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DETERMINATION OF AISI 4340 AND 8640 STEELS USED IN M9 BERETTA PISTOL SLIDES BY EMISSION SPECTROSCOPY AND X-RAY FLUORESCENCE SPECTROSCOPY

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Determination of AISI 4340 and 8640 Steels Used In M9 Beretta Pistol Slides By Emission Spectroscopy and X-Ray Fluorescence Spectroscopy

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Abstract

Emission spectroscopy and x-ray fluorescence spectroscopy are investigated as chemical analysis techniques for AISI 4340 and 8640 low alloy steels. These steels are used in M9 Beretta pistol slides and were provided by that source. Tellurium, selenium, and calcium are specifically investigated in these types of materials.

Emission spectroscopy was demonstrated as a viable offline nondestructive technique for the analysis of Te, Se, Ca, and twenty other elements in these pistol slide materials with regard to precisions and detection limits using certified standard reference materials (SRM's). The disadvantages of the technique are its offline sampling and its ten minute sampling time. This experiment was conducted at Benét.

X-ray fluorescence spectroscopy was also demonstrated using these materials as a viable online nondestructive technique for the analysis of Te, Se, and Ca using low alloy steel standard reference materials. Concentration ranges were similar to those used in these pistol slides. Precisions, detection limits and acceptable sampling time were also considered. This original experiment was conducted at Tracor's main applications lab in Ft. Collins, Co.

This original x-ray fluorescence experiment was followed by similar but more extensive experiments at Tracor and Benét. These latter experiments verify results reported here and used the same set of standard reference materials. As a result of this initial experiment and similar follow-up experiments, the U.S. Army is in the process of adopting online energy dispersive x-ray fluorescence analysis to identify tellurium, selenium, and calcium in these types of materials.

Keywords

chemical analysis, M9 Beretta pistol slides, AISI 4340, AISI 8640, low alloy steels, emission spectrometry, x-ray fluorescence spectrometry, online and offline analyses, tellurium, selenium, calcium

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Introduction

Emission spectroscopy and x-ray fluorescence spectroscopy are investigated as chemical analysis techniques for AISI 4340 and 8640 low alloy steels. These steels are used in M9 Beretta pistol slides and were provided by that source. Tellurium, selenium, and calcium are specifically investigated in these types of materials.

The chemical analysis of low alloy steel samples by emission spectrometry is an extensively used and well known technique. A comprehensive explanation of the theory and background of this complex technique is given elsewhere (1) and is useful for the evaluation of this chemical analysis technique.

The chemical analysis of low alloy steel samples by x-ray fluorescence spectrometry is also an extensively used and well known technique. A comprehensive explanation of the theory and background of this complex technique is also given elsewhere (2) and is useful for the evaluation of this chemical analysis technique.

Approach

Strict analytical chemistry methods and procedures are followed throughout this experimental section. An excellent source of reference for these methods and procedures is by Fritz and Schenk (3).

Many solid standard reference materials (SRM) are used. These SRM's are selected to completely cover the operating concentration ranges of normal production type 4340 and 8640 low alloy steels.

The experimental conditions for these low alloy steel determinations by the Angstrom direct reading emission spectrometer are identical to those given in a previous reference (1) and are not repeated here. The elements determined are Al, As, B, C, Ca, Cr, Cu, Fe, Mn, Mo, Nb, Ni, P, Pb, S, Si, Sn, Ti, V, W, and Zr. This part of the experiment was conducted in-house.

The experimental conditions for the low alloy steel determinations by the Tracor online and offline x-ray fluorescence spectrometers vary slightly from the reference above (2). The elements determined are Te, Se, and Ca with an analysis time per replicate of 240 seconds. This part of the experiment was conducted at Tracor X-ray Corporation's main applications lab in Ft. Collins, CO.

Both Angstrom and Tracor publish manuals which are an excellent source of reference for operation and maintenance of these instruments (4-5).

The experimental approach included calibration and standardization with solid standard reference materials followed by analysis with solid sample materials. Calibration and standardization data were used to determine analyte concentrations of samples.

Descriptions of the operating conditions of the Tracor Online Spectrace Model 7000/7100 and the Tracor Offline Laboratory Spectrace Model 5000 are given in a previous report by this author (2). A complete listing of other x-ray fluorescence instrument manufacturers are available in the same report (2).

Results and Discussion

Table 1 reports data for the chemical analyses of these M9 Beretta pistol slides by emission spectroscopy. Two AISI 4340 low alloy steel pistol slide samples labelled E3 and E11 were analyzed in-house. Certified SRM 1261 was used as a reference sample and was compared to its certified values. Lab numbers are 891019.22, 891019.23 and 891019.30 for sample E3, sample E11 and SRM 1261 respectively. Over twenty certified SRM's are used for calibration and eight certified SRM's are used for standardization of this low alloy steel matrix (1). All reported values are a mean of three replicates for samples and SRM's.

All elemental concentration values for both emission and x-ray fluorescence spectrometry are either in weight percent (%) or parts per million (ppm) where 0.0001 % equals 1 ppm.

For the x-ray fluorescence experiment, four SRM's were used for Te, three SRM's were used for Se and three SRM's were used for Ca. Only the high concentration standards for Te, Se and Ca were run in triplicate while other standards were each run once. Each of these sixteen runs were 240 seconds in duration. Standard deviation (one sigma) of about 10% relative precision was found for each of the high concentration SRM's of Te, Se and Ca. It is assumed that this holds uniformly for each standard and each element used.

Many standard reference materials were available for this experiment which contained Te, Se and Ca. The low alloy steel SRM's available are 1261, 1262, 1263, 1264, and 74A. The high alloy steel SRM's available are 1152, 1154, 1156, and 1170B. The cast iron (not steel) SRM's available are 1, 2, 3, 4, 5, 6, and 7.

Table 2 shows the chemical specifications for the American Iron and Steel Institute's (AISI) 4340 and 8640 nickel-chromium-molybdenum low alloy steels (6). Samples E3 and E11 from Table 1 generally meet the AISI specifications for AISI 4340. The materials in Table 1 use either AISI 4340 or AISI 8640 low alloy steel.

Table 3 presents data for the chemical determination of tellurium in SRM alloy steel by x-ray fluorescence spectroscopy. This Table provides a good calibration curve for Te in low alloy steel using certified SRM's 1261, 1262, 1152 and 1154. The range of the calibration curve is 0.0006 to 0.0150 % or 6 to 150 ppm Te. Raw data for Te was normalized so that the high Te SRM 1154 has a value of one hundred. Standard deviations (precisions) were suitable and expected (calculated) normalized peak heights again agreed well.

Table 4 presents data for the chemical determination of selenium in SRM alloy steel by x-ray fluorescence spectroscopy. This Table provides a good calibration curve for Se in low alloy steel using certified SRM's 1261, 1262 and 1154. The range of the calibration curve is 0.0012 to 0.0078 % or 12 to 78 ppm Se. Raw data for Se was normalized so that the high Se SRM 1154 has a value of one hundred. Standard deviations (precisions) were suitable and expected (calculated) normalized peak heights again agreed well.

Table 5 presents data for the chemical determination of calcium in SRM alloy steel by x-ray fluorescence spectroscopy. This Table provides a good calibration curve for Ca in low alloy steel using certified SRM's 1261, 1262 and 1156. The range of the calibration curve is 0.00003 to 0.00100 % or 0.3 to 10 ppm Ca. Raw data for Ca was normalized so that the high Ca SRM 1156 has a value of one hundred. Standard deviations (precisions) were suitable and expected (calculated) normalized peak heights again agreed well.

The data presented in Tables 3-5 were acquired both online and offline and were identical for the purposes of this experiment.

Table 6 gives the certified values for the available low alloy steel SRM's 1261, 1262, 1263, 1264 and 74A which are Te, Se or Ca bearing SRM's. Table 7 gives the certified values for the available high alloy steel SRM's 1152, 1154, 1156 and 1170B which are Te, Se or Ca bearing SRM's.

Tables 8A and 8B give the certified values for the available cast iron (not steel) SRM's 1, 2, 3, 4, 5, 6 and 7 which are Te, Se or Ca bearing SRM's. None of these cast iron SRM's were used since they are not steels but they are listed since they were available.

The x-ray fluorescence part of this experiment was conducted at Tracor X-ray Corp.'s main applications lab in Fort Collins, Co. since they were the best available source at the time.

Emission spectroscopy does provide nondestructive, offline analyses of these materials with excellent detection limits and precisions at about ten minutes per sample. At present, the emission spectrometer can analyze these elements listed in Table 1 plus Ca, Te, and Se. Precisions for these twenty-two elements will be about five percent and detection limits will be about 0.1 ppm or 0.00001 percent by weight.

One advantage of x-ray fluorescence spectroscopy is that it has nondestructive, online capabilities while emission spectrometry is only an offline technique. Another advantage of x-ray fluorescence spectroscopy is that good detection limits and precisions are achieved in half the time of emission spectrometry for this application.

For metallic elements in solid samples, energy dispersive x-ray fluorescence spectrometry (EDXRF) detection limits are about 1 to 5 ppm and wavelength dispersive x-ray fluorescence spectrometry (WDXRF) detection limits are about 0.1 to 1 ppm. It is probably not warranted, but if a better technique is needed for this application, then WDXRF provides better detection limits and precisions at about twice the cost of EDXRF.

Energy dispersive and wavelength dispersive x-ray fluorescence spectroscopy are the two basic types of instrumentation associated with this techniques differing in how x-rays are sorted and measured (2).

Chemical analysis by x-ray fluorescence is non-destructive and applicable to multiple solid sampling lines. In addition, calibration, standardization and maintenance are minimal.

For the determination of Te, Se and Ca in these materials, the online energy dispersive x-ray fluorescence spectroscopy (EDXRF) method is the only promising and practical nondestructive technique available at this time that meets the U.S. Army's necessary criteria for analysis time, detection limit, precision, accuracy and online chemical analysis. The Tracor model 7000/7100 online EDXRF spectrometer achieves this goal.

Emission spectroscopy was demonstrated as a viable offline nondestructive technique for the analysis of Te, Se, Ca and twenty other elements in these pistol slide materials with regard to precisions and detection limits using certified standard reference materials (SRM's). The disadvantages of the technique are its offline sampling and its ten minute sampling time. This experiment was conducted at Benét Laboratories.

X-ray fluorescence spectroscopy was also demonstrated using these materials as a viable online nondestructive technique for the analysis of Te, Se, and Ca using low alloy steel standard reference materials. Concentration ranges were similar to those used in these pistol slides. Precisions, detection limits and acceptable sampling time were also considered. This experiment was conducted at Tracor's main applications lab in Ft. Collins, Co.

This original x-ray fluorescence experiment was followed by similar but more extensive experiments at Tracor and Benét Laboratories. These latter experiments verify results reported here and used the same set of standard reference materials. As a result of this initial experiment and similar follow-up experiments, the U.S. Army is in the process of adopting online energy dispersive x-ray fluorescence analysis to identify tellurium, selenium and calcium in these types of materials.

Table 1. Chemical Analyses Of M9 Beretta Pistol Slides By Emission Spectroscopy

Element	Sample E3 AISI 4340	Sample E11 AISI 4340	Ref Sample SRM 1261	Actual SRM SRM 1261
Ag	ND*	ND	ND	0.0004
Al	0.053	0.049	0.036	0.021
As	0.014	0.018	0.024	0.017
B	< 0.001	< 0.001	< 0.001	0.0005
Be	ND	ND	ND	<0.00001
Bi	ND	ND	ND	0.0004
C	0.391	0.379	0.397	0.39
Ca	0.0013	0.0022	0.0012	0.00003
Cd	ND	ND	ND	<0.00001
Ce	ND	ND	ND	0.0014
Co	ND	ND	ND	0.032
Cr	0.666	0.700	0.701	0.69
Cu	0.188	0.193	0.039	0.042
Fe	**	**	**	**
Hf	ND	ND	ND	0.0002
La	ND	ND	ND	0.0004
Mg	ND	ND	ND	0.00018
Mn	0.726	0.742	0.682	0.66
Mo	0.232	0.245	0.196	0.19
Nb	0.001	0.004	0.025	0.022
Nd	ND	ND	ND	0.00029
Ni	1.617	1.697	1.974	1.99
P	0.024	0.016	0.014	0.015
Pb	< 0.001	< 0.001	< 0.001	0.00003
Pr	ND	ND	ND	0.00014
S	0.004	0.004	0.015	0.015
Sb	ND	ND	ND	0.042
Se	ND	ND	ND	0.004
Si	0.261	0.284	0.262	0.223
Sn	0.008	0.010	0.008	0.011
Sr	ND	ND	ND	0.0005
Ta	ND	ND	ND	0.02
Te	ND	ND	ND	0.0006
Ti	< 0.0001	< 0.0001	0.0181	0.02
Tl	ND	ND	ND	<0.00001
V	0.005	0.005	0.012	0.011
W	< 0.001	< 0.001	0.015	0.017
Zn	ND	ND	ND	0.0001
Zr	< 0.001	< 0.001	0.011	0.009

* ND=Not Determined

** Remainder Is Iron

Table 2. Chemical Specifications For American Iron and Steel Institute 4340 and 8640 Ni-Cr-Mo Steels

Element	AISI 4340	AISI 8640
Ag	NA	NA
Al	NA	NA
As	NA	NA
B	NA	NA
Be	NA	NA
Bi	NA	NA
C	0.37-0.44	0.37-0.44
Ca	NA	NA
Cd	NA	NA
Ce	NA	NA
Co	NA	NA
Cr	0.65-0.95	0.35-0.65
Cu	NA	NA
Fe	*	*
Hf	NA	NA
La	NA	NA
Mg	NA	NA
Mn	0.55-0.90	0.70-1.05
Mo	0.20-0.30	0.15-0.25
Nb	NA	NA
Nd	NA	NA
Ni	1.55-2.00	0.35-0.75
P	0.035 max	0.035 max
Pb	NA	NA
Pr	NA	NA
S	0.040 max	0.040 max
Sb	NA	NA
Se	NA	NA
Si	0.15-0.35	0.15-0.35
Sn	NA	NA
Sr	NA	NA
Ta	NA	NA
Te	NA	NA
Ti	NA	NA
Tl	NA	NA
V	NA	NA
W	NA	NA
Zn	NA	NA
Zr	NA	NA

* Remainder Is Iron

Table 3. Chemical Determination Of Tellurium In SRM Alloy Steel By X-Ray Fluorescence Spectroscopy

SRM	Te %	Te ppm	NPH	S. D. (NPH)	Expected NPH
1261	0.0006	6	2	1	4
1262	0.0011	11	8	1	7
1263	0.0009	9	NA	NA	NA
1264	0.00018	1.8	NA	NA	NA
74A	0.032	320	NA	NA	NA
1152	0.0091	91	58	6	61
1154	0.015	150	100	10	100
1156	<0.00001	NA	NA	NA	NA
1170B	<0.00001	NA	NA	NA	NA
1	0.011	110	NA	NA	NA
2	0.002	20	NA	NA	NA
3	0.002	20	NA	NA	NA
4	0.007	70	NA	NA	NA
5	0.005	50	NA	NA	NA
6	0.002	20	NA	NA	NA
7	0.031	310	NA	NA	NA

NOTE: NPH=Normalized Peak Height (N=100)

Table 4. Chemical Determination Of Selenium In SRM Alloy Steel By X-Ray Fluorescence Spectroscopy

SRM	Se %	Se ppm	NPH	S. D. (NPH)	Expected NPH
1261	0.004	40	52	5	51
1262	0.0012	12	11	2	15
1263	0.00016	1.6	NA	NA	NA
1264	0.00021	2.1	NA	NA	NA
74A	<0.00001	NA	NA	NA	NA
1152	0.024	240	NA	NA	NA
1154	0.0078	78	100	10	100
1156	<0.00001	NA	NA	NA	NA
1170B	0.23	2300	NA	NA	NA
1	<0.00001	NA	NA	NA	NA
2	<0.00001	NA	NA	NA	NA
3	<0.00001	NA	NA	NA	NA
4	<0.00001	NA	NA	NA	NA
5	<0.00001	NA	NA	NA	NA
6	<0.00001	NA	NA	NA	NA
7	<0.00001	NA	NA	NA	NA

NOTE: NPH=Normalized Peak Height (N=100)

Table 5. Chemical Determination Of Calcium In SRM Alloy Steel By X-Ray Fluorescence Spectroscopy

SRM	Ca %	Ca ppm	NPH	S. D. (NPH)	Expected NPH
1261	0.00003	0.3	2	1	3
1262	0.00014	1.4	9	2	14
1263	0.00013	1.3	NA	NA	NA
1264	0.00004	0.4	NA	NA	NA
74A	<0.00001	NA	NA	NA	NA
1152	<0.00001	NA	NA	NA	NA
1154	<0.00001	NA	NA	NA	NA
1156	0.001	10	100	10	100
1170B	<0.00001	NA	NA	NA	NA
1	<0.00001	NA	NA	NA	NA
2	<0.00001	NA	NA	NA	NA
3	<0.00001	NA	NA	NA	NA
4	<0.00001	NA	NA	NA	NA
5	<0.00001	NA	NA	NA	NA
6	<0.00001	NA	NA	NA	NA
7	<0.00001	NA	NA	NA	NA

NOTE: NPH=Normalized Peak Height (N=100)

Table 6. Low Alloy Steel Certified SRM's

Element	SRM 1261	SRM 1262	SRM 1263	SRM 1264	SRM 74A
Ag	0.0004	0.0011	0.0037	0.00002	<0.00001
Al	0.021	0.095	0.24	0.008	0.003
As	0.017	0.092	0.01	0.052	<0.00001
B	0.0005	0.0025	0.0009	0.011	<0.00001
Be	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Bi	0.0004	0.002	0.0008	0.0009	<0.00001
C	0.39	0.16	0.62	0.87	0.06
Ca	0.00003	0.00014	0.00013	0.00004	<0.00001
Cd	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Ce	0.0014	0.0015	0.0014	0.00022	<0.00001
Co	0.032	0.3	0.048	0.15	<0.00001
Cr	0.69	0.3	1.31	0.065	0.04
Cu	0.042	0.5	0.098	0.249	0.03
Fe	*	*	*	*	*
Hf	0.0002	0.0003	0.0005	0.0013	<0.00001
La	0.0004	0.0004	0.0006	0.00007	<0.00001
Mg	0.00018	0.00062	0.00049	0.00015	<0.00001
Mn	0.66	1.04	1.5	0.255	1.05
Mo	0.19	0.068	0.03	0.49	0.014
Nb	0.022	0.29	0.049	0.157	<0.00001
Nd	0.00029	0.00064	0.0006	0.00007	<0.00001
Ni	1.99	0.59	0.32	0.142	0.036
P	0.015	0.042	0.029	0.01	0.061
Pb	0.00003	0.0004	0.0022	0.024	0.22
Pr	0.00014	0.00012	0.00018	0.00003	<0.00001
S	0.015	0.038	0.008	0.028	0.278
Sb	0.042	0.012	0.002	0.034	<0.00001
Se	0.004	0.0012	0.00016	0.00021	<0.00001
Si	0.223	0.39	0.74	0.067	0.007
Sn	0.011	0.016	0.104	0.008	0.005
Sr	0.0005	0.0005	0.0005	0.0005	<0.00001
Ta	0.02	0.02	0.053	0.11	<0.00001
Te	0.0006	0.0011	0.0009	0.00018	0.032
Ti	0.02	0.84	0.05	0.24	<0.00001
Tl	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
V	0.011	0.041	0.31	0.105	<0.00001
W	0.017	0.2	0.046	0.102	<0.00001
Zn	0.0001	0.0005	0.0004	0.001	<0.00001
Zr	0.009	0.19	0.049	0.068	<0.00001

* Remainder is Iron

Table 7. High Alloy Steel Certified SRM's

Element	SRM 1152	SRM 1154	SRM 1156	SRM 1170B
Ag	0.0001	0.0025	<0.00001	<0.00001
Al	0.004	0.004	0.047	<0.00001
As	0.016	0.03	<0.00001	<0.00001
B	0.004	0.0018	0.003	<0.00001
Be	<0.00001	<0.00001	<0.00001	<0.00001
Bi	0.0001	0.001	<0.00001	<0.00001
C	0.148	0.086	0.023	0.052
Ca	<0.00001	<0.00001	0.001	<0.00001
Cd	<0.00001	<0.00001	<0.00001	<0.00001
Ce	<0.00001	<0.00001	<0.00001	<0.00001
Co	0.22	0.38	7.3	0.096
Cr	17.81	19.06	0.2	17.42
Cu	0.102	0.4	0.025	0.199
Fe	*	*	*	*
Hf	<0.00001	<0.00001	<0.00001	<0.00001
La	<0.00001	<0.00001	<0.00001	<0.00001
Mg	<0.00001	<0.00001	<0.00001	<0.00001
Mn	0.96	1.42	0.21	0.738
Mo	0.43	0.07	3.1	0.248
Nb	0.16	0.23	<0.00001	<0.00001
Nd	<0.00001	<0.00001	<0.00001	<0.00001
Ni	10.88	12.92	19.	8.89
P	0.021	0.06	0.011	0.129
Pb	0.0047	0.0178	<0.00001	<0.00001
Pr	<0.00001	<0.00001	<0.00001	<0.00001
S	0.0064	0.053	0.012	0.013
Sb	0.0015	0.023	<0.00001	<0.00001
Se	0.024	0.0078	<0.00001	0.23
Si	0.8	0.5	0.184	0.654
Sn	0.013	0.024	<0.00001	<0.00001
Sr	<0.00001	<0.00001	<0.00001	<0.00001
Ta	0.001	0.075	<0.00001	<0.00001
Te	0.0091	0.015	<0.00001	<0.00001
Ti	0.011	0.004	0.21	<0.00001
Tl	0.00005	0.0007	<0.00001	<0.00001
V	0.03	0.135	<0.00001	0.058
W	<0.00001	<0.00001	<0.00001	<0.00001
Zn	0.01	0.011	<0.00001	<0.00001
Zr	0.004	0.004	0.004	<0.00001

* Remainder is Iron

Table 8A. Cast Iron (Not Steel) Certified SRM's

Element	SRM 1	SRM 2	SRM 3	SRM 4	SRM 5
Ag	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Al	0.007	0.007	0.02	0.005	0.056
As	0.012	0.005	0.004	0.07	<0.00001
B	0.0011	0.0004	0.0006	0.0052	0.001
Be	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Bi	0.002	0.0006	0.002	0.0005	0.003
C	3.91	3.86	4.32	2.02	2.9
Ca	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Cd	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Ce	<0.00001	0.02	0.02	0.006	0.059
Co	0.013	0.002	0.062	0.026	0.15
Cr	0.056	0.021	0.1	2.11	0.22
Cu	0.024	0.11	0.3	0.02	2.11
Fe	*	*	*	*	*
Hf	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
La	0.001	0.01	0.009	0.002	0.03
Mg	0.001	0.005	0.001	0.001	0.064
Mn	0.82	0.31	2.42	0.29	1.5
Mo	0.051	0.1	0.01	1.6	0.31
Nb	0.005	0.006	0.004	0.019	0.01
Nd	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Ni	0.13	0.085	0.028	5.27	2.99
P	0.059	0.089	0.01	0.57	0.041
Pb	0.003	0.002	0.005	0.005	0.016
Pr	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
S	0.05	0.01	0.071	0.23	0.018
Sb	0.11	0.19	0.002	0.01	0.05
Se	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Si	1.6	0.96	0.315	3.44	0.55
Sn	0.003	0.1	0.002	0.015	0.19
Sr	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Ta	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Te	0.011	0.002	0.002	0.007	0.005
Ti	0.16	0.077	0.009	0.037	0.17
Tl	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
V	0.021	0.21	0.076	0.028	0.069
W	0.006	0.03	0.045	0.02	0.078
Zn	0.008	0.005	0.005	0.02	0.012
Zr	0.02	0.005	0.01	0.039	0.01

* Remainder is Iron

Table 8B. Cast Iron (Not Steel) Certified SRM's

Element	SRM 6	SRM 7
Ag	<0.00001	<0.00001
Al	0.02	0.01
As	<0.00001	<0.00001
B	0.0005	<0.00001
Be	<0.00001	<0.00001
Bi	0.002	0.0004
C	3.37	2.99
Ca	<0.00001	<0.00001
Cd	<0.00001	<0.00001
Ce	0.0075	<0.00001
Co	0.007	0.084
Cr	0.028	0.092
Cu	0.51	0.047
Fe	*	*
Hf	<0.00001	<0.00001
La	0.008	0.002
Mg	0.12	0.006
Mn	0.9	0.18
Mo	0.55	0.021
Nb	0.032	0.004
Nd	<0.00001	<0.00001
Ni	1.76	0.41
P	0.01	0.063
Pb	0.002	0.005
Pr	<0.00001	<0.00001
S	0.003	0.018
Sb	0.002	0.001
Se	<0.00001	<0.00001
Si	1.32	2.9
Sn	0.003	0.002
Sr	<0.00001	<0.00001
Ta	<0.00001	<0.00001
Te	0.002	0.031
Ti	0.025	0.009
Tl	<0.00001	<0.00001
V	0.002	0.36
W	0.01	0.01
Zn	0.011	0.002
Zr	0.016	0.005

* Remainder is Iron

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