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**Steel — Determination of vanadium  
content — Flame atomic absorption  
spectrometric method (FAAS)**

*Aciers — Détermination des teneurs en vanadium — Méthode par  
spectrométrie d'absorption atomique dans la flamme (SAAF)*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 1, *Methods of determination of chemical composition*.

This second edition cancels and replaces the first edition (ISO 9647:1989), which has been technically revised. The main changes compared to the previous edition are as follows:

- a complete reevaluation of the precision data;
- amendment of the field of application.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

# Steel — Determination of vanadium content — Flame atomic absorption spectrometric method (FAAS)

## 1 Scope

This document specifies a flame atomic absorption spectrometric method (FAAS) for the determination of the vanadium content in steel.

The method is applicable to vanadium contents between 0,01 % (mass fraction) and 0,80 % (mass fraction), provided that the tungsten content in a 1,0 g test portion is not higher than 1,0 % and/or the titanium content is not higher than 0,5 %.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 648, *Laboratory glassware — Single-volume pipettes*

ISO 1042, *Laboratory glassware — One-mark volumetric flasks*

ISO 3696, *Water for analytical laboratory use — Specification and test methods*

ISO 14284, *Steel and iron — Sampling and preparation of samples for the determination of chemical composition*

## 3 Terms and definitions

[ISO 9647:2020](https://standards.iteh.ai/catalog/standards/iso/c24e3054-b782-45a6-8345-6497243229f6/iso-9647-2020)

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

## 4 Principle

Dissolution of a test portion in hydrochloric, nitric and perchloric acids.

Addition of an aluminium chloride solution as spectrochemical buffer.

Nebulisation of the test solution into an acetylene/nitrous oxide flame of an atomic absorption spectrometer.

Spectrometric measurement of the atomic absorption of the 318,4 nm spectral line emitted by a vanadium hollow-cathode lamp.

NOTE Other suitable radiation sources can also be used.

## 5 Reagents

During the analysis, unless otherwise specified, use only reagents of recognized analytical grade and only grade 2 water as specified in ISO 3696.

**5.1 Pure iron**, containing <0,000 5 % of vanadium or of low and known vanadium content.

**5.2 Hydrochloric acid**,  $\rho$  approximately 1,19 g/ml.

**5.3 Nitric acid**,  $\rho$  approximately 1,40 g/ml.

**5.4 Perchloric acid**,  $\rho$  approximately 1,67 g/ml.

**WARNING — Perchloric acid vapour can cause explosions in the presence of ammonia, nitrous fumes or organic material in general.**

**5.5 Hydrochloric acid solution**, 1 + 50.

Add 10 ml of hydrochloric acid (5.2) to 500 ml of water and mix.

**5.6 Aluminium solution**, 20 g/l.

Dissolve 90 g of aluminium chloride hexahydrate ( $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$ ) in about 300 ml of water, add 5 ml of hydrochloric acid (5.2), dilute to 500 ml with water and mix.

**5.7 Vanadium standard solution**, 2,0 g/l.

**5.7.1 Preparation using vanadium metal**

Weigh ( $1,000 \pm 0,001$ ) g of vanadium ( $V \geq 99,9 \%$ ) and transfer it into a 400 ml beaker. Add 30 ml of a mixture of three volumes of hydrochloric acid (5.2) and one volume of nitric acid (5.3).

Cover with a watch glass and if necessary, heat gently to assist dissolution. When dissolution is complete evaporate the solution to just before dryness and add 20 ml of hydrochloric acid (5.2).

Allow to cool to room temperature and transfer the solution quantitatively into a 500 ml one-mark volumetric flask. Dilute to the mark with water and mix.

1 ml of this solution contains 2,0 mg of vanadium.

**5.7.2 Preparation using ammonium metavanadate**

Dry several grams of ammonium metavanadate ( $\text{NH}_4\text{VO}_3$ ) (purity >99,9 %) in an oven at 100 °C to 105 °C for at least one hour and allow to cool to room temperature in a desiccator.

**NOTE** A drying temperature over 110 °C will cause decomposition of ammonium metavanadate. Keep strictly to the drying temperature specified.

Weight 2,296 g of the dried product into a 600 ml beaker, add about 400 ml of hot water and gently simmer to dissolve.

Allow to cool, transfer the solution quantitatively into a 500 ml one-mark volumetric flask. Dilute to the mark with water and mix.

1 ml of this solution contains 2,0 mg of vanadium.

### 5.8 Vanadium standard solution, 0,08 g/l.

Transfer 10,0 ml of vanadium standard solution (5.7) into a 250 ml one-mark volumetric flask. Dilute to the mark with water and mix.

Prepare this solution immediately prior to use.

1 ml of this solution contains 0,08 mg of vanadium.

## 6 Apparatus

All volumetric glassware shall be class A, in accordance with ISO 648 or ISO 1042, as appropriate.

Ordinary laboratory apparatus and the following shall be used.

### 6.1 Atomic absorption spectrometer

The spectrometer shall be equipped with a vanadium hollow-cathode lamp and supplied with dinitrogen monoxide and acetylene sufficiently pure to give a steady clear fuel-lean flame, free from water and oil, and free from vanadium.

The atomic absorption spectrometer used will be satisfactory if, after optimization according to 8.3.3, the limit of detection and characteristic concentration are in reasonable agreement with the values given by the manufacturer and it meets the performance criteria given in 6.1.1 to 6.1.3.

The instrument should also conform to the additional performance requirement given in 6.1.4.

#### 6.1.1 Minimum precision (see Annex C)

The standard deviation of 10 measurements of the absorbance of the most concentrated calibration solution shall not exceed 1,0 % of the mean absorbance of this solution.

The standard deviation of 10 measurements of the absorbance of the least concentrated calibration solution (excluding the zero member) shall not exceed 0,5 % of the mean absorbance of the most concentrated calibration solution.

#### 6.1.2 Limit of detection (see Annex C)

The limit of detection is a number, expressed in units of concentration (or amount) that describes the lowest concentration level (or amount) of an element that can be determined to be statistically different from an analytical blank.

The limit of detection of vanadium in a matrix similar to the final test solution shall be less than 0,3 µg/ml.

#### 6.1.3 Calibration linearity (see Annex C)

The slope of the calibration line covering the top 20 % of the concentration range (expressed as a change in absorbance) shall not be less than 0,7 times the value of the slope for the bottom 20 % of the concentration range determined in the same way.

For instruments with automatic calibration using two or more standard solutions, it shall be established prior to the analysis, by obtaining absorbance readings, that the above requirements for calibration linearity are fulfilled.

#### 6.1.4 Characteristic concentration (see Annex C)

The characteristic concentration for vanadium in a matrix similar to the final test solution shall be greater than 1 µg/ml.

## 6.2 Ancillary equipment

Scale expansion can be used until the noise observed is greater than the readout error and is always recommended for absorbances below 0,1. If scale expansion has to be used and the instrument does not have the means to read the value of the scale expansion factor, the value can be calculated by measuring a suitable solution with and without scale expansion and then dividing the signals obtained.

## 7 Sampling

Carry out sampling in accordance with ISO 14284 or appropriate national standards for steels.

## 8 Procedure

### 8.1 Test portion

Weigh to the nearest 0,001 g a test portion according to the presumed vanadium content as follows:

- a) for vanadium contents from 0,01 % to less than 0,20 %: a test portion of approximately 1,00 g;
- b) for vanadium contents from 0,2 % to 1,0 %: a test portion of approximately 0,20 g.

### 8.2 Blank test

In parallel with the determination and following the same procedure, carry out a blank test using the same quantities of all reagents as used for the determination, including pure iron (5.1) instead of the test portion.

### 8.3 Determination

#### 8.3.1 Preparation of the test solution

Place the test portion (8.1) into a 250 ml beaker. Add 10 ml of hydrochloric acid (5.2) and 4 ml of nitric acid (5.3), and cover the beaker with a watch-glass. After effervescence ceases, add 10 ml of perchloric acid (5.4) and evaporate the solution until fumes of perchloric acid are visible, then remove the watch-glass and evaporate until no more fumes come out of the beaker.

Allow to cool, add 10 ml of hydrochloric acid (5.2) and 20 ml of water, and heat gently to dissolve the salts. Filter through a medium texture filter paper into a 100 ml one-mark volumetric flask. Wash with warm hydrochloric acid (5.5) and add the washing fractions to the flask.

Allow to cool, add 10,0 ml of aluminium solution (5.6), dilute to the mark with water and mix.

#### 8.3.2 Preparation of the calibration solutions

##### 8.3.2.1 Vanadium contents <0,2 %

Transfer into a series of 250 ml beakers (1,00 ± 0,01) g of the pure iron (5.1), add 10 ml of hydrochloric acid (5.2) and 4 ml of nitric acid (5.3) to each beaker and cover them with watch-glasses. After effervescence ceases, allow to cool and then respectively add the volumes of vanadium standard solution (5.8) given in Table 1.



**Table 1 — Calibration solutions for vanadium contents <0,2 %**

Vanadium standard solution volume (5.8)	Corresponding vanadium mass
ml	mg
0 <sup>a</sup>	0
1,0	0,08
2,0	0,16
2,5	0,20
5,0	0,40
10,0	0,80
15,0	1,20
20,0	1,60
25,0	2,00

<sup>a</sup> Zero member.

Proceed as specified in 8.3.1 from "...add 10 ml of perchloric acid (5.4)..." (2<sup>nd</sup> sentence of 1<sup>st</sup> paragraph) to the end.

### 8.3.2.2 Vanadium contents between 0,2 % and 1,0 %

Transfer into a series of 250 ml beakers (0,20 ± 0,01) g of the pure iron (5.1), add 10 ml of hydrochloric acid (5.2) and 4 ml of nitric acid (5.3) to each beaker and cover them with watch-glasses. After effervescence ceases, allow to cool and then respectively add the volumes of vanadium standard solution (5.8) given in Table 2.

**Table 2 — Calibration solutions for vanadium contents between 0,2 % and 1,0 %**

Vanadium standard solution volume (5.8)	Corresponding vanadium mass
ml	mg
0 <sup>a</sup>	0
5,0	0,40
10,0	0,80
15,0	1,20
20,0	1,60
25,0	2,00

<sup>a</sup> Zero member.

Proceed as specified in 8.3.1 from "...add 10 ml of perchloric acid (5.4)..." (2<sup>nd</sup> sentence of 1<sup>st</sup> paragraph) to the end.

### 8.3.3 Adjustment of the atomic absorption spectrometer

Fit the vanadium hollow-cathode lamp (see 6.1) to the atomic absorption spectrometer (6.1), switch on the current and allow it to stabilize. Adjust the wavelength in the region of 318,4 nm to minimum absorbance, if possible. Following manufacturer's instructions, fit the correct burner, light the flame, adjust it to a red feather and the observation height in the flame to about 20 mm and then allow the burner temperature to stabilize. Taking careful note of the manufacturer's instructions regarding the minimum flow rate of acetylene, nebulize alternately the calibration solution of highest concentration and the zero member, adjust the gas flow and burner position (horizontally, vertically and rotationally) until the difference in absorbance between the calibration solutions is at a maximum.

NOTE Other suitable radiation sources can also be used.

**WARNING** — The manufacturer's recommendations should be closely followed, and particular attention is drawn to the following safety points:

- a) the explosive nature of acetylene, and regulations concerning its use;
- b) the need to shield the eyes of the operator from ultraviolet radiation by means of tinted glass;
- c) the need to keep the burner head clear of deposits because a badly clogged burner may cause a flashback;
- d) the need to ensure that the liquid trap is filled with water;
- e) the need always to spray water between the test solutions, blank solution and/or calibration solutions.

Evaluate the criteria of [6.1.1](#) to [6.1.3](#) and the additional performance requirement of [6.1.4](#) to ensure that the instrument is suitable for the determination.

### 8.3.4 Spectrometric measurements

#### 8.3.4.1 Spectrometric measurement of the calibration solutions

Nebulize the relevant series of calibration solutions ([8.3.2.1](#) or [8.3.2.2](#)) depending on the expected vanadium content in succession into the flame and measure the absorbance for each solution. Take care to keep the aspiration rate constant throughout the preparation of the calibration curve. Nebulize water through the burner after each measurement, see note.

NOTE For certain types of apparatus it is preferable to use a solution containing the attack reagents in the same concentrations as in the test portion solutions, instead of water.

##### 8.3.4.1.1 Calibration curves

Subtract the mean absorbance value obtained for the zero-member calibration solution from the mean absorbance values obtained for the other calibration solutions.

Establish the appropriate calibration curve by plotting the net absorbance values of the calibration solutions against the concentration of vanadium, expressed in micrograms per millilitre. Use appropriate spectrometer software or an off-line computer for regression calculations or prepare a graphical representation.

If pure metals and reagents have been used, the zero member should have a negligibly small absorbance.

If, however, the zero member has a significant absorbance a more complicated procedure is required. In this case, the concentration of vanadium  $c_z$ , expressed in micrograms per millilitre ( $\mu\text{g/ml}$ ), in the zero member can be calculated using [Formula \(1\)](#)

$$c_z = c_{c1} \times \frac{A_z}{A_{c1} - A_z} \quad (1)$$

where

$c_{c1}$  is the concentration of vanadium, expressed in micrograms per millilitre ( $\mu\text{g/ml}$ ) added to the first calibration solution;

$A_z$  is the absorbance of the zero member;

$A_{c1}$  is the absorbance of the first calibration solution.

The  $c_z$  value is then added to each of the nominal calibration concentrations in order to obtain a mean calibration graph passing through the origin.