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# Gamma Ray Interaction and "Neutron Capture Gamma Ray Technique for the Analysis of Cu-Ni Alloys"

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### Abstract

The neutron capture gamma-ray technique was used for the analysis of Cu-Ni alloys, widely used in industry. The two elements, which are very close in atomic number, have widely separated characteristic capture gamma quanta. A sensitivity of $7x10^{-7}$ counts per unit thermal neutron flounce per 1% change in Ni/Cu ratio was obtained. Samples of any shape can be analyzed without a need for any special preparation. The neutron capture gamma quanta method used in this work is nondestructive and contactless.

### Introduction

The determination of variations in elemental constituents of an alloy from a specified elemental ratio in a fast and nondestructive way has clear advantages. The XRF method, although fast, provides information from only a very thin surface layer of few microns [1, 2]. The wet chemistry analytical method, can analyze usually only a limited number of samples. The results of the analysis may not, accurately, indicate the constituents of the whole alloy material, unless the material is very homogeneous, or a large number of samples are analyzed.

The neutron capture gamma quanta technique was used for the analysis of widely-used Cu-Ni alloys, where the proportion of the two elements determines their chemical and mechanical properties. These methods are nondestructive, contactless, the results of tests can be conveniently displayed, and on line measurements can be executed.

In the capture gamma quanta method the intensities of the characteristic gamma rays emitted from each element of the alloy is proportional to its concentration. This technique is particularly useful for nondestructively analyzing deeper layers beneath the surface for alloys of irregular shapes. In Cu-Ni alloys the difference in the energy of the emitted characteristics gamma rays of the element that has very close atomic number values is quite large. Accordingly interference from one element with another is unlikely.

The capture gamma quanta method has found wide applications in geophysics and mineral ore analysis with some application in the medical field [3]. Recently Abdul Majid has used the technique successfully in corrosion measurement [4, 5] and in identifying inorganic [6] and organic scales accumulated inside pipes [7, 8].

### Materials and Methods

The arrangement for the capture gamma ray method is shown in Fig. 1. It consisted of a 11.1 x 1010 Bq (3 Ci) $^{241}$Am-Be neutron source emitting $6.6x10^{6}$ n/s with a tolerance within 10% surrounded by an 8 cm thick paraffin wax cylinder to moderate the fast neutrons. This increase the slow neutrons flux at the sample position, and accordingly the capture efficiency. The sample lateral dimensions were 15x10 cm. The gamma ray detection system consisted of an HPGe detector of 10% relative efficiency whose FWHM was 3 keV at 1.332. The detector was separated from the moderator by 10 cm of lead to reduce gamma quanta coming directly from the source or from the moderator following capture processes in it. The energy calibration was performed by using several well known gamma ray emitters. The properties of the Cu-Ni and gold alloys used, are shown in Table 1.

Table 1. Compositions and Effective Atomic number ($Z_{eff}$) of Alloys

| Type of Alloy | Composition (% of weight) | $Z_{eff}$(n=2.95) | $Z_{eff}$(n=3.45) | $Z_{eff}$(n=3.95) |
|---|---|---|---|---|
| C70600 | 90Cu, 10Ni | 28.89 | 28.89 | 28.89 |
| C71000 | 80Cu, 20Ni | 28.799 | 28.80 | 28.80 |
| C71500 | 70Cu, 30Ni | 28.699 | 28.70 | 28.70 |

The effective atomic numbers $Z_{eff}$ were calculated from the formula [9]:

$$Z_{eff} = \sqrt[n]{a_1 Z_1^n + a_2 Z_2^n + ---} \qquad (1)$$

The n value can vary from 2.95 to 3.95 and $a_i$ is the atomic ratio of an element in the alloy or compound. As can be seen from the Table using different values of n can only produce insignificant changes in the value of $Z_{eff}$.

## Results

The experiment set-up is shown in Fig. 1. The spectrum for Cu-Ni alloys type C71500 obtained in 6 hours counting time is shown in Fig. 2. As can be seen, the Cu 7.636 MeV, 7.914 MeV and Ni 8999 MeV full (f), single escape (s) and double escape (d) peaks were clear and were much above background. The net counts for Ni peaks versus Ni content are shown in Fig. 3. The counts increased with the Ni content increase, particularly the double escape peak. The measured thermal neutron flux (below Cd cut off) was found to be $4x10^3$ n $cm^{-2}s^{-1}$. This would give a sensitivity of about $7x10^{-7}$ count per unit flounce change per 1% change in Ni content. Because the alloys are very close in $Z_{eff}$, the gamma-ray backscattering method can not successfully apply.

## Discussion and Conclusion

In the capture gamma quanta technique a sample of any shape can be tested, without a need for sample preparation. Moreover, the alloy elemental constituents are identified, not only the deviation in the alloy elemental ratios, as in gamma interaction methods. Because the neutron absorption cross sections of Cu and Ni are close in value, the change in the alloy elemental ratio would not, significantly, change the neutron flux within the sample. Considering that a difference in counts of two standard deviations is measurable, a change in Ni of 1% in the alloy would be detectable at a thermal neutron flux of $4x10^3$ n $cm^{-2}$-$s^{-1}$. It is quite possible to use a neutron source that would give a higher thermal neutron flux by more than two orders of magnitude. At that higher flux level a concentration change of 0.1% would be detectable. Using a source like $^{252}Cf$ that has softer neutron spectrum would give even higher detection sensitivity. Other possible improvements can be achieved by using a higher efficiency gamma detector. Improvement in geometry may also be possible by reducing the gamma-ray background coming directly from the source, and by surrounding the sample by a neutron scattered in order to increase the slow neutron flux.

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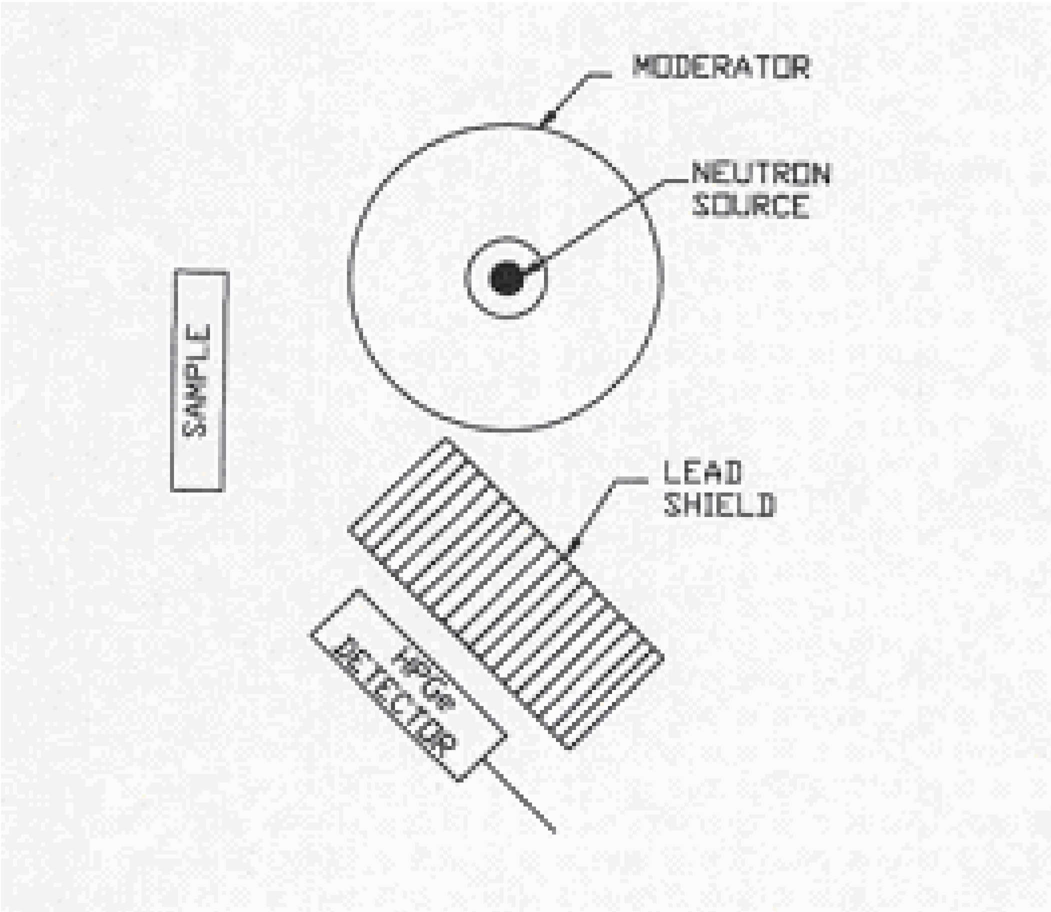


Fig. 1 Setup for capture gamma ray technique

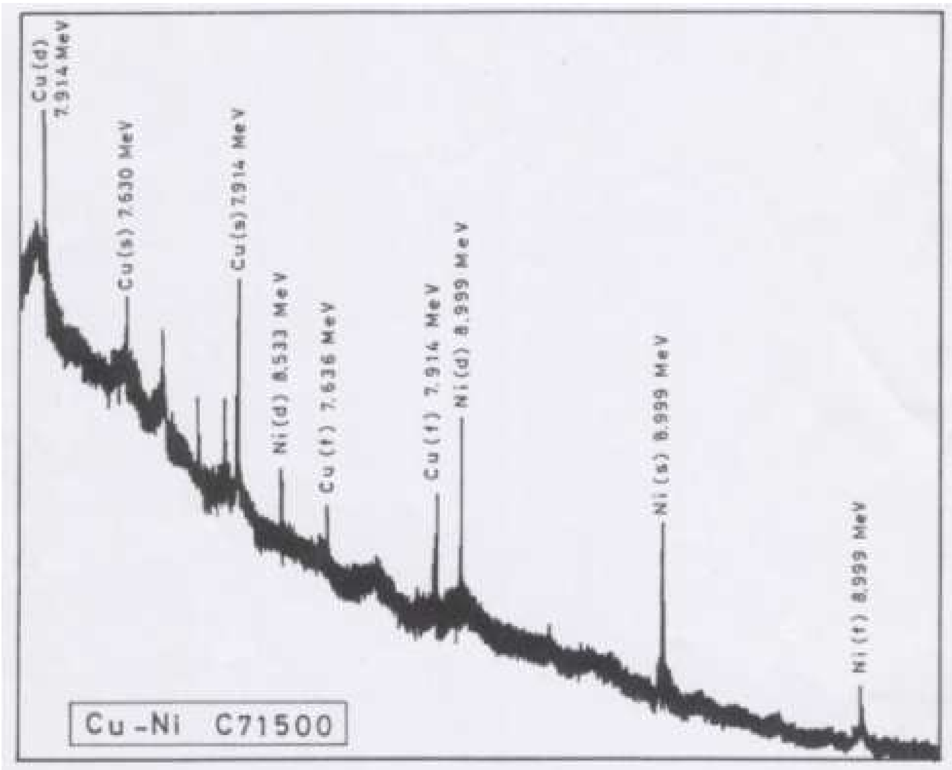


Fig. 2 Spectrum of capture gamma rays emitted from Cu- Ni alloy type C71500

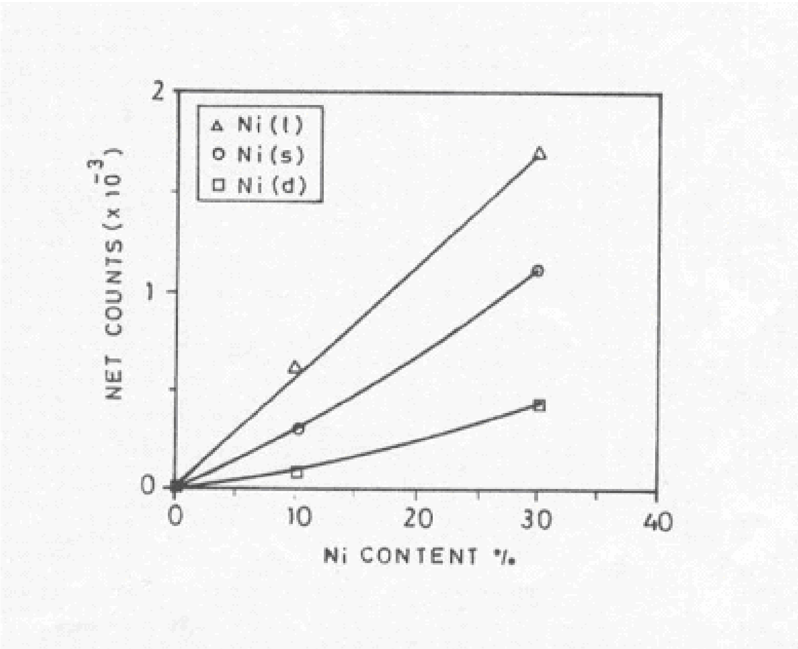


Fig. 3 Net count for 6 h of 8.999 MeV full, single escape and double escape capture gamma rays versus Ni ratio in Cu – Ni alloy.