PTC 20.2 - 1965

Overspeed Trip Systems for Steam Turbine-Generator Units

POWER TEST CODES

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
United Engineering Center
345 East 47th Street New York, N.Y. 10017

Overspeed Trip Systems for Steam Turbine-Generator Units

POWER TEST CODES

Printed in the United States of America

FOREWORD

POWER Test Code Committee No. 20 on Speed-Responsive Governors was established by the ASME Power Test Codes Committee in 1921 and the Test Code for Speed-Responsive Governors as prepared by this committee was issued in May, 1927. Subsequently, since it was found that this Code was inadequate, Power Test Code Committee No. 20 was reorganized in 1940 and its scope expanded to include speed, temperature, and pressure responsive governors for prime movers.

In 1941 the Joint AIEE-ASME (IEEE-ASME) Committee on a Recommended Specification for Prime-Mover Speed Governing was formed. The fundamental studies for prime-mover speed governing were made. The fundamental studies for the preparation of the code for testing were identical with those for the preparation of the recommended specification. Close coordination of the work by both committees to assure the successful completion of their respective assignments, was accomplished by the appointment of personnel common to both groups.

By mutual agreement, the work of the Specification Committee took precedence over that of PTC Committee No. 20 whose labors were interrupted during World War II.

In order to facilitate the use of the Code, PTC Committee No. 20 decided in 1946 to issue their assignment in several publications, and in the following sequence:

(1) Test Code for Speed-Governing Systems for Steam Turbine-Generator Units
(2) Test Code for Emergency Governors for Steam Turbine-Generator Units
(3) Test Code for Pressure-Regulating Systems for Steam Turbine-Generator Units.

With the issuance of AIEE (IEEE) Publication No. 600 in May, 1949, covering "Recommended Specification for Speed-Governing of Steam Turbines Intended to Drive Electric Generators Rated 500 Kw and Up" by the Joint AIEE-ASME (IEEE-ASME) Committee, the way was cleared to proceed with the preparation of the first code in the series. This Code was issued as PTC 20.1-1958 in November, 1958. In December, 1961, the PTC Committee No. 20 was reorganized in order to write the second part of the Code under the modified title of "Test Code for Overspeed Trip Systems for Steam Turbine-Generator Units."

Since there was no established specification for the performance of turbine overspeed trip systems, the committee considered it necessary to include a "Recommended Specification" in the section on Guiding Principles of this power test code.

This Code was approved by the Power Test Codes Committee on October 1, 1964. It was approved and adopted by the ASME Council as a standard practice of the Society by action of the Board on Codes and Standards on March 3, 1965.

June, 1965

PERSONNEL OF POWER TEST CODE COMMITTEE NO. 20 ON SPEED, TEMPERATURE, AND PRESSURE RESPONSIVE GOVERNORS

M. A. Eggenberger, *Chairman*

M. A. Eggenberger, Turbine Control Systems Engineer, Turbine Division, General Electric Company, 1 River Road, Schenectady 5, New York

C. E. Kenney, Senior Development Engineer, Thermal Power Division, Mechanical Design Section, Allis-Chalmers Manufacturing Company, Box 512, Milwaukee 1, Wisconsin

S. Logan Kerr, President, S. Logan Kerr & Company, Inc., P. O. Box No. 6, Flourtown, Pennsylvania

M. E. Leum, Engineer, Woodward Governor Company, 5001 North 2nd Street, Rockford, Illinois

C. L. Mount, Engineer, Maintenance Division, Station Operation Department, Philadelphia Electric Company, 2610 South Delaware Avenue, Philadelphia 48, Pennsylvania

E. G. Noyes, Jr., Section Engineer, Large and Medium Turbine Engineering, Westinghouse Electric Corporation, Lester Branch P. O., Philadelphia 13, Pennsylvania, (Assisted by D. Conrad)

R. L. Nugent, Superintendent, Conners Creek Power Plant, The Detroit Edison Company, 2000 Second Avenue, Detroit 26, Michigan

J. B. Prather, Mechanical Engineer, Engineering Department, Gibbs & Hill, Inc., 393 Seventh Avenue, New York 1, New York

H. Steen-Johnsen, Chief Engineer, Power Equipment, Elliott Company Division, Carrier Corporation, 900 North 4th Street, Jeannette, Pennsylvania (Assisted by M. Banda)

H. E. Stickle, Head, Technical Section, Production Department, Boston Edison Company, 39 Boylston Street, Boston 12, Massachusetts

Personnel of Power Test Codes Committee

W. G. McLean, *Chairman*
J. W. Murdock, *Vice Chairman*

J. H. Anderson
Theodore Baumeister
H. S. Bean
K. C. Cotton
R. C. Dannettel
J. M. Driscoll
M. D. Engle
V. F. Estcourt
J. H. Fernandes
F. K. Fischer
L. J. Hooper
R. M. Johnson
T. J. Judge
R. C. King, Jr.
E. L. Knoedler
P. H. Knowlton, Jr.
F. H. Light
J. F. McLaughlin, Jr.
R. T. Mathews
W. T. Moore
W. C. Osborne
W. A. Pollock
J. F. Sebald

ASME POWER TEST CODES

Test Code for Overspeed Trip Systems For Steam Turbine-Generator Units

CONTENTS

SECTION 0, INTRODUCTION

0.01 This Code is applicable to steam turbine-generator units of 500 kw and larger and provides:

0.01.1 Recommended specifications for the performance of overspeed trip systems subject to modifications by mutual agreement between the parties concerned and

0.01.2 Standard procedures for acceptance tests to determine the performance of overspeed trip systems.

0.02 Reference is made to other ASME Power Test Codes for measuring techniques and evaluation of test results.

SECTION 1, OBJECT AND SCOPE

The purposes of this Code are:

1.01 To establish guiding principles and specifications for overspeed trip systems that will apply to the equipment covered under this Code.

1.02 To establish test procedures to determine the following characteristics of overspeed trip systems:

1.02.1 Setting of overspeed trip

1.02.2 Short term deviation of trip speed

1.02.3 Long term deviation of trip speed

1.02.4 Signal transmission delay time

1.02.5 Emergency stop valve (s) closing time.

1.03 To determine over-all system performance from data obtained under Par. 1.02.

SECTION 2, DEFINITION OF TERMS

2.01 Components of Overspeed Trip Systems.

2.01.1 Overspeed trip: The device which initiates a tripping action when the turbine-generator rotor attains trip speed.

2.01.2 Emergency Stop Valve(s): The valve (s) in series with the governor controlled valves that, when closed, will reduce the turbine steam flow to less than no load flow at rated speed. Reheat stop valves are included under this term.

2.01.3 Trip Test Device: An arrangement by which the functioning of portions of the overspeed trip system can be tested at rated speed, with the unit carrying load while the trip action of the overspeed trip system is temporarily rendered ineffective by means of an interlocking device.

2.02 Functions and Characteristics.

Par.	Term	Symbol	Definitions and Descriptions	Unit
2.02.1	Rated speed	N_r	Speed stated on manufacturer's name plate	rpm
2.02.2	Trip speed	N_t	Turbine speed at which the overspeed trip responds while the unit is accelerating at a rate of less than 5 per cent of rated speed per minute.	rpm
2.02.3	Relative trip speed	n_t	Trip speed referred to rated speed	per cent
2.02.3-1			$n_t = \frac{N_t}{N_r} \times 100$	per cent
2.02.4	Mean trip speed	N_{t_m}	Average trip speed of $k-1$ tests where k is the number of tests performed within three days. The result of the first test is not used (see long term deviation).	rpm
2.02.4-1			$N_{t_m} = \frac{N_{t_2} + N_{t_3} + \ldots N_{t_k}}{k-1}$	rpm
2.02.5	Relative mean trip speed	n_{t_m}	Mean trip speed referred to rated speed	per cent
2.02.5-1			$n_{t_m} = \frac{N_{t_m}}{N_r} \times 100$	per cent
2.02.6	Short term deviation of relative trip speed	Δn_s	Maximum variation between the relative trip speed and the relative mean trip speed for the test series used to establish the mean trip speed	per cent
2.02.6-1			$\Delta n_s = \left(n_{t_{max_s}} - n_{t_m}\right)$ short-term	per cent

2.02 Functions and Characteristics. (Cont'd.)

Par.	Term	Symbol	Definitions and Descriptions	Unit
2.02.7	Relative short term maximum deviating trip speed	$n_{t_{max_S}}$	Short term relative trip speed of maximum deviation with respect to the relative mean trip speed	per cent
2.02.8	Long term deviation of relative trip speed	Δn_L	Maximum variation between the relative trip speed and the relative mean trip speed for a series of three or more trip tests with the period of time between tests in excess of 1 week during which the overspeed trip has not operated	per cent
2.02.8-1			$\Delta n_L = \left(n_{t_{max_L}} - n_{t_m}\right)$ long term	per cent
2.02.9	Relative long term maximum deviating trip speed	$n_{t_{max_L}}$	Long term relative trip speed of maximum deviation with respect to relative mean trip speed	per cent
2.02.10	Acceleration drift	$\Delta n_{(a)}$	Difference between the relative trip speed at a specified acceleration a and the relative mean trip speed	per cent
2.02.10-1			$\Delta n_{(a)} = \left(n_{t_a} - n_{t_m}\right)$	per cent
2.02.11	Signal delay time	T_d	Average time interval between overspeed trip action and start of emergency stop valve closure, of k tests	sec
2.02.11-1			$T_d = \dfrac{T_{d_1} + T_{d_2} + \ldots T_{d_k}}{k}$	sec
2.02.12	Emergency stop valve closing time.	T_v	Time between the end of T_d and the moment when the respective emergency stop valve is closed	sec

2.03 Computations.

Par.	Term	Symbol	Definitions and Descriptions	Unit
2.03.1	Instantaneous acceleration at trip speed	a_t	Acceleration at the trip speed under conditions of maximum energy input to the turbine without load on the generator	rpm per sec
2.03.2	Relative instantaneous acceleration at trip speed	a_{t_r}	Instantaneous acceleration at trip speed referred to rated speed	per cent per sec

2.03 Computations. (Cont'd)

Par.	Term	Symbol	Definitions and Descriptions	Unit
2.03.2-1			$a_{t_r} = \frac{a_t}{N_r} \times 100$	per cent per sec
2.03.3	Kinetic energy at trip speed	E_t	Kinetic energy of the rotor system at the actual mean trip speed	kw sec
2.03.4	Delay time energy input	ΔE_1	Energy input to the rotor system during signal delay time	kw sec
2.03.5	Closing time energy input	ΔE_2	Energy input to the rotor system during emergency stop valve closing time	kw sec
2.03.6	Entrained energy	ΔE_3	Energy input to rotor system resulting from expansion of entrapped steam within the turbine system	kw sec
2.03.7	Emergency overspeed	N_e	Maximum speed attained by the rotor system if it were suddenly relieved of maximum generator output when the speed of the rotor system is dependent only on the operation of the overspeed trip system	rpm
2.03.8	Relative emergency overspeed	n_e	Emergency overspeed referred to rated speed	per cent
2.03.8-1			$n_e = \frac{N_e}{N_r} \times 100$	per cent
2.03.9	Ultimate kinetic energy	E_e	Kinetic energy of the turbine rotor system at the emergency overspeed N_e	kw sec
2.03.10	Actual mean trip speed	N_{t_a}	Calculated mean trip speed of the overspeed trip when the rotor is accelerating at the rate of a_t including the effect of long term drift	rpm
2.03.10-1			$N_{t_a} = \frac{n_{t_m} + \Delta n_a + \Delta n_L}{100} \times N_r$	rpm
2.03.11	Maximum output	$P_{g(max)}$	Maximum expected electrical output of the turbine generator with valves wide open as specified or agreed upon by the parties concerned	kw
2.03.12	Inertia	WR^2	Total weight moment of inertia of rotor system	$lb\text{-}ft^2$

2.03 Computations. (Cont'd)

Par.	Term	Symbol	Definitions and Descriptions	Unit
2.03.13	Power reduction factor	f	Factor to account for the reduction of power input to the turbine during the emergency valve closing time (function of the flow-position characteristic of the valve (s)).	dimensionless
2.03.14	Entrapped steam (initial condition)	W_1, $W_{1_1} \ldots W_{1_n}$	Weight of the various quantities of steam (including water that can flash into steam) contained within the various spaces $(1 \ldots n)$ of the turbine system available to do work when operating at maximum output	lb
2.03.15	Entrapped steam (after expansion)	W_2, $W_{2_1} \ldots W_{2_n}$	Weight of steam in the spaces $(1 \ldots n)$ defined for W_1 after expansion has ceased	lb
2.03.16	Internal energy (initial)	u_1, $u_{1_1} \ldots u_{1_n}$	Internal energies for the quantities $(1 \ldots n)$ of steam W_1 estimated at the actual pressures and temperatures that exist at the various zones when operating at maximum output	Btu per lb
2.03.17	Internal energy (after expansion)	u_2, $u_{2_1} \ldots u_{2_n}$	Internal energies for the quantities $(1 \ldots n)$ of steam W_2 after *isentropic expansion*	Btu per lb

Note: For a non-reheat unit and for the intermediate-pressure and low-pressure zones of a reheat unit all steam quantities expand to no load condenser pressure. Steam upstream of the reheater expands to the average reheat pressure at maximum load.

Par.	Term	Symbol	Definitions and Descriptions	Unit
2.03.18	Enthalpy of expanded steam	h_2, $h_{2_1} \ldots h_{2_n}$	Enthalpies of the various quantities $(1 \ldots n)$ of steam after *isentropic expansion*	Btu per lb

Note: The values of h_2 will be different for each of the quantities W_1 because of different entropies. The values of h_2 are to be determined for each quantity W_1.

Par.	Term	Symbol	Definitions and Descriptions	Unit
2.03.19	Efficiency of energy transfer	η	Ratio of energy transfer to the rotor system to the internal energy available	dimensionless

Note: This efficiency factor accounts for steam reheat and losses. Normally $\eta = 0.8$. A value differing from 0.8 may be employed upon agreement of the parties to the test provided that it and the reason for its adoption are described in the test report.

SECTION 3, GUIDING PRINCIPLES

3.01 An overspeed trip system is a safety device to protect the steam turbine and generator against excessive overspeed.

3.02 The performance of the system may be specified explicitly as part of the agreement between the parties to the test. If such specifications are not stated in the agreement, the following may be used:

3.03 Recommended Specifications.

Par.	Item	Definition or Reference	Recommended Value (in per cent of rated speed)
3.03.1	Relative trip speed	Par. 2.02.3	110 to 112 per cent or that value necessary to assure compliance with the specified emergency trip system performance.
3.03.2	Minimum adjustment range	The minimum range within which the relative trip speed can be adjusted	105 to 115 per cent
3.03.3	Reset speed of overspeed trip	The speed at which the overspeed trip will reset to normal operating position	Not more than 9 per cent below trip speed setting
3.03.4	Short term deviation	Par. 2.02.6	Not to exceed ± 0.5 per cent
3.03.5	Long term deviation	Par. 2.02.8	Not to exceed + 1 to − 0.5 per cent
3.03.6	System performance	The system shall perform such that upon loss of maximum generator output, with the speed governing system incapacitated, the calculated speed attained does not exceed the maximum speed agreed to by the parties concerned.	

3.04 Guiding Principles for Test.

3.04.1 The overspeed trip system shall be carefully checked and properly adjusted prior to test. This shall be done to the satisfaction of the parties to the test.

3.04.2 The parties to the test shall agree in advance as to what conditions will be permissible with respect to the safety of the unit, including:

(a) Permissible acceleration rate

(b) Maximum speed

(c) Adverse vibrations

(d) Adverse stress conditions

(e) Possible effect on the plant equipment.

3.04.3 No correction or changes in setting of the overspeed trip system shall be permitted during the test except as otherwise set forth in the agreement.

3.04.4 Preliminary test runs with log records are recommended to determine if the equipment is in condition to undergo test, to check instruments and methods of measurement, and to train personnel. A preliminary test may be considered an acceptance test, if mutually agreed upon, provided it has complied with the requirements of this Code.

3.04.5 Any allowances for instrument calibrations or for variations in precision of measurements shall be agreed to by the parties to the test, prior to the testing, and shall be clearly stated in the test report.

3.04.6 Agreement shall be reached in advance as to the personnel required to conduct the test. All parties to the test shall be entitled to have present such members of their staff as may be required for them to be assured that the tests are conducted and the observations taken in accordance with this Code.

3.04.7 The parties to the test may designate a person to direct the test and serve as arbitrator in the event of any dispute regarding precision of observations, test conditions or methods of operation.

3.04.8 Following is a list of typical items upon which agreement shall also be reached:

(a) Intent of contract specification

(b) Procedure for use and calibration of instruments

(c) Method of operating any auxiliary equipment, the performance of which may influence the test results.

(d) Operating conditions and maintenance policy

(e) Test agenda, including schedule of test runs.

3.04.9 It is not prudent to disable the speed governor system and dump full load so that the emergency overspeed (N_e) may be determined experimentally. The emergency overspeed (N_e) must be calculated by use of design values and test data that will all become part of the test record. Such a calculation is described in Section 5.

3.04.10 When an acceptance test performed under the rules of this Code is required, it should be undertaken shortly after the turbine-generator unit is first placed in commercial service, provided no serious operating difficulty exists. In any event, except with written agreements to the contrary, the acceptance test shall take place within the warranty period specified in the contract.

3.04.11 For acceptance test, if the turbine-generator unit does not meet the full requirements of the contract, a separate agreement will be required between the various interested parties. This agreement shall outline the departures from guaranteed performance and set forth methods whereby such departures are allowed for in establishing performance of the overspeed trip system.

3.04.12 The test results shall be reported as described in Section 6.

3.04.13 If the test reveals malfunctioning of any apparatus affecting the results of the test, the defects shall be corrected and the test series repeated.

SECTION 4, INSTRUMENTS AND METHOD OF MEASUREMENT

4.01 General. This section describes the instruments required to determine the performance characteristics of overspeed trip systems.

4.02 To determine the performance characteristics of overspeed trip systems it is necessary to measure the following:

(a) Speed or frequency

(b) Motion or travel

(c) Time.

Pressure and temperature measurements to calculate the emergency overspeed are not within the scope of this Code. To perform these calculations it is necessary to have the design or test values of these quantities available.

4.03 Speed Measuring Instruments.

4.03.1 Accuracy. The principle speed measuring instrument shall be accurate to ± 0.05 per cent of rated speed within the speed range to be measured.

4.03.2 Calibration. The speed measuring instruments are to be calibrated immediately prior to and following the test. If the calibrations of the principal speed measuring instrument before and after test in the trip speed range differ by more than ± 0.05 per cent, the test shall be rejected.

The digital counter is suitable to calibrate other types of speed measuring instruments.

4.03.3 Instruments. Suggested instruments for measuring the trip speed are:

Instrument	Suitability
(a) Chronometric tachometer, PTC 19.13, Par. 16	As a secondary speed measurement
(b) Centrifugal tachometer, PTC 19.13, Par. 17	As a secondary speed measurement
(c) Pulse counter by means of capacitor discharge current, PTC 19.13, Par. 40	As principal speed measurement
(d) Digital counter with a counting period of 1 second or less, PTC 19.13, Pars. 42 and 43	As principal speed measurement suitable for use as a primary standard
(e) Strobotachometer, PTC 19.13, Par. 48	As secondary speed measurement

4.04 Motion or Travel Measuring Instruments. Motion or travel measurements are necessary for the emergency stop valves. The position-time record will be used to establish the signal delay time T_d and the valve closing time T_v.

4.04.1 Position Transducers. Suitable for this measurement are:

(a) Potentiometer travel transducer

(b) Differential transformer position transducer.

4.05 Time Measuring Instruments.

4.05.1 The signal delay time T_d and the valve closing time T_v shall be measured by suitable instruments accurate to ±0.01 second.

4.05.2 A suggested instrument for time measurement is an oscillograph which records a suitable time reference, an event marker for trip action and valve position traces. (A photographic record or a direct recording on a fast moving chart is suitable.)

4.10 Trip Speed (N_t). The procedure to measure the trip speed is as follows:

4.10.1 Approach the trip speed at an acceleration of less than 5 per cent of rated speed per minute.

4.10.2 Record speed N_t when the overspeed trip operates.

4.10.3 Make k ($k \geqq 5$) consecutive trip tests.

4.10.4 Calculate the mean trip speed and the relative mean trip speed as follows:

4.10.4.-1 $$N_{t_m} = \frac{N_{t_2} + N_{t_3} + \ldots + N_{t_k}}{k - 1} \quad \text{[rpm]}$$

4.10.4-2 $$\Delta n_{t_m} = \frac{N_{t_m}}{N_r} \times 100 \quad \text{[per cent]}$$

4.10.5 Calculate the short term deviation:

4.10.5-1 $$\Delta n_s = n_{t_{\max_s}} - n_{t_m} \quad \text{[per cent]}$$

4.11 Signal Delay Time (T_d).

4.11.1 With the time measuring equipment in service, operate the overspeed trip k times ($k \geqq 3$) by overspeeding the unit to the trip speed. This measurement may also be taken at rated speed by using the oil trip device if it is available.

4.11.2 For each test determine T_d for each valve.

4.11.2-1 $$T_d = \frac{T_{d_1} + T_{d_2} + \ldots T_{d_k}}{k} \quad \text{[sec]}$$

4.12 Valve Closing Time (T_v).

4.12.1 The methods for obtaining valve closing times are listed in the following paragraphs in order of preference.

4.12.2 Determine the valve closing time T_v under maximum steam flow conditions at rated pressure. With the recording equipment operating, trip the valves closed at maximum steam flow and obtain T_v for each valve from the recording.

4.12.3 Determine the valve closing time under zero steam flow conditions. With the turbine at standstill and the recording equipment operating, trip the valves closed. Obtain the uncorrected valve closing time from the recording, and apply a correction for the steam forces to obtain the applicable closing time T_v.

4.12.4 Use the valve closing time given by the manufacturer.

4.13 Long Term Deviation.

4.13.1 After a period of one week or more of undisturbed operation, measure and record the trip speed for the first test. Repeat test after approximately the same period of time to obtain k ($k \geqq 3$) test results.

4.13.2 Calculate the long term deviation Δn_L:

4.13.2-1 $$\Delta n_L = n_{t_{\max_L}} - n_{t_m} \quad \text{[per cent]}$$

4.14 Acceleration Drift (Δn_α). When the turbine is suddenly relieved of a maximum power output the unit will accelerate. Normally, the effect of this angular acceleration is to increase the speed at which the overspeed trip responds. This increase, in per cent, is the acceleration drift.

4.14.1 The test for acceleration drift on typical overspeed trips is normally performed only on a factory test stand.

The result of this test is a curve of deviation of the trip speed versus acceleration.

A typical acceleration drift curve is shown in Fig. 1

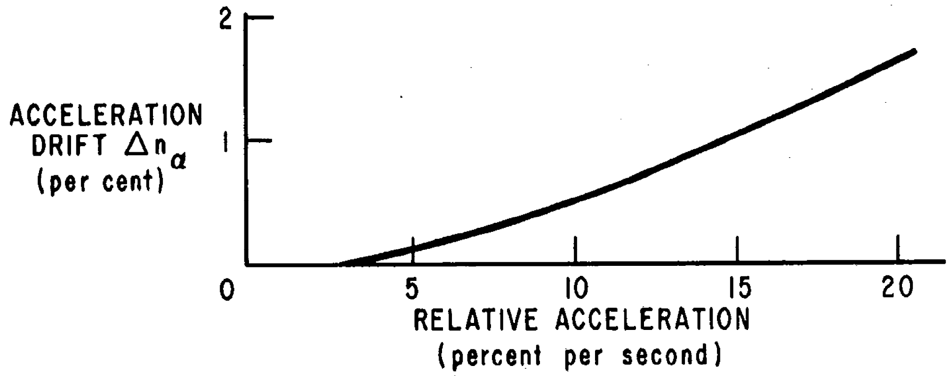

FIG. 1 TYPICAL ACCELERATION DRIFT CURVE

4.15 Test Procedure for Cross Compound Units.

4.15.1 On cross compound units the trip speed N_t must be measured for the overspeed trip on each shaft.

4.15.2 On units where the overspeed trip action can be locked out by a test device, the test for the trip speed and for the signal delay time T_d is performed twice, once with the trip action on the second shaft locked out and once with the trip action on the first shaft locked out.

4.15.3 On units with trip systems not equipped with the lock-out features the interested parties must establish a suitable testing procedure.

SECTION 5, COMPUTATION OF EMERGENCY OVERSPEED (N_e)

5.01 Following actuation of the overspeed trip the speed of the rotor system would increase due to the summation of the following causes:

5.01.1 The increase in speed due to the energy input to the turbine during the signal delay time, T_d. This power input corresponds to the maximum generator output.

5.01.2 The increase in speed due to the energy input to the turbine during emergency stop valve (s) closing time, T_v. This power input corresponds to a certain fraction (f) of the maximum generator output.

5.01.3 The increase in speed due to the energy input to the turbine from any steam contained within the turbine system when the turbine is operating at maximum output. For a non-reheat condensing type turbine, steam will expand to the condenser pressure. Steam upstream of a reheater, for a reheat type turbine, will expand to the lowest set point of the reheat relief valves. The power from this source may be partly or wholly expanded during the time the emergency valve is closing, or after the valve has become closed, according to the speed at which the valve operates. It is assumed that a certain fraction of this power is available for accelerating the rotor system.

5.02 The emergency overspeed may be determined by the following calculation method:

5.02.1 With data obtained from actual steady-state overspeed trip tests, the mean trip speed, N_{t_m}, and the relative mean trip speed, n_{t_m} can be determined. For the calculation of the emergency overspeed (N_e), on cross compound units the trip speed and signal delay time must be used which will result in the higher values of N_e.

5.02.2 The instantaneous rotor acceleration at the overspeed trip setting can be determined by

5.02.2-1 $$a_t = 2.16 \times 10^6 \times \frac{P_{g(max)}}{N_{t_m}\ WR^2}$$ [rpm per sec]

(See any engineering handbook for significance of constant factors.)

5.02.2-2 $$a_{t_r} = \frac{a_t}{N_r} \times 100$$ [per cent per sec]

5.02.3 Determine the acceleration drift from data obtained on the test stand.

5.02.4 The actual mean trip speed is determined by:

5.02.4-1 $$N_{t_a} = \frac{n_{t_m} + \Delta n_a + \Delta n_L}{100} \times N_r$$ [rpm]

5.02.5 The rotational kinetic energy of the rotor system at the actual mean trip speed N_{t_a} is

5.02.5-1 $$E_t = 2.31 \times 10^{-7}\ WR^2 (N_{t_a})^2$$ [kw sec]

5.02.6 The energy input to the rotor system during the signal delay time is

5.02.6-1 $$\Delta E_1 = T_d P_{g(max)}$$ [kw sec]

5.02.7 The energy input to the rotor system during the emergency stop valve closing time is

5.02.7-1 $$\Delta E_2 = f\ T_v\ P_{g(max)}$$ [kw sec]

5.02.8 The energy input to the rotor system from the expansion of steam entrapped within the turbine system is

5.02.8-1 $$\Delta E_3 = 1.056\ \eta \{\Sigma W_1 u_1 - \Sigma W_2 u_2 - \Sigma (W_1 - W_2) h_2\}$$ [kw sec]

(1 Btu = 1.056 kw sec)

5.02.9 The kinetic energy of the rotor system at the emergency overspeed N_e is

5.02.9-1 $$E_e = E_t + \Delta E_1 + \Delta E_2 + \Delta E_3$$ [kw sec]

5.02.10 The calculated emergency overspeed is

5.02.10-1 $$N_e = \sqrt{E_e \frac{4.33 \times 10^6}{WR^2}}$$ [rpm]

SECTION 6, REPORT OF TESTS

6.01 The "Report of Tests" shall include test and calculated information, sufficient to prove that the performance of the overspeed trip system is within limits provided by this Code.

6.02 General Information.

1. Owner
2. Owner's designation of unit
3. Name and location of plant
4. Rated speed, nameplate rating, steam conditions and type of unit
5. Manufacturer of unit
6. Serial number of unit
7. Date of first commercial operation
8. Report number, date of tests and date of report
9. Persons engaged in or observing the test and their affiliation
10. Person in charge of test.

6.03 Conclusions. Brief summary of test results and calculated values, including any significant history of overspeed trip system operation.

6.04 Record of Agreements. Agreements specified by this Code and any other agreement affecting the test results must be included in the test report.

6.05 Description and Results of Tests.

6.05.1 Detailed description of test.

6.05.2 Data taken according to Section 4.

6.05.3 Design data of the unit being tested.

6.05.4 Calculated results.

6.06 Appendix of Test Report. This part of the report is to include copies of the original data sheets and records of calibration of instruments, detailed calculations not in body of report and any curves showing source data and test results.

SECTION 7, APPENDIX

7.01 Examples of Overspeed Trip Systems.

7.01.1 Overspeed trip systems for small turbine with bolt type overspeed trip.

See Fig. 2

7.01.2 Overspeed trip system for large turbine-generator with ring type overspeed trip and testing device.

See Fig. 3

7.01.3 Overspeed trip system for large turbine-generator with bolt type overspeed trip and testing device.

See Fig. 4

7.01.4 Overspeed trip system for large turbine-generator with bolt type overspeed trip and testing device.

See Fig. 5

7.02 Example of Emergency Overspeed (N_e) Calculation.

7.02.1 Data from Manufacturer.

(a) Maximum generator output –

$P_{g(\max)}$ = 224,000 [kw]

$P_{g\,(h-p)}$ = 60,000 [kw] Maximum power developed by the high pressure section of the turbine.

$P_{g\,(i-p \text{ and } 1-p)}$ = 164,000 [kw] Maximum power developed by the intermediate and low pressure sections of the turbine

(b) Steam conditions –

High pressure steam: 2400 psig, 1000 F

Reheat steam: 485 psig, 1000 F

(c) Rotor system inertia –

WR^2 = 308,000 [lb-ft²]

(d) Acceleration drift under maximum acceleration at trip speed –

Δn_a = 0.5 [per cent] (at 11 per cent per sec)

(e) Power reduction factor –

For main inlet stop valves f_{sv} = 0.84

For reheat stop valves f_{rsv} = 0.88

(f) Energy of entrapped extraction steam –

ΔE_{3_4} = 22,100 [kw sec]

7.02.2 Entrapped Steam.

(a) Between stop valve and first stage nozzle –

W_{1_1} = 150 lb — h_{1_1} = 1460 Btu per lb

u_{1_1} = 1328 Btu per lb

W_{2_1} = 43.5 lb — h_{2_1} = 1275 Btu per lb

u_{2_1} = 1172 Btu per lb

(b) Between reheat stop valve and reheat turbine –

W_{1_2} = 175 lb $\quad h_{1_2}$ = 1520 Btu per lb

u_{1_2} = 1364 Btu per lb

W_{2_2} = 0.47 lb $\quad h_{2_2}$ = 925 Btu per lb

u_{2_2} = 857 Btu per lb

(c) Cross-over pipes between intermediate-pressure and low-pressure turbines –

W_{1_3} = 130 lb $\quad h_{1_3}$ = 1283 Btu per lb

u_{1_3} = 1183 Btu per lb

W_{2_3} = 0.5 lb $\quad h_{2_3}$ = 965 Btu per lb

u_{2_3} = 936 Btu per lb

(d) Extractions and turbine shell –

Since this contribution is relatively small, but consists of a large number of even smaller components, it is acceptable to use the corresponding energy contribution ΔE_{3_4} (in kw sec) obtained from the turbine manufacturer. For this example

$$\Delta E_{3_4} = 22{,}100 \text{ kw sec}$$

7.02.3 Test Data.

(a) Overspeed trip tests –

N_{t_1} = 3982 rpm $\quad N_{t_4}$ = 3966 rpm

N_{t_2} = 3971 rpm $\quad N_{t_5}$ = 3974 rpm

N_{t_3} = 3968 rpm $\quad N_{t_6}$ = 3976 rpm

(b) Signal delay time –

T_d = 0.10 sec

(c) Valve closing time –

T_{sv_1} = 0.29 sec (Main stop valve #1)

T_{sv_2} = 0.27 sec (Main stop valve #2) $\quad T_{sv}$ = 0.29 sec

T_{rsv_1} = 0.13 sec (Reheat stop valve #1)

T_{rsv_2} = 0.11 sec (Reheat stop valve #2) $\quad T_{rsv}$ = 0.13 sec

7.02.4 Computation.

(a) Mean trip speed –

$$N_{t_m} = \frac{3971 + 3968 + 3966 + 3974 + 3976}{5} = 3971 \text{ rpm}$$

(b) Relative mean trip speed –

$$n_{t_m} = \frac{3971}{3600} \times 100 = 110.3 \text{ per cent}$$

(c) Short term deviation of relative trip speed –

$$\Delta n_s = \frac{3976 - 3971}{3600} \times 100 = +0.14 \text{ per cent}$$

(d) Long term deviation of relative trip speed –

$$\Delta n_L = \frac{3982 - 3971}{3600} \times 100 = +0.30 \text{ per cent}$$

(e) Acceleration at trip speed –

$$a_t = \frac{2.16 \times 10^6 \times 224{,}000}{3971 \times 308{,}000} = 396 \text{ rpm per sec}$$

$$a_{t_r} = \frac{396}{3600} \times 100 = 11 \text{ per cent per sec}$$

Acceleration drift $\Delta n_a = 0.5$ per cent (from manufacturer)

(f) Actual mean trip speed at maximum acceleration –

$$N_{t_a} = \frac{n_{t_m} + \Delta n_a + \Delta n_L}{100} \times N_r = \frac{110.3 + 0.5 + 0.3}{100} \times 3600$$

$$N_{t_a} = 4000 \text{ rpm}$$

(g) Rotational energy at actual trip speed –

$$E_t = 2.31 \times 10^{-7}\, WR^2 \,(N_{t_a})^2$$

$$= 2.31 \times 10^{-7} \times 308{,}000\,(4000)^2$$

$$E_t = 1{,}139{,}000 \text{ [kw sec]}$$

(h) Energy input during signal delay time –

$$\Delta E_1 = T_d P_{g(\max)}$$

$$= 0.10 \times 224{,}000$$

$$\Delta E_1 = 22{,}400 \text{ [kw sec]}$$

(i) Energy input during valve closing time –

$$\Delta E_{2_{sv}} = f_{sv}\, T_{sv}\, P_{g(h-p)}$$

$$= 0.84 \times 0.29 \times 60{,}000$$

$$\Delta E_{2_{sv}} = 14{,}600 \text{ [sec]}$$

$$\Delta E_{2_{rsv}} = f_{rsv}\, T_{rsv}\, P_{g(i-p \text{ and } 1-p)}$$

$$= 0.88 \times 0.13 \times 164{,}000$$

$$\Delta E_{2_{rsv}} = 18{,}700 \text{ [kw sec]}$$

$$\Delta E_2 = \Delta E_{2_{sv}} + \Delta E_{2_{rsv}} = 33{,}300 \text{ [kw sec]}$$

(j) Energy input from entrapped steam –

$$\Delta E_3 = 1.056\,\eta \{(W_{1_1} u_{1_1} + W_{1_2} u_{1_2} + W_{1_3} u_{1_3}) - (W_{2_1} u_{2_1} + W_{2_2} u_{2_2} + W_{2_3} u_{2_3}) - (W_{1_1} - W_{2_1}) h_{2_1} - (W_{1_2} - W_{2_2}) h_{2_2} - (W_{1_3} - W_{2_3}) h_{2_3}\} + \Delta E_{3_4}$$

$$\Delta E_3 = 1.056 \times 0.8 \{(150 \times 1328 + 175 \times 1364 + 130 \times 1183) - (43.5 \times 1172 + 0.47 \times 857 + 0.5 \times 936) - (150 - 43.5) \times 1275 - (175 - 0.47) \times 925 - (130 - 0.5) \times 965\} + 22{,}100$$

$$\Delta E_3 = 121{,}400 \text{ [kw sec]}$$

(k) Total energy at peak speed –

$$E_e = E_t + \Delta E_1 + \Delta E_2 + \Delta E_3$$

$$= 1{,}139{,}000 + 22{,}400 + 33{,}300 + 121{,}400$$

$$E_e = 1{,}316{,}100 \text{ [kw sec]}$$

(m) Emergency overspeed –

$$N_e = \sqrt{E_e \frac{4.33 \times 10^6}{WR^2}}$$

$$= \sqrt{1.3161 \times 10^6 \frac{4.33 \times 10^6}{0.308 \times 10^6}}$$

$$N_e = 4300 \quad \text{[rpm]}$$

$$n_e = 119.4 \quad \text{[per cent]}$$

The speed N_e must not exceed the maximum speed agreed to by the parties concerned.

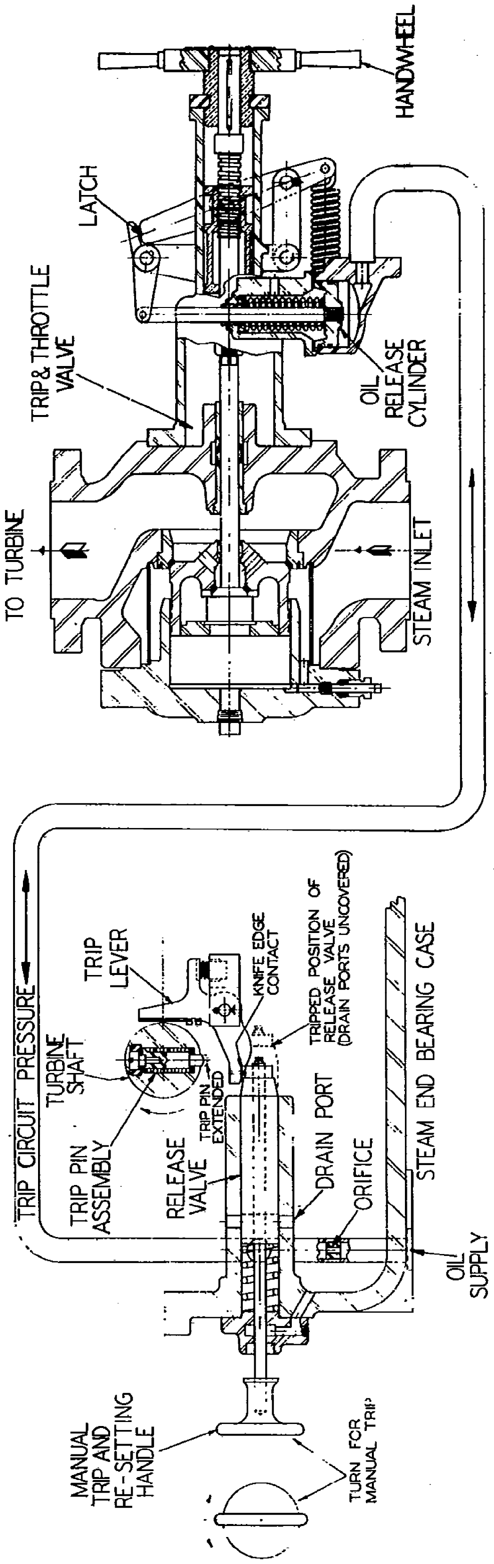

FIG. 2 TYPICAL OVERSPEED TRIP CIRCUIT

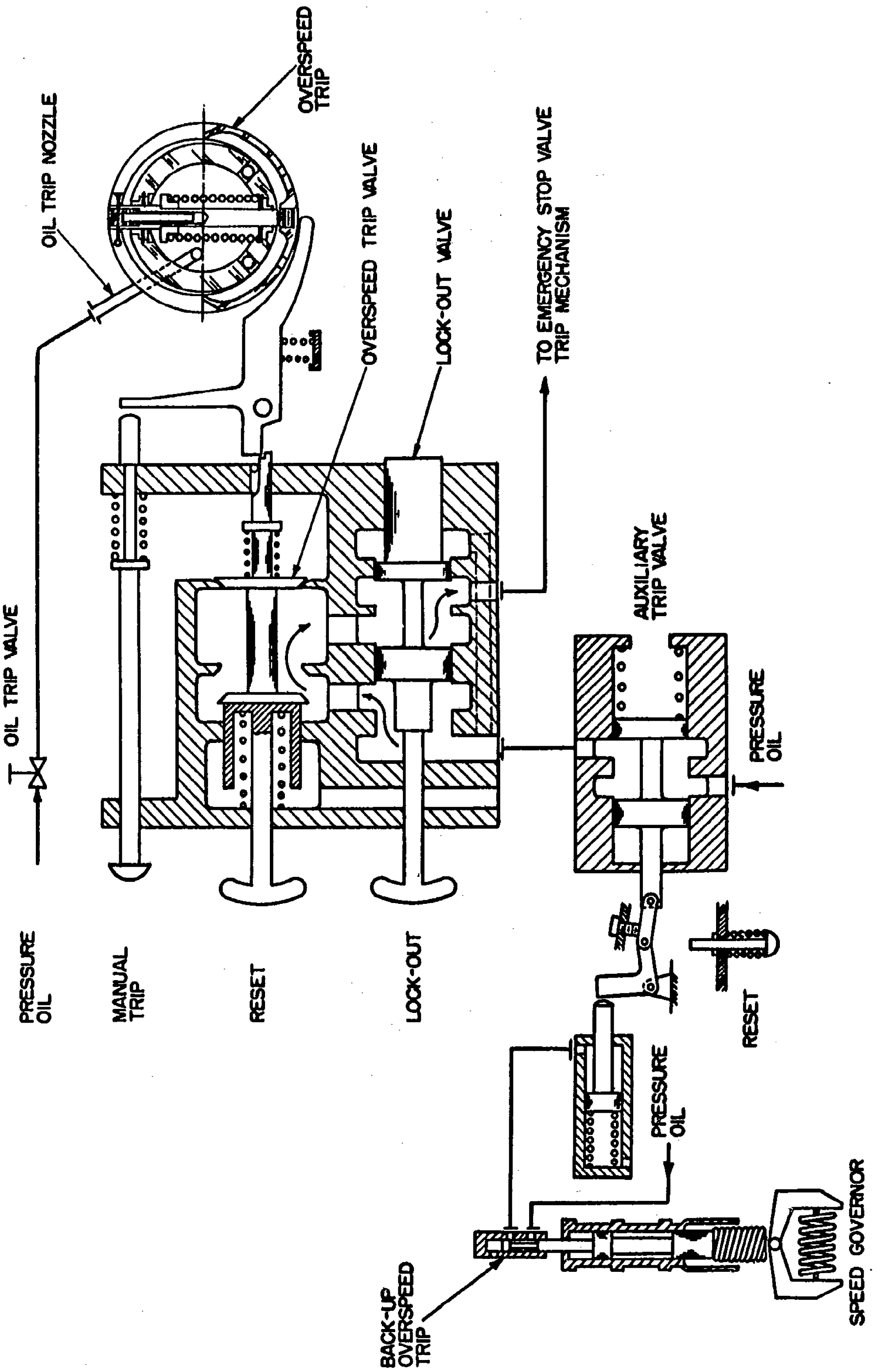

FIG. 3 TYPICAL RING TYPE OVERSPEED TRIP SYSTEM WITH TEST DEVICE

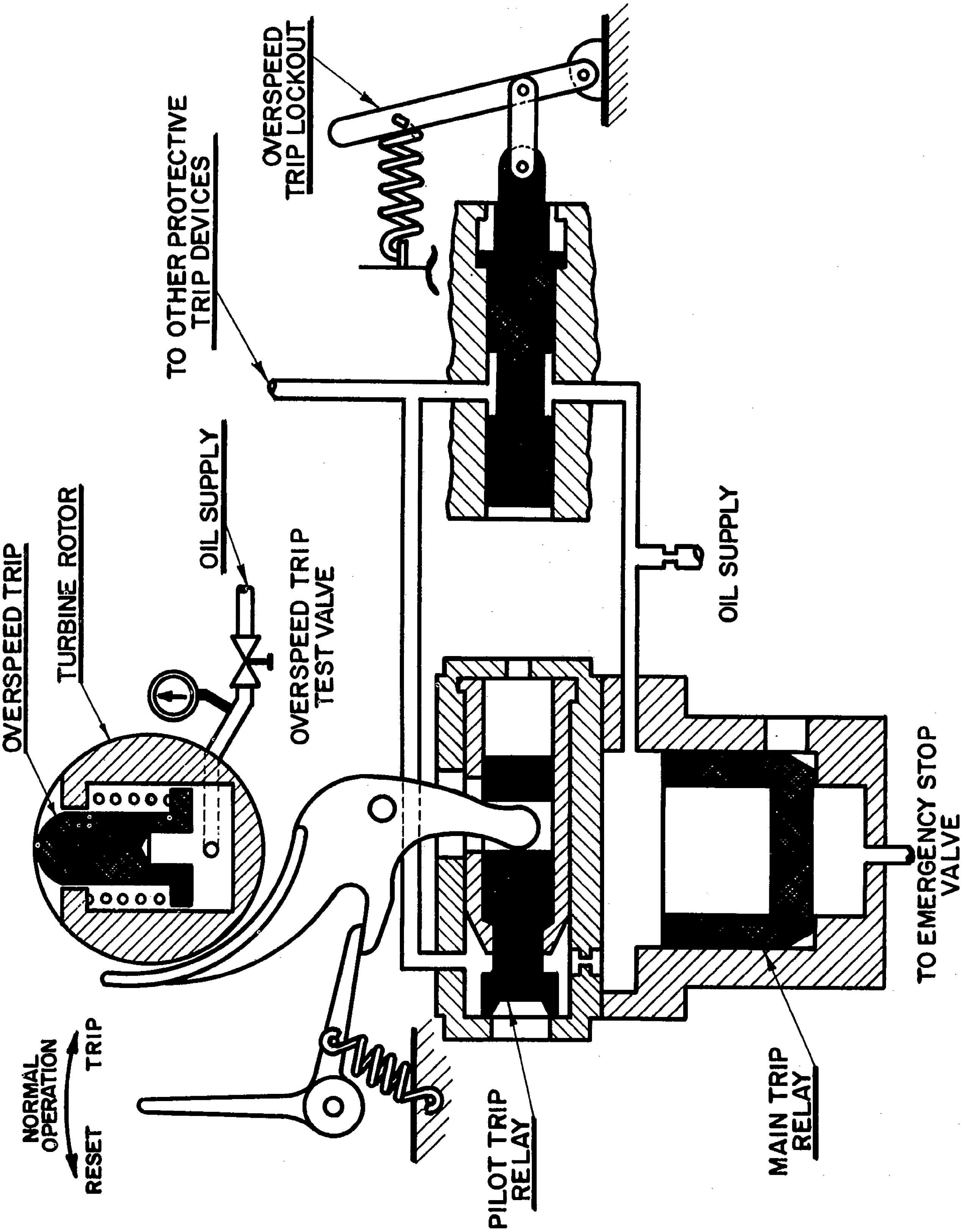

FIG. 4 TYPICAL BOLT TYPE OVERSPEED TRIP SYSTEM WITH TEST DEVICE

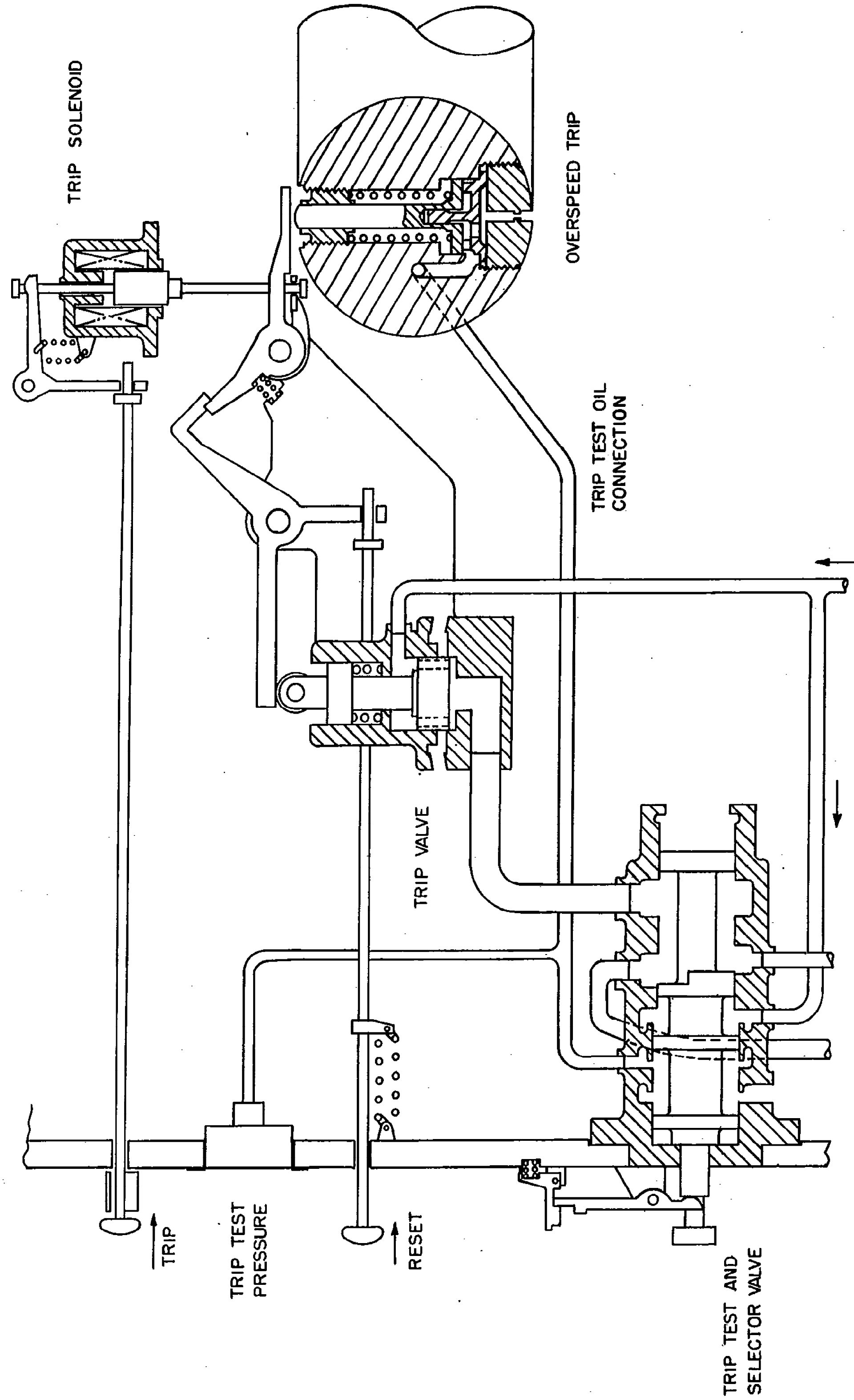

FIG. 5 TYPICAL BOLT TYPE OVERSPEED TRIP SYSTEM WITH TEST DEVICE

POWER TEST CODES

While providing for exhaustive tests, these Codes are so drawn that selected parts may be used for tests of limited scope.

A specially designed binder for holding these pamphlets is available.

A complete list of ASME publications ... upon request.

Power Test Codes Now Available