

Recommended Specification
for
**SPEED GOVERNING OF
INTERNAL COMBUSTION
ENGINE-GENERATOR UNITS**

Prepared by Subcommittee of the
Joint AIEE and ASME Committee on
Recommended Specifications for Prime Mover Speed-Governing

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Recommended Specifications
For the Speed-Governing of Internal Combustion
Engine-Generator Units**

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FOREWORD

Economic disadvantages of concern to purchasers and manufacturers alike have resulted, too frequently, from lack of uniform concepts concerning prime mover speed-governing characteristics and performance requirements. This was recognized earlier in the field of application of larger steam turbines and led to formation of the Joint AIEE-ASME Committee on Recommended Specifications for Prime Mover Speed-Governing and the publication of a recommended specification for the larger steam turbines. Somewhat later, another committee under this same sponsorship published a similar recommended specification applying to larger hydraulic turbines. Revised from time to time these formulations are now widely accepted as standard purchase specifications and as such have proved to be of great commercial value.

In September 1949, the Joint AIEE-ASME Committee, encouraged by the wide acceptance of the two earlier recommended specifications, formed another committee for the purpose of preparing Recommended Specifications for the Speed-Governing of Internal Combustion Engine-Generator Units. The diversified phases of interest in the field of application of internal combustion engines is well represented by the members of this committee.

In the preparation of the latter Recommended Specifications, it has been the committee's concept that engine users are primarily concerned with generally acceptable speed-governing performances, and that requirements beyond this introduce unwarranted technical refinements and augmented costs. It is recognized that observed speed-governing performances are necessarily influenced by the electrical and mechanical characteristics of: the connected load; the engine-generator unit itself; and any other prime mover-generator units with which the engine-generator unit may be paralleled. Hence the committee has given special attention to development of specification statements which distinguish the variable or other incidental operating characteristics of the connected load and of the engine-generator unit from those characteristics which are inherent in the speed-governing system itself. It is also recognized that for practical acceptance testing purposes, the speed-governing performance requirements must be specified on basis of reproducible operating conditions. For these reasons the specifications have been limited to the minimum equipment and performance requirements that are: (1) generally recognized in the field of application of reciprocating internal combustion engines which are directly connected to electric generators, (2) capable of being met by manufacturers with equipment of substantially standard design, and (3) capable of being measured under reproducible test conditions.

While deviations from these Recommended Specifications are not favored, there is nothing to preclude purchasers from specifying, or manufacturers from agreeing to include, additional equipment or performance requirements and thus changing the requirements stated in these specifications.

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This specification applies to speed-governing systems used on reciprocating internal combustion engine-generator units which are intended for an industrial or commercial type electric power service. It covers conditions of independent operation and, if separately agreed to, also covers parallel operation with other reciprocating internal combustion engine-generator units when connected to an alternating-current or a direct-current electric power system. For this type of electric power service, the numerical limits used for the speed-governing stability performances are more liberal in effect than those used in Specification Sections III and IV. Because of the nature of this type of power service, the refinements of equipment needed to achieve the alternate and more exacting performance requirements contemplated in the latter two Sections are not justified economically.	
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APPLICATION OF THE RECOMMENDED SPECIFICATIONS

1. The Recommended Specifications consist of four sections. Specification Sections II, III and IV are complete purchase specifications. They cover alternate arrangements and performance requirements of speed-governing systems for internal combustion engine-generator units. These are printed as individual forms. To gain the maximum benefit from these standards, particularly under normal conditions, it is recommended that the applicable section be included in full and as a part of the complete purchase specifications for the particular engine-generator unit. The Terminology, Section I, includes definitions and applications of terms and some explanatory comments. Pertinent portions of Section I, while not ordinarily transcribed in full, are made an integral part of each speed-governing specification as indicated in paragraphs 2 of Specification Sections II, III, and IV.

2. In connection with the general application of the Recommended Specifications, it is helpful to consider some of the background relating to their preparation. As an early step many speed-governing specifications were obtained from a wide variety of sources and reviewed. Significant weaknesses were found in most of these specifications. Admittedly, a purchase specification should be brief and concise, and yet define clearly the pertinent requirements. It is natural to expect this in a specification dealing with the speed-governing of prime movers, particularly engines, because of the large numbers that have been installed over the years. Certainly the internal combustion engine-generator units of today are performing successfully under all manner of electric power service conditions. However, during recent years these conditions have become more exacting and so have the speed-governing requirements. In older specifications, to meet conditions associated with modern power service requirements, the tendency has been simply to add generalized statements. This has resulted in a general lack of clarity due in part to the confused terminology that has become associated with these loosely phrased specifications.

3. The Recommended Specifications have been formulated to correct this situation. The specification requirements and the related terminology are clearly expressed in terms of measurable quantities. Of particular importance is the concept that all required performances shall be measurable under test conditions that can be reproduced in the typical installation and in the factory.

4. To further explain application of the Recommended Specifications, it is helpful to consider some of the interrelationships that are introduced by: action of the speed-governing system; action of the balance of the engine-generator unit; and effects caused by actual variations in the load as imposed at the generator terminals.

5. The speed-governing system, as an automatic control device, enables the engine within its power output capacity to drive the generator at desired mean speeds cor-

responding to different values of constant load as imposed on the unit, or with due consideration to the time-lag characteristic of the engine and generator as an assembly, to recover quickly the desired mean speeds following rapid changes in load. Two typical operating conditions are indicated—one, with steady-state electric loads and gradual changes between these loads and the other, with rapidly-changing loads. Two basic governing properties, regulation and stability, are involved under all conditions of operation. However, the regulation characteristic predominates under the first set of operating conditions. Here conditions of equilibrium are most favorable due to the limited influences of various possible disturbances, particularly the external load disturbances. It is under the second set of operating conditions that the stabilizing influence contributed by the speed-governing system is of particular importance.

6. It was concluded from the review mentioned in paragraph 2 above, that the specifications then in use were in general agreement as to requirements covering the essential assembly and accessory features constituting a speed-governing system. Also, the relation of the steady-state speed regulation performance to engine operation appears to be understood generally.

7. Based on this review and on wide operating experience, it was concluded that it is not necessary to specify the steady-state incremental speed regulation performance for engine-generator units except when intended for parallel operation with turbine-generator units. This follows since the steady-state speed-power output characteristic of the typical internal-combustion engine as used for generator service is essentially a straight line, or perhaps somewhat convex, over the full extent of its power output range. Almost invariably it is substantially free from the wave-like irregularities observed particularly in speed-power output curves of steam turbines. If the speed-governing system of a turbine controls in the zones of any marked irregularities along its speed-power output curve, objectionable power surging may result. Because of this, the nature of the steady-state speed-power output curve and any material variations in steady-state incremental speed regulation at load points along this curve are of particular interest to utility engineers when considering various types of prime-mover-generator units for parallel operation with steam turbine-generator units.

8. Definitions for steady-state speed regulation and steady-state incremental speed regulation as used in the Recommended Specifications are based on observations that can be made under reproducible operating conditions. They have practical meaning in terms of engine applications. Determinations of steady-state speed regulation performances are simple. The results are not influenced, too critically, by minor variations from the prescribed generator load conditions or by factors introduced by some irregular conditions of the various elements of the

engine-generator unit and its associated accessories. Determinations of individual steady-state incremental speed regulation performances, while relatively simple, are time consuming. To be of practical value, the determinations must be made under conditions of numerous part loads with rated speed obtaining at each load point.

9. Because of considerations indicated in the preceding paragraphs, the steady-state incremental speed regulation is not required in Specification Sections II and III but is included in Specification Section IV.

10. As previously mentioned, need for speed-governing stability under dynamic load conditions has been recognized in many of the specifications heretofore prepared by purchasers. However, most of these have expressed unattainable performance requirements or have included performance requirements that cannot be evaluated by practical means.

11. The problem has been to specify speed-governing stability performances that can be evaluated in the final installation by use of satisfactory testing facilities. The practical solution treats the speed-governing system as one of the elements among those which together determine a fundamental characteristic, one that is of primary importance to the user, namely the stability of the complete electro-mechanical power system. This basic characteristic is defined and discussed further in paragraphs 31 and 32 of Section I.

12. In the Recommended Specifications, four separate governing characteristics are used to evaluate the stability of the speed-governing system. These are termed: "Steady-State Governing Speedband"; "Momentary-Overspeed"; "Momentary-Underspeed"; and its coincident "Recovery Time." These characteristics are defined in terms of performance requirements which are critical from the design and operating viewpoints. They have great significance even though no one alone directly expresses the stability characteristics of the speed-governing system in terms of general operating conditions. However, results of tests, made in accordance with these requirements, when considered together, effectively imply the stability performance under indiscriminate or general dynamic load conditions.

13. It is helpful at this point to review some of the considerations which justify the above conclusion. Pre-supposing a properly coordinated engine-generator unit, the load at the generator shaft coupling must change, or tend to change, the speed of the engine in order to actuate the speed-governing system. This causes the speed-governing system in turn to adjust the rate of fuel being supplied to the engine cylinders. Thus the speed-governing system senses speed or load changes as they occur. Its direct control action is limited. Physically it can only position the fuel-metering equipment of the engine. Beyond its direct control are complex interacting forces which characterize the combustion and also the mechanical functioning of the power cylinders and running gear of the engine. Thus, under dynamic load conditions as

well as steady-state electric load conditions, the extent and nature of the control movements of the speed-governing system may be influenced to a considerable extent by variations in the driving torque at the engine shaft coupling as produced momentarily by forces and other influences within the engine itself. Included may be influences of torque irregularities which result from unequal power outputs as developed by the various cylinders due to effects of misadjustment and other factors. In all cases the stabilizing influence, or restoring effect of the speed-governing system is expected to compensate in some degree for the component speed variations or errors which are introduced because of these operating considerations.

14. Also influencing the resultant speed changes and beyond the engine are other interacting forces peculiar to conditions of the load at the generator, or more particularly the related resisting torque effects imposed at the engine shaft coupling. These may be induced by momentary impulse forces, electric and mechanical, which are external to the engine-generator unit. Other disturbing influences include interacting forces that may be introduced by various automatic control devices possibly associated with the operating engine-generator unit, and the performances of which are not under control of the speed-governing system. The stabilizing influence of the speed-governing system is often expected, but occasionally unable, to compensate effectively for the component speed variations or errors caused by these forces. Under all conditions of operation, including those noted in the preceding paragraph and those in this paragraph, the normal speed-governing system endeavors to minimize changes in speed regardless of causes. These influences are listed in paragraph 33 of Section I.

15. While momentary variations in speed of the engine-generator unit can be determined for any condition of operation, the problem is to determine the component stabilizing influence or the restoring effect actually contributed by the speed-governing system in relation to all the disturbing and restoring influences in the complete electro-mechanical power system for all conditions of operation. This is particularly difficult under the general dynamic load conditions occurring at the engine shaft coupling. The problem is further complicated under conditions of parallel operation. Results from an ideal testing procedure would account for each of the disturbing and restoring influences in the complete electro-mechanical power system under any condition of operation. Theoretically this would include evaluations of the component restoring forces actually introduced by the speed-governing system. Such a procedure would provide an evaluation of the inherent stability of the speed-governing system itself. As indicated in paragraph 34, Section I, a practical acceptance test and evaluation procedure meeting these requirements is not envisioned at this time.

16. Consideration of the factors involved, however, does lead to a practical treatment for specifying speed-governing stability under conditions of sudden changes in load

at the generator and also under certain steady-state load conditions. In such a specification separate speed-control performance requirements may be so specified that evaluations in terms of observed speed changes can be made when indiscriminate disturbances in the complete electro-mechanical power system external to the engine-generator unit have been eliminated as far as possible. To this end the unit is operated as the only source of power for the system and other simplifications are adopted. Thus various operating conditions may be prescribed which, in general, can be reproduced from plant to plant. Under these conditions simultaneous measurements can be made of the momentary speed changes and the time required to re-establish specified allowable deviations of speed following sudden changes between steady-state electric loads at the generator terminals. Also, limits can be specified for recurring speed changes and the performances evaluated under conditions with given steady-state loads.

17. In the Recommended Specifications, two extreme test conditions are prescribed. In one case, load is suddenly rejected. The test results evaluate the Momentary-Over-speed characteristic. In the other case, load is suddenly applied. The test results evaluate the Momentary-Under-speed and the coincident Recovery Time characteristics. Observations are also made of recurring speed changes that may exist when operating with an essentially unvarying load. This test evaluates the Steady-State Governing Speedband characteristic. Definitions and other details applying to these performance characteristics are given in paragraphs 35 through 45 of Section I.

18. This becomes a really practicable treatment for

specifying the inherent stability of the speed-governing system if all relating considerations of design, construction, operation and maintenance are required to be properly representative. This is noted in paragraphs 34 and 36 of Section I. For these reasons, it is presumed in each of the Recommended Specifications that those considerations which may affect the performance results, and are beyond the scope of the Recommended Specifications, will be controlled separately by specification or otherwise provided for as needed to meet the requirements of accepted standards and good practice. Further, these qualifications are of importance, first, because the components of complete installations, even engines and generators, may be procured separately and variously assembled by the buyers, and second, because the performances of the components included in the complete installation depend upon the manner of assembly and also to a considerable extent upon the nature of the maintenance and operating techniques. Because of these considerations, it may be necessary to conduct other conventional tests before evaluating performances of the speed-governing system to determine its inherent stability.

19. Experience in the field of application of larger steam and hydraulic turbine-generator units indicates that limits for deadband are desirable when used in the speed-governing specifications applying to these prime movers. This is largely due to size effects. However, in specifications for engine-generator units, deadband is not featured because experience indicates that this is not necessary. The actual deadband is very small and its effect, in any event, is included in the observed performances, particularly when evaluating the stability performances.