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شرکت ملی گاز ایران

مدیریت پژوهش و فناوری

امور تدوین استانداردها

IGS

مشخصات فنی خرید

شتاب نگارزلزله در سیستم قطع خودکار ایستگاههای گاز شهری

Earthquake accelerometers in automatic shut-off system of urban gas stations

برای استفاده از استانداردها فقط به آخرین نسخه منتشرشده درسایت استانداردها مراجعه گردد

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شرکت ملی گازایران

دفترمدیرعامل

ابلاغ مصوبه هیأت مدیره

مدیر محترم پژوهش و فناوری و رئیس شورای استاندارد

باسلام،

به استحضار می‌رساند در جلسه ۱٦٤٦ مورخ ۱۳۹٤/٦/۱ هیأت مدیره، نامه شماره گ۹/۰۰۰/٦٥۰٥۷ مورخ ۹٤/٥/۱۰ مدیر پژوهش و فناوری و رئیس شورای استاندارد درمورد تصویب نهایی استاندارد تحت عنوان "شتاب نگار زلزله در سیستم قطع خودکار ایستگاه‌های گاز شهری" به شماره تقاضای IGS-M-IN-305(0) مطرح و مورد تصویب قرارگرفت .

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ناصر آبگون
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FOREWORD

This standard is intended to be mainly used by NIGC and contractors and has been prepared on interpretation recognized standards , technical documents , knowledge , backgrounds and experiences in gas industries at national and international levels .
Iranian gas standards (IGS) are prepared , reviewed and amended by technical standard committees within NIGC Standardization division and submitted to the NIGC's "STANDARDS COUNCIL" for approval .
IGS Standards are subject to revision , amendment or withdrawal , if required , thus the latest edition of IGS shall be checked/inquired by NIGC users .
This standard must not be modified or altered by the end users within NIGC and her contractors .
Any deviation from normative references and / or well known manufacturers specifications must be reported to Standardization division .
Any comments from concerned parties on NIGC distributed IGS are welcome to technical standards committees and will receive serious attention and consideration should a revision to standards is recommended .

GENERAL DEFINITIONS :

Throughout this standard the following definitions , where applicable , should be followed :

1- "STANDARDIZATION DIV." has been organized to deal with all aspects of industrial standards in NIGC . Therefore , all queries for clarification or amendments are requested to be directed to mentioned div.
2- "COMPANY" : refers to national Iranian gas company .
3- "SUPLIER" : refers to a firm who will supply the service , equipment or material to IGS specification whether as the prime producer or manufacturer or a trading firm.
4- "SHALL " : is used where a provision is mandatory .
5- "SHOULD" : is used where a provision is advised only .
6- "MAY" : is used where a provision is completely discretionary .

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Contents

1) Scope

This standard provides minimum requirements for acceleration sensors used in earthquake-induced automatic gas shut-off systems. These sensors must be able to detect different seismic phases (P and S phases and surface waves) for earthquakes with focal distance less than 50 km.

2) References

1) INSTRUMENTATION GUIDELINES FOR THE ADVANCED NATIONAL SEISMIC SYSTEM, 2007, U.S. Geological Survey and ANSS National Implementation Committee

2) GUIDELINE FOR ANSS SEISMIC MONITORING OF ENGINEERED CIVIL SYSTEMS, (2005), UGSG, Open file Report 2005-1039

3) Definition

3-1) Sensor

A sensor is a device that detects changes in physical quantities such as vibration, displacement, pressure, temperature, humidity and provides a corresponding analog or digital electrical output to changes.

3-2) Accelerometer

Accelerometer or strong-motion sensor is a sensor that measures ground motion acceleration. Accelerometers are classified into simple pendulum (one degree of freedom) and force-balanced systems.

3-3) Simple pendulum accelerometer

Simple pendulum accelerometer works as an open loop sensor. Nowadays, due to the various measurement limitations they rarely used in macro sensors. This method is widely used in the manufacturing of MEMS (Micro Electro-Mechanical Sensors) sensors.

3-4) Force-balanced accelerometer

In such accelerometer, external force that applied to the mass of accelerometer is compensated by an equal electromagnetic force in the opposite direction in a way that the mass remains stationary. In this approach, moving of the mass is prevented with the aid of a feedback circuit.

4) Type of Acceleration Sensor

It is possible to use force-balance or MEMS accelerometer for shutting off the gas in earthquakes provided that the specifications of Section 5 of this standard are met.

5) Specifications of Shut-off Accelerometer

The minimum acceptable sensor performance specifications for applying in earthquake early warning systems and automatic gas shut off devices are represented in Table 1.

Table 1: minimum acceptable sensor performance specifications

No.	Performance Metric	Value	Definition Item
1	**Number of Components/axes**	3	5-1
2	**Clip-level**	1.5g	5-2
3	**Sensor Dynamic Range**	>=80dB	5-3
4	**Sensor resolution (A/D)**	>=16 bits	5-4
5	**Sampling rate**	>= 50 sps	5-6
6	**Corner Frequency (Force-Balanced)**	>=100 Hz	5-5
7	**Bandwidth desired**	0.01 Hz ~ 25 Hz	5-6
8	**Generator Constant at Output**	≥1.0V/g	5-7
9	**Self-noise (RMS)**	$< 100\ \mu g / \sqrt{Hz}$	5-8
10	**Sensitivity Accuracy**	<1% <10Hz	5-9
11	**Total Harmonic Distortion**	<-35 dB	5-10
12	**Cross axis coupling**	<-35 dB	5-11
13	**Linearity**	<-35 dB	5-12
14	**Temperature-Induced Sensitivity Errors**	<0.5% over -20 to +40°C	5-9
16	**Operational Temperature Range**	-20~60 °C	5-13
17	**Clip recovery**	<1 sec	5-14
18	**Expected lifetime**	5 years	5-15

5-1) Number of components

Seismological and engineering practice in Gas industry requires a minimum of three-orthogonal component linear-motion data. These components shall be independent to each other.

5-2) Clip-level

The maximum recordable acceleration signal by sensor is called clip level. Clipping level depends on the sensor mechanics and digitizer specifications. The clip level of the sensor shall be at least 1.5 times the ground acceleration (g). This value is obtained from statistical analysis of strong motion data recorded in Iran and specific application of accelerometers for shutting off the gas stations. The maximum recorded PGA in Iran, regardless of soil condition, is approximately 1.0g. On the other hand, the common threshold values of PGA for shutting off the gas are much less than 1.0g. Thus, the value of 1.5g for clip-level introduces a conservative value in this regard.

5-3) Sensor Dynamic Range

Dynamic range is the ratio of the largest to the smallest recordable signal. The smallest recordable signal depends on the sensor self-noise and digitizer resolution. The largest recordable signal depends on the clipping level of the sensor. Dynamic range is usually expressed in dB.

$$Dynamic\,Range = 20 \times \log_{10}\left(\frac{clip\ level}{RMS\ of\ self-noise}\right) \qquad (dB)$$

The minimum value of dynamic range for shut-off accelerometer shall be 85dB. Considering the minimum clip level of 1.5g, the maximum RMS of sensor self-noise shall be less than 0.08 cm/s^2. This value of self-noise is much less than common power of ambient and mechanical noise sources. Indeed, the threshold value of PGA required for shutting off the gas is much more than the valued of 0.08 cm/s^2.

5-4) Sensor Resolution

The minimum recordable vibration change by the sensor is called resolution. This parameter is a function of digitizer sensitivity usually expressed in bit. Digitizer is a device that converts analog signal (voltage) to digital signal which is commonly placed in the sensor box. Therefore the output of accelerometer will be digital.

In a sensor with *n* bit resolution, one bit is usually kept for sign of the voltage signal. The minimum measurable voltage or acceleration is equal to:

$$\text{minimum measurable voltage} = \frac{\text{maximum measurable voltage/acceleration range}}{2^{n-1}}$$

The resolution of the sensor is the resolution of analog-to-digital convertor or digitizer of the sensor. Considering the clip level value of 1.5g and dynamic range of 85 dB, the minimum resolution of accelerometer shall be 16 bits. In this regard, the minimum resolvable acceleration is $1.5 \times 981/(2^{16-1}) = 0.04\ m/s^2$ which is less than acceptable noise level of 0.08 cm/s^2.

5-5) Corner Frequency (Force-Balanced)

In force-balanced sensors, corner frequency specifies the point where the response begins to decline. This parameter is a function of natural frequency of the system. The corner frequency of sensors shall be at least 100Hz. This value is to ensure that the corner frequency of sensor is far enough from desired bandwidth of the sensors.

5-6) Bandwidth desired

Frequency range desired for a specific application is called desired bandwidth. This frequency range shall be less than flat response frequency bandwidth of acceleration.

Flat response frequency bandwidth is the frequency range in which the response function of the sensor is flat. In other words, flat response frequency bandwidth is the range of ground motion frequencies that can be accurately reproduced by the resulting digital data (Figure 1). This limit is usually considered as the range between -3 dB points less than maximum frequency response of the sensor.

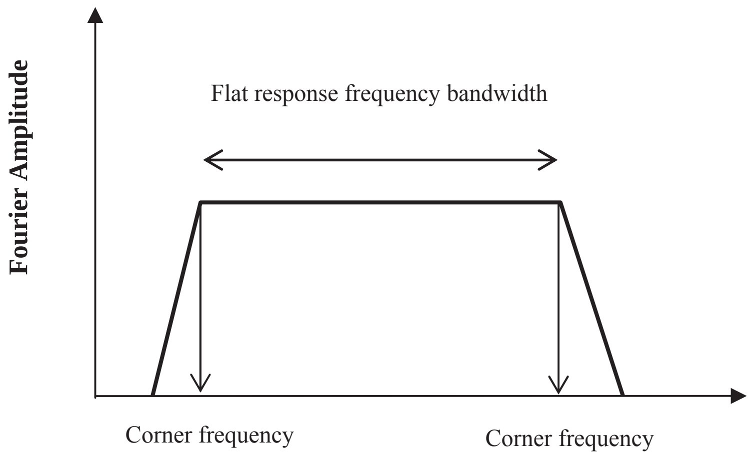

Figure 1.Frequency response of accelerometer and its parameters

The minimum bandwidth of the accelerometers shall be between 0.01~ 25 Hz. The most destructive energy of the earthquakes is in this frequency band. However, it is recommended that the upper bound of this range be 50Hz. In this regard, the minimum sampling rate shall be 50 sps.

5-7) Generator Constant at Output

Generator constant at output is the voltage generated by the accelerometer for 1 m/s or one time of gravity acceleration. This parameter is a function of vibration frequencies and shall be measured at 1 Hz. The generator constant at output for shut-off accelerometers shall be more than 1.0V/g.

5-8) Self-noise (RMS)

All electrical components and electronic accelerometers generate noise. In the absence of external and ambient vibrations, the self noise is also available. This parameter is expressed as the root mean square (RMS) of measured noise. The procedure for calculation of RMS is as follow (ANSS 2007):

- using time series without weightening
- using welch method for calculation of PSD

- using time history pieces with an overlap of 50%
- using Hanning Window function
- the minimum number of time history pieces shall be equal to 10
- cutting of the time history so that the length of each pieces is an integer number of second

The RMS of accelerometer self-noise shall be less than $<100\,\mu g/\sqrt{Hz}$. Thus, the minimum acceptable RMS of noise shall be

$$\begin{aligned} rmsNoise &= (100\,\mu g\ /\sqrt{Hz}\,)\times(\sqrt{BW}\,) \\ &= 100\times\sqrt{25} = 500\,\mu g\ = 0.49\ cm\ /\ s^2 \end{aligned}$$

It shall be noted that clip level of 1.5g and dynamic range of 85dB will fulfill this criterion. However, the RMS of self-noise of the accelerometers shall be determined by an acceptable method in order to compute the dynamic range of the sensor.

5-9) Sensitivity Accuracy

The deviation of the sensitivity of the acceleration from the sensitivity set by manufacturer is called sensitivity accuracy or sensitivity error. Temperature change is a significant factor in sensitivity error.

The accuracy of the accelerometer shall be within 1% deviation from manufacture specified for frequencies less than 10 Hz. The temperature induced sensitivity error shall also be less than 2% over -20 to +40 °C.

5-10) Total Harmonic Distortion

The total harmonic distortion (THD), of a signal is measurement of the existing harmonic distortion and defined as the ratio of the power of the fundamental frequency to the sum of the powers of all harmonic components. The THD for shut-off accelerometers shall be less than -35dB. The measurement is most commonly done as the ratio of the RMS amplitude of the fundamental frequency to RMS amplitude of a set of other harmonic frequencies. To measure THD, the accelerometer shall be excited with a specific frequency and calculation is done according to output of the sensor.

5-11) Cross axis coupling

Cross axis sensitivity or coupling is a measure of how much output is seen on one axis when acceleration is imposed on a different axis, typically specified as a percentage or dB. The coupling between two axes results from a combination of alignment errors, etching inaccuracies, and circuit crosstalk.

Cross-axis sensitivity is defined as:

$$CrSens = 20Log_{10}\left(\frac{\sqrt{A_y^2 + A_z^2}}{A_x}\right)$$

where Ax is the measured sensitivity in measuring direction, Ay and Az are the measured sensitivities in cross-axis directions. Sensitivities used in cross-axis calculation should be in the cm/s2 unit. The value of CrSens shall be less than -35dB. In other words, if the acceleration of 1g is exerted to one axis of the sensor, the root square of acceleration measured on two other axes shall be less than 0.018g.

5-12) Linearity

An ideal sensor is one that behaves as a linear system so that if we e.g. double the input, the output will also be doubled. In other words, linearity specifies a linear relationship among input and output of the sensor. The linearity is the maximum deviation of output from a best fit straight line in static tilt calibration and measured in dB. The linearity error of accelerometers shall be less than -30dB.

5-13) Operational Temperature Range

This is the temperature range that the device will meet the performance specifications. According to the local environmental condition of different parts of Iran, the shut-off accelerometers shall be operational over -20~60 °C.

5-14) Clip recovery

The time duration required for accelerometer to start recording after experiencing vibration higher than clip level shall be less than 1.0 second. This is to ensure that sensor is operational after a large shock.

5-15) Expected lifetime

Expected operational lifetime of systems is called expected lifetime. In the lifetime of the accelerometers, the characteristics of sensors shall remain in the limits specified in this standard.

5-16) Radio-frequency interference

When the instruments are located in environments with radio interference, there shall not be any detectable effect on the output signal. RFI performance of the sensor shall be tested, as per NIGC request, according to IEC 61326:2002.

6) Sensor Analytical and Executive Specifications

The shut-off acceleration sensor unit shall be capable to:

- Compute the Peak Ground Acceleration (PGA), Peak Ground Velocity (PGV), Cumulative Absolute Velocity (CAV), Spectral Intensity (SI) and send these parameters to distant control center and/or save them on an internal storage
- Send shut-off command to shut-off valves based on customized shut-off criteria
- Receive shut-off command from distant control center and send it to shut-off valves
- Receive shut-off criteria from distant control center
- Save continuous acceleration waveform for at least 15 days on an internal storage

7) Sensor calibration

The digital output of accelerometers is a set of integer numbers. For converting these numbers to physical unit of acceleration (m/s^2), it is necessary to measure the output of a sensor in response to an accurately known input at a specific frequency. Indeed, cross axis error of the sensor shall also be determined and required correction be applied at the output of the sensor. Method of calibration shall be provided by the manufacture and be approved by NIGC. In the lifetime of accelerometer, no calibration procedure shall be applied to the sensors.

8) Technical documentation of acceleration

8-1) The accelerometer sensor vendors are required to provide all specifications listed in table 1 in the form of technical documents of accelerometer. This document is required to be delivered inside the sensor packages.

8-2) The calibration coefficients of each sensor is required to be represented in the form of a leaf with sensor. Indeed, the method of calibration shall be represented in the technical documents.

8-3) The accelerometer vendor is required to accurately described the output format of acceleration data in the technical documentation.

8-4) The specifications of output cables and the map of output connection pins (connectors) shall be represented in the technical document.

9) Accelerometer Accessories

The items listed in this section are minimum accessories that required to be packed with each accelerometer. Other additional accessories may be provided by the vendor.

9-1) <u>Connection cables</u>

Connection cables of the sensor must be able to transmit digital data reliably up to a distance of at least 100 meter.

9-2) <u>Connection and Controlling software of sensors</u>

Connection and controlling software shall be provided by the vendor as a part of sensor package.

10) Environmental condition and installation specifications

- Sensors shall be resistance to moisture according to IEC standard IP67
- Sensors shall be installed in a way that records the motions of the earth rather than response of the structures. For protecting the sensors and reducing the environmental noise, it is recommended to install sensors at the depth of one meter beneath the ground surface.
- Sensors shall be installed in way that they can withstand the acceleration as much as 3.5 times of ground motion acceleration in three orthogonal directions.

11) Inspection and Testing

In addition to manufacturers' validation testing for their own purposes, verification testing of performance shall be conducted as part of the procurement process. NIGC may test samples of all items in the above mentioned specifications that are applicable to that particular sensor. Random and targeted acceptance tests of instruments (the deliverables) may be performed by NIGC to verify ongoing compliance with specifications, testing all or portions of applicable specifications as deemed appropriate by NIGC.

The intention of vendor and NIGC testing described here is to reduce the lifecycle cost of these instruments and to verify their performance. Therefore, significant initial expense is tolerated where it is likely to reduce long-term expense, failures, and uncertainties in performance, reliability, or the validity of the data for their intended uses.

11-1) Validation Testing

Validation testing by the manufacturer checks whether the product design satisfies or fits the intended usage. Such high-level testing is generally part of the design process and as such may be used by vendors to prepare for performance verification tests described later. Such validation testing may be part of the vendors' research and development, pre-qualification, and manufacturing-development processes leading to their confidence in their product.

11-2) Performance Verification Testing

Verification testing confirms that products meet specified performance requirements. In the NIGC context, this should be a formal step in which vendors complete formal performance verification testing, under close NIGC observation, of final versions of two randomly-selected sensors. Test specifications should be prepared in advance of any procurement and be approved by NIGC. All resulting data and analyses should be provided for NIGC in sufficiently complete form that NIGC can analyze the test data and confirm test results.

It is recommended that two or more test specimens be selected at random from a batch of eight or more final manufactured copies of final versions of the proposed sensor.NIGC requires that tests be witnessed in person by NIGC staff or their representative(s) and possibly recorded in video and sound (by NIGC) for documentation and external review. NIGC may require that original test data be supplied to the witness for direct transfer to NIGC at the time of the testing.

11-3) Acceptance Tests

Acceptance tests of randomly selected units may be performed upon delivery or shortly afterward to verify whether the components and systems meet NIGC contract specifications. If they do not: (i) the components/systems should be returned to the vendor for repair, (ii) additional units of similar manufacturing lots or serial numbers should be tested by NIGC, and (iii) if a pattern of vendor non-compliance emerges, that the vendor's history may be considered substantially unresponsive in subsequent requisitions.