ANSI/IEEE Std 125-1988
(Revision of ANSI/IEEE Std 125-1977)

An American National Standard

IEEE Recommended Practice for Preparation of Equipment Specifications for Speed-Governing of Hydraulic Turbines Intended to Drive Electric Generators

Sponsor
**Power Generation Committee
of the
Power Engineering Society**

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Foreword

(This Foreword is not a part of ANSI/IEEE Std 125-1988, IEEE Recommended Practice for Preparation of Equipment Specifications for Speed-Governing of Hydraulic Turbines Intended to Drive Electric Generators).

The 1977 revision of IEEE Std 125 was prepared by a joint IEEE-ASME Working Group formed in December of 1971. The personnel of this Working Group were appointed by J. T. Madill, Chairman, Hydroelectric Power Subcommittee, IEEE, at the direction of W. S. Morgan, Chairman, Power Generation Committee, IEEE, in cooperation with ASME.

The 1988 revision of the standard was initiated in 1982 by R. D. Handel, Chairman, Hydroelectric Power Subcommittee, Power Generation Committee, IEEE, in cooperation with W. O. Hays, Director, Power Test Codes, ASME. The Working Group that formulated the 1988 standard included representatives from IEEE and ASME.

The standard includes the latest practices on the North American continent and, insofar as possible, has been made consistent with ANSI/ASME Std PTC29-1980 (R1985), Speed-Governing Systems for Hydraulic Turbine-Generator Units, and IEC Std 308-1970, International Code for Testing of Speed Governing Systems for Hydraulic Turbines.

As the title implies, this document is a recommended practice and not a complete specification. It has been developed to be used by prospective purchasers of hydraulic turbine governors in preparing detailed procurement specifications for such equipment. In certain cases, performance criteria such as temperature range or fluid velocity, representative of North American practice, have been included; the specification writer may wish to verify their applicability to his job.

Section 2. defines terms, functions, and characteristics as commonly used in North America. Wherever possible, the 1988 revision utilizes symbols adopted by IEC Std 308-1970, International Code for Testing of Speed Governing Systems for Hydraulic Turbines. A number of definitions covering detailed aspects of control system frequency response have been deleted from the 1988 revision, as these definitions are well covered in ANSI Std MC85.1M-1981, Terminology for Automatic Control.

Section 3. describes specific components that may be included in a governor system. The purchaser should specify only those components he feels are required to interface with his equipment. The practice should not be incorporated verbatim, as it contains certain explanatory comments directed to the specification writer. When convenient, these explanatory comments have been enclosed in parentheses. The 1988 revision addresses equipment aspects that have gained prominence since release of the 1977 standard, in particular those related to electric-hydraulic governors. Included are new guide specifications on power supply design (reliability and redundancy considerations), transient immunity (emi and rfi), electronic components, test facilities, and accessories such as generation control circuits. Also, a number of the equipment specifications have been revised to reflect the latest industry practices and to provide consistency in terminology. In particular, clarification has been provided on the sizing of the hydraulic pressure tank for adjustable blade and impulse turbines. In addition to the special considerations affecting electric governors outlined above, guide specifications have been added for items common to both non-electric and electric governors. These include auxiliary components for pump turbines, cabinet construction, ac and dc control power, rotor creep detector, fire protection system, emergency stop controls, and hydraulic pressure supply system accessories.

Section 4. defines the performance characteristics of a good governor system and adjustments and tests to obtain and confirm the desired performance. Prior to or concurrent with the writing of the specification, the purchaser should make studies to determine the required performance and the adjustments associated with that performance. The purchaser should also determine what tests are necessary to confirm that the desired performance has been obtained. Specifications related to the adequacy of the damping system have been clarified in the 1988 revision. A paragraph has also been included on the requirements for stability studies to be conducted by the governor manufacturer.

Section 5. is intended to make sufficient information available to the purchaser so that he can assure himself that the governor equipment will interface properly with other equipment. It is also intended to provide adequate information for maintenance purposes.

Section 6. deals with the criteria for acceptance tests.

Section 7. lists the data that will be furnished by the purchaser. Tests for evaluating the speed control performance, included in Appendix I, have been clarified in the 1988 revision to reflect the current practices of users.

At the time of approval of the 1977 standard the personnel of the Joint IEEE/ASME Working Group on Updating IEEE Specification No 125 Covering Speed-Governing of Hydraulic Turbines Intended to Drive Electric Generators was as follows:

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CLAUSE PAGE

An American National Standard

IEEE Recommended Practice for Preparation of Equipment Specifications for Speed-Governing of Hydraulic Turbines Intended to Drive Electric Generators

1. Introduction

1.1 Purpose

The purpose of this practice is to recommend minimum performance characteristics and equipment relating to governors for controlling hydraulic turbines intended to drive electric generators and to aid in preparation of procurement specifications.

1.2 Scope

This practice shall apply to mechanical-hydraulic or electric-hydraulic type governors for all types of hydraulic turbines including but not limited to the following types:

a) Impulse Turbines
b) Francis Turbines
c) Fixed Blade (Axial or Mixed-Flow) Turbines
d) Adjustable Blade (Axial or Mixed-Flow) Turbines
e) Pump Turbines

It is recommended that the issue in effect on the date of invitation to bid of ANSI/ASME PTC29-1980 (R1985), Speed-Governing Systems for Hydraulic Turbine-Generator Units [4],[1] be used with this practice.

Only those paragraphs that apply to the specific equipment to be purchased should be used when preparing the procurement specifications.

1.3 References

This recommended practice shall be used in conjunction with the following publications:

[1]The numbers in brackets correspond to those of the References in 1.3.

[1] ANSI Std B93.11M-1981, Seamless Low Carbon Steel Hydraulic Line Tubing.[2]

[2] ANSI Std MC85.1M-1981, Terminology for Automatic Control.

[3] ANSI/ASME Std B31.1-1986 (SI Edition, 1983), Power Piping.[3]

[4] ANSI/ASME Std PTC29-1980 (R1985), Speed-Governing Systems for Hydraulic Turbine-Generator Units.

[5] ANSI/IEEE Std C37.90.1-1974 (R1980), Relays-Surge Withstand Capability (SWC) Test.[4]

[6] ANSI/SAE Std J514-1980, Hydraulic Tube Fittings.[5]

[7] IEC Std 308-1970, International Code for Testing of Speed Governing Systems for Hydraulic Turbines.[6]

2. Glossary of Terms, Functions, and Characteristics

2.1 Glossary of Terms

governing system. The combination of devices and mechanisms that detects speed deviation and converts it into a change in servomotor position. It includes the speed sensing elements, the governor control actuator, the hydraulic pressure supply system, and the turbine control servomotor. The terms “governor” and “governor equipment” are commonly used in the industry to describe the governing system and will be used interchangeably with the term “governing system” in this specification.

speed sensing elements. The speed responsive elements that determine speed and influence the action of other elements of the governing system. Included are the means used to transmit a signal proportional to the speed of the turbine to the governor.

governor control actuator. The combination of devices and mechanisms that detects a speed error and develops a corresponding hydraulic control output to the turbine control servomotors, but does not include the turbine control servomotors. Includes gate, blade, deflector, or needle control, or all equipment as appropriate.

hydraulic pressure supply system. The pumps, means for driving them, pressure and sump tanks, valves and piping connecting the various parts of the governing system, and associated and accessory devices.

electric-hydraulic governor. A governor in which the control signal is proportional to speed error and the stabilizing signals are developed electrically, summed by appropriate electrical networks, and are then hydraulically amplified. Electrical signals may be derived by analog or digital means.

mechanical-hydraulic governor. A governor in which the control signal proportional to speed error and necessary stabilizing signals are developed mechanically, summed by a mechanical system, and are then hydraulically amplified.

2.1.7 distributing valve. The element of the governor-control actuator that controls the flow of hydraulic fluid to the turbine-control servomotor(s).

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[2]All of the standards referenced in this recommended practice are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.
[3]ASME publications can be obtained from the Order Department, American Society of Mechanical Engineers, 22 Law Drive, Fairfield, NJ 07007.
[4]IEEE publications are available from the Service Center, the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.
[5]SAE publications are available from the Order Department, Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.
[6]IEC publications are available in the US from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

speed changer. A device for changing the governor speed reference (see 2.2.19).

speed regulation changer. A device for changing the speed regulation (see 2.2.5).

speed droop changer. A device for changing the speed droop (see 2.2.5).

servomotor limit. A device that acts on the governor system to prevent the turbine-control servomotor from opening beyond the position for which the device is set.

turbine control servomotor. The actuating element that moves the turbine-control mechanism in response to the action of the governor control actuator. Turbine-control servomotors are designated as:

a) gate servomotor
b) blade servomotor
c) deflector servomotor
d) needle servomotor.

slow closure device. A cushioning device that retards the closing velocity of the servomotor from a predetermined servomotor position to zero servomotor position.

servomotor velocity limiter. A device that functions to limit the servomotor velocity in either the opening, closing, or both directions exclusive of the operation of the slow closure device (above).

governor control actuator rating. The governor control actuator rating is the flow rate in volume per unit time that the governor actuator can deliver at a specified pressure drop. The pressure drop shall be measured across the terminating pipe connections to the turbine control servomotors at the actuator. This pressure drop is measured with the specified minimum normal working pressure of the hydraulic pressure supply system delivered to the supply port of the actuator distributing valve.

2.2 Functions and Characteristics	**Unit**	**Symbol**
2.2.1 Servomotor Stroke. Travel of the turbine-control servomotor from minimum (zero) position to maximum position without overtravel at the maximum position or “squeeze” at the minimum position (sometimes referred to as “effective servomotor stroke”). For a gate or needle servomotor this shall be established as the travel of the servomotor required to change the gate or needle position from nodischarge to maximum discharge. For a blade servomotor this shall be established as the travel of the servomotor required to change the blade position from “flat” to “steep.” For a deflector servomotor this shall be established as the travel of the servomotor required to change the deflector position from the “no deflection” position to the “full flow deflected” position with maximum discharge under maximum specified head, including over-pressure due to water hammer.	inch or millimeter	Y_M
2.2.2 Servomotor Position. The instantaneous position of the turbine-control servomotor measured from its zero position expressed as a percentage of the servomotor stroke. This is commonly referred to as gate position, needle position, blade position, or deflector position, although the relationship between servomotor stroke and the position of the controlled device may not always be linear.	percent	Y
2.2.3 Servomotor Time. The elapsed time for one servomotor stroke (either opening or closing) at maximum servomotor velocity (see Fig 1). Servomotor time can be qualified as follows:	second	T
(a) gate	second	T_G
(b) blade	second	T_B
(c) deflector	second	T_D
(d) needle	second	T_N

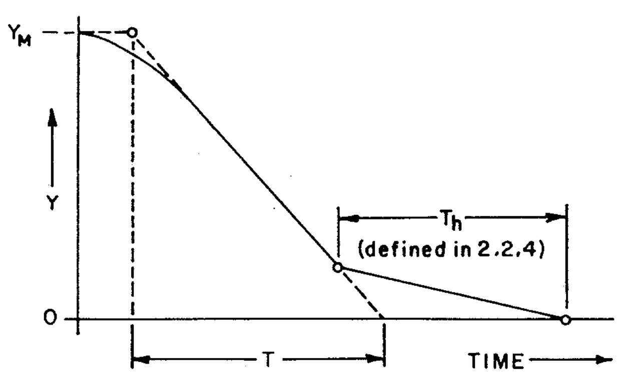
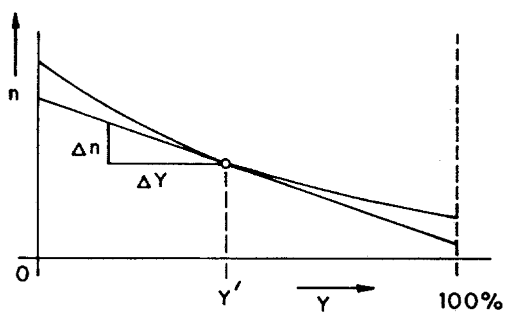


Figure 1—Servomotor Time and Cushioning Time

2.2.4 Cushioning Time. The elapsed time during which the closing rate of servomotor travel is retarded by the slow closure device (see Fig 1).	second	T_h

2.2 Functions and Characteristics	Unit	Symbol
2.2.5 Speed Droop and Speed Regulation. The speed droop graph describes the relationship between the steady state speed *n*, expressed as a percentage of rated speed, and the steady state turbine servomotor position *Y*, expressed as a percentage of servomotor stroke, at a particular setting of the governor speed reference. The speed regulation graph describes the relationship between the steady state speed n and the steady state generator power output P, expressed as a percentage of rated power output, at a particular setting of the governor speed reference. The speed droop and speed regulation graphsmay indicate a nonlinear relationship between the two measured variables depending on the setting of the governor speed reference and the quantity (servomotor position or generator power output) used to develop the feedback signal used in the governor system. Speed droop and speed regulation are considered positive when speed increases with a decrease in gate position or power output.		
2.2.5.1 Speed Droop.  **Figure 2—Speed Droop Graph** NOTE — n, Δn defined in 2.2.18 and 2.2.20 respectively. The slope of the speed droop graph at a specified point of operation Y'. $b = \left(\frac{-\Delta n}{\Delta Y}\right) \cdot (100).$ Speed droop is classified as either permanent or temporary.	perecent	b
(1) Permanent speed droop. The speed droop that remains in steady state after the decay action of the damping device has been completed.	percent	b_p
(2) Temporary speed droop. The speed droop in steady state that would occur if the decay action of the damping device were blocked and the permanent speed droop were made inactive.	percent	b_t

<table>
<tr><th>2.2 Functions and Characteristics</th><th>Unit</th><th>Symbol</th></tr>
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2.2.5.2 Speed Regulation.

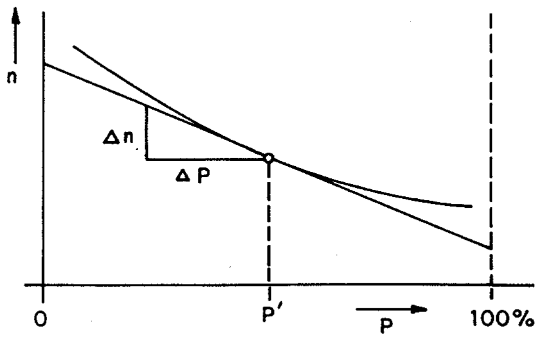

Figure 3—Speed Regulation Graph

The slope of the speed regulation graph at a specified point of operation P'

$$R_s = \left(\frac{-\Delta n/100}{\Delta P/Pr}\right) \cdot (100)$$

NOTE — Δn, P, Pr are defined in 2.2.20, 2.2.21, and 2.2.22, espectively.

</td><td>percent</td><td>R_s</td></tr>
<tr><td>

2.2.6 Governor Speed Deadband. The maximum change in steady-state speed, expressed as a percentage of rated speed, required to reverse the direction of travel of the turbine-control servomotor.

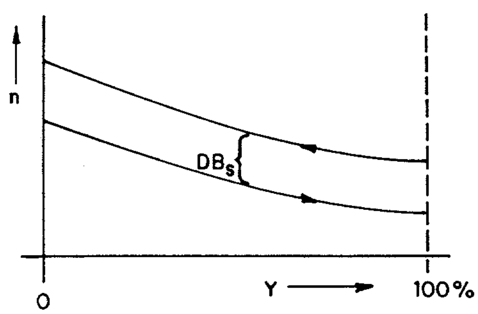

Figure 4—Speed Deadband

One half of the governor speed deadband is termed the governor speed insensitivity.

</td><td>percent</td><td>DB_s</td></tr>
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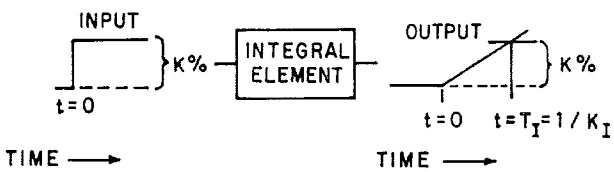
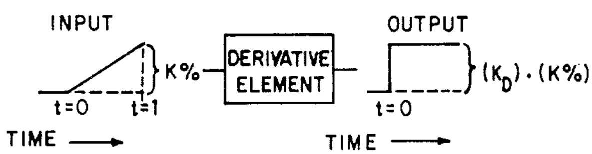
2.2.7 Blade Control Deadband. The maximum change in the blade control cam follower position required to reverse the travel of the blade control servomotor. The deadband is expressed as a percentage of the change in cam follower position required to move the blades from extreme "flat" to extreme "steep."

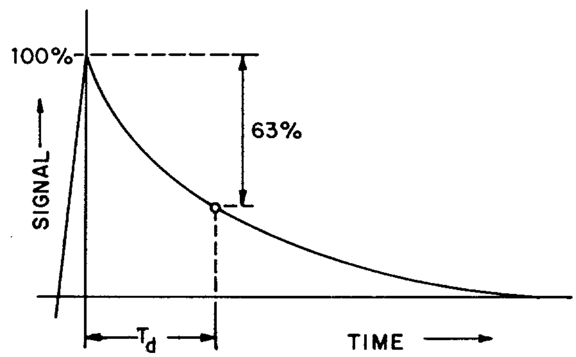
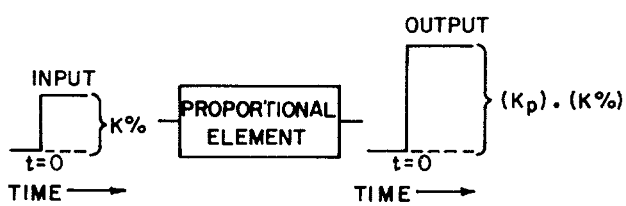
</td><td>percent</td><td>DB_B</td></tr>
<tr><td>

2.2.8 Governor Dead Time. Dead time is the time interval between the initiation of a specified change in steady-state speed and the first detectable movement of the turbine-control servomotor.

</td><td>second</td><td>T_q</td></tr>
</table>

2.2 Functions and Characteristics	Unit	Symbol
2.2.9 Stability. The capability of the governor and the system controlled by the governor to limit oscillations of speed or power under sustained conditions, to damp oscillations of speed following rejection of load, and to damp speed oscillations under isolated load conditions following sudden load changes.		
2.2.10 Rated Speed. The value stated on the unit nameplate.	rpm	n_N
2.2.11 Overspeed. Any speed in excess of rated speed expressed as a percentage of rated speed.	percent	n_t
2.2.12 Underspeed. Any speed below rated speed expressed as a percentage of rated speed.	percent	n_u
2.2.13 Maximum Momentary Speed Variation. The maximum momentary change of speed when the load is suddenly changed a specified amount, expressed as a percentage of rated speed.	pecent	
2.2.14 Runaway Speed. The speed for that position of the turbine-control servomotor(s) that produces the maximum steady state speed, with the machine disconnected from the load, not excited, and at maximum head, expressed as a percentage of rated speed. Characterized by failure of the governor or turbine-control mechanism(s) to respond to overspeed conditions.	percent	n_R
2.2.15 Rated Head. The value stated on the turbine nameplate.	foot or meter	H_r
2.2.16 Steady-State Governing Speed Band. The magnitude of the envelope of the speed variations caused by the governing system, expressed as a percentage of rated speed when the generating unit is operating independently and under steady-state load demand. Also called speed stability index.	percent	I_s
2.2.17 Steady-State Governing Load Band. The magnitude of the envelope of load variations caused by the governing system, expressed as a percentage of rated power output, when the generating unit is operating in parallel with other generators and under steady-state load demand. Also called power stability index.	percent	I_c
2.2.18 Speed. The instantaneous speed of rotation of the turbine expressed as a percentage of rated speed.	percent	n
2.2.19 Speed Reference. An adjustable setting that is compared to the actual speed of the turbine for purposes of controlling the speed or power output to a desired steady state value, expressed as a percentage of rated speed.	percent	n_{ref}
2.2.20 Speed Deviation. The instantaneous difference between the actual speed and the speed reference, expressed as a percentage of rated speed.	percent	Δn
2.2.21 Power Output. The electrical output of the turbine-generator unit as measured at the generator terminals.	watt	P
2.2.22 Rated Power Output. The value stated on the generator nameplate.	watt	P_r
2.2.23 Maximum Power Output. The maximum output that the turbine-generator unit is capable of developing at rated speed with maximum head and maximum gate.	watt	P_{max}

2.2 Functions and Characteristics	Unit	Symbol
2.2.24 Governor Feedback Control System. A closed loop or feedback control system is a control system in which the controlled quantity is measured and compared with a standard or reference representing the desired value of the controlled quantity and the comparison used to effect control. In hydraulic governors, any deviation from the reference is fed back into the control system in such a sense that it will reduce the deviationbetween the controlled quantity and the reference, providing negative feedback. Examples of controlled quantities are speed, servomotor position, and generator power output.		
2.2.25 Integral Gain. The integral gain of an integrating element is the ratio of the element's percent output to the time integral of the element's percent input. (The integral time constant of an integrating element, TI, is the reciprocal of its integral gain).  **Figure 5—Integral Gain**	(second)$^{-1}$	K_I
2.2.26 Derivative Gain. The derivative gain of a derivative element is the ratio of the element's percent output to the time derivative of the element's percent input (also referred to as the derivative time constant).  **Figure 6—Derivative Gain**	second	K_D

2.2 Functions and Characteristics	**Unit**	**Symbol**
2.2.27 Time Constant of the Damping Device. A time constant that describes the decay of the output signal from the damping device. (See Fig 7.)  **Figure 7—Time Constant of the Damping Device**	seond	T_d
2.2.28 Proportional Gain. The proportional gain of a proportional element is the ratio of the element's percent output to its percent input. A linear relationship is assumed.  **Figure 8—Proportional Gain**		K_p
2.2.29 Water Inertia Time. A characteristic time, usually taken at rated conditions, due to inertia of the water in the water passages from intake to exit defined as: $T_w = \frac{Q_r}{gH_r}\int\frac{dL}{A} \approx \frac{Q_r}{gH_r}\sum\frac{L}{A}$ where: A =area of each section, ft^2 L =corresponding length of each section, ft Qr =rated discharge, ft^3/s H_r =rated head, ft g =acceleration due to gravity, 32 ft/s^2	second	T_ω

2.2 Functions and Characteristics	Unit	Symbol
2.2.30 Mechanical Inertia Time. A characteristic of the turbine-generator due to the inertia of the rotating components defined as: $T_M = \frac{(Wk^2)(nN)^2(10^{-6})}{(1.61)(HP)}$ where: W =weight of turbine and generator rotating parts, pounds k =radius of gyration, feet n_N =rated speed, rev/min HP =rated output of turbine, horsepower. NOTES: 1 — T_M is also approximately equal to 2H, where H is the inertia constant. 2 — To calculate T_M using SI units, $T_M = J\omega_0^2/P_o$ where *J* is the polar moment of inertia in kg·m2 calculated by dividing Wk^2 in $N{\cdot}m^2$ by acceleration of gravity, 9.81 $m/s^2 = Mk^2 = GD^2/4g$; $\omega = 2\pi N/60$, rad/second; and P_o is the rated output of turbine, watts.	second	T_M

3. Equipment Specifications

3.1 General

3.1.1 Terms and Definitions

All terms and definitions used are in accordance with Sec 2 of this specification.

3.1.2 Cooperation of Manufacturers

The manufacturer of the governor shall cooperate to the fullest extent possible with the turbine and generator manufacturers to ensure that the purchaser is furnished with a complete and properly coordinated governor system capable of functioning to properly regulate the speed and load of the turbine.

3.1.3 Governor Equipment

The governors furnished under these specifications shall sense the speed of turbine rotation, generate a signal proportional to the difference between the turbine speed and the governor speed reference, and therefrom develop a hydraulic control signal of sufficient power to regulate the main servomotors to control a hydraulic turbine in accordance with the requirements of this specification. The governor control actuator rating shall be adequate to operate the turbine control servomotors in the minimum time specified by the purchaser, taking into account the pressure drops of piping external to the actuator. The governor equipment shall be complete with speed sensing elements, governor control actuator, hydraulic pressure supply system, and all parts and specified accessories required to control the speed or load or both of the generating unit to which it is applied. (Many commonly used auxiliary devices are described by this practice and only those applicable to a particular installation should be included in the governor specification. The main control servomotors may be supplied by the turbine manufacturer.)

3.1.4 Governor Cabinet Construction

The governor control actuator and related accessories shall be housed in a steel cabinet that shall provide physical protection for the components. (The specification writer may include detailed requirements related to cabinet size, paint system, grounding, cable access, and wiring). For electric-hydraulic governors the electrical mechanisms shall be mounted in a separate housing located within the governor cabinet, or may instead be mounted in a panel or cabinet located remotely from the governor cabinet.

3.1.5 Special Considerations Affecting Electric-Hydraulic Governors

(If an electric-hydraulic governor is specified, the following clauses may be included. The possible added cost of these features should be considered in relation to the size and importance of the turbine-generator unit).

3.1.5.1 Power Supplies

A reliable power supply system shall be provided for powering the governor electronic circuits. The power supply system shall include redundant converters (dc-dc) connected to the station battery source such that failure of any regulated output voltage shall cause instantaneous transfer to a redundant converter without affecting normal governor operation in any way. (Non-redundant power supplies may be specified, in which case protection should be provided to lock the governor or trip the turbine-generator unit upon power supply failure). Contacts shall be provided to alarm on power supply failure and local indication shall be provided to identify the failed functional block. The manufacturer shall provide full details of the proposed power supply system for approval by the purchaser.

3.1.5.2 Transient Immunity

The governing system shall be immune from false operation or failure from high voltage, high frequency transients that may be conducted in the control circuitry and power supplies internal and external to the governor system. To reduce the transients coupled from external sources, the purchaser may provide shielded cables for connection to external equipment and will ensure that surge suppression devices are installed on inductive devices supplied by others. The manufacturer shall assume, however, that high voltage, high frequency transients will persist in the external circuitry. Special precautions shall be taken to limit exposure of sensitive governor electronic circuits connected to remote equipment. The manufacturer shall isolate these circuits by means of solid state optically coupled or transformer coupled isolation amplifiers. All inductive devices, such as relays and solenoids shall be provided with suppression devices to limit surge voltages that may be generated when the coil circuits are interrupted. The governing system shall be designed and tested for surge withstand capability in accordance with ANSI/IEEE Std C37.90.1-1974 (R1980) , Relays-Surge Withstand Capability (SWC) Test [5]. The governing system shall be designed and tested to be insensitive to radiated high frequency interference such as that coupled from portable radio transmitters. (A field strength withstand level may be specified for the governing system. Typical values range between 10 V/m and 20 V/m over the frequency range of 25 MHz to 1000 MHz, measured at the equipment location. Alternatively, the power rating and frequency of the purchaser's transceivers and the operating distance between transceiver and equipment location may be specified.)

3.1.5.3 Electronic Equipment

All electronic equipment such as amplifiers and logic circuits shall be of solid state design using industrial or military grade discrete transistors or integrated circuits, bearing JEDEC or EIA registered device numbers. All components shall be suitable for operation at temperatures between 0 °C and 70 °C.

3.1.5.4 Test Facilities

The output of each functional block within the electronic portion of the governor shall be wired to a test jack accessible from the front to facilitate convenient measurement of circuit performance with a portable voltmeter or oscilloscope. The manufacturer shall isolate the test points electrically to ensure that grounding of a test jack does not cause a change in the output of the circuit under test. The controls shall be arranged to permit the electronic circuits to be tested and replaced while the turbine-generator unit is in service.

3.1.5.5 Governor Balance Meter

An indicating voltmeter, connected to measure the input to the main electric-hydraulic transducer, shall be provided on the governor cabinet. The voltmeter shall indicate the degree of misbalance or error between the desired servomotor position computed by the electric circuits and the actual servomotor position, for effecting bumpless transfer from manual to automatic governor control.

3.1.5.6 Actuator Lock

For electric-hydraulic governors, an automatic locking device shall be supplied that will cause the turbine control mechanism to lock at its last position in the event of speed sensor failure, power failure, or operation of other protective devices. The device shall allow the turbine control servomotors to close under action of the servomotor limit and automatic shutdown devices.

3.2 Components or Auxiliary Devices

3.2.1 Speed Changer

The speed changer shall cause the governor to vary the speed or power output of the turbine within the limits specified in Sec 4. The speed changer shall be suitable for synchronizing the generator for parallel operation with other generators, and for varying the speed or power output of the turbine. The speed changer shall permit manual adjustment by means of a control knob at the governor, and shall permit remote adjustment by means of a reversing drive motor. The setting of the speed changer shall be indicated at the governor by means of a dial calibrated in % of rated speed. (As an option, the functions of speed setting and load setting may be separated. Circuits for interfacing to automatic generation control systems may be specified for electric-hydraulic governors.)

3.2.2 Servomotor Limit

Equipment shall be provided to establish the maximum allowable position of the main turbine servomotor, adjustable from zero to full servomotor stroke. The adjustment shall be by means of a control knob at the governor with indication by a dial graduated in percent of servomotor stroke. The equipment shall also permit remote adjustment by means of a reversing drive motor and remote indication.

3.2.3 Speed Droop Changer

A device shall be provided to adjust the permanent speed droop over the range specified in Sec 4. The adjustment shall be by means of a control knob at the governor with indication by a dial graduated in percent speed droop.

3.2.4 Speed Regulation Changer

A device shall be provided to adjust the speed regulation over the range of values specified in Sec 4. The adjustment shall be by means of a control knob at the governor with indication by a dial graduated in percent speed regulation.

3.2.5 Servomotor Velocity Adjustment

Both the opening and closing servomotor velocities shall be independently adjustable. The method of adjustment shall be such that operation of any control, automatic, or auxiliary device cannot cause the turbine gate servomotors to move at a velocity greater than that set by the adjustments. These velocities may be expressed in servomotor times if preferred.

3.2.6 Restoring Connections

A system shall be provided for transmitting the position of the turbine servomotors to the governor. The connections shall be provided and arranged such that any failure in the restoring system will cause the turbine control servomotors to respond in the manner specified by the purchaser.

3.2.7 Speed Sensor Source

The signal source for the speed sensor shall be either potential transformer(s) connected to the generator terminals or an independent source coupled to or surrounding the main shaft. If the source is coupled to or surrounds the main shaft, it shall be furnished by the governor manufacturer. Potential transformers are usually furnished as part of the electric equipment and not with the governor equipment. The range and accuracy of the speed sensor source shall be compatible with the governor performance requirements and the adjustment range specified for the electrically actuated speed switches (see 3.2.19.2). If the speed sensor source is coupled to or surrounds the main shaft, it shall be capable of withstanding a specified maximum overspeed.

3.2.8 Manual Control

The governor shall have means for controlling the turbine gate position manually. A suitable changeover device shall be provided so that the change from governor to manual control can be made rapidly and conveniently and without the possibility of releasing the gates from both controls simultaneously.

3.2.9 Servomotor Position Indicator

Indication shall be furnished at the governor to indicate the position of the turbine-control servomotor. The scale shall be calibrated in percent of servomotor stroke. (This device may be combined with the servomotor limit indication, see 3.2.2, in a dual indicator.)

3.2.10 Automatic Shutdown

Devices shall be furnished to cause automatic closure of the turbine control servomotors on occurrence of specified actions or system limits. The devices shall cause partial shutdown to speed-no-load or complete shutdown, or both. Limit switches shall be provided on each device for indication and control purposes.

3.2.11 Emergency Stop Pushbutton

A pushbutton shall be provided, to initiate emergency shutdown of the turbine. Contacts shall be provided on the emergency stop pushbutton for use in the purchaser's protection equipment.

3.2.12 Generator Air Braking System Control

A solenoid-operated air valve, with provisions for emergency hand operation, shall be supplied for controlling the operation of the generator air brakes. Control of the solenoid operation of the air valve shall be initiated by a control switch mounted at the governor or at a remote location. Electrical operation of the solenoid valve shall not occur until the turbine control servomotors are fully closed, the generator is disconnected from the bus, and the speed of the unit has decreased to the setting of an underspeed switch. Unless otherwise specified, the control shall cause the generator brakes to be applied continuously and not be released after the unit has come to a stop.

A hand control device shall be provided on the solenoid valve to permit manual application of the brakes. This device shall include a spring-loaded hand release that shall operate an interlock to break the electrical circuit to the solenoid and shall be independent of the electrical circuit. It shall be possible to latch the manual control in the "brakes on" po sition.

3.2.13 Air Brake Pressure Gauge

Dual indication, graduated in specified units for indicating the air pressure in the air supply system and also in the generator brake cylinders shall be furnished at the governor.

3.2.14 Speed Indicators

An electrically operated speed indicator, complete with suitable means for producing an electrical signal proportional to turbine speed, shall be mounted at the governor. The dial shall be calibrated in hertz, rpm, or percent of rated speed. The rated speed point shall be at the midscale point with the pointer in a vertical position.

Provisions shall be made for calibrating the speed indicator.

3.2.15 Adjustable Blade Control

3.2.15.1 General

For adjustable blade type turbines the necessary controls shall be provided to position the turbine runner blades in accordance with the turbine manufacturer's requirements for an optimal relationship between the gates, blade angle, and head. The control shall be arranged such that upon loss of governor oil pressure the blades are allowed to move to the position of steepest pitch.

3.2.15.2 Blade Controller

A controller shall be provided to program the optimal blade position as a function of main servomotor position and head. The steady state blade position shall not deviate by more than 1% of full scale from the required value over the full range of main servomotor position and over the full range of head.

3.2.15.3 Blade Lock Solenoid

A solenoid operated device shall be provided that, when energized/de-energized, shall prevent further movement of the turbine runner blades. This device shall maintain the fixed runner blade position regardless of normal hydraulic fluid leakage in the control system, turbine fluid head, or blade servomotor.

The solenoid may be interlocked through the following devices:

1) governor hydraulic fluid pressure switch
2) blade angle position switch
3) turbine fluid head level switch
4) blade tilt solenoid auxiliary switch

3.2.15.4 Manual Control

A manual control for runner blade position shall be provided that will disable the blade controller and make it possible to set and hold the blade angle at any pitch for test purposes.

3.2.15.5 Blade Angle Indicator

A blade angle indicator shall be supplied at the governor to show the position of the turbine runner blades. The blade angle indicator shall be field-calibrated to show runner blade angular position as a percentage of full range.

3.2.16 Impulse Turbine Needle(s) and Deflector(s) Control

Controls shall be provided within the governing system to position the turbine needles and jet deflectors as required to control the impulse turbine in accordance with the specification. The difference in position between any two needles or between any two deflectors shall be less than 1% of full scale over the full operating range.

Under normal conditions, the needles shall control the flow of water to the turbine and the needles of all nozzles in service shall operate simultaneously, except when the number of needles in service is variable.

The deflector operation shall be coordinated with the needle operation so that upon an increase in speed a portion of each jet will be quickly deflected until the needles have closed a sufficient amount to allow passage of only enough water to maintain speed and power with the deflectors out of the stream. The deflectors shall enter the jets when the rate of load change is faster than can be handled by the needles.

3.2.17 Hydraulic Pressure Supply System

3.2.17.1 Pressure Pumps

The pressure pump(s) shall be motor-driven direct-connected positive displacement type. An unloading valve shall be provided that bypasses when the pressure has reached the maximum normal working pressure, so that the pump(s) is (are) working under pressure only when delivering fluid to the pressure tank. Alternatively, a pressure-actuated motor control shall be provided to stop and start the motor. A relief valve of sufficient capacity to pass the full delivery of the pump at a pressure 10% above the nominal system pressure (pressure at which the pumps normally stop) shall also be provided. The combined pumping capacity shall be not less than 25% of the sum of the individual servomotor volumes divided by the respective servomotor time. (It is recommended that all installations have dual pumps.)

3.2.17.2 Pressure Tank(s)

The pressure tank(s) shall be of welded construction, designed, built, and tested in accordance with the ASME Pressure Vessel Code, Section VII, Division I in effect at the time of issuing invitations to bid. The supplier shall be responsible for obtaining certification of the pressure tank(s) by the appropriate authority(ies) having jurisdiction in the purchaser's area. The tanks shall be fitted with a suitable pressure gauge safety valve, and a liquid level gauge glass with shutoff fittings. A float valve or other positive means of preventing air from entering the hydraulic piping system shall be provided.

When commencing with the oil level at the minimum normal operating level, and with the pressure pumps inoperative, the tank(s) shall be sized to provide a specified minimum number of strokes of each servomotor with a pressure drop not exceeding the difference between the nominal system pressure (pressure at which the pumps normally stop) and the minimum system pressure. (For a Francis turbine, a minimum of 2.5 or 3 strokes of each gate servomotor is often specified. For an adjustable blade turbine, blade control may be limited during gate operation and thus only 1 stroke of each blade servomotor may be required in addition to 2.5 or 3 strokes of each gate servomotor. Similar considerations exist for impulse turbines. It is recommended that pressure tank sizing be discussed with turbine and governor suppliers prior to finalizing the governor specification).

Necessary manholes shall be provided for cleaning and inspection.

3.2.17.3 Sump Tank

The sump tank shall be of cast or welded construction and provided with fine mesh screen strainers that are readily accessible for cleaning (mesh size of strainer to be specified or discussed with supplier). A gauge glass or other indicator shall be installed to show the level in the tank. The tank volume shall be not less than 110% of the volume of fluid that can be returned to the sump by system pressure and by gravity. Necessary manholes shall be provided for cleaning and inspection.

3.2.17.4 Automatic Air Admission System

An air admission system shall be provided that will automatically maintain the proper fluid-to-air ratio in the pressure tank. The air admission system shall be complete with necessary air compression devices, piping, and level or pressure sensors. (Automatic air admission may not be required in some cases.)

3.2.17.5 Electric Motors and Starters

(The purchaser must state his requirements for electric motors and starters and related equipment.) All electric motors and auxiliary equipment shall be capable of withstanding without injury overfrequencies and overvoltages accompanying maximum load rejection of the turbine-generator unit.

3.2.17.6 Piping and Fittings

All piping shall be suitable for use over a temperature range of -20 °F to +150 °F. Piping larger than 1 in nominal diameter shall conform to the edition in effect at the time of invitation for bid of ANSI/ASME Std B31.1-1986 (SI Edition, 1983), Power Piping [3], and all joints shall be of the bolted, flanged type. Threaded pipe may be used for piping 1 in and under. Piping shall be cleaned inside to remove mill scale. Unless otherwise specified, the fluid velocity in the pipes shall not exceed 18 ft/s. For adjustable blade turbine governors, provision shall be made to prevent the flow of electric currents in the piping to the runner blade servomotor. Control piping smaller than 1/2 in in diameter shall be hydraulic line seamless tubing conforming to the edition in effect at the time of invitation for bid of ANSI Std B93.11M-1981, Seamless Low Carbon Steel Hydraulic Line Tubing [1]. Fittings on control pressure piping shall be 37 degree flare fittings conforming to the edition in effect at the time of invitation for bid of ANSI/SAE Std J514-1980, Hydraulic Tube Fittings [6].

3.2.17.7 Hydraulic Pressure Supply System Pressure Gauge

An indicator shall be furnished at the governor, graduated in specified units, for indicating the working pressure of the hydraulic pressure supply system.

3.2.18 Nameplate

A permanent metal nameplate shall be provided on each governor, clearly marked or stamped to show:

1) The manufacturer’s name and address.
2) The serial number, model number, or type number, or both, and the date of manufacture.
3) The maximum safe working governor hydraulic pressure.
4) The minimum normal working governor hydraulic pressure.
5) The rated capacity in volume per unit time at the minimum normal working governor hydraulic pressure.

3.2.19 Switches

All switches shall have electrically separate contact circuits that shall be readily changeable from circuit opening to circuit closing as desired and have a minimum operating accuracy of 2% of their adjustment range. The contact circuits shall be suitable for continuous duty over a specified range of dc voltages and shall be capable of interrupting 1.5 A dc in a non-inductive circuit. When specified to be readily adjustable, a device shall be provided with a positive “non-critical” method of adjustment that does not require special tools. Where ready accessibility is required, the device shall be accessible from a reasonably upright position without the need for removing panels or other equipment. (The following switches, with the specified number of contact circuits, may be specified. The specification writer should prepare a table listing the desired modes of operation of each switch. It may be desirable to specify “screwdriver adjust” or equivalent to guard against unauthorized adjustment of certain switches.)

3.2.19.1 Overspeed Switch

An overspeed switch shall operate at a specified percent of rated speed and reset at not less than 105% of rated speed. This switch shall be operated mechanically by means of a positive coupling to the rotating elements of the turbine generating unit. (The overspeed switch is used to initiate protective shutdown sequences including intake gate or inlet valve closure, as required by the purchaser. Alternative mechanical-hydraulic overspeed shutdown devices may also be specified.)

3.2.19.2 Speed Switches

Speed switches shall be actuated mechanically by means of a positive coupling to the rotating elements of the turbine generator unit or shall be actuated electrically by comparing the governor speed signal to a reference signal. The speed switches shall be independently adjustable to operate over a specified range of turbine speeds.

3.2.19.3 Servomotor Limit Position Switch Assembly

Position switches on the gate limit device shall be readily adjustable to operate at any desired point throughout the full range of the gate-limit mechanism. Individual switch adjusting devices shall be readily accessible.

3.2.19.4 Servomotor Position Switch Assembly

Each position switch shall be readily adjustable to operate at any desired point throughout the full range of the servomotor motion. Individual switch adjusting devices shall be readily accessible.

3.2.19.5 Blade Angle Position Switch Assembly

Switches operated by the turbine runner blade motion for governors that control adjustable blade turbines. The switches shall be readily adjustable over the range specified.

3.2.19.6 Hydraulic System Pressure, Level, and Temperature Switches

Pressure, level, and temperature switches with adjust-able set points as specified. As a minimum, a low pressure switch shall be provided to initiate unit shutdown.

3.2.19.7 Coincidence Switch

A switch that will operate when the servomotor position equals the servomotor limit setting. This switch may be used as an interlock in the raise circuit of the speed changer motor or to provide remote indication.

3.2.19.8 Speed Changer Auxiliary Switches

Auxiliary switches operated by the speed changer adjusting mechanism. The switches shall be readily adjustable (stepwise or continuously) over the range specified.

3.2.19.9 Air Brake Pressure Switch

A pressure switch mounted in the governor cabinet shall be provided that operates on low pressure in the air supply system for the generator brakes.

3.2.20 Automatic Servomotor Lock Control

At the option of the purchaser, a hydraulic servomotor lock control assembly shall be provided that shall automatically lock the turbine control servomotor in the fully closed position when the unit is shut down. The piping shall be arranged to permit the servomotor lock to be controlled by manually operated valves located at the governor. The servomotor lock mechanism and its operating servomotor will be furnished by the turbine manufacturer and will include limit switches that operate when the servomotor lock mechanism is engaged or disengaged. (Solenoid operated servomotor locks may be furnished by the turbine manufacturer as an alternative to hydraulically operated locks. Governor control requirements should be discussed with the turbine manufacturer.)

3.2.21 Remote Control

Provision may be specified for remote control of any of the following:

1) control gain changing devices
2) speed changer
3) load changer
4) servomotor limit
5) speed droop/regulation
6) Automatic generator brake control

Except as otherwise specified, the equipment supplied by the manufacturer as specified herein is to be exclusive of control devices at points of remote control and also exclusive of any connecting means between points of remote control and the specified equipment.

3.2.22 Remote Indication

Provision may be specified for remote indication, including the instrument at the receiving position of:

1) servomotor position
2) runner blade angle for adjustable blade turbine governors
3) servomotor limit
4) load changer setting
5) speed droop/regulation
6) speed changer setting
7) shaft speed (rpm)
8) turbine start, stop, or creep detector indication
9) governor hydraulic pressure
10) pressure tank fluid level
11) governor balance

3.2.23 Automatic Control

Provisions shall be made for automatic starting and stopping of the turbine and governor pressure system as specified by the purchaser. These provisions may include partial (speed-no-load) or complete shutdown of the turbine and governor pressure system, or both.

3.2.24 Electrical Control Power

Dc control power will be made available from the purchaser's station battery within a specified range of voltage. All control solenoids, relays, power supplies, potentiometer drive motors, position transmitters, or other such governor equipment shall be operable within the stated voltage range. Three-phase and single-phase 60 Hz (50 Hz where applicable) ac power will be made available within specified ranges of voltage. The ac supplies will be subject to overfrequency following generator load rejection. It should be recognized that the ac supply is not secure and any system that uses the ac supply must be equipped with an alternate supply provided by the manufacturer so as to maintain security of the governor system. Assuming that adequate hydraulic pressure exists and that dc control power is available to the governor equipment, the turbine-generator shall be capable of being started with no ac power available.

3.2.25 Auxiliary Components for Pump Turbines

The following auxiliary components may be specified for pump turbine applications:

1) turbine runner drain valve control
2) adjustable gate servomotor rate control, both pumping and generating
3) gate servomotor vs net head optimizer
4) tailwater depression control

3.2.26 Rotor Creep Detector

A rotor creep sensing device shall be provided to give an alarm and to initiate protective control action when, upon braking, the rotor of the generator does not come to a complete stop after a suitable time delay, or after having come to a complete stop begins to creep due to brake failure or excessive water leakage or both. Upon energization, the device shall sense a subsequent angular displacement of 3 ° of arc or less, without reference to rate of movement. It shall respond to the creep condition by closing its output contacts and sealing-in until reset by external circuitry.

3.2.27 Fire Protection System

The governor cabinet may be provided with an automatic fire protection system including detectors (thermal or combustion products), discharge equipment, and the required control system. (Include detailed requirements for detectors, extinguishing agent, alarms, control and protection interlocks and circuit supervision, and reference to NFPA, FM, or other standards.)

3.2.28 Spare Parts and Accessories

The supplier shall provide a recommended spare parts list with price and delivery information. A list of any special tools and accessories necessary for operation and maintenance shall also be provided.

4. Performance Specification

4.1 Stability

The governor system shall be capable of controlling, in a stable manner, the speed of the turbine at all power outputs between zero and maximum power output inclusive when the generating unit is operating isolated, or the power output when the generating unit is operating in parallel with other generators.

The range of conditions covered by stability requirements includes sustained conditions, load rejection, and sudden changes of isolated load, both large and small.

4.1.1 Sustained Conditions

1) The steady-state governing speed band (also called speed stability index) under either speed-no-load or loaded conditions shall be no more than 0.3% with the unit operating at 5% speed droop or speed regulation.
2) The steady-state governing load band (also called power stability index) shall be no more than 0.4% with the unit operating at 5% speed droop or regulation.

4.1.2 Load Rejection

Following rejection to zero of any load within the capability of the governed unit, speed shall be returned to the speed reference as may be modified by speed droop or regulation, with no more than one underspeed deviation not to exceed 5% and one overspeed deviation not to exceed 5% subsequent to the initial overspeed deviation. This specification presumes that the turbine control servomotor cushion retards servomotor move-ment only in the closing direction and at servomotor positions less than speed-no-load. (Retardation by the turbine servomotor cushion system of servomotor movement in the opening direction may degrade recovery of speed control following rejection to zero load. Inclusion of this paragraph will require turbine model data and may require additional hardware.)

4.1.3 Speed Control, Fluctuating Isolated Load Basis

This requirement pertains to suitability of the principal damping system such as temporary speed droop or proportional, integral, and derivative action essential to loaded operation of hydraulic turbine governors. Performance for this isolated load condition is separately specified, since adequacy of the damping system for this condition is not ordinarily revealed by performance under sustained conditions or by the no-load condition following load rejection.

1) *Capability of Damping System*. The range and effectiveness of the primary damping system of the governor shall be capable of providing suitably damped control of speed when the unit serves an isolated resistive load. Suitably damped control of speed should be demonstrated while the unit is carrying an isolated resistive load of approximately 90% of rating. The hydraulic head should be within plus or minus 10% of rating for this demonstration. Suitability of damping of the speed deviations in the time domain should be shown following a sudden load change (increase or decrease) of not more than 5% of rating. Suitably damped control will be shown by attenuation of the second speed deviation of the same sign as the first deviation to not more than 25% of the first deviation. In the frequency domain, the suitability of damping will be shown by a frequency response test performed at the operating point detailed above with signal levels within the linear response range of the governing system. The frequency response of interest is the open-loop response from the turbine shaft speed input to the governor to turbine shaft speed. This can best be obtained by cascading the frequency response taken from the governor shaft speed input to gate position, with the response taken from gate position to shaft speed under isolated conditions. Suitably damped control will be shown by a phase margin at gain crossover of greater than 30 ° and a gain margin of greater than 8 dB.
   (The control of a resistive load is the natural standard of performance capability. It represents the strongest dependence upon the governor damping system likely to be needed in normal service. Evaluation may be achieved by tests, by computation, or by a combination of tests and computation as may be agreed between the purchaser and manufacturer. Several techniques for evaluation are described in Appendix A.)
2) *Service Adjustments*. If the user's load conditions are known to differ from characteristics of the resistive load, the service adjustments and evaluation of adequacy of damping may be based upon such load characteristics by mutual agreement between the purchaser and the manufacturer. For this condition the purchaser must specify the inertia of the load and its load regulation characteristic (ordinarily the voltage will be maintained constant by the voltage regulator, and voltage dependency of the load need not be considered). The same degree of damping for the specified load shall be achieved as for the reference resistive load.

4.1.4 Stability Studies

As a result of the complex interrelated effects between the penstock, generator, turbine, governor, and power system, it is highly desirable that a mathematical simulation of the entire system be performed. This is of particular importance if a large percentage of the system generation is supplied from one unit or if the physical characteristics of any parts of the system raise concern. The following text may be added if a simulation study is required to be performed by the governor supplier:

The supplier shall simulate, using appropriate methods, the interaction of penstock, turbine, generator, load, and governor in order to prove that the system is stable under all load conditions when adequate adjustments of the governor parameters are set and the pressure and transient speeds after load rejection are within the specified limits when the gate closing time is appropriately adjusted. The stability studies shall cover the operating range between maximum and minimum net heads with the discharge corresponding to the full load under each respective net head. Studies shall be conducted for conditions including parallel operation with an infinite system, supply of an isolated resistive load, and supply of isolated loads with special speed regulation characteristics specified by the user. The studies shall indicate the setting range of the governor parameters for which the control circuit remains stable after any disturbance. The quality of regulation shall be demonstrated in diagrams indicating the transient response of the frequency of the isolated system to load variations (increase and decrease) for various net heads and the transient response of power for changes of the speed or generation changer when supplying an infinite system.

4.2 Permanent Speed Droop/Speed Regulation

For governors in which servomotor position is fed back through a proportional gain element to subtract from speed error, the permanent speed droop shall be capable of adjustment to values between 0 and 5% (unless otherwise specified) when the speed adjustment is set to give rated speed with full servomotor stroke. The speed-versus-servomotor position curve shall be substantially linear over the full range from zero to full servomotor stroke; that is, the change in speed shall be substantially the same for equal increments of servomotor position. For governors in which generator power is fed back through a proportional gain element to subtract from speed error, the speed regulation shall be capable of adjustment to values between 0 and 5% (unless otherwise specified) when the speed adjustment is set to give rated speed with 100% generator power. The speed-versus-power curve shall be substantially linear over the full range from zero to full power; that is, the change in speed shall be substantially the same for equal increments of generator power.

4.3 Dead Band

a) The speed dead band at rated speed shall not exceed 0.02%.
b) For adjustable blade turbines, the blade control dead band shall not exceed 1.0%.

4.4 Dead Time

For a step load change of more than 10% of the capacity of the turbine, the dead time of the governor shall not be more than 0.2 seconds.

4.5 Range of Speed Changer Adjustment

Speed control shall cover the range from 85% of rated speed at no load and zero speed droop/regulation to 105% rated speed at maximum servomotor position/power and maximum speed droop/regulation. If remote control of the speed changer is provided it shall be possible to adjust the speed changer so that the minimum time to reduce the power output setting from maximum to zero or vice versa may be set to any desired value between 20 and 40 s.

4.6 Manual Governor Control

Under manual governor control, it shall be possible to move the turbine control servomotors through full stroke in both directions in not more than 40 s and in not less than the minimum time specified by the purchaser.

4.7 Governor Time Adjusment

The governor shall operate the turbine servomotors in accordance with the range of servomotor time specified by the purchaser and as dictated by the permissible water-hammer effect in the water passages of the turbine and the permissible overspeed following load rejection.

4.8 Governor Adjustments

Unless otherwise specified, the various parameters shall be provided with the following range of adjustment:

4.8.1 Temporary Speed Droop Adjustments

The decay time constant of the damping device shall be continuously adjustable from 0 to 30 s. The temporary speed droop shall be continuously adjustable from 0 to 150%. Provisions may be specified for changing the time constant and gain of the damping device to either of two preset values from a remote control point.

4.8.2 Proportional, Integral, and Derivative Adjustments

The proportional gain shall be continuously adjustable from 0 to 20. The derivative gain shall be continuously adjustable from 0 to 5 s. The integral gain shall be continuously adjustable from 0 to 10 per s. Provisions may be specified for changing from a remote control point to either of two preset values of the above parameters. The proportional, integral, and derivative gains are defined from governor speed input to governor system output.

5. Information To Be Provided By the Manufacturer

5.1 Information To Be Provided at the Time of Submission of Proposals

The manufacturer shall furnish diagrams or drawings of the speed governing system together with a written description clearly explaining the principle of operation. This information shall include outline drawings showing major dimensions and appropriate mathematical models for use in dynamic computer studies.

5.2 Drawings

(The following are suggested as reasonable requirements for furnishing of drawings and materials by the manufacturer. The specification writer should modify the requirements to suit his particular needs, including the times allowed for submission.) The manufacturer shall submit drawings and material to the purchaser for approval as follows:

1) Not later than four months after acceptance of the proposal, general arrangement drawings showing confirmed overall dimensions and weights of the principal parts of the governor, sufficient to allow concrete foundation work in the powerhouse to proceed.
2) Not later than six months after acceptance of the proposal, drawings showing full details of foundation requirements, required erection procedures, required erection provisions, piping schematics, functional descriptions, wiring drawings, and schematic diagrams for all parts of the governor system, including all necessary components and auxiliary devices, as listed in Sec 3 required to make a complete system. (Four and six months are considered to be representative submittal times; the specification writer should verify whether the times are appropriate for his specific case.)

5.3 Operation and Maintenance Manuals

The manufacturer shall provide operation and maintenance manuals describing in detail the construction and recommended procedure for assembling, dismantling, maintaining, diagnosing trouble, and operating the governor and all its components.

Without restricting the generality of the foregoing, the manuals shall include at least the following:

1) Technical and design data including weights of all major components.
2) All pertinent bulletins and instruction manuals prepared by the various manufacturers of component parts of the governor. Manufacturers' bulletins shall be suitably annotated to clearly indicate those items that form a part of the complete assembly.
3) Procedures for assembling, dismantling, operating, diagnosing trouble, and maintaining the governor.
4) Procedures and technical data required to properly adjust the governor.
5) Lubrication requirements, including a list of recommended lubricants for all components of the governor.
6) A complete index of all the contractor's drawings and a list of all assembly bulletins and drawings prepared by the manufacturers of components of the governor.
7) A selected set of arrangement, schematic, and wiring drawings for the governor, reduced in size to suit the instruction manuals.
8) A set of assembly drawings or printed bulletins that show all individual components of the equipment, and that indicate and identify each component item number including the common commercial designation.

Two copies of the manual shall be submitted in draft form to the purchaser for approval at least three months before the first component of the governor is to be delivered. Following approval by the purchaser, six suitably bound copies of the manual shall be supplied at least one month before the first component of the governor is to be delivered.

Should the manufacturer find it appropriate or necessary thereafter to amend such instruction manuals, he shall, after obtaining purchaser's approval, promptly provide six copies of any such ammendments.

(Six copies of the manual is considered representative; the specification writer should determine the appropriate number. Three months before equipment delivery is considered a reasonable time for submission of the draft manual; however, the specification writer should specify the appropriate time.)

6. Acceptance Tests

Tests, specified by the purchaser to determine the performance, shall be governed by the provisions of the edition of the ANSI/ASME Std PTC29-1980 (R1985), Speed-Governing System for Hydraulic Turbine-Generator Units [4] in effect at the time of request for bids, with such exceptions as may be mutually agreed to by the purchaser and the manufacturer.

7. Data To Be Furnished by the Purchaser

The purchaser shall furnish the governor manufacturer with as much information as possible, including the following where applicable:

1) Rated turbine output
2) Net head (including variations)
3) Speed
4) Rated discharge
5) Type of setting
6) Ambient conditions

7) Seismic requirements
8) Surge tank dimensions and type
9) Water inertia time (penstock, scroll-case, and draft tube)
10) Relief valve capacity under full head
11) Unit Wk^2
12) Station service ac and dc voltages including ranges of variation, for governor control and power circuits
13) Powerhouse drawings showing suggested location of equipment
14) Combined gate servomotor volume and stroke
15) Deflector servomotor volume and stroke
16) Needle servomotor volume and stroke, when governor operated
17) Runner blade servomotor volume
18) Servomotor design operating pressure
19) Turbine control servomotor connection sizes
20) Servomotor travel direction to close
21) Minimum differential pressure required to move servomotors
22) Gate shaft or deflector shaft direction and angular travel to close
23) Required governor capacity
24) Governor time: opening and closing
25) Runner blade or needle servomotor times: opening and closing
26) Results of turbine “index” tests, if available
27) Type, size, and any special characteristics of switchboard instruments to be supplied with the governor for remote mounting, if required
28) Current carrying capacity and operating rpm of speed and overspeed switches
29) Brake actuating medium and pressure
30) Required interfacing for purchaser furnished controls including required electrical ratings
31) Special design considerations, eg, electric governor, joint control, 3D cams.
32) Required initial adjustments for all governor components that have a range of adjustment
33) Complete four quadrant prototype turbine data or turbine model data together with model to prototype scaling. These data shall cover the range of zero to full gate opening (see 4.1.2. and 4.1.4).

8. Annex (Informative)

(This Appendix is not a part of ANSI/IEEE Std 125-1988, IEEE Recommended Practice for Preparation of Equipment Specifications for Speed-Governing of Hydraulic Turbines Intended to Drive Electric Generators, but is included for information only.

Following are several techniques that may be used to evaluate the speed control performance of the governor.

A1 Tests With Isolated Resistive Load

Where a controllable resistive load is available, such as an electrolytic plant, water rheostat, or dc transmission terminal, response of speed following a small or large step change of load is the simplest, most conclusive test available. Contribution of self-regulating influence from the turbine is automatically included. Test results are in the time domain.

A2 Tests by Simulated Isolation

This test technique permits operating the turbine generating unit in parallel with a power system, and it allows wide flexibility in load magnitude and representation of load characteristics. The generator power output to the system is measured and that signal is integrated to produce a simulated speed signal just as the actual turbine torque deviations (Δm) would be integrated by the Wk^2 of the turbine and generator in the speed response of the unit when isolated. The integration rate or gain is thus $1/T_M$ and speed deviation

$$\Delta n = \frac{1}{T_M}\int_{o}^{t} \Delta m dt$$

The power deviation signal to be integrated is the difference between total power output and an adjustable reference. When the simulated speed signal so produced is substituted for the actual speed deviation signal, the turbine governor responds to change of the simulator power reference just as an isolated unit responds to change of load. (The simulated speed deviation signal may also be delivered to the governor input in addition to the regular speed deviation signal since the latter will remain essentially constant while the test unit remains synchronized to the power system.)

For simulating a purely resistive load a positive (unstabilizing) feedback from the simulated signal to the junction for summing the power signal and its reference is necessary to make the power deviation proportional to the product of speed and torque. The turbine self-regulating effect also can be represented by a negative (stabilizing) feedback from the simulated speed deviation signal to the junction for summing the power signal and its reference. Net feedback to be represented is the sum of these two. With Francis-type turbines near full load, the self-regulation is near unity and these two effects essentially cancel. Other load regulations and turbine regulations can be represented by the net feedback if desired. Inertia in the load along with inertia of the unit can be reflected in the integration rate as appropriate for representing other than resistive loads (for example, rotating loads).

Simulated isolation tests are performed by applying step inputs to the adjustable power reference. Transient response of the simulated speed deviation signal following the step changes is observed in the time domain. The functions are illustrated in the block diagram in Fig A1.

A3 Damping Determinations in the Frequency Domain

Frequency response may be determined purely by computation, but accuracy of the method hinges upon the accuracy with which characteristics of all components are known. Also, the influence of inadvertent nonlinearities in equipment such as valves and dashpots is not revealed.

Measurement of the frequency response of the governor system from the governor speed input to and including the gate servomotor supplemented by the computed frequency response of the hydraulic turbine and the rotational inertia is feasible and preferable over computation of the total system. Knowledge of the turbine self-regulating characteristics is needed.

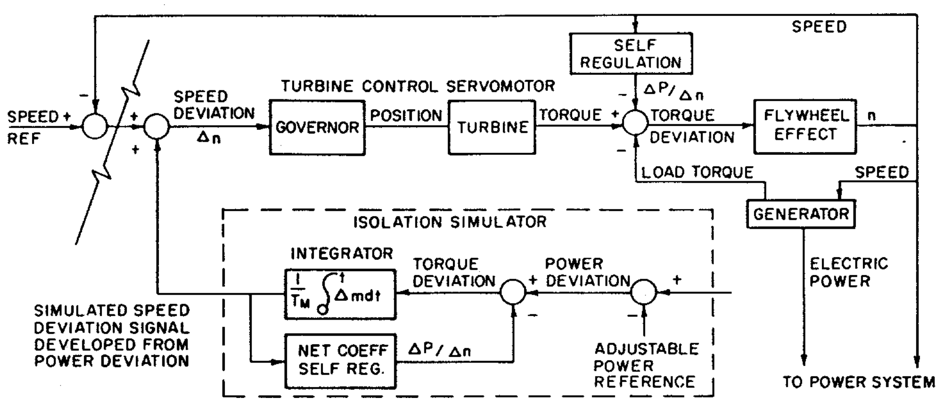


Figure A1 —Block Diagram of Goveror Speed Control Loop Closed Through Isolation Simulator

Measurement of the frequency response of the governor and turbine from the governor speed input to generator power output while the unit is operating in parallel with a power system is more direct and representative in that all actual characteristics are included in the measurement except influence of turbine self-regulation. Influence of the rotational inertia of the unit and turbine self-regulation must be computed, but the computation is less tedious, and error from inadvertent nonlinearities is less likely.

Frequency domain simulated isolation tests may also be performed. This is most easily accomplished in two steps. The first step involves inserting a sinusoidally varying input into the adjustable power reference of the isolation simulator. The frequency response from the simulated speed signal to gate position is taken during this step.

The second step involves inserting a sinusoidally varying input into the governor speed summing junction. The frequency response from gate position to the simulated speed signal is taken during this step. By cascading these two frequency responses, the open-loop frequency response from governor speed input to shaft speed can be obtained. Gain and phase margins can then be determined directly from this open-loop response. Various load regulation and load inertia properties can be included in this test as explained in A2.

A4 Computation of Time Response

This computation, which may be made by analog or digital computer, consists of computing performance of a mathematical model of the closed-loop control system. It requires accurate knowledge of characteristics of the governor system and turbine self-regulating characteristics or the complete turbine performance data.