positions. Thus water turbine starts to rotate through a certain leading water unit restriction. When opening restriction units arrives at a certain open measure that the unload is much bigger, the block piece limited position of opening restriction unit makes switch limited position move. The miniate motor 84 of opening restriction stops rotation. The rotational speed of unit rise gradually in the process of starting. The rotational speed of flying pendulum motor one supplied electricity by valve motor also rise. The position of rotational sleeve 7 gradually moves upward. The procedure oil can come into upper position of restriction plug pin without any trouble through leading valve before rotational speed of flying pendulum reaches fixed rotational speed. Therefore main pressure valve plug pin 25 is completely controlled by opening restriction plug pin 33. When the rotational speed of flying pendulum reaches fixed rotational speed, rotational sleeve is situated to a certain middle position of plug pin. The upper and down valve tray stops

up the upper and down oil exit of rotational sleeve. This time the unit is not operated by opening restriction unit, but controlled by flying pendulum through auto-adjust unit.

When the unit starts and finished operation, using electric motor 84 to let pointing needle 89 (red needle) of opening restriction to a certain position, so that let unit can carry load.

If the power source of flying pendulum electric motor is directly supplied by bus or supplied to unit by transformer, and reaches certain rotational speed. This time unit can be auto-control by flying pendulum.

(2) Using oil pressure by self-adjust of operating restriction to start unit:

Circling plug 35 of auto-valve by self-adjust is situated to position of self adjust through handwheel 78 of opening restriction unit. At the time pressure oil is directly come into middle valve tray's upper position of opening restriction plug pin 33 by circling plug 35, not through leading valve. The handwheel of 78 of opening restriction unit makes vane start to the opening direction. The starting process is likely similar with above-mentioned things.

When units are merged into as the time, load can be increased by self-adjust through opening restriction unit. And also valve plug pin 35 by self-adjust and auto-adjust can be changed to auto position after the unit merged into. And this moment flying pendulum starts to operate, and the unit can be adjusted automatically.

(3) Using self-adjust unit to start unit:

When there is no oil source of pressure, unit can be started by self-opening unit. First handwheel is moved, to make bush 53 move to the left, till down notch of slide circle 51 made into locked plug and locks. And let the handle 46 turn 90 degrees to self adjust position. Thus cock 47 is connected with oil of relayer. Again rotating handwheel 49 and let leading water unit start. This moment the unit is also started.

3. STOP UNIT

(1) Normal Stop:

First using rotational speed adjust unit, according to unit of electrified wire netting that is operating and putting into. This time putting load down of unit and let it into unload position. Let unit and system open, the unit is situated closed position by opening restriction unit. The handwheel 78 of opening restriction can be used to stop the machine by operating oil pressure. The miniate motor 84 can also used to operate. Flying pendulum's power source is supplied by motor's bus or pressure reduced and supplied to unit through transformer. And demanding circuit break breaker not to put out magnet, the magneto electric valve for stopping machine can be used to stop machine after circuit breaker applies break.

(2) Stopping machine when there is an incident

As flying pendulum's motor source breaks down or speed that is over caused by some other reasons. The axle of water turbine's temperature increases and overtakes allowable value. The oil pressure of governor reduces to low pressure of incident and so on. The incident signal for stopping machine is given out by leak detector, can be joined to magneto electric valve for stopping machine and carrying out urgent stopping through it.

The magnetelectric valve 36 for stopping machine that is showed in system diagram is direct current. Electric magnet is losed when unit is in normal operation. Piston 38 is withstand on upper position by spring 37. The oil road from main pressure valve relayer to valve 35 is connected by magneto electric valve. Under certain incidents, electric magnet excite, valve wick and piston at the same time are put into. The oil road of changed valve of relayer is broken off by piston 38. And relayer is connected with piston 38. The relayer can give off oil with open road. The piston 25 of main pressure valve moves upward. Thus relayer close, and the unit stops the machine.

There is another alternating current magnetoelectric valve for stopping machine, it is opposite to direct current. It electrified all the time when unit is in normal operation. And it is similar to direct current. The user can decide which magnetoelectric valve for stopping machine they can use according to the operation power source of electric station.

(3) Stopping machine by self-adjust unit:

Turn handle 46 to the position of self-adjust, rotate handle 49, and make leading water unit close, till close completely.

4. THE EACH OTHER'S CHANGE OF SELF-ADJUST AND AUTO-ADJUST OF THE UNIT:

(1) Self-adjust is changed into auto-adjust

When the unit is operated bself-adjust. The operating process of auto-adjust is following explained:

A) Self-adjust is changed into auto-adjust by oil pressure:

First change valve 35 is changed from position of self adjust to position of auto-adjust. Then opening restriction unit is opened to limited position of open measure. At this time adjustment system is changed into state of auto-adjust.

B) Self-adjust of self adjust unit be changed into auto-adjust:

First handle 46 is rotated 90 degree to auto position. Two cavity of the relayer is separated Closed valve 108 is opened and opening restriction unit is operated, and make open measure of restriction and leading water unit similar. This pointing needle 89 (red needle) of opening restriction is situated coincided position of restriction pointing needle 91 (black needle) of leading water unit. And power source of flying pendulum electric motor will be checked. The locked plug on down notch of sliding flock 51 is come apart. The rotation handwheel 49

is moved from right to end part by bush 53. Thus place chance valve 35 to auto position. Therefore, opening restriction unit is moved to limited position. At the time adjustment system is changed into auto-adjust.

(2) Auto-adjust be changed into self-adjust:

When unit is in auto operation, the operating process of self adjust is following explained:

A) Oil pressure is changed into self-adjust:

First opening restriction is moved to limited position, that is to say, red needle 89 is on the coincided position of black needle 91. Then change valve 35 is changed from auto position to self position. At this time adjustment system is changed into self adjust by operation of oil pressure.

B) Some things of self-adjust when changing from self adjust unit to it:

First handwheel 49 is moved, sleeve tube 53 is moved from left to upper part. The down notch of sliding block is locked by locked plug. Then unload valve 108 is closed and handle 46 is rotated 90 degrees, and relayer's oil is connected open. This time handwheel 49 can be used to operate unit.

5. SOME EXPLANATIONS OF OIL PRESSURE UNIT

The oil pressure unit of governor is supplied to motor of water turbine and energy equipment of pressure oil that uses to operate speed-adjust system. It must have enough volume, stable oil pressure that gives off and higher dependable property.

The oil pressure unit of governor is consisted of reverse oil tank, pressure oil pot, middle oil tank, air valve, oil pump of screw and other accessories. Now the following will explain simply:

(1) Reverse oil tank:

Reverse oil tank is a container that stores up oil when there is no pressure. It is also the base of the governor. There are certain quantity No.30. Turbine engine oil stored in the tank and is used for adjustment system.

It is divided into two parts by filter oil's net 104 - clean oil and dirty oil districts. The oil when governor is operating and leaked oil is sent to dirty oil district of reverse oil tank through reverse oil pipe. The oil pump absorbs clean oil through filter oil's net 104 that has been filtered from clean oil district and is sent into pressure oil tank. There are two filter oil's nets and can be cleaned alternately. The front side of reverse oil tank is fixed indicator 103 of oil position. And can be directly observed some things of oil position of reverse oil tank.

(2) Pressure oil tank:

Oil pressure units can store pressure into pressure oil tank and is supplied to operating energy that is needed of speed-adjust system. It is an important element of oil pressure unit.

There are about 2/3 compressed air in pressure oil tank. Others are pressure oil. When operating, its normal operating pressure force is not only kept, but also keep its fixed oil position. An incident will be caused when oil position is higher or lower. If oil position is lower, compressed air is merged into speed-adjust system and there is danger shaken fiercely caused by it. If oil position is higher, when governor needs continuous oil supplied, it will perhaps cause oil pressure reduce. It will lose working ability. The oil position of pressure oil tank can be observed by indicator 106.

(3) Middle oil tank and air valve:

Middle oil tank and air valve is set up in the oil pressure unit of governor. This is the main characteristics of the governor. They and oil pump are connected together to work. And they can charge automatically to pressure oil tank. And they can supply oil and keep normal oil position of pressure oil tank when operating.

The system diagram showed is oil pump 102, it passes air valve 98 and unload valve 96 and supply oil to pressure oil tank through middle air tank 97. When oil pressure of pressure oil tank increase to normal limited valve of working oil pressure. The pressure relay 93 turns off power source of motor 101 of oil pump. The oil pump stops to pump oil. Under some conditions of oil pressure of pressure oil tank, the stop valve closes. At the time air valve piston 99 moves upward under effects of down spring. When air valve piston 99 is situated on upper position, down valve tray of piston breaks off the road from middle oil tank to oil pump. The upper part of piston necking makes middle oil tank connected with pipe 105 of drawing air that stretching into reverse oil tank. As oil quantity coming into governor is limited, so when there is little air in pressure oil tank (pressure oil is over more). Thus oil surface of reverse oil tank is much lower. For this reason the entrance of pipe drawing air reveals in the atmosphere. The upper part of middle oil tank is connected with the atmosphere. Thus oil in middle oil tank under effect of itself flows into reverse oil tank through air valve and pipe giving off oil, and replaces and air fills the tank. When oil pressure of pressure oil tank reduces to normal working oil pressure, pressure relay is connected with motor's power source of oil pump. This time oil pump begins to supply oil again. The air valve piston 99 moves downward under some effects of oil pressure, and breaks off the road from middle oil tank to the pipe of drawing air. Pressure air passes through middle oil tank, and makes air of middle oil tank come into pressure oil tank 95 through unload valve 96. Thus makes an effect of filling air. If there is much more air in pressure oil tank (There is little pressure oil), thus oil surface of reverse tank is much higher. Thus the entrance of pipe 105 of drawing air is invaded into oil under reverse oil tank. Therefore when piston 99 moves upward and connects middle oil tank cannot flow out automatically as there is effect of atmosphere. When oil pump suppliers oil again, the air cannot come into any longer.

This way of using oil surface of reverse oil tank carry auto control and fills air, not only can keep the normal position of pressure oil tank under working pressure when operating, but also it can

finish the work of filling air from pressure oil tank. And it is necessary for small power station when there is no air compressor. When using air valve and middle oil tank fill air first toward pressure oil tank, the operating principle and auto fill air under normal operation is similar to it. First when air pump pumps oil from pressure oil tank. The oil position of pressure oil tank is higher than normal oil position and stops pumping, causes the pipe of drawing air of air valve expose in the atmosphere. In order to shorten time of filling air first as possible, the oil pump should be started at once when air of middle oil tank gives off. When the tank of air presses into oil tank but oiling is not more, should stop pump. (the oil surface of oil increases and not more). Therefore, the pressure scope of oil pump can be properly adjusted when starting and stopping through pressure relayer. The speed of giving off is properly adjusted through valve 107 of giving off oil and let them get proper coordination. Obviously, the oil of middle oil tank auto flows and gives off air have direct relation to the speed of filling air. The time needed automatically is decided by sticking of air. The Time needed automatically is decided by sticking of air. And turbine oil's sticking changes obviously according to the temperature. When oil temperature is 20℃, the time of flowing out in middle oil tank is about one miunte. Time should be first arranged before filling air, pressure relayer and valve of giving off oil be adjusted according to it. When the air of pressure oil tank is much more, air can be given off through vapve 113 of giving off air. And let scale of air in it resume normal. When oil position of pressure oil tank is normal, the side of pipe 105 of drawing air should connects with oil surface of reverse oil tank properly.

(4) Screw lever oil pump:

The oil pump of the governor adopts vertical screw lever, the leading screw lever is in the middle, operated directly by motor, and there is a very small driven screw lever on both sides. While operating, the leading screw lever and it rotates to opposite direction by leading screw lever. And this time screw lever that is rotating and bush consists of all kinds of small empty cavity. The pipe of drawing oil of its pump is on the bottom, and pipe of pressing oil is on upper part. When pump of screw lever rotates in normal direction (watching from the top of motor.) This will cause empty cavity to move from cavity of absorbing oil to pressure cavity. At first the small empty cavity of room of absorbing oil is open, and forms vacuum. The oil is absorbed into the cavity through reverse oil tank's pipe of absorbing oil that is stretching out. The empty cavity moves upward and forms closed stage. After this, the oil situated in closed empty cavity is pressed by screw and always moves to pressing oil room along screw groove. Finally the pressing oil room is opened by empty cavity and pushed oil into pipe of pressing oil. Thus, oil pump press oil into pressure oil tank continuously.

The oil pump of screw lever is efficiency, good sealed function, shows scarcely and sign of wear and tear, operates smoothly and noise shocks much lower.

The oil pump of screw lever is required to have better precision and fixing quality. The oil used

must be clean, otherwise, the things of "gang up" of screw lever can easily happen.

6. OTHERS

1. Safety valve:

This safety valve 100 is fixed on housing of air valve 98. When pressure relay not work or air valve get stuck as to same certain reasons. Under the effect of oil pump motor not cut off the electricity supply, when oil pressure increases and overtakes upper limit 0.1-0.2 Mpa of working pressure, the steel ball of safety valve is butted. Pressure oil is overflowed to reverse oil tank by safety valve. Safety valve can protect oil pump and pledge the safety of oil unit.

2. Pressure relay:

Pressure relay 94 control screw lever oil pump's starting or stopping through control return circuit, according to oil pressure's change of pressure oil tank. Thus make oil pressure of pressure oil tank keep allowable scope. The operating principle of pressure relay and adjusting method see technical manual.

3. Contact Pressure Meter

The oil pressure valve of pressure oil tank can be directly watched by contact pressure meter 94. Arranging its lower limit contact. And it may give out signal of reducing oil pressure or operating urgent to stop machine.

Lower oil pressure valve of incident see attached list:

Attached List:

The model of governor

The type of oil pressure	YT300						YT600						YT1000					
Working oil pressure	2.4	2.2	2.0	1.8	1.6	1.4	2.4	2.2	3.0	1.8	1.6	1.4	2.4	2.2	2.0	1.8	1.6	1.4
Operating pressure valve of signal of lower oil pressure of incident (Mpa)	2.2	2.0	1.8	1.6	1.4	1.2	2.0	1.9	1.7	1.5	1.3	1.2	2.0	1.8	1.7	1.5	1.3	1.1
Incident's pressure valve when lower oil pressure ends (Mpa)	2.0	1.8	1.7	1.5	1.3	1.1	1.9	1.7	1.6	1.4	1.2	1.1	1.9	1.7	1.6	1.4	1.2	1.1

Notes:

1) Working oil pressure is relied on upper, lower limit's middle valve of working pressure.
2) Compute valve is depended on 2S as closed time.
3) The governor's leakage quantity of oil is counted on 0.1 L/s
4) Pressure valve showed above is all indicated by oil pressure meter of pressure oil tank.

7. SOME MAIN PRINCIPLE EXPLANATIONS OF THE GOVERNOR

1. Flying Pendulum and leading valve of the Governor

Flying pendulum and leading valve (see diagram 3T0-0009, 3T2-0012)

Flying pendulum is rhombus steel ribbon style centrifugal flying pendulum, and is driven by 2JCF22-4 induction engine. And it is used to measure signal devitation of rotational speed of unit. It is one of the most important elements of the governor. Its intertia is small, precision is higher, and is connected directly with leading valve. Rotational sleeve of leading valve is also the flying pendulum's axle. And it is driven by flying pendulum. And it rotates continuously at high speed.

Flying pendulum steel ribbon is consisted of two equal steel ribbon. And really working is one side outside. And inside one is necessary when needing. It connects with heavy block of flying pendulum and down supporting block 19. And screw 2 is fixed on upper supporting block 7. The upper supporting block is connected with rotational sleeve through pin 18 and cylinder pin21.

The heavy block of flying pendulum is consisted of limited screw 12 that is connected. Centrifugal force and elastic force of spring 15 produced by it balance when rotating. If rotational speed of flying pendulum changes, and centrifugal force produced by heavy block changes at the same time. And let heavy block change in the ventral position according to plug pin 11 relatively. Therefore main press valve and relayer is controlled. The fixed rotation speed of flying pendulum is according to different parameter of flying pendulum motor, can be adjusted during 1400-1500 rpm. When screw nut 14 rotates a turn, it is equal to 5% of flying pendulum. Screw nut can be fixed on the position of one fourth's turn by split pin 13.

The whole process of flying pendulum rotational sleeve is ±7.5mm , the change scope of certain flying pendulum rotational speed is ±25%. If flying pendulum rotational speed overtakes its scope, two limited screw lever12 is limited by upper supporting block 7. The heavy block cannot expand outward continuously. There are three rows of oil hole (upper,

middle, down) on rotational sleeve. Its upper oil hole is connected with pressure oil comes from change valve through upper oil pipe of leading valve housing 9 and oil filter. The middle oil hole passes change valve through middle oil pipe of housing. Magnetoelercric valve for stopping machine is connected with assist relayer piston. The upper holes are holes that gives off. The oil giving off is poured into reverse oil tank through oil pipe under the housing. There are two rows of oil hole (upper and down) on fixed sleeve. They part correspond to upper, middle hole. As inside and outside fixed sleeve have wider ring cavity, so when rotational sleeve off the middle position, it still can connect with oil pipe on the housing through holes of fixed sleeve.

There are two cylinder style valve tray on plug pin11, and its middle is connected with necking part. The plug pin moves inside rotational sleeve. The quantity of each side of rotational sleeve's hole and plug pin is +0.10-+0.15mm. The plug pin is guided direction by rubber membrance 13 and fork 16 and not turn it. And the fork is supported to one lever of main transfer lever (3T-0005) and is tightened on it by spring 20.

Rotational sleeve sends out adjusting instruction signal according to change of rotational speed. Plug pin sends out operating instruction according to the signal of rotational speed adjusting unit. And it is comprehensive part of feedback. It reduces the signal.

2. Main Press Valve: (see diagram 3T10021)

The main press valve is used to control operating leading water unit of relayer. And leading press valve is controlled by flying pendulum leading valve.

The main press valve piston 5 is fixed in sleeve 2, and sleeve is fixed in housing 1 by screen 4 through gland 3. There are three rows of hole on the sleeve, and upper, down holes and connected with left, right cavity of relayer. The quantity of this hole and each side of piston is about +0.2 mm, and the form is ladder-shaped. The middle hole is connected with pressure oil of pressure oil tank through flange. The giving off cavity is designed in the upper, down part of main press valve piston.

Upper dics's diameter is 25 mm. Under the effect of same pressure oil, it forever foes and tends upward. Main press valve piston is tightened on assist relayer piston 12. The top of main press valve piston is connected with spherical surface of assist relayer piston. Thus is can prevent main press piston from blocking, when fixing is not situable or it happens move.

The movement speed of relayer, that is to say, the closed and started time of leading water unit relayer, is controlled by process of main press valve. And the process of it is adjusted by two limited screw nut 10.

The closed time of relayer is controlled by upper one limited screw nut. The closed and started time of relayer can be wantonly adjusted during the scope of 2-6S according to the requirement of power station.

3. Buffer : (see diagram 3T1-000, 3T2-0006)

Our governor adopts hydraulic pressure spring type buffer. As a soft reply element, it can let unit operate according to no different characteristics. At the same time buffer can get adjusting function of adjusting system (wave motion's frequency, quantity of over adjust and adjusting time) improved. Therefore buffer is one of the most important elements of the governor.

The housing 1 of buffer is filled with No.30 turbine engine oil. The housing is divided into upper, down cabity by piston. The upper part of main piston 5 is connected with lever (see item 14 of system diagram 3T0-0003). The spring 7 is used to eliminate the stifled process between piston and lever (see item 13 of system diagram 3T0-0003). No matter driver piston moves upward and or downward, the inside spring 8 is always pressed. But outside spring 6 is used to counteract the weighty of driven piston and so other spare parts. Thus outside spring can store energy only when driven piston moves downward and is used to help the driven piston move upward.

The plug pin 2 is hung on cylinder pin 15 through adjusting screw 13 and lever 16. Cylinder pin and driven piston are fixed together to move. But lever 16 only can move around cylinder pin 23. Therefore, when driven piston moves upward, lever withstand the left screw and left plug pin move a certain distance opposite to driven piston. Gradually it open down notch of plug pin 2 and let oil pressure pass the hole and its pressure reduces a lot. On the contrary when driver piston moves downward, the right adjusting screw is put on the lever and let plug pin move a certain distance opposite to driven piston, and form the hole and it reduces a lot when oil pressure passes it. And it is opened gradually. When driven piston extends to middle position, the hole of oil pressure is reduced little by little. The installation for adjusting throttle pin makes buffer possess better repayable characters. Adjusting screw 13 is firmly connected with lever 16 by spring 10.

"A" valve can be changed by twisting handle 21. That is to say, the opposite position of plug pin and driven piston is also changed, Thus hole of oil pressure and constant Td of bugger time are changed. Spin two adjusting screw 13 and will cause the same effect.

Gradually speaking, if constant Td of buffer time is adjusted more, two adjusting screw 13 can be used. Handle 21 is used when turning.

4. The unit of steady rotation difference and installation of rotational speed adjusting unit (see diagram 3T0-0011)

This unit is hard feedback unit.

When screw nut 22 is moved to a certain position toward right by the rotational central line of frame 27. Thus it gains constant of certain steady rotation difference. The whole value is

indicated by indicator 24 of steady rotation difference's constant..

Rotation screw lever 9 makes screw nut 22 move. The constant bp of steady rotation difference can be adjusted during the scope of 0-8 %. And screw nut 42 is made to move up and down. The rotational speed of flying pendulum can be changed and the scope is -15% ～＋10%.

Spring 45 tries to pull speed change lever 43 firmly and makes it face upward. And two shaky connected ends of link lever 35 is produced each other's pull force. And stifled process during spare parts is eliminated. Therefore the work's degree of accuracy is improved.

When screw nut 25 is moved towards right by rotation center of frame 22s7. The value of short rotation difference's constant bt is adjusted during the scope of 0 - 100%

When Flame 27 turns round, arm 12 is transmitted to opening restriction unit and causes the return effect to the plug pin of opening restriction.

Rolling bearing 56 can reduce frictional force of frame 27 when rotating. And therefore resistance of moment of force of speed change unit is reduced while working.

Table Name of Governor Parts

No.	NAME	No.	NAME
1	PENDULUM MOTOR	36	STOP ELECTROMAGNETIC VALVE
2	PENDULUM	37	SPRING OF ELECTROMAGNETIC VALVE
3	HEAVY BLOCK	38	PISTON OF ELECTROMAGNETIC VALVE
4	ADJUSTING NUT	39	SPRING
5	PENDULUM SPRING	40	LINK
6	GUID VALVE	41	ROLLING WHEEL
7	TURNING SLEEVE	42	CONE
8	NEEDLE PLUG	43	PISTON ROD OF SERVMOTOR
9	TIE SPRING	44	PISTON OF SERVMOTOR
10	TIE SPRING	45	"O" TYPE SEALING RING
11	LEVER	46	HANDLE
12	LINK	47	SPIRAC PULG
13	LINK	48	PIN NUT
14	LEVER	49	HAND WHEEL
15	ADJUSTING SCREW	50	THRUST BEARING
16	PIN	51	SLIDE BLOCK
17	LEVE	52	FLANGE
18	HAND WRENCH	53	SLEEVE
19	INNER SPRING	54	CERTAIN AXLE
20	OUTER SPRING	55	SQUARE FRAME
21	NEDLE PLUG	56	POINTER
22	SECONDARY PISTON	57	ADJUSTING SCREW
23	PRIMARY PISTON	58	SCREW
24	LINER BUSH OF MAIN PRESSURE VALV	59	ADJUSTING SCREW
25	PISTON OF MAIN PRESSURE VALVE	60	LINK
26	PISTON OF AUXUARY SERVMATOR	61	NUT
27	LIMIT NUT	62	PULLEY
28	ADJUSTING SCREW	63	OIL FILTER
29	LEVER	64	LINK
30	SUPPORTING FRAME	65	LINK
31	LEVER	66	NUT
32	PIN NUT	67	SCREW
33	LIMIT NEEDLE PLUG	68	LEVER
34	LINER BUSH OF LIMIT VALVE	69	LINK
35	SWITCHING VALVE	70	OPENING LIMIT SCREW

No.	NAME	No.	NAME
71	OPENING LIMIT NUT	105	AIR SUCTION PIPE
72	PRIMARY GEAG	106	OIL LEVEL INDICATOR OF PRESSURE OIL TANK
73	SECONDARY GEAG	107	OIL DISCHARGE VALVE
74	PRIMARY GEAR	108	GLOBE VALVE
75	SECONDARY GEAR	109	SLIDE BLOCK
76	SPRING	110	CROSS BLOCK
77	HANDWHEEL OF SPEED ADJUSTING DEVIC	111	ARM HANDLE
78	HANDWHEEL OF OPENING LIMIT DEVICE	112	GOVERNING VALVE
79	LIMIT SWITCH DOG		
80	LIMIT SWITCH DOG		
81	LIMIT SWITCH DOG		
82	LIMIT SWITCH		
83	REDUCTOR OF OPENING LIMIT DEVICE		
84	MOTOR OF OPENING LIMIT DEVICE		
85	REDUCTOR OF SPEED ADJUSTING DEVICE		
86	MOTOR OF SPEED ADJUSTING DEVICE		
87	ORESSURE GAUGE		
88	THROTTLE GATE		
89	POINTER OF OPENING LIMIT		
90	POINTER OF SPEED ADJUSTING DEVICE		
91	OPENING POINTER OF GUIDE VANE RING		
92	PULLY DEVICE		
93	PRESSURE SIGNALYZE		
94	ELECTRIC CINTACT PRESSURE GAUGE		
95	PRESSURE OIL TANK		
96	NON-RETURE VALVE		
97	MILD OIL TANK		
98	SUPPLEMENTARY AIR VALVE		
99	PISTON OF SUPPLEMENTARY AIR VALVE		
100	SAFTY VALVE		
101	OIL PUMP MOTOR		
102	SCREW PUMP		
103	OIL LEVEL INDICATOR OF OIL RETURN BOX		
104	OIL SCREEN		

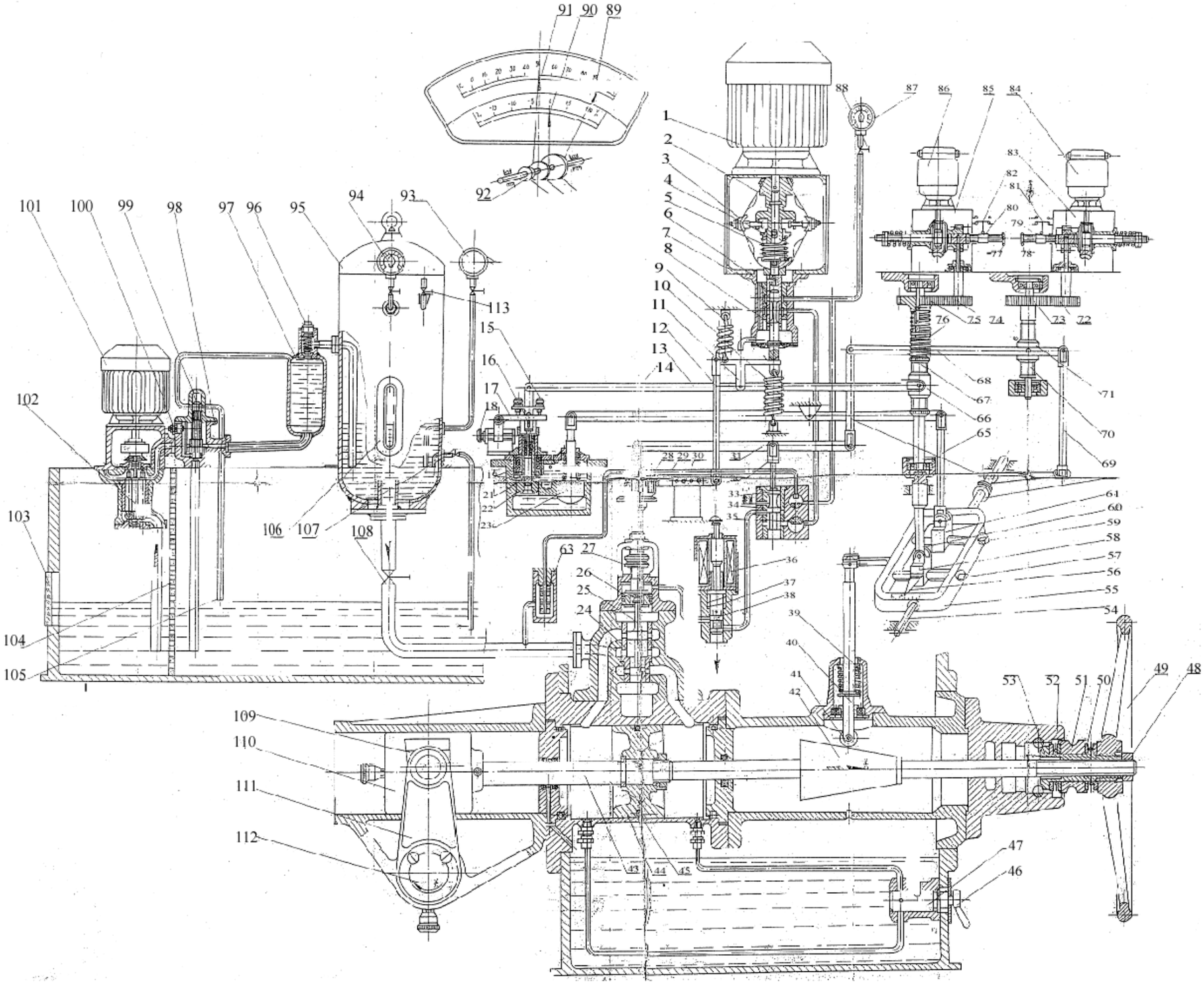


Figure Structure of Governor

Appendix 7

OPERATION INSTRUCTION
OF
THYRISTOR EXCITATION UNIT
FOR
SYNCHRONOUS GENERATORS TYPE KGLF-OOF

JIAXING ELECTRICAL CONTROL APPARATUS WORKS

THE PEOPLE'S REPUBLIC OF CHINA

（Reproduced by JICA Study Team in 2003）

Thyristor exciter of synchronous generator is a stalie unit, which is fed directly from the transformer at the generator terminals and regulated automatically by the variation of the terminal voltage. It can be used with generators of several hundred kW up to ten thousands kW. IT can be reliably and safely operated under different conditions of power networks, applicable to both generators and phase-regulators.

1. MAIN TECHNICAL DATA

Automatic voltage regulated range of the exciter is 70 %~115 % of the rated stator voltage; Manual voltage regulating range is 40 %~130 % of the rated stator voltage; Maximum compensating rate of reactive current is 10 %; Accuracy of voltage regulation in steady state is less than 1%; when stator voltage drops to 80 % of the rated value, 1.6 times of the forced excitation can be attained.

The built up time of forced excitation is not longer than 0.1s. In case of being short-circuited at the generator terminals, self-compound exciting circuits can provide 1.6 times of the forced excitation.

Overall dimension: 800 x 600 x 2140.

2. NORMAL SERVICE CONDITIONS

This unit, suitable for indoor use, can be normally operated in the following conditions;

(1) The altitude does not exceed 1000 m.

(2) Ambient temperature is ranging from 0 degree-C to 40 degree-C.

(3) Relative humidity does not exceed 85% (T = 20 ° ±5 degree-C)

(4) The unit shall be mounted in places free from any conductive and explosive dusts and any corrosive gases and vapors which would destroy metals and insulations.

(5) There is no severe vibration and shock in mounting places, the vertical inclination should not exceed 5 %.

3. PRINCIPLE

The self shunt exciting circuit of Type KGLF-11F is fed from stator voltage.

The self compound exciting circuit of Type KGLF-21F is fed from stator voltage and current.

The schematic diagrams I and 2 are as follows;

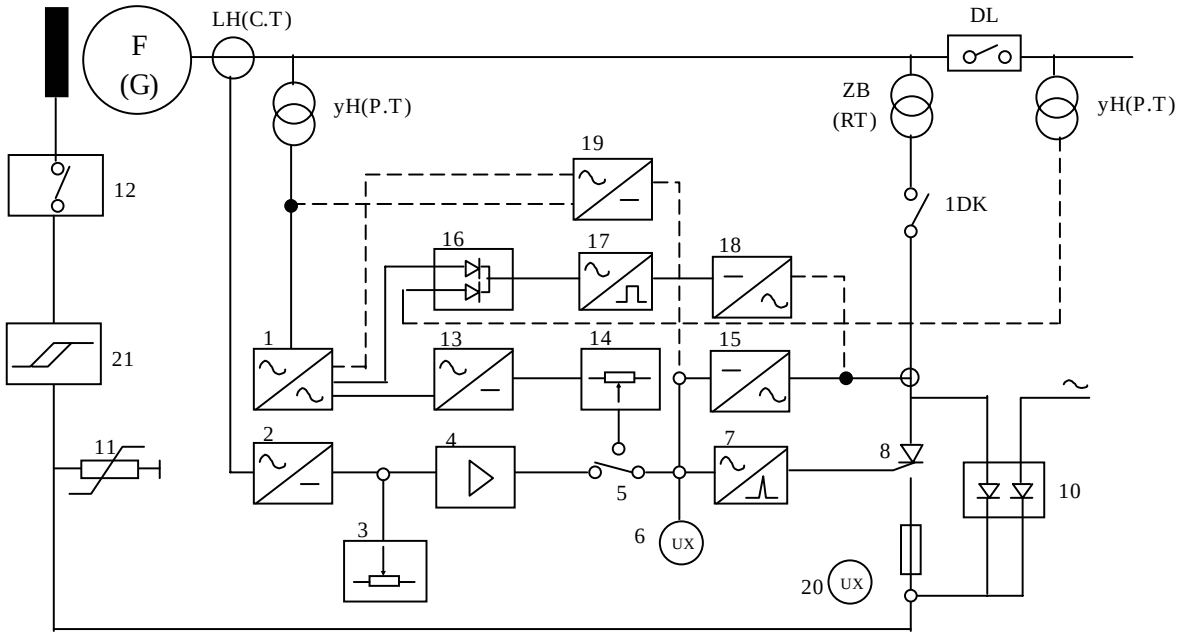


Figure 1 Schematic diagram for type KGLF-11F

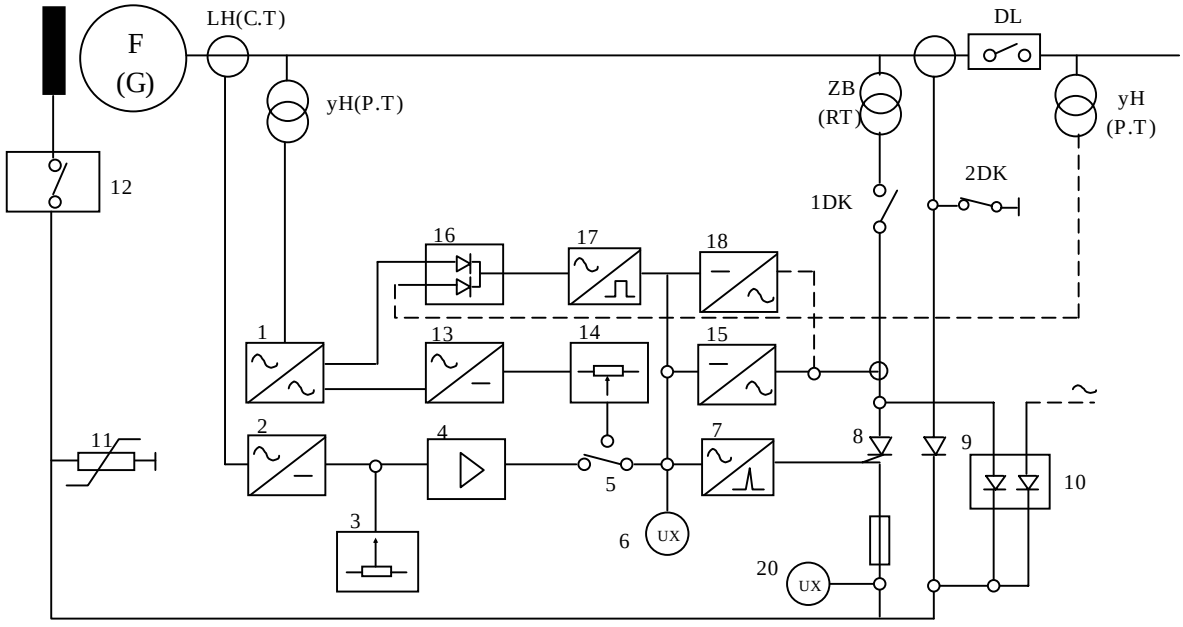


Figure 2 Schemetic diagram for type KGLF-21F

(1) Signal source

(2) Reactive current compensator

(3) Given values of automatic regulation

(4) Amplifier

(5) Automatic-manual changeover (Auto/Hand changeover)

(6) Measurement for control voltage Uk

(7) Phase shift trigger

(8) 3-phase half-controlled rectifier bridge

(9) 3-phase rectifier bridge

(10) Starting of excitation

(11) Overvoltage protection

(12) De-excitation switch

(13) Rectifier

(14) Given values of manual regulation

(15) Over excitation limit

(16) Anti-malfunction forced exciting device

(17) Forced excitation control

(18) No-load excitation control

(19) Under excitation limit

(20) Monitoring for control angle

(21) Protection for de-excitation

3.1 Main exciting circuit

All exciting current for self-shunt exciting circuit are fed from a 3-phase half controlled rectifier bridge. The exciting voltage can be varied by changing the conductance angle of the thyristor. The exciting current for self-compound exciting circuit is fed from two circuits in series:

One of them is from rectifying transformer ZB to a 3-phase half controlled rectifier bridge, it is uncontrollable. But its current value is proportional to the stator current. 3-phase half-controlled rectifier bridge is equipped with the elements of commutation, overvoltage protection and d.c. side overvoltage protection.

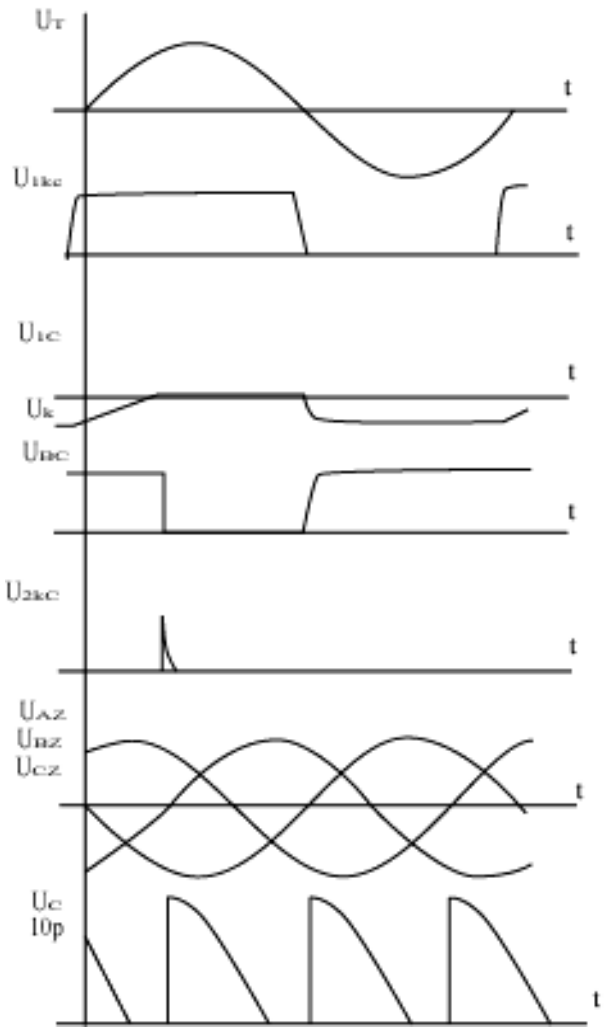
3.2 Automatic voltage regulator

Voltage signal rectified at the generator terminals and the given voltage are set to PID regulator. PID regulator is used for obtaining food dynamic and static features and maintaining the generator terminal voltage substantially constant. PID regulator transmits a signal to phase-shift trigger to generate trigger pulses which may change its phase from the control voltage Uk. In order to get a definite phase

relation between these pulse and the main circuit, synchronous signal U_T should be transmitted into the phase shift trigger.

The waveforms for rated outputs are shown as Fig. 3.

3.3 Manual-operating, cut-off and changeover



Signal Uk can be transmitted by the mannal regulator. In fact, the manual regulation is a weak negative feedback of the generator terminal voltage, thus approximately maintaining a constant excitation.

Manual regulator may be used as an auxiliary one for the automatic regulator, applicable in some special cases. Auto/Hand changeover is carried out according to Uk'-Uk. The voltmeter Uk indicates the value Uk in operation, after depressing the push button IANb, it indicates the value Uk', then, the changeover can be made.

In cut-off position value Uk is so raised as to minimize the conductance angle of the thyristor, then controlled bridge may be inhibited.

Figure 3

3.4 Starting

This unit adopts the combination of residual magnetism starting and separate excitation starting. It is unnecessary to use special power supply for this purpose.

3.5 Role of the testing position

It can be used for checking the regulator and the main circuit before starting. In FMK or 3DK and the testing position, A.C. power is connected to the regulator so that low voltage power source can be obtained in the main circuit. 2RL is its load.

3.6 Additional elements

This unit is attached with the following elements:

- Over excitation limiter
- Forced exciting controller
- Reactive current compensating link
- Remote control panel
- De-excitation protection; (KGLF-11F with one)

The following elements may be supplied if on request;

- Under excitation liniter
- No-load excitation limiter
- Anti-malfunction forced excitation device
- Thyrstor control angle monitoring device, etc…

Notes:

Over excitation limiter is provided for preventing overcurrent of the rotor, The limiting value can be adjusted by means of switch 1Kc.

Forced excitation controller is used to detect signals due to sudden drop of the stator voltage to changeover the over excitation limit to the multiple limit of forced excitation and after 20 seconds the over excitation limit is restored to original limit value. The potential meter is provided for changing multiples of forced excitation.

Reactive current compensator transmits reactive current signal to stator voltage signal to obtain characteristics as shown in Fig.4. In favour of attaining stable, reasonable distribution of reactive current in case of multi-generators.

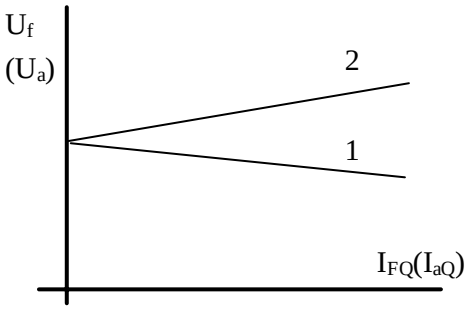


Figure 4

Wiring shall be connected according to characteristic 1 before the device is delivering from the factory. Compensating rate can be adjusted by means of switch 1 Ka. The higher the compensating rate, the stabler the reactive power.

De-excitation protection : Under current delay 61 EJ in excitation circuit operates, FMK trips and gives a signal.

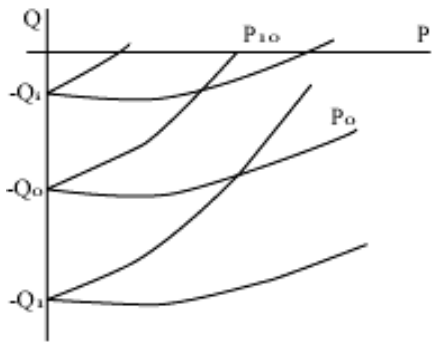


Figure 5

Remote controller is used for automatic

regulation, manual regulation and changeover operation from a remote position.

Under-excitation limiter: prevent asynchronization of the generators due to low excitation. The characteristic curve of under excitation limit is given as Fig.5.

The common point in the limiting line and axis Q may be determined by switch "Q". The slope of limiting line may be determined by switch "P".

Anti-malfunction forced excitation device: prevent from the malfunction of forced excitation which is not caused by the sudden voltage drop other than that in the stator by melting of the fuses in the potential transformer.

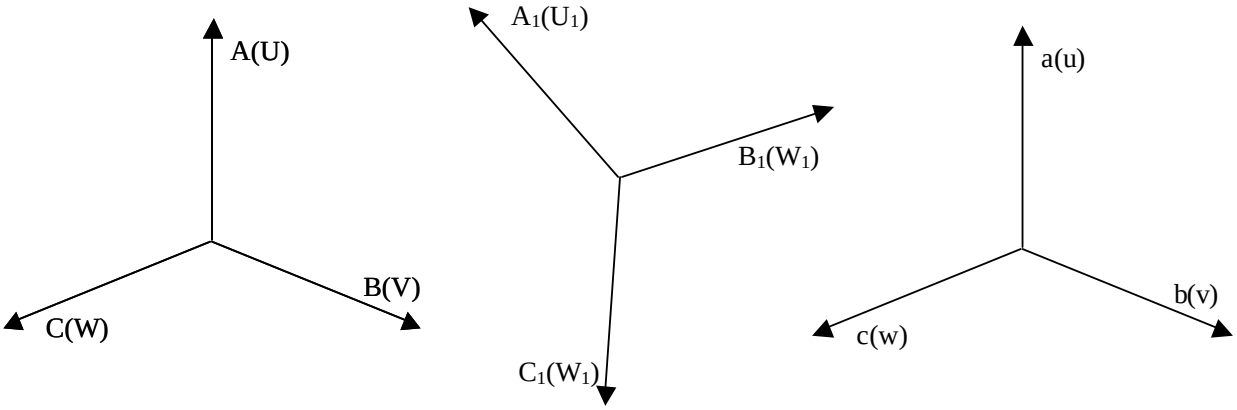
4. PREPARATION FOR OPERATION

(1) Set operating value of the starting relay 62 YJ to 50 % of the rated voltage.

(2) Set operating value of no-loaded overvoltage relay 61 YJ to 125 % of the rated voltage.

(3) The current phase of the lead wires must be ensured.

Attention shall be paid to the polarity of 3-phase current transformer used for current compensation.



Stator voltage | Secondary voltage of rectifying transformer | Secondary voltage of the stator voltage transformer

Figure 6

(4) In self-compound exciting circuit, when active power is at rated value coϕ =1.0 the controlled bridge shall still provide about 10% exciting current (stable). If such fitgure is too big, then the turns of the secondary winding of the converter shall be reduced, If it is not stable, its turns shall be increased, When the generator is operating at the rating, the current of controlled bridge is about 40 % of the exciting current.

(5) D.C. control voltage can be obtained by rectified A. C. source or directly by D.

C. electric source. If you will change the A. C. supplyint source instead of D. C., please take out the fuse 61 RD. 62 RD from the unit of control circuit of this cubicle, then let the D.C> control source through the outer fuse to connect on the connectors 601(+) and 602(-) of the cubicle.

Note: At this time, A.C. source should be still supplied, that will be used for fan operation and test.

5. NORMAL OPERATION

(1) Preparation

a. After the testing of the set of the generators, it is proved to be normal.

b. Relay protection and operation system are normal.

c. Check up testing position of this device being normal.

d. Position of each switch of this device

(Note; The need of each following item shall be determined by the selected circuits)

1DK	Secondary drawn-in of rectifying transformer	Closed
2DK	Secondary short circuit of the converter	Open
3DK	Output of controlled rectifier bridge	closed
61LP	Automatic starting	According to needs
62LP	No-load over voltage and de-excitation	Closed
61XJ	Fault signal relay	Manual reset
61DK	Making power supply	Closed
1K	Fan switch	Closed
ZK	Fan protective switch	Closed
1Ka	Reactive current compensation	Setting value for test
2Ka	Test-off-operation	Operation
1Kb	Remote control-near control	According to needs
2Kb	Automatic-manual cutoff	Automatic
1Wb	Near control "automatic" given value	No-load rating setting to corresponding number of turns
2Wb	Near control "manual" given	No-load rating setting

	valve	to corresponding number of turns
3Wb	Adjustment of stability	Setting value for test
4Wb	Adjustment of multiplying factor	Setting value for test
1Kc	Over excitation limiting value	Setting value for test
1Wc	Forced excitation multiplying factor	Setting value for test
Kg(1kg)	Remote control, automatic-manual cut off	Automatic
2Kg	Selection of manual range	40~130 %
1Wg	Given value for remote control "automatic"	No load rating setting to corresponding number of turns
2Wg	Given value for remote control "manual"	No load rating setting to corresponding number of turns
1Kh	Under excitation limit "-Q"	Setting value for test
2Kh	Under excitation limit "P"	Setting value for test

e. Supply operation power: ±KM, ±HM, ±XM, X_{11}, X_{12}, X_{13}

(2) Starting of the set

Start the prime mover, rotating speed up to 95-105% of rating.

(3) Quasi synchronous operation

a. Set synchronous switch to "Quasi Synchronization", FMK closes.

b. Depress the starting button, build up voltage to rating.

c. If it is automatic start, then the speed relay operates, closes its contacts and voltage builds up to rating.

d. Operate according to quasi synchronization sequence and connect the generator in parallel with the network.

(4) Self-synchronous operation

a. Set 1Wb or 1 Wg number of turns corresponding to the system voltage.

b. Synchronous switch is set in #self-synchronization" DL closes to start excitation thus pulling into synchronization.

c. Set the rotation speed of the generators to required value.

(5) De-excitation and stopping

a. Transfer the loads

b. DK opens, thus make FMK open and get de-excitation

c. Brake the prime mover

(6) Hand-automatic changeover

(7) Remote-near control changeover

(8) The changeover is carried out with the same number of turns I the same mode of operation.

Appendix 8[*1]: Testing Method of Turbine Efficiency

In the course of the operation of power station, it is important to grasp the performance of hydraulic turbine. However, in general, it is hard to measure directly the output of hydraulic turbine, consequently, the turbine efficiency is estimated by measurement of the generator output in place of measurement of the turbine output as follows:

$\eta = P_G / (9.8 \cdot H_e \cdot Q)$, and

$\eta_T = \eta / \eta_G$

Where,

η : overall efficiency, P_G: generator output (kW), H_e: effective head (m), Q: discharge (m^3/s),

η_T: turbine efficiency, η_G: generator efficiency (which is generally available from the factory test.)

In reference to this formula, it is clear that such a measurement of turbine efficiency is subject to measurements of; (i) the generator output, (ii) the effective head, and (iii) the discharge, which are as described below:

1. Effective Head

The effective head (H_e) is estimated by adding the suction head to the statistic water head between the water level in the upper pondage and the turbine center after deduction of head loss of the penstock.

In addition, the measurement method of the effective head for each type of turbines such as Propeller or Kaplan turbine, Pelton turbines, etc. is described in Clause 11 Specifc Hydraulic Energy in SECTION FOUR-MEATHODS OF MEASUREMENT in IEC60041[*1].

2. Generator Output

The generator output (P_G) is measured by a power meter.

On the other hand, integrating electrical insruments (watt-hour-meter and counters) are more suitable in those cases where integrating discharge measurements are made. The measurement method of the generator output is to be referred to Clause 12 Power in SECTION FOUR-MEATHODS OF MEASUREMEN.T in IEC60041[*1].

3. Discharge

The measurement of discharge is performed mainly through the measurement of a flow velocity in the penstock. The discharge itself is achieved with multiplying the flow velocity by the sectional area of the penstock.

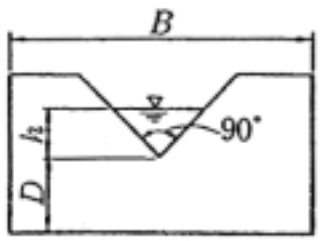
Note ; *1: (1) "IEC60041 – 1991: FIELD ACCEPTANCE TESTS TO DETERMINE THE HYDRAULIC PERFORMANCE OF HYDRAULIC TURBINES, STORAGE PUMP AND PUMP-TURBINE. (2) The IEC is to be directly referred to and no copies are provided due to the Copyright – all right reserved in IEC.

Depending on the locations of flow velocity measurement, the measurement methods of flow velocity are as follows in reference to Clause 10 Discharge in SECTION FOUR-MEATHODS OF MEASUREMEN.T in IEC41[*1].

1) Current-meter method referring to Sub-clause 10.2 (for the waterway and the penstock).
2) Pitot tubes method referring to Sub-clause 10.3 (for the penstock).
3) Pressure-time method (often called as "Gibson method") referring to Sub-clause 10.4 (for the penstock).
4) Weir method referring to Sub-clause 10.6 (for the tailrace).

In addition to the weir method specified above in Sub-clause 10.6 of SECTION FOUR-METHODS OF MEASUREMENT in IEC41*1, three weir methods are given as follows for reference:

A weir with a right triangle shape:



$Q = K \cdot h5/2$

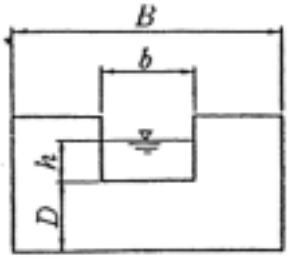
$K = 1.354 + 0.004 / h + (0.14 + 0.2/\sqrt{D}\ ) \times (h/B - 0.09)2$

Where, $B = 0.5 \sim 1.2$ (m)

$h = 0.07 \sim 0.26$ (m) $< B/3$

$D = 0.1 \sim 0.75$ (m)

A weir with a rectangular shape:



$Q = K \cdot b \cdot h^{3/2}$

$K = 1.785 + 0.0295 / h + 0.237 \times h / D - 0.428 \times / \sqrt{\ }[(B - b) \cdot h / (B \cdot D)\ ]$
$+ 0.034 \times \sqrt{\ }[B / D]$

Where, $B = 0.5 \sim 6.3$ (m)

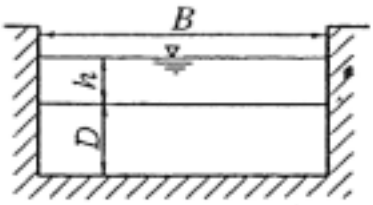
$b = 0.15 \sim 5.9$ (m)

$D = 0.15 \sim 3.5$ (m)

$bD / B^2 \geq 0.06$

$h = 0.03 \sim 0.45 \quad \sqrt{\ } b$ (m)

A weir with an overall width of overflow:



$$Q = K \cdot B \cdot h^{3/2}$$

$$K = 1.785 + (0.0295 / h + 0.237 \times h / D) \times (1 + \varepsilon)$$

Where, ε: adjustment factor (ε = 0 when D ≦1 m, and ε = 0.55 x (D – 1) when D > 1 m)

B ≧ 0.5 (m)

D = 0.3 ~ 2.5 (m)

h = 0.03 ~ D (m) ≦ 0.8 m and ≦ B / 4

It is noted for the symbols as follows:

Q: overflow discharge ($m^{3/}s$)

B: width of weir

b: width of notch

h: overflow depth

D: height from the bottom of channel to the edge of weir

4. Acoustic Method of Discharge Measurement

Acoustic method is relative measurement. It can not only measure discharge from outside of a penstock easily but also be applicable, thus it is widely used practically. Measurement method introduced in IEC is as follows:

4.1 General

Experience with the acousitic methods of discharge measurement is limited. While the methods have yet to be accepted as primary methods, their application is permissible by mutual agreement or in conjunction with an established method of discharge measurement, in which case the latter method will prevail in the comparison with the guarantees.

4.2 Principle of Measurement

The acoustic method of discharge measurement is based on the fact that the propagation velocity of an acoustic (generally ultrasonic) wave and the flow velocity are summed vectorically. It follows that an acoustic pulse sent upstream travels at a lower absolute speed than an acoustic pulse sent downstream (see Figure 4.1) By measuring the times of the traverse of pulses sent in the two directions, the average axial velocity of the fluid crossing the path of the pulse is determined. Experience has shown that such time measurements must be done repeatedly to establish an average and to minimize the random error.

An acoustic discharge measurement system includes transducers installed in the measurement section; an electronic equipment is required to operate the transducers, make the measurements, process the measured data, and display or record the results, It also includes a verification program to ensure that the equipment and program are functioning properly.

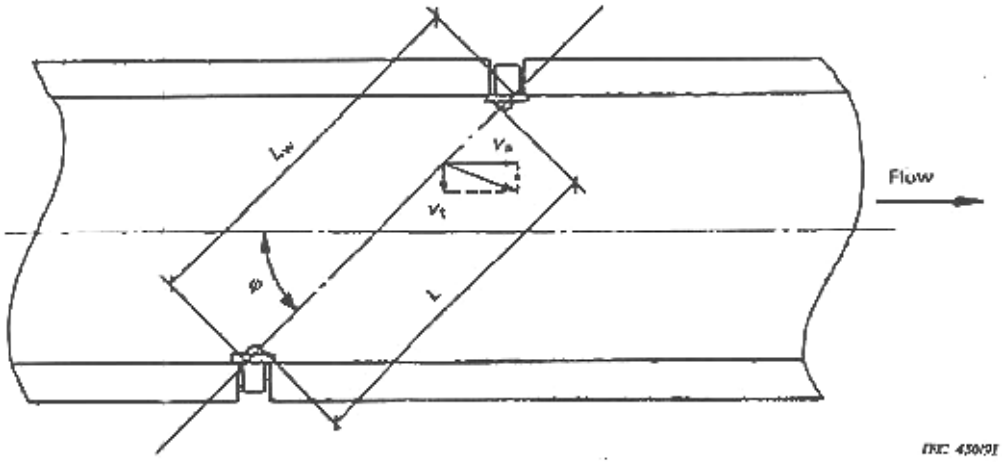


Figure 4.1 Acoustic Method – Schematic Representation to Illustrate Principle

Several methods of acoustic discharge measurement exist, but all have demonstrated that they are capable of achieving the accuracy required for field performance tests. Currently not included are devices based on the measurement of the refraction of an acoustic beam by fluid velocity and

devices which measure the Doppler frequency shift of an acoustic wave reflected by the flowing fluid of by moving particles. The only acceptable methods are based on the measurement of the transit time of an acoustic pulse along chordal paths.

In order to reduce the systematic uncertainty due to effects of transverse flow components, the use of two acoustic planes A and B as shown in Figure 4.2 is required. In circular cross-sections, if the velocity distribution were fully axi-symmetric, the average velocity measured along a single path located in an axial plane could be assumed proportional to the mean flow velocity in the conduit. In practice, it is necessary to take into account the actual velocity distribution by installing several pairs of transducers at opposite ends of a number of paths located in the measurement planes at angle ϕ to the longitudinal axis of the conduit and distributed symmetrically about this axis (See Figure 4.2)

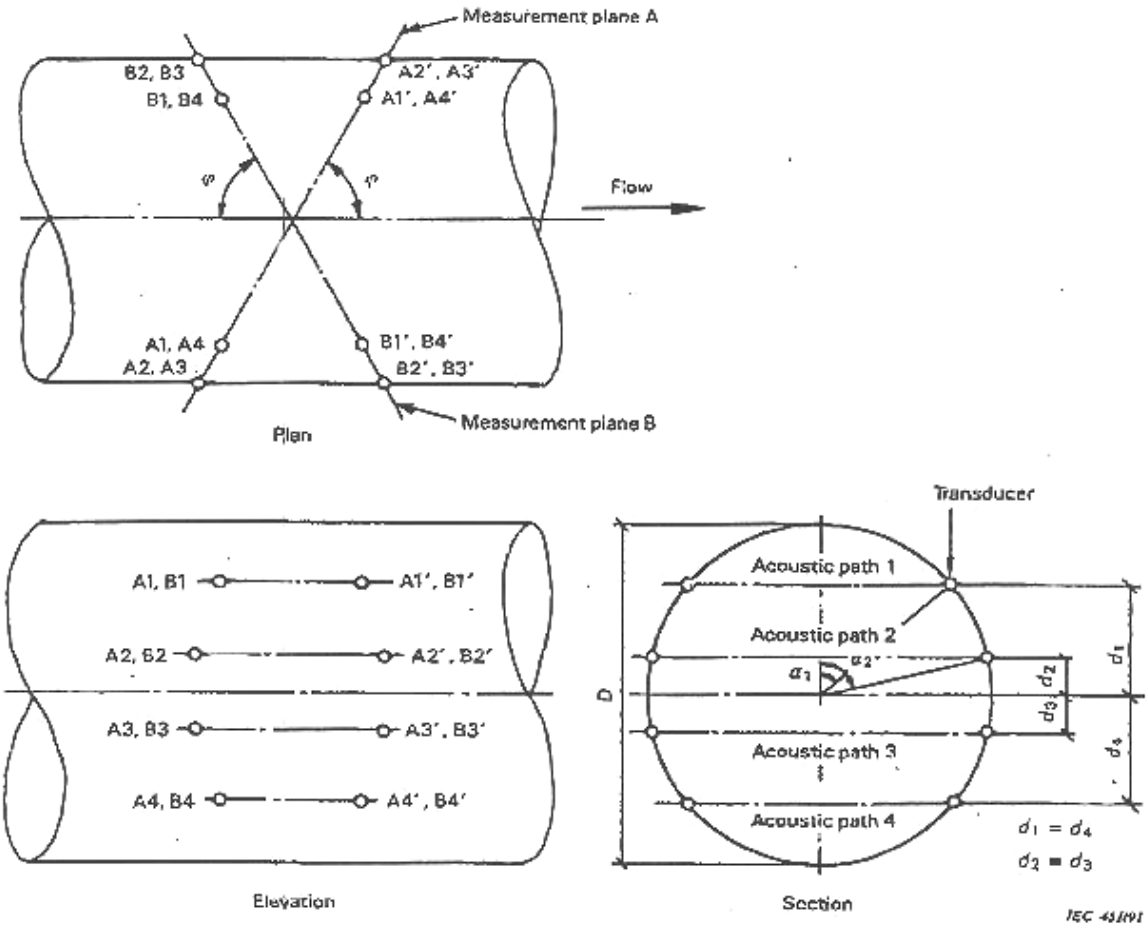


Figure 4.2 Acoustic Method – Typical Arrangement of Transducers in a Circular conduit

In a rectangular cross-section, the measurement of the average velocity v, conducted simultaneously or consecutively for a well chosen number of parallel paths, will permit a linear integration of the discharge over the whole section. In circular sections, the integration ins done using numerical analysis methods:;

A systematic uncertainty, depending upon Reynolds number, conduit size and the shape and size of the transducer mount (projecting or recessed) is introduced by the local distortion of the velocity profile along the acoustic path compared to that which would exist if the transducer mount were not present. The systematic uncertainty shall be included in the error analysis as discussed in 4.7.

4.3 Methods of timing

There are two main methods of transit time measurements, with some variations. The first consists in measuring directly the transit time in each direction between the two transducers. A variant of this method measures additionally the time difference in reception of signals transmitted simultaneously upstream and downstream.

In the second, the so-called "sing-around method", the frequency with which signals are transmitted is determined by the transit time, since each signal arriving at the receiver triggers off a new pulse at the opposite transmitter in the same direction, and the difference in frequency of both series of pulses is measured.

Both methods have their advantages and disadvantages and their choice depends on the size of the conduit, the magnitude of the velocity to be measured and the precision and cost of the timing device available on the market.

The time delays in the electronic circuit and cables are the times for the acoustic pulse to traverse any non-water parts of the acoustic path, such as the acoustically transparent material in the face of the transducer holder, shall be determined and taken into account.

If the above conditions are fulfilled, and by measuring the travel time of an acoustic pulse along a given path in both the upstream and downstream directions, the final results will be virtually independent of the fluid's composition pressure and temperature.

4.4 Discharge measurement and calculation

To make velocity measurement along a given path, the transmitter and receiver are arranged in such a way that signals are transmitted upstream and downstream at an angle ϕ relative to the axis of the conduit (see figure 4.1). Angles from 45 to 75 degree have shown to be satisfactory for the acoustic discharge measurement methods.

$$t = \frac{L}{c + \varepsilon v_a \cos\phi}$$

Where,

L is the distance in fluid between the transducer faces
(The distance L depends on the particular design of the transducers applied)

c is the sonic speed in the fluid at the operating conditions

ϕ is the angle between the axis of the conduit and the acoustic path

v_a is the axial flow velocity averaged over distance L

ε = +1 for signals traveling downstream

ε = -1 for signals traveling upstream

Since the transducers are generally used both as transmitters and receivers, the difference in travel time may be determined with the same pair of transducers. Thus, the mean axial velocity crossing the path is given by:

$$\bar{v}_q = \frac{L}{\cos\phi}\left(\frac{1}{t_d} - \frac{1}{t_u}\right) = \frac{L}{2\cos\phi}\left(f_d - f_u\right)$$

Where:

T_d and t_u, or f_d and f_u are the transit times or frequencies of an acoustic pulse traveling downstream and upstream respectively.

If there are transverse flow components, then:

$$t = \frac{L}{c + \varepsilon\left(\bar{v}_q \cos\phi + Y\bar{v}_q \sin\phi\right)}$$

Where

V is the transverse component of the flow velocity (having a component $v_1 \sin\phi$ parallel to the acoustic path) averaged over distance L

Y is a factor equal to +1 or -1 depending upon the direction of the transverse component of the flow parallel to the acoustic path and depending upon the orientation of the acoustic path (i.e. path in plane A or B in Figure 2). For a given transverse flow component: Y = ± 1 for an acoustic path in plane A and Y = $\mp$ 1 for an acoustic path in plane B.

The average axial velocity crossing a path may be taken as:

$$\bar{v}_q = -Y\bar{v}_q \tan\phi + \frac{L}{2\cos\phi}\left(\frac{1}{t_d} - \frac{1}{t_u}\right)$$

When two acoustic planes are used as shown in Figure 2, symmetrically disposed relative to the conduit centerline, and their velocities averaged, then the error due to the measurement of transit times caused by the transverse flow component is eliminated as the terms ($-Yv_t \tan\phi$) cancel.

If certain mathematical conditions such as continuity and differentiability are met by the velocity distribution, the discharge Q can be obtained from the general equation:

$$Q = k\frac{D}{2}\sum_{i=1}^{n} W_i \bar{v}_{ai} L_{wi} \sin\phi$$

With $L_{wi}\sin\phi = B$ for rectangular sections

Where:

- L_{wi} is the distance from conduit wall to conduit wall along the acoustic path i
- D is the dimension of the conduit parallel to the intersection of the two acoustic planes, as shown in Figure 2
- B is the dimension of the conduit perpendicular to D in the case of rectangular sections
- W_i are weighting coefficients depending on the number of paths and the integration technique used
- v_{ai} is the axial flow velocity averaged along the path I as calculated from measured transit times
- n is the number of acoustic paths in one plane
- k is a correction coefficient which naccounts for the error introduced bythe integration technique chosen and the shape of the conduit
- αi defines angular location of the end path *i* relative to D (see figure 2)

The inherent difficulty of some integration techniques to integrate over sections of different configurations requires a shape factor k to be used. One can demonstrate that, then applying for instance the Gauss-Legendre method to a circular section, the value of k is 1,000. Conversely. When applying the gauss-Jacobi method to a circular section, no correction coefficient is required, i.e. k = 1,000 and when it is applied to a rectangular section, the value of k is 1,034.

The Fauss-Legendre and the Gauss-Jacobi quadrature integration methods meet the requirements of this standard. At least four paths shall be used for a proper determination of the discharge. For a four-path arrangement, the location of the paths, the weighting coefficients and the correction coefficients for the Gauss-Legendre and Gauss-Jacobi quadrature integration methods are as follows:

Table 1

		Gauss-Legendre method		Gaiss-Jacobi method	
		Paths 1 and 4	Paths 2 and 3	Paths 1 and 4	Paths 2 and 3
$\frac{d}{D/2}$		±0.86136	±0.339981	±0.809017	±0.309017
W		0.347855	0.652145	0.369317	0.597667
K	Circular section	0.994		1.000	
	Rectangular section	1.000		1.000	

Where:

d is the distance from the centerline of the conduit to the acoustic path (see Figure 2)

When one of these methods is applied to a truly circular section, with the paths located ezactly at the specified distance from the center, the general formula is often used in the simpler form:

$$Q = \frac{D^2}{2} \sum_{i=1}^{n} W_i \bar{v}_{ai}$$

Since in this case $L_{wi}\sin\phi$ for each given path is independent of ϕ :

$$W_i' = W_i \frac{L_{wi} \sin\phi}{D} = W_i \sin\alpha_i$$

Table 2

	Gauss-Legendre method	Gauss-Jacobi method
$W_1' = W_4'$	0.176841	0.217079
$W_2' = W_3'$	0.6113298	0.568320

4.5 Selection of measuring section and conditions of installation

The layout of transducer locations and measurement of as-built dimensions must be doen using accurate methods. For large conduits surveying techniques and for smaller conduits careful shop measurements can be used. In either case the uncertainties of the as-built measurements must be accounted for in the error analysis (see clause 4.7)

Special care shall be taken for large conduits which may not have perfectly symmertrical shapes. A representative dimension D shall be determined in the measuring section and perpendicular to the direction of the acoustic paths. At least five equally spaced measurements of D shall be taken (See Figure 4.3) including one at the centre of the measuring section and one at each end. These measurements shall be averaged to be representative of the conduit dimension, in the measuring section.

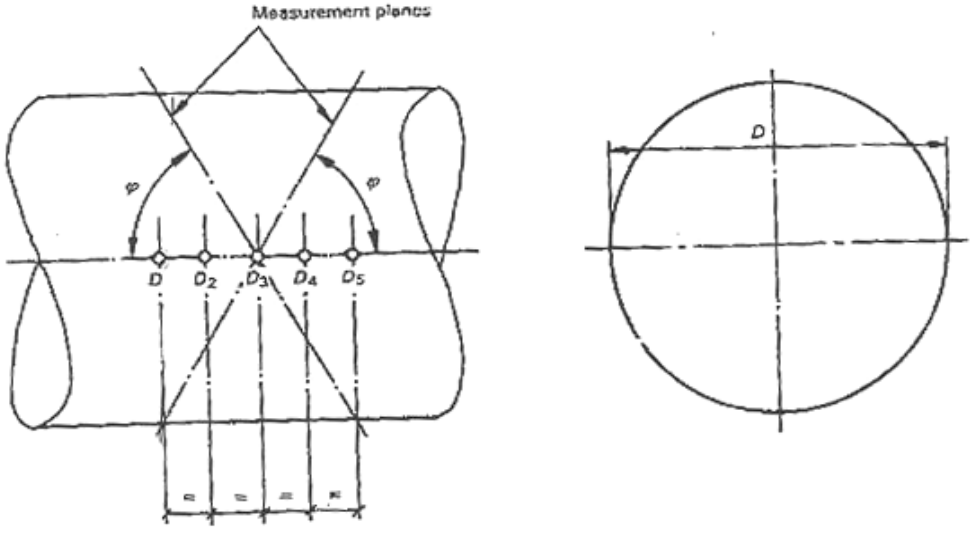


Figure 3 Locations for Measurements of D

A sufficient number of other measurements shall be taken to determine the shape of the conduit for purposes of determining the effect of the conduit shape on the numerical integration correction coefficient k.

Accurate measurements of as-built dimensions of D (and possibly B) of the conduit, acoustic path lengths between transducer faces, path lengths between the walls of the conduit along the acoustic paths and the location of the acoustic paths and their angles relative to the center of the conduit are to be used in the calculation of the discharge.

Misplacements of transducer locations must be accounted for in the error analysis or by correction to the calculated discharge.

As distortion of the velocity profile may be caused by a bend, the intersection of the two acoustic planes should be in the plane of the bend to minimize the effects of the transverse flow components on the accuracy of the measurement. Individual measurements of velocity v shall be made for each path in order to obtain an indication of any distortion in the velocity profile and the extent of any transverse flow components.

Although the use of two four-path planes compensates for most of the transverse velocity components, the measuring section should be chosen as far as possible from any upstream disturbances, such as a bend, that could create asymmetry of the velocity distribution, l swirl or large scale turbulence. Other factors that may produce transverse velocity components or distortion of the velocity profile are flow conditions upstream of the intake, the shape of the intake, the number of bends upstream of the measuring section, changes in upstream conduit diameter and the proximity of bends or changes in conduit diameter downstream.

It is recommended that there should be a straight length of upstream conduit between the measuring section and any important irregularity of at least ten conduit diameters. Similarly, there should be a straight length of at least there conduit diameters between the measuring section and important downstream irregularity. Experience has shown that satisfactory results can be obtained with a single four path acoustic plane located downstream of a straight length of twenty conduit diameters or more providing a uniform flow distribution in the measuring section.

Measurement of discharge using a single path in one or two measuring planes is not permitted under the rules of this standard.

Provision in the design and construction of the flow meter must be made for demonstration that the equipment is operating correctly. It shall be possible to make such checks as:

- showing acoustic pulses and their detection on an oscilloscope:

- internal elecustic tests of the program and constants:

- comparison of calculated values of the speed of sound using the measured acoustic path transit times and path lengths with published values corrected for water temperature:

- separate measurement of the average velocity along each individual path.

It may be desirable to measure the acoustic pulse transit times independently and compare with the results given by measurement system.

4.6 Conditions of use and limitations

Flow velocity and diameter of the conduit shall be large enough to permit an accurate determination of the difference in acoustic pulse transit times taking into account the accuracy of the timer. Measurements with flow velocities less than 1,5 m/s and diameters of conduits less than 0.8m should be avoided.

Bubbles, sediment and acoustic noise may disrupt the operation of the acoustic flow measurement system and should be avoided. If the disruption results in missed samples, enough valid samples must be obtained to be compatible with the assumptions used in the error analysis. The design of the data acquisition and treatment system shall permit checking of the proportion of lost pulses.

4.7 Uncertainty of measurement

Both random and systematic uncertainties have to be taken into account. For a detailed analysis, see ISO5168. Specifically, the following sources of uncertainty have been identified.

- measurement of path lengths L and L_w

- measurement of acoustic path angles ϕ;

- measurement of path spacing d and conformity with the positions prescribed;

- measurement of D;

- time measurement and time resolution;

- non-water path time estimation;

- internal computational precision;

- uncertainty due to flow components;

- existence of transverse flow components;

- flow profile distortions;

- spatial variations of speed of sound;

- variations of flow velocity, speed of sound and discharge with time.

The first eight items listed are usually combined into an overall instrument uncertainty.

This next four items are associated with the flow field and its treatment and may result in a correction factor and possibly and additional systematic uncertainty. This systematic and may result in a correction with the instrument uncertainty in a root mean square relationship to produce an overall systematic uncertainty. The last item associated with the time variations of low velocity and speed of sound results in a random uncertainty.

Limited experience with the use of this method does mot permit the reliable assessment of a two-plane meter will likely reduce the overall systematic uncertainty which might be assumed as being of the same order of magnitude as for currtent meters used in the same conditions, i.c. between ±1.0% and ±2.0%.

Appendix 9
Water Hammer[*1]

1. General

Pressure waves occur at the location of closer of hydraulic turbine in corresponding to the change of velocity inside of penstock, which will be caused by operation of closer for increase or decrease of plant discharges. These pressure waves with constant propagation velocities reciprocate inside the penstock and give pressures to penstocks. Such a pressure is called as 'Water Hammer'. The water hammer is at the maximum equivalent to 10 – 30 % of statistic water head at the location of closers and is gradually decreased along the penstock toward the upstream, eventually disappearing at the locations of water surfaces around the inlet of penstock.

The closer of hydraulic turbine is not carried out by the main valves of penstock but by the guide vanes for both types of Francis and Kaplan hydraulic turbines and by the needle valves for the type of Pelton type hydraulic turbines. The water hammer is to be calculated for designs of penstock in assumption that the end point of penstock is at the center of hydraulic turbine and accordingly the closer is located at the center of hydraulic turbine.

2. Propagation Speed of Pressure Waves

Such a propagation waves as occurs at the location of the closer and reciprocates inside conduit is given by the following equation:

$$a = \frac{1}{\sqrt{\frac{w}{g}\left(\frac{1}{K}+\frac{1}{E}\frac{D}{t}\right)}} \quad \cdots\cdots (1)$$

Where,

a : Propagation velocity of pressure waves (m/sec),

D : Diameter of penstock (m),

t : Thickness of penstock steel liners (m),

w : Unit weight of water （=1[t/m^3]）,

g : gravity acceleration (= 9.8[m/sec^2])

K : Elastic coefficient of volume for water (≒2×10^5[t/m^2])

E : Modulus of elasticity for steel liners (≒2.1×10^7[t/m^2])

Note: *1: Source from 'Exercise on Water Power Engineering', pp.364 to 368, S. Chiaki, Japan

To calculate 'a' by use of Eq. (1), it is necessary to determine 't' of thickness of steel liners for penstock in advance. Table 1 is useful for this preliminary determination of 't'.

Table 1 Approximate Values of Propagation Velocity

H_0 (m) Statistic water head prior to closing	a (m/sec) Water hammer
10	665
30	717
60	777
100	837
140	883
300	1000
600	1110
1000	1184

See the note shown on page A9-1.

In the case when sectional areas of penstock are variable, a constant area of A_m equivalent to variable sectional areas, a constant velocity of v_{0m} equivalent to variable velocities and a constant propagation velocity of a_m equivalent to variable propagation velocities are applicable as determined below.

$$A_m = \frac{\Sigma L_i}{\Sigma\left(\frac{L_i}{A_i}\right)} \quad \cdots\cdots (2)$$

$$v_{0m} = \frac{Q_0}{A_m} \quad \cdots\cdots (3)$$

$$a_m = \frac{\Sigma L_i}{\Sigma\left(\frac{L_i}{a_i}\right)} \quad \cdots\cdots (4)$$

Where,

L_i, A_i and a_i: Length, sectional area and propagation velocity of the i^{th} section of penstock

3. Water Hammer in The Case of Rapid Closing

In the case when the length of penstock, the propagation velocity and the closing time of closer are respectively presented as L, a and T, the rapid closing and the slow losing

are respectively corresponding to T ＜ 2L/a and T ＞ 2L/aThe value of water hammer in the case of rapid closing is presented by the following Joukowsky's equation:

$$h = \frac{a.v_0}{g} \quad \cdots\cdots (5)$$

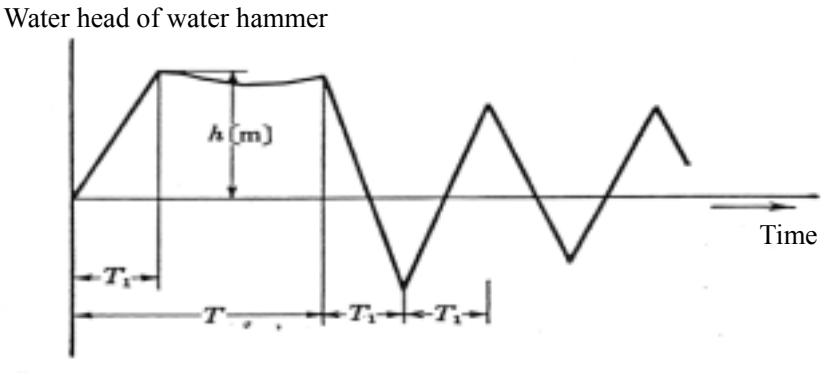
Where,

h：Water head of water hammer (m)、

v_0：Velocity inside of penstock before closing (m/sec)

In the case of g = 9.8(m/sec^2)、a = 1000(m/sec)、v_0 = 5(m/sec), h: water head of water hammer is calculated as h ≒ 500(m), which shows that extremely big pressure rise will be cased by a rapid closing.

4. Water Hammer in The Case of Slow Closing

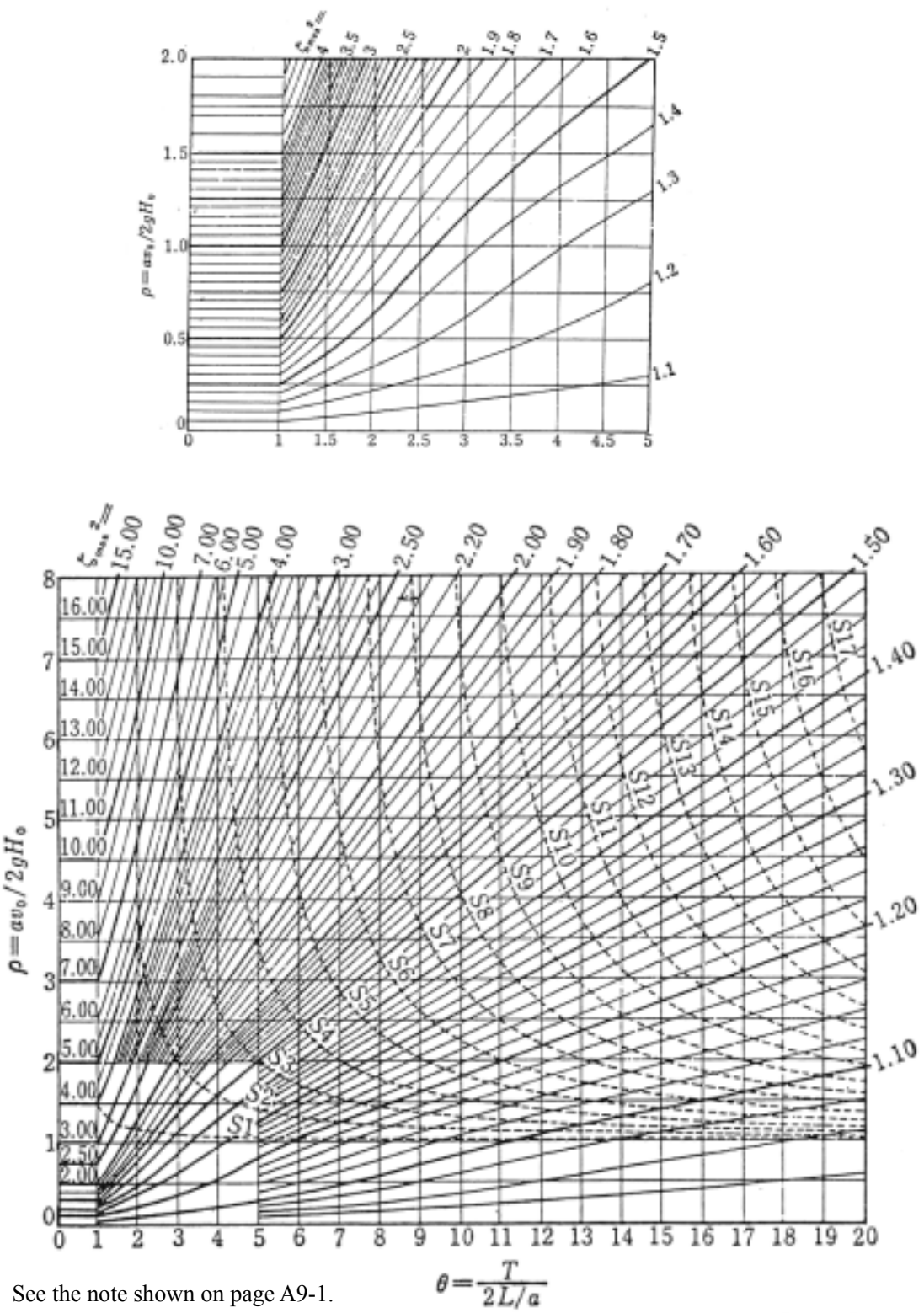


T: Closing Time ＞ T1=2L/a

Figure 1 Change of Water Hammer at The Closer according to Change of Time

Due to the result mentioned in the above case study, it is necessary to adjust the closing time to satisfy T ＞ 2L/a (slow closing).

Figure A1.10.1 shows the water hammer in the case of the slow closing which changes in line with passing time. As is shown in this figure, the water hammer reciprocates several times between the closer and the inlet of penstock and during reciprocation it gives rise to the maximum pressure rise. After closing the closer, plus pressure waves or negative pressure waves repeatedly occur and those pressure waves eventually disappear due to frictions.



See the note shown on page A9-1.

Figure 3 Nomogram of Maximum Pressure Rise in The Case of Rectilinear Slow Closing

Figure A1.10.3 is nomograms to calculate the maximum pressure rise at the closer in the case of the slow closing, which Allievi prepared. It includes maximum pressure rises (a full line) and occurrence cycles of maximum pressures (a dashed line) as well. The symbols used in the figure are as follows:

$$\rho = \frac{av_0}{2gH_0}, \qquad \theta = \frac{av_0}{\frac{2L}{a}}, \qquad \zeta_{max^2} = \frac{h_m+H_0}{H_0}$$

S_i = i^{th} cycle number when the maximum pressure rise occurs

Where,

H_0 : Statistic water head at the location of the closer (m)

h_m : Maximum water pressure rise due to water hammer (m)

L : Penstock length (m)、

v_0 : Water velocity inside conduit (m/sec)

T : Closing time (sec)、

a : Propagation velocity of water hammer (m/sec)

'ρ' is called as a conduit constant and its values are subject to the values of H_0 as shown in Table 3

Table 3 Range of Conduit Constant of 'ρ'

H_0 (m)	ρ
1000 - 200	0.1 – 1.0
200 - 30	1.0 - 6
30 - 15	6 - 12

See the note shown on page A9-1.

As is clear from Figure A 1.10.3, the maximum water hammer occurs at the 1st cycle in the case of $\rho <$ 1.0. The values around the end of closing become almost invariable, accordingly Allievi provided the approximate formula to calculate the final water hammer as follows:

$$h_m = (\zeta_m{}^2 - 1)H_0$$

Where,

$$\zeta_m = \frac{p}{2\theta} + \sqrt{\left(\frac{p}{2\theta}\right)^2 + 1} \qquad \cdots\cdots(6)$$

or

$$h_m = \frac{NH_0}{2} + \frac{H_0}{2}\sqrt{N^2+4N} \qquad \cdots\cdots(7)$$

Where,

$$N = \left(\frac{Lv_0}{gTH_0}\right)^2$$

In addition, the Spare' formula is provided below to cover the ratio water pressure rise less than 50 %, which was obtained by further simplification of the Allievi's approximate formula.

$$\zeta_m^2 - 1 = \frac{p}{\theta}\,\frac{2}{\left(2 - \frac{p}{\theta}\right)} \quad \cdots\cdots(8)$$

In the case when both of ρ and θ are big, the final water hammer of 'h_m' achievable by Eq. (8) gives the maximum pressure rise.

Such an Allievi's nomogram and an approximate formula as discussed above are applicable for a penstock without bifurcation. As to a penstock with bifurcation, a penstock with surge tank and a penstock of pumped storage power plants, it is advised to refer to other references[*2] for calculations of water hammer.

5. Ratio of Water Pressure Rise for Hydraulic Turbines Design

The maximum water pressure rises by water hammer are generally defined as the ratios of water pressure rise at the center of hydraulic turbines to design hydraulic turbines and casings as shown in Table 4.

Table 4 Ratio of Water Pressure Rise at Center of Hydraulic Turbines

Type of Hydraulic Turbines	Ratio of Water Pressure Rise (h_m/H_0)
Pelton-type Hydraulic Turbine with Deflector	0.10 – 0.15
Francis-type Hydraulic Turbine with Pressure Controller	0.10 – 0.20
Francis-type Hydraulic Turbin without Pressure Controller	0.20 – 0.30
Propeller-type Hydraulic Turbines	0.30 – 0.40

See the note shown on page A9-1.