

August 2, 1977

MEMORANDUM

TO: S. H. Ward

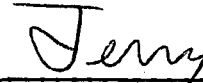
FROM: G. W. Hohmann ✓

SUBJECT: Inductively Coupled Plasma Spectrograph (ICP) for Geothermal Water and Rock Trace Element Analyses.

Enclosed is a preliminary evaluation of the ICP by Jim Cardwell, who worked in Kennecott's geochemical lab and who is now employed by Rocky Mountain Geochemical Corp. His report is based on extensive AA experience, a literature survey, and discussions with the Bureau of Mines, who have an ICP.

This initial evaluation is quite encouraging but we need to investigate the subject more extensively before deciding to acquire one. We will consult other users of the instrument, including the OSHA lab in Research Park.

The purpose of acquiring an ICP would be to reduce greatly the analytical costs of multi-element determinations.



G. W. Hohmann

GWH:srm

cc: R. Bamford
M. Wright

Evaluation of the
Inductively Coupled Plasma Spectrograph
for
Geothermal Water and Rock Trace Element Analysis.

Consultant Report
by
J. Cardwell

In the analysis of waters for metal content, the analyst's major concern is the precise, specific determination of many metals in large numbers of samples. The amounts of metal to be determined may range from trace levels to quite high concentrations although most analysis will involve determination at low or trace levels.

One of the most widely used approaches for routine trace analysis is atomic absorption. However, many times atomic absorption falls short of being an ideal approach because of limited sensitivity and the time required for multielement analysis. With the introduction of graphite furnace or carbon rod atomizer, the problem of limited sensitivity has been somewhat overcome.

As work on inductively coupled plasmas (ICP) has progressed, it has become clear that when coupled to a multichannel emission quantometer, a significant number of major advantages are realized. Table 1 is a list of some of these advantages which are characteristic of this analytical system.

In order to compare one analytical technique with another, it is necessary to compare sensitivity. A commonly accepted comparison is the limit of detection. Not only can limit of detection be used for comparison purposes, it can be directly related to practical concentrations for

quantitative analysis. Table 2 presents an overall comparison of the analytical performance obtained for eleven elements with the inductively coupled plasma, atomic absorption and carbon rod atomizers. Data for Table 2 was taken from the literature (1,2,3) where a wide variety of working conditions has been optimized for each individual element. Using the work of Carl F. Austin and coworkers (4), these eleven elements were chosen for comparison because of their role in geothermal waters.

The physical arrangement of the ICP is such that the narrow central channel of the flame, where the excited atoms of the sample are observed, is surrounded by a transparent layer of argon at high temperature. This arrangement tends to minimize self-absorption, so that element concentration ranges of from 3 to 5 orders of magnitude are commonly achieved with straight line calibration curves. This is in contrast to both atomic absorption and carbon rod atomizers which are limited to less than 2 orders of magnitude.

Table 3 is a comparison of the ranges of calibration for the ICP, atomic absorption (A.A.) and the carbon rod atomizer (CRA). Data for this table is taken from a memo from Dr. Stan Church of the Applied Research Laboratory (ARL) (5) and the instrumental operating parameters of the Perkin Elmer Corporation (2) and Varian Techtron (3).

Table 4 lists further elements within the ICP's capability and the detection limits for these from the same solution along with the eleven elements previously compared. These determinations are simultaneous from the same 5 milliliters of solution. All results are printed out from the computer in a final concentration form.

Using the environmental list of metals for analysis (6), it becomes apparent that potential applications of the ICP extend to many other types of samples in addition to geothermal waters. For example, applying the technique of Ingamells and others (7) using a lithium meta-borate fusion for the dissolution of rocks and soils in ICP's potential is unlimited.

In summary, the inductively coupled plasma can provide true multi-element capability under a single set of conditions: superior powers of detection at the part per billion level, superior dynamic range, minimal interelement effects, and minimal or no sample preparation.

This system provides the analyst with a powerful tool which can make it possible to handle the ever increasing workloads while providing better analytical quality under less demanding sample handling requirements.

TABLE 1

ANALYTICAL ADVANTAGES
OF THE
INDUCTIVELY COUPLED PLASMA

1. True simultaneous multielement capability under one set of conditions.
2. Powers of detection in the nanogram to fractional microgram per milliliter range overall comparable or superior to flame atomic absorption.
3. Dynamic range superior to atomic absorption and carbon rod atomizers.
4. Minimal interelement effects.
5. Directly applicable to liquid samples with minimal or no preparation.
6. Operating costs less than the cost of running a nitrous oxide flame.

TABLE 2

INSTRUMENTAL DETECTION LIMIT COMPARISONS OF
SPECIES COMMONLY ANALYZED IN
GEOHERMAL WATERS

<u>Element</u>	<u>ICP (a)</u>	<u>CRA (b)</u>	<u>A A (c)</u>	<u>A.A. Hydride Generation (d)</u>
Si	0.005	0.035	1.8	
Al	0.003	0.015	1.0	
Fe	0.001	0.003	0.12	
Mn	0.0005	0.0006	0.055	
As	0.04	0.100	0.8	0.001 (20 ml sample)
Ca	0.001	0.0003	0.08	
Mg	0.0002	0.00006	0.007	
Na	0.05	0.0002	0.015	
K	0.2	0.001	0.04	
Li	0.0005	0.002	0.035	
B	0.0005	----	1.5	

(a) Inductively Coupled Plasma

(b) Carbon Rod Atomizer

(c) Atomic Absorption Spectrophotometry

(d) Atomic Absorption Hydride Generation Technique

TABLE 3

TYPICAL INSTRUMENTAL RANGES OF CALIBRATION

Reported in ug/ml

<u>Element</u>	<u>ICP</u>	<u>CRA</u>	<u>A A</u>	<u>A A Hydride Generation</u>
Si	100-0.005	3-0.05	150-2	
Al	100-0.02	1-1-0.02	50-1	
Fe	3000-1	0.2-0.005	5-0.12	
Mn	100-0.005	0.1-0.005	5-0.06	
As	50-0.1	3-0.1	50-0.8	1.0-0.05
Ca	100-0.02	0.1-0.001	5-0.8	
Mg	100-0.02	0.02-0.001	2-0.01	
Na	500-0.1	0.03-0.001	2-0.02	
K	500-0.1	0.05-0.001	5-0.04	
Li	20-0.001	0.05-0.001	5-0.04	
B	50-0.005	---	500-15	

TABLE 4

<u>Element</u>	<u>Detection Limit ug/ml</u>
Ag	0.01
Ba	0.0005
Be	0.0002
Cd	0.002
Co	0.004
Cr	0.006
Cu	0.001
Hg	0.020
Mo	0.007
Ni	0.010
Pb	0.050
Sb	0.040
Se	0.060
Sn	0.080
Sr	0.0003
Ti	0.005
V	0.006
W	0.5
Y	0.0002
Zn	0.003

References

1. P. D. Dalager, A. L. Davidson and R. M. Ajhar, Applied Research Laboratories Bulletin #7006 Fig. 4
2. "Analytical Methods for Atomic Absorption Spectrophotometry", Perkin Elmer Corp. Rev. Sept. 1975
3. "Carbon Rod Atomizer Analytical Data", Varian Techtron #85-100110-00
4. C. F. Austin, W. H. Austin Jr. and G. W. Leonard, "Geothermal Science and Technology a National Program", Tech. Series #45-029-72
5. S. Church, Applied Research Laboratories, memo to R. Bamford May 31, 1977
6. "Manual of Methods for Chemical Analysis of Water and Wastes", EPA-625-/6-74-003 pg. 79
7. N. H. Suhr and C. O. Ingamells, Anal. Chem., 38, 730(1966)
"Solution Technique for Analysis of Silicates"