Manual of Petroleum Measurement Standards Chapter 5—Metering

Section 5—Fidelity and Security of Flow Measurement Pulsed-data Transmission Systems

SECOND EDITION, AUGUST 2005

REAFFIRMED, AUGUST 2015

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AMERICAN PETROLEUM INSTITUTE

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FOREWORD

Chapter 5 of the API Manual of Petroleum Measurement Standards (API *MPMS*) provides recommendations, based on best industry practice, for the custody transfer metering of liquid hydrocarbons. The various sections of this Chapter are intended to be used in conjunction with API *MPMS* Chapter 6 to provide design criteria for custody transfer metering encountered in most aircraft, marine, pipeline, and terminal applications. The information contained in this chapter may also be applied to non-custody transfer metering.

The chapter deals with the principal types of meters currently in use: displacement meters, turbine meters and Coriolis meters. If other types of meters gain wide acceptance for the measurement of liquid hydrocarbon custody transfers, they will be included in subsequent sections of this chapter.

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Chapter 5—Metering

Section 5—Fidelity and Security of Flow Measurement Pulsed-Data Transmission Systems

5.5.1 Introduction

The purpose of this publication is to serve as a guide for the selection, operation, and maintenance of various types of pulsed-data, cabled transmission systems for fluid metering systems to provide the desired level of fidelity and security of transmitted flow pulse data. This publication does not endorse or advocate the preferential use of any specific type of equipment or systems, nor is it intended to restrict future development of such equipment.

5.5.2 Scope

The recommendations set forth in this publication are concerned only with the fidelity and security of pulsed-data, cabled transmission systems between a flow meter or flow meter transducer and a remote totalizer.

5.5.3 Field of Application

In order to achieve different levels of security that can be applied to transmission systems, criteria and recommendations for the design, installation, use, and maintenance of the relevant equipment are described in this publication. The levels of security are designated E to A from the lowest to the highest order of security, respectively. Chapter 5 Section 5 does not define which levels of security are to be used for a particular system application.

5.5.4 Referenced Publications

The current editions of the following API *MPMS* Standards contain information applicable to this chapter:

Chapter 1 “Vocabulary”

Chapter 21.2 “Electronic Flow Measurement”

NFPA[1]

493 *Intrinsically Safe Apparatus in Division 1 Hazardous Locations*

ISA[2]

RP 12.6 *Installation of Intrinsically Safe Instrument Systems in Class 1 Hazardous Locations*

[1]National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts, 02169. www.nfpa.org.

[2]The Instrumentation, Systems, and Automation Society, 67 Alexander Drive, Research Triangle Park, North Carolina, 27709. www.isa.org.

5.5.5 Definitions

See API *MPMS* Chapter 1, “Vocabulary,” for additional definitions.

5.5.5.1 fidelity: is defined as the exactitude with which the primary indication reproduces the inherent precision of the measurement.

5.5.5.2 methods of comparision (as used in Levels A through D): is the determination of the fidelity of primary indication by use of a redundant, alternate, or secondary source to verify the desired level of security.

5.5.5.3 noise: is unwanted signals that may affect fidelity and which occur for periods exceeding 0.2 seconds.

5.5.5.4 scaler: is an electronic device that accepts flow pulses representing arbitrary volume or mass increments and outputs flow pulses scaled to represent more useful volume or mass increments, 1 pulse per barrel for example.

5.5.5.5 transients: are disturbances having a duration of 0.2 seconds or less.

5.5.6 Levels of Security

Five levels of security protection are identified and designated, of which Level E represents the minimum acceptable level. Typical examples of these five levels are shown diagrammatically in Figures 1 through 5. A metering system may comprise sections having the same or different levels of security protection, where the outputs are used for different purposes. Figures 1 through 5 show typical functional arrangements of modules required to achieve the specified levels of security. These function modules may be housed separately or in combination.

In the examples, emphasis has been placed on the transmission system because this is considered the most vulnerable area of the whole. Fidelity and security for scaler and totalizer are not illustrated and are considered to be acceptable to Level E for the majority of applications. It may, however, be considered necessary in some circumstances to duplicate the scaler and/or totalizer section.

5.5.6.1 LEVEL E

Error reduction at Level E is achieved solely by correctly installed apparatus of good quality. This is a straightforward totalizer system. Figure 1 illustrates a simple system with no built-in provisions for error monitoring. Only good quality components and subunits, correctly installed, will lead to confidence in the security of the system. The use of a preamplifier transmitter to drive the transmission line is considered beneficial for the majority of applications, as is the provision of signal conditioning. The system, though simple, does not differ in hardware quality from more secure systems that use the same elements.

5.5.6.2 LEVEL D

A Level D system consists of manual error monitoring at specified intervals by methods of comparison. This level of security is intended to give protection against functional errors and failures and is a method of verification by manual action. The readout can be visually checked against an independent totalizing system.

Figure 2 illustrates a simple system with means of making a periodic manual assessment of security. The secondary readout may be permanent or temporary, local or remote. Manual comparison made during a periodic check will monitor the integrity of the transmission and totalizer elements. It may be less convenient than provisions of Level C, as the system may have to be stopped for readings to be taken. Overall security is mainly inferred from the performance during the error monitoring period

5.5.6.3 LEVEL C

A Level C system consists of automatic error monitoring and error indication at specified intervals by methods of comparison. This level of security is intended to give protection against functional errors and failures and may be achieved by design methods. The time intervals for error monitoring may be subject to revision in the light of experience gained. Figure 3 illustrates a dual transmission system with a dual pulse comparator of simple design. If the pulses delivered become numerically out of a step, warning will be given by the comparator (differential counter). Level C security will be defeated by other disturbances dealt with by higher level security systems. For example, simultaneous interference superimposed on both channels will not be detected because a numerical difference between channels is not caused. It is intended that this form of error monitoring be carried out periodically; the monitoring equipment may thus be shared with other metering systems.

Level C security is inferred from the results obtained during the monitoring period.

5.5.6.4 LEVEL B

Level B consists of continuous monitoring, error indication, and alarm signaling by methods of comparison. This level of security is intended to give warning of transients and other spurious influences, in addition to functional errors and failures. Figure 4 illustrates a dual transmission system with dual pulse comparator in which the pulse trains are continuously monitored for number, frequency, phase, and sequence and any irregularity is indicated. Simultaneous interfering pulses must be detected and indicated. Alarm is given if pulses are lost or gained on either channel. It may not be possible to determine if pulses are lost on a channel or gained on the other channel.

5.5.6.5 LEVEL A

Level A consists of continuous verification and limited correction by methods of comparison. This level of security is intended to give protection against transients and other spurious common mode influences, in addition to functional errors and failures. Figure 5 illustrates a dual transmission system protected against both dynamic faults arising from monitoring the duplicated pulses and by static testing the electrical integrity of the transmission circuits. The system should still operate as a Level E system if one of the transmission channels fails. An incidental advantage of Level A is its ability to detect some mechanical faults in the transducer. Simultaneous pulses caused by symmetrical interference are automatically rejected and do not influence the system. Other than a complete failure of one of the transmission channels, no attempt is made to automatically compensate for lost or gained pulses on either transmission channel. Alarm will be given in all circumstances when impaired pulses are received by the comparator. It may be desirable to provide redundancy in one or all of the elements shown.

5.5.7 System Design Considerations

5.5.7.1 GENERAL DESIGN CRITERIA

The most important consideration is to prevent the occurrence of spurious pulses rather than rely upon the provision of verification circuitry to provide protection against the results of false measurement. The design approach shall, therefore, take into account the noise environment. Poorly designed units and inadequate regard for noise pick-up can seriously influence the performance of the equipment. Low-level high-impedance signals become attenuated by line losses, and the overall signal-to-noise ratio can further be impaired by the greater probability of noise in longer lines. A secure and reliable pulsed-data transmission system will be achieved most readily by concentrating on the elimination of error sensitive elements. Addition of dual circuits or other techniques aimed at increasing security will guard against influences that are beyond the control of the designer.

As a precaution, suppliers of signal processing equipment should be advised of radio frequencies used in close proximity so radio frequency interference immunity can be investigated.

5.5.7.2 TOTALIZERS

5.5.7.2.1 Primary Totalizer

Accurate and secure measurement requires that the value of the totalizer count cannot be impaired during normal delivery operations. The use of such a counter is mandatory for custody transfer and revenue accounting systems, and is recommended for all other non-custody and check meter systems. In custody transfer electronic flow measurement systems, the primary totalizer is contained in the Tertiary device as described in API *MPMS* Chapter 21. It shall be non-resettable during normal delivery operations, but can be reset by authorized personnel for the purposes of maintenance or commissioning of equipment. Security and audit trail requirements of the primary totalizer are covered in API *MPMS* Chapter 21.

5.5.7.2.2 Secondary Indication

Where it is acceptable to the parties concerned in a transaction, ancillary devices need not have as high a degree of security protection as the primary indication. However, such devices should be given basic approval as part of an overall approval and should be compatible with it. Representative secondary indicators include a counter directly driven by a flow meter, an electromechanical counter, or an electronic counter equipped with a standby battery.

5.5.7.3 TYPICAL CAUSES OF ERROR

Typical causes of error which should be taken into consideration are as follows:

1. Electromagnetic interference.
2. Transients.
3. Power supply variations and/or interruption.
4. Inadequate signal level as a result of line loss.
5. Common-mode noise induced in cabling.
6. Series-mode noise induced in cabling.
7. Noise introduced from ground loop problems.
8. Excessive gain and frequency response of the system elements.
9. Spurious signals induced from other meters sharing the same multicore cable.
10. Short circuit or open circuit of conductor pair or short circuit of either conductor to ground or shield.
11. Bad connections, temperature variations and extremes, vibration shock, and adverse environmental conditions.

5.5.7.4 SIGNAL PRE-AMPLIFIERS

A signal pre-amplifier should be introduced into the transmission system at the transducer, if transmission distance or manufacturer's requirements so dictate.

5.5.7.5 STANDBY POWER SUPPLY

Where a power interruption could result in a significant error in measurement, provision for an uninterruptible power supply should be considered.

5.5.7.6 TEST REQUIREMENTS

Careful consideration should be given to the form of tests to be applied to the electronic system for fidelity and security purposes. The tests should take into account the major environmental hazards that experience shows are likely to be encountered on site.

5.5.7.7 GENERAL PRECAUTIONS

The gain and frequency response of the system elements should be restricted to that required by the application. Sensitivity controls on pre-amplifiers, scalers, and others shall not be capable of unauthorized adjustment. The totalized pulse counts existing at the time of any power failure shall be retained. Cable pairs and the instrument input circuit shall be protected from excessive transient voltages or currents as well as electrical storms.

5.5.8 Installation

5.5.8.1 SIGNAL AMPLITUDE

The following points shall be observed so that the signal amplitude from the transducer to the receiver can be maintained at a high level. The installation recommendations specified by the manufacturers shall be carefully followed, while complying fully with statutory requirements and/or safety codes. The length of transmission lines from the meter to the readout equipment shall be held to a minimum. The appropriate signal transmission cables shall be used. The supply voltages to preamplifiers and constant amplitude pulse generating systems shall be checked to ensure that they are of proper magnitude and do not exceed noise or ripple maximums as specified by the equipment manufacturer.

5.5.8.2 SIGNAL-TO-NOISE RATIO

The following points should be observed so that the signal-to-noise ratio can be optimized. Only shielded transmission cable of the proper material, size, and number of conductors shall be used.

Individual twisted shielded pairs afford the maximum protection against noise. Helical lay cables are acceptable for many installations. Parallel lay cables should be avoided. The shield of a transmission cable should be grounded at one point only, to prevent formation of ground loops.

A continuous run of transmission cables should be used whenever possible. Where joints are unavoidable, continuity of the shield shall be assured. Joints should be encapsulated to maintain the electrical specifications and security of the cable.

When multi-readout devices are used and wired in parallel, shielded cables should be used for connecting wiring.

The data transmission lines should not share a conduit with anything other than shielded cables or cables from direct current temperature sensors. If the maximum electrical power carried by any one transmission cable is ten or more times greater than the minimum power carried by any flowmeter signal data transmission cable, separate conduits should be provided. In the event that separate conduits are not feasible, additional cable shielding should be incorporated and circuits tested to verify necessary fidelity of signals. Data transmission cables should not be run in parallel with power cables. When this is not possible the cables should be sufficiently spaced to prevent interference or be adequately shielded.

If it is necessary for transmission cables and power cables to cross, this should be at right angles whenever possible. When transmission cables are run in ducts or inside control cabinets, every attempt should be made to keep the shielded cable bundle intact and separate from other conductors. All spare transmission cable and conductors that are run in a conduit with an active transmission line should have the shield and conductors grounded at the same single point as the active line.

The grouping of cables to intrinsically safe devices with other current-carrying cables requires special consideration in hazardous areas, and governing regulations must be followed. Typical references are NFPA 493, *Intrinsically Safe Apparatus in Division 1 Hazardous Locations*, and ISA RP 12.6, *Installation of Intrinsically Safe Instrument Systems in Class I Hazardous Locations.*

5.5.8.3 COMMISSIONING

5.5.8.3.1 General

Before commissioning an installation, the commissioning engineer shall ensure:

a. Correct mechanical installation of the equipment.

b. A satisfactory electrical installation, with particular attention to the weatherproofing of the electrical devices, especially the field junction boxes.

c. Satisfactory wiring, in compliance with applicable standards and electrical safety codes.

5.5.8.3.2 Testing

The commissioning of different types of systems will demand different procedures, which shall be clearly defined by the manufacturers. Many manufacturers are able to provide relatively simple equipment for testing individual parts of a system after installation, and the initial testing and calibration of the equipment can often and conveniently be carried out before an attempt is made to check the whole system. Typical electrical test apparatus, would include an oscilloscope and pulse generator The pulse generator used should be capable of emulating the pulse term of the particular type of transducer being substituted. Such equipment must be of a type which is electrically safe for the environment in which it is to be used.

The preferred test method consists of injecting a known number of test pulses into a transmission system at the flow transmitter connections. This test signal should have a strength of not more than 50 percent at the normal transmitter signal and consist of at least 100,000 pulses. If redundant transmission channels are used, the phase difference between the two pulse trains must fall within the phase tolerance specified by the manufacturer of the flow transmitter. The test signal shall be monitored by the installed receiving apparatus, and the number of pulses registered must be equal to the number transmitted.

A test can also be conducted by injecting a pulse train of known frequency into the transmission system. This test signal should have a strength of not more than 50 percent of the normal transmitter signal. If redundant transmission channels are used, the phase difference between the two pulse trains must fall within the phase tolerance specified by the manufacture of the flow transmitter. The test signal shall be monitored by the installed receiving apparatus. The indicated frequency should match the transmitted frequency to an accuracy of +/- 0.01 percent. This second test method is less precise than the preferred test method because it introduces the additional uncertainties of the signal generator and receiving apparatus time-bases and display readout resolutions. Injecting the test signal in place of the normal transmitter signal also means that the pulse frequency generator could be operated in extreme operating environments with the potential of introducing stability and drift errors.

Tests should be performed at two conditions that represent the maximum and minimum flows between which the meter normally operates, except during startup and shutdown.

5.5.9 Inspection and Maintenance

5.5.9.1 NEED FOR INSPECTION AND MAINTENANCE

It is essential that regular inspection and maintenance of all apparatus, systems, and installations (including cable conduit and the like) is carried out with competent personnel according to a schedule that has been agreed upon after consultation between the manufacturers, their agents, and the users. It should be noted that an apparently correct functional operation of a system does not necessarily ensure compliance with the selected level or levels of security.

5.5.9.2 GUIDELINES

5.5.9.2.1 General

All normal precautions relating to safety must be taken into account, especially those pertaining to work in hazardous atmospheres. Although production or other operational requirements should be considered, these should not result in the postponement of essential inspection, maintenance, or repairs. Following any repairs, adjustments or modifications, those parts of the installation that have been disturbed should be checked for compliance with the system specification by testing the integrity of the pulse transmission channels as described in 5.5.8.3.2.

5.5.9.2.2 Ground Continuity

Unless special ground fault protection is employed, the ground path impedance of each circuit should be low enough to permit the passage of a current at least three times the current rating of the circuit fuse or protective device.

All grounding connections (including those of any supplementary grounding conductors) shall be checked to ensure that they are clean and tight, and the ground path impedance associated with each item of apparatus shall be measured when the system is commissioned, and at appropriate intervals thereafter as determined by system performance (i.e. a poor ground is likely to degrade system performance and cause alarms and warnings to occur). Ground path impedance measurements shall be made as follows, depending upon the area classification and the results of any necessary certification testing by the responsible authority. If there is no likelihood of a flammable atmosphere being present, impedance measurements shall be made at current of not less than 15 amperes.

When there is any risk of a flammable atmosphere being present, impedance measurements shall be made with an intrinsically safe continuity tester. It must be appreciated, however, that in the case of these instruments, because of the very low current level involved, no indication can be given at the current carrying capacity of the circuit under test. Furthermore, the tests can be adversely affected by stray current. Grounding continuity does not guarantee the effectiveness of cable shielding.

5.5.9.2.3 Protective Devices

At commissioning of the system and at appropriate intervals thereafter, as determined by system performance, all protective devices (such as alarms, trips, and standby equipment) shall be examined and, if considered necessary, tested to ensure that equipment is operating at design settings.

5.5.9.2.4 Outside Interference

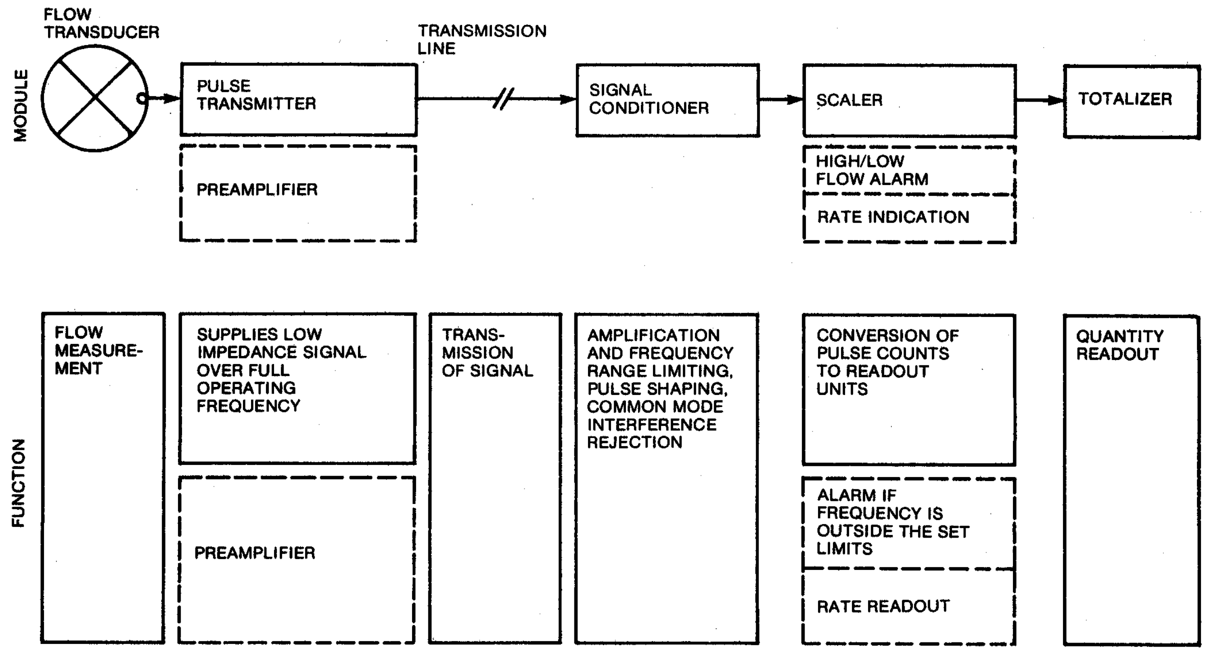
Checks should be made to ensure that no additional extra apparatus having the potential to interact with the pulse data transmission system has been installed in the vicinity of the system. If such apparatus has been installed since the last inspection, then the system shall be tested to ensure that no signal is induced into the system by the adjacent apparatus.

5.5.9.2.5 Records

A system shall be established to record the results of inspections and tests for all apparatus, systems, and installations and the details of corrective actions taken. The records shall include details of all modifications. additions, or deletions, none of which are to be made without prior permission.

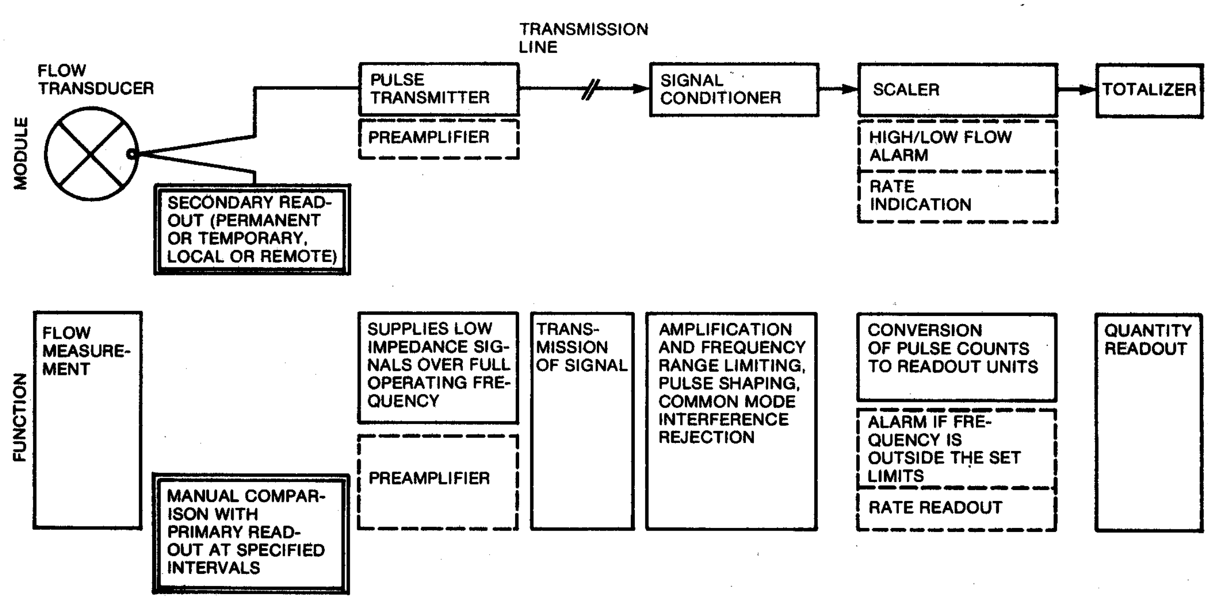
5.5.9.2.6 Spares

Vital spares, according to the manufacturers' recommendations, should be readily available for the correct maintenance of equipment.



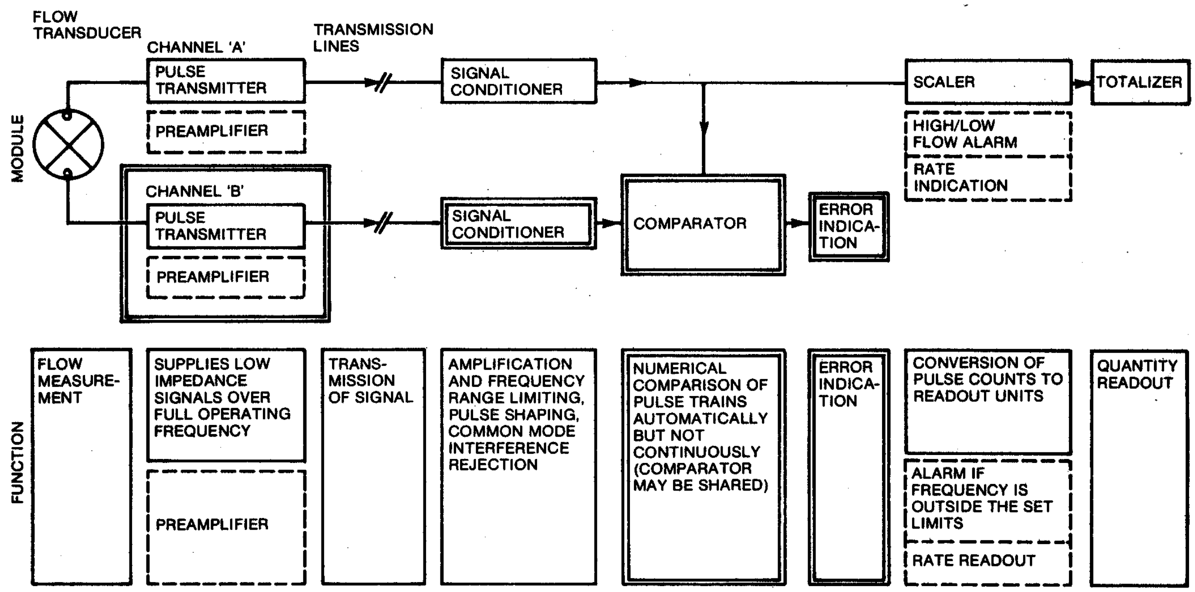
NOTE: The modules and functions shown in full are essential. Those shown dotted are optional.

Figure 1—Typical Functional Arrangement for a Level E Pulse Security System



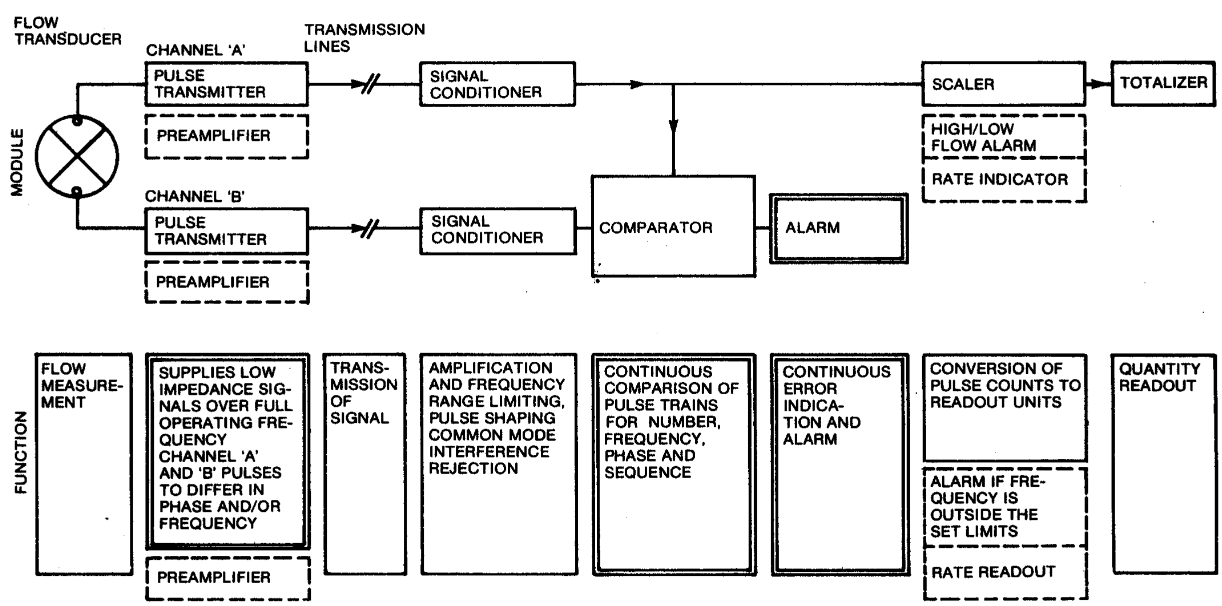
NOTE: The modules and functions shown in full are essential. Those shown dotted are optional. The modules and functions boxed in double lines indicate the difference from Level E.

Figure 2—Typical Functional Arrangement for a Level D Pulse Security System



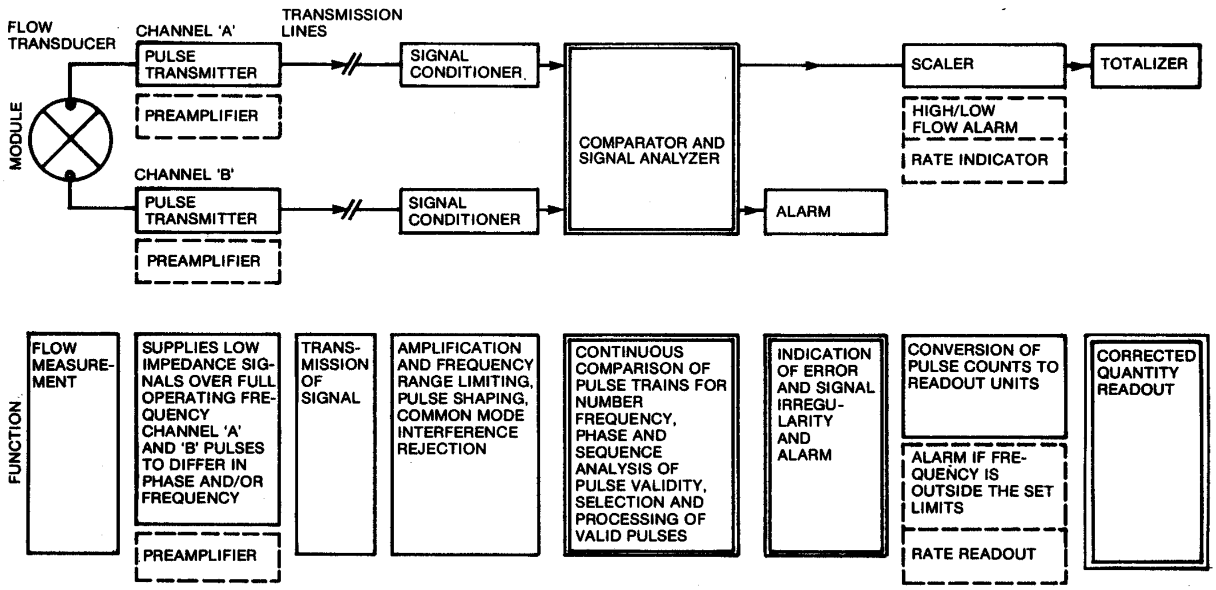
NOTE: The modules and functions shown in full are essential. Those shown dotted are optional. The modules and functions boxed in double lines indicate the difference from Level D.

Figure 3—Typical Functional Arrangement for a Level C Pulse Security System



NOTE: The modules and functions shown in full are essential. Those shown dotted are optional. The modules and functions boxed in double lines indicate the difference from Level C.

Figure 4—Typical Functional Arrangement for a Level B Pulse Security System



NOTE: The modules and functions shown in full are essential. Those shown dotted are optional. The modules and functions boxed in double lines indicate the difference from Level B.

Figure 5—Typical Functional Arrangement for a Level A Pulse Security System

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