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Acoustic Emission Sensing of Tool-Bit Contact with Plutonium During Machining Composite Structures

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ACOUSTIC EMISSION SENSING OF TOOL-BIT CONTACT WITH PLUTONIUM DURING MACHINING COMPOSITE STRUCTURES

by

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ABSTRACT

Acoustic emission was investigated as a sensing technique to detect when a cutting tool encounters plutonium while machining composite structures. Such a sensing technique is required if plutonium chips are to be segregated at the source from non-plutonium chips in automated machining. The rms acoustic emission dropped substantially when a cutoff tool passed from 304 stainless steel, beryllium, or vanadium into plutonium. The sharp drop in acoustic emission when the parting tool hit plutonium establishes acoustic emission as a potential sensing technique for detecting when plutonium is encountered in automatic machining of composite parts.

INTRODUCTION

Acoustic emission (AE) is a transient elastic wave produced by a sudden release of energy within a material. These elastic waves are usually detected with piezoelectric transducers mounted on the material or structure being investigated. Information about the nature and location of the AE sources can be obtained from the detected signals. Many AE sources in materials and structures have been identified, including crack propagation, twinning, martensitic phase transformations, dislocation motion, inclusion fracture, high-pressure gas leaks, and rubbing friction between moving surfaces in contact [1,2].

Acoustic emission is being investigated in the U.S. and elsewhere for monitoring manufacturing processes [3]. One application is continuously monitoring tool condition (or wear) during machining [4]. The primary AE source in machining was widely believed to be deformation involved in creating machining chips [5]. However, recent single-point machining tests on a variety of metals (and teflon) have demonstrated that the primary source of AE under ordinary machining conditions is rubbing friction between the nose and/or flank of the tool and the freshly machined surface [6]. Thus, the AE produced during machining strongly depends on the metal being machined because the frictional characteristics of different metals vary substantially. For example, the amount of AE (as measured by the rms value of the AE signal) produced by machining lead is about 100 times less than that produced by machining 304 stainless steel under identical conditions [7].

Minimizing mixed waste is a significant issue in machining plutonium-containing structures. If plutonium chips are to be segregated from non-plutonium chips in automated machining, a basic requirement is to develop a sensing technique that detects when the cutting tool encounters plutonium while machining composite structures. The experiments reported here were conducted to determine if AE is a potential sensing technique for this application.

PRELIMINARY EXPERIMENTS AND AE MONITORING SYSTEM

The AE results from machining lead and stainless steel suggest that AE can be used to detect when a cutting tool passes from one material to another in cutting composite structures. This possibility was explored with a simple experiment [8]. A lead cylinder was press-fit into a section of thick-wall 304 stainless steel pipe. The resulting composite cylinder was mounted in a standard lathe and cut using a carbide insert in a parting tool. Acoustic emission was monitored as the tool cut through the stainless steel and into the lead. Acoustic emission was detected with a Physical Acoustics μ30 transducer epoxied to the parting tool. The transducer output signal was amplified 100X, fed through a band pass filter (10-2000 Khz), and then measured with a Hewlett Packard 3400A rms voltmeter. The voltmeter output was recorded with a Soltec SDA2000 transient recorder.

The rms AE signal level dropped dramatically when the cutting tool contacted the lead at about 38 sec into the cut, as shown in Figure 1. Because the rms voltmeter has a limited dynamic range on a given scale, large changes in rms voltage cannot be adequately represented on a single scale. The scale selected in Figure 1 was appropriate for machining lead, but the rms AE signal at the start of the cut while machining stainless steel was completely off-scale. When a higher scale appropriate for stainless steel was used instead on another cut, the result shown in Figure 2 was obtained.

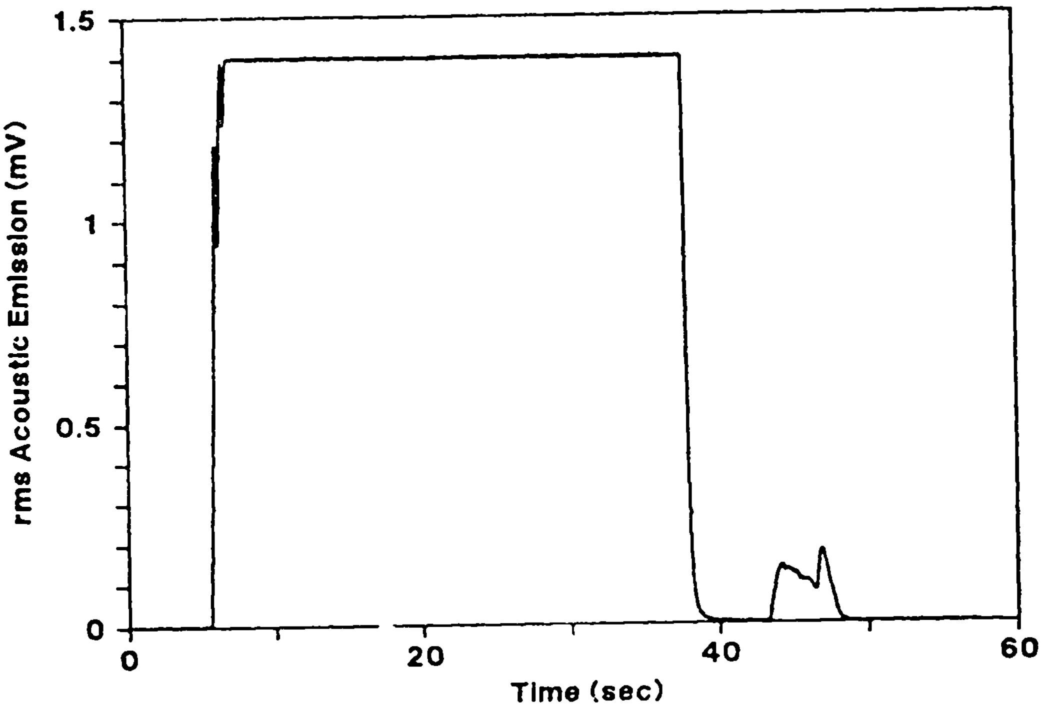

Figure 1. Change in AE rms voltage (referred to the transducer output) while cutting a 304 stainless steel pipe filled with lead as the cutting tool cuts through the stainless steel into the lead. The transition to lead occurred at about 38 sec in this cut. Carbide cut-off tool. Voltmeter setting 0.1 volt full scale after 100X signal amplification.

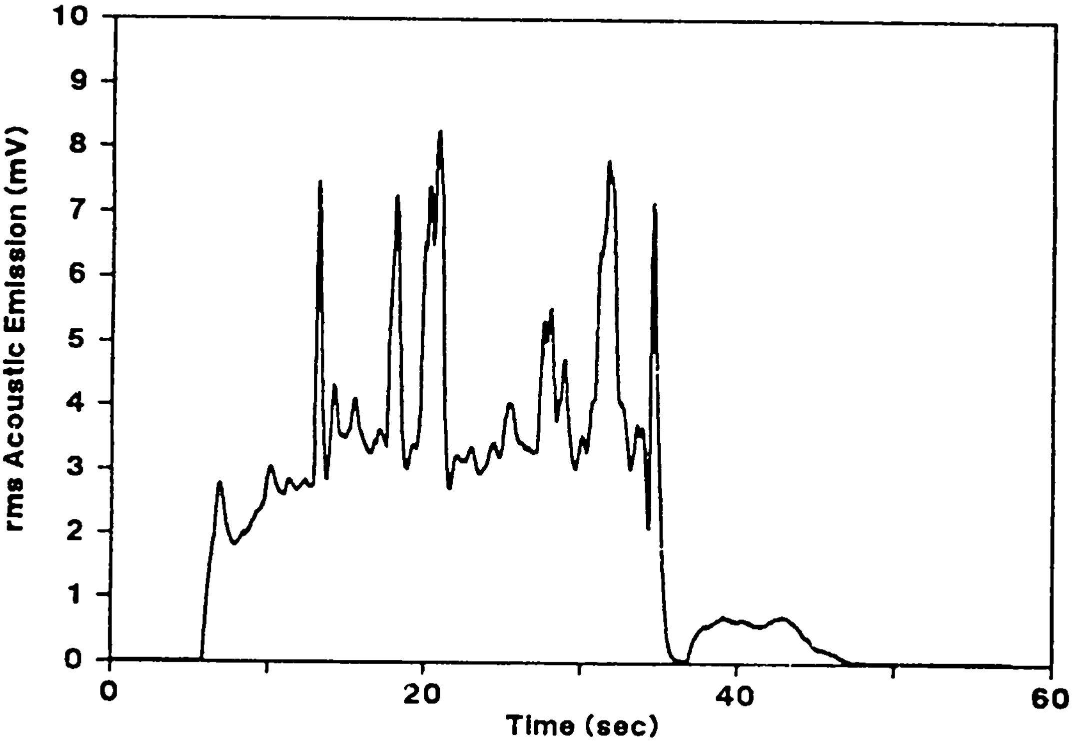

Figure 2. Change in AE rms voltage (referred to the transducer output) while cutting a 304 stainless steel pipe filled with lead as the cutting tool cuts through the stainless steel into the lead. The transition to lead occurred at about 30 sec in this cut. Carbide cut-off tool. Voltmeter setting 1.0 volt full scale after 100X signal amplification.

The level of AE produced by machining plutonium was unknown, so an additional preliminary experiment was conducted to determine if the promising results obtained in the stainless steel-lead experiment would be repeated for stainless steel-plutonium. A cylinder of headwind plutonium was cast and machined into approximately a 1-inch-diameter cylinder and press fit into a section of thick-wall (1/8-inch) 304 stainless steel pipe. The resulting composite cylinder was mounted in a lathe and cut using a carbide insert in a standard parting tool. Acoustic emission was monitored as the tool cut through the stainless steel and into the plutonium. The AE sensing technique was the same as that used for the stainless steel-lead experiment, except that the AE signal was large enough with the machining parameters employed so that no amplification was required.

Machining parameters were typical of those used for this type of operation. Spindle speed was 450 rpm (about 145 ft/min or 75 cm/sec), and the feed rate was 0.001 or 0.002 in/sec (0.003-0.006 mm/rev). Cuts were made both with and without freon coolant.

In all cuts, the rms AE dropped sharply when the cutting tool contacted the plutonium. Results from a dry cut where the spindle speed was increased during cutting to maintain a constant cutting speed are shown in Figure 3. Results from the other tests were similar.

RESULTS AND DISCUSSION OF UNIT TESTS

In view of the promising results obtained in the plutonium-filled pipe experiment, AE was monitored during machining of three stockpile units that were being sectioned as part of the surveillance program. The AE monitoring system was the same as that used for the plutonium pipe test, except no band pass filter was used for the second unit. In addition, a strip chart recorder was used to provide a backup record of the rms voltmeter output for the second and third units.

The unit tests differed in several important respects from the earlier pipe experiments. First, manual rather than automatic feed was used. Thus, the depth of cut changed during sectioning. Second, AE had never been monitored during machining beryllium, which was used for the outer layer of the first and second units, or during machining vanadium, which was used for the outer layer of the third unit. It was anticipated that the AE level produced by machining beryllium would be high, but there was no assurance this expectation would be realized. Based on machining characteristics, it was anticipated that the AE from machining vanadium would be somewhat similar to that from stainless steel, but again there was no assurance this expectation would be realized. Third, there was appreciable runout in the machining setup. Finally, the unit was not solid. All previous work had been on solid samples.

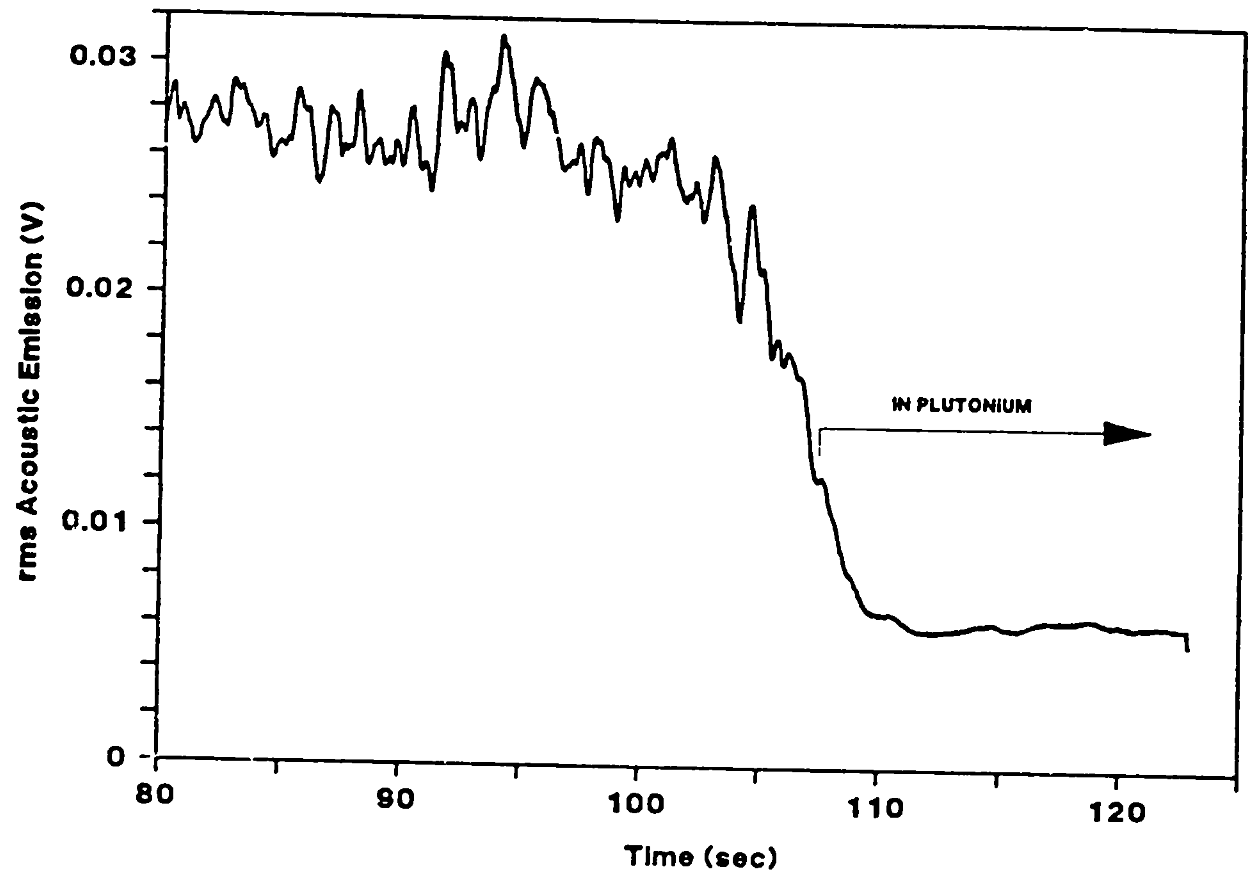

Figure 3. Change in AE rms voltage while cutting a 304 stainless steel pipe filled with plutonium as the cutting tool cuts through the stainless steel into the plutonium. Carbide cut-off tool. Machining conditions: 75 cm/sec cutting speed, 0.003 mm/rev feed speed, no coolant.

The variations in depth of cut associated with manual feed resulted in substantial additional variability in the AE generated from cutting the beryllium or vanadium layers. A typical rms AE record while machining beryllium in the second unit is shown in Figure 4. A relatively sensitive voltmeter scale was used so that the rms AE level while machining plutonium would be detected; as a consequence, the maximum rms levels from machining beryllium were well off-scale.

The AE record during the transition from beryllium into plutonium is shown in Figure 5. As indicated in the figure, the tool had been withdrawn from the groove and reinserted just before breaking through into the plutonium. In spite of this complication, there was a clear and substantial drop in rms AE when the tool encountered plutonium. Similar results were obtained for the transition from vanadium into plutonium in the third unit, Figures 6 and 7.

The results from the pipe and unit tests are similar. The rms AE dropped substantially when the cutoff tool passed from 304 stainless steel, beryllium, or vanadium into plutonium. The transition was more clearly defined in the pipe tests because the automatic feed was used and part runout was less.

CONCLUSIONS

The initial results reported here establish AE as a potential sensing technique to detect when the cutting tool encounters plutonium during automatic machining of composite parts. However, the variability in the rms AE level associated with manual feed indicates that the technique is unlikely to be useful for manual machining.

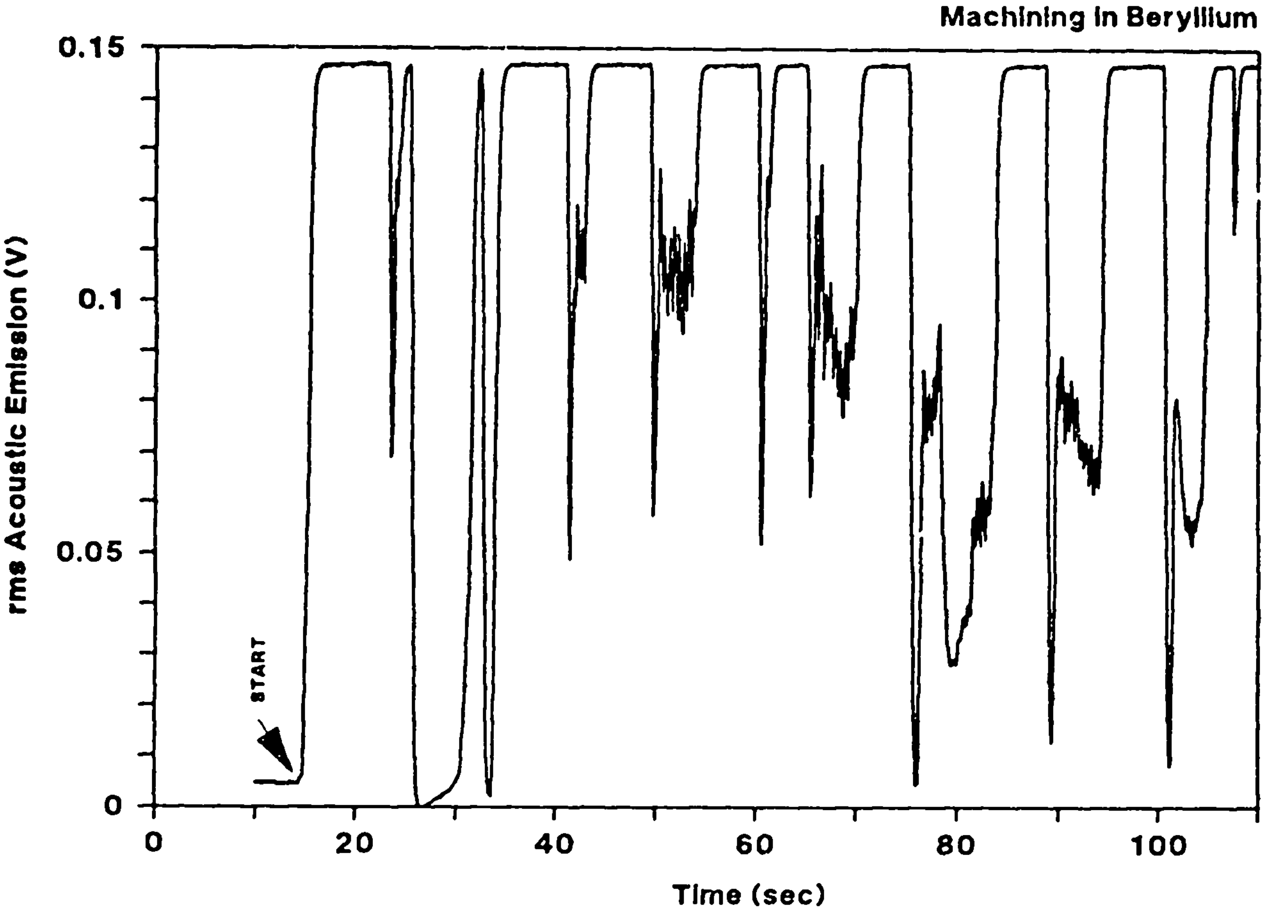

Figure 4. Acoustic emission rms voltage produced by cutting the beryllium outer layer of unit 2. Carbide cut-off tool, manual feed. Voltmeter setting 0.1 volt full scale.

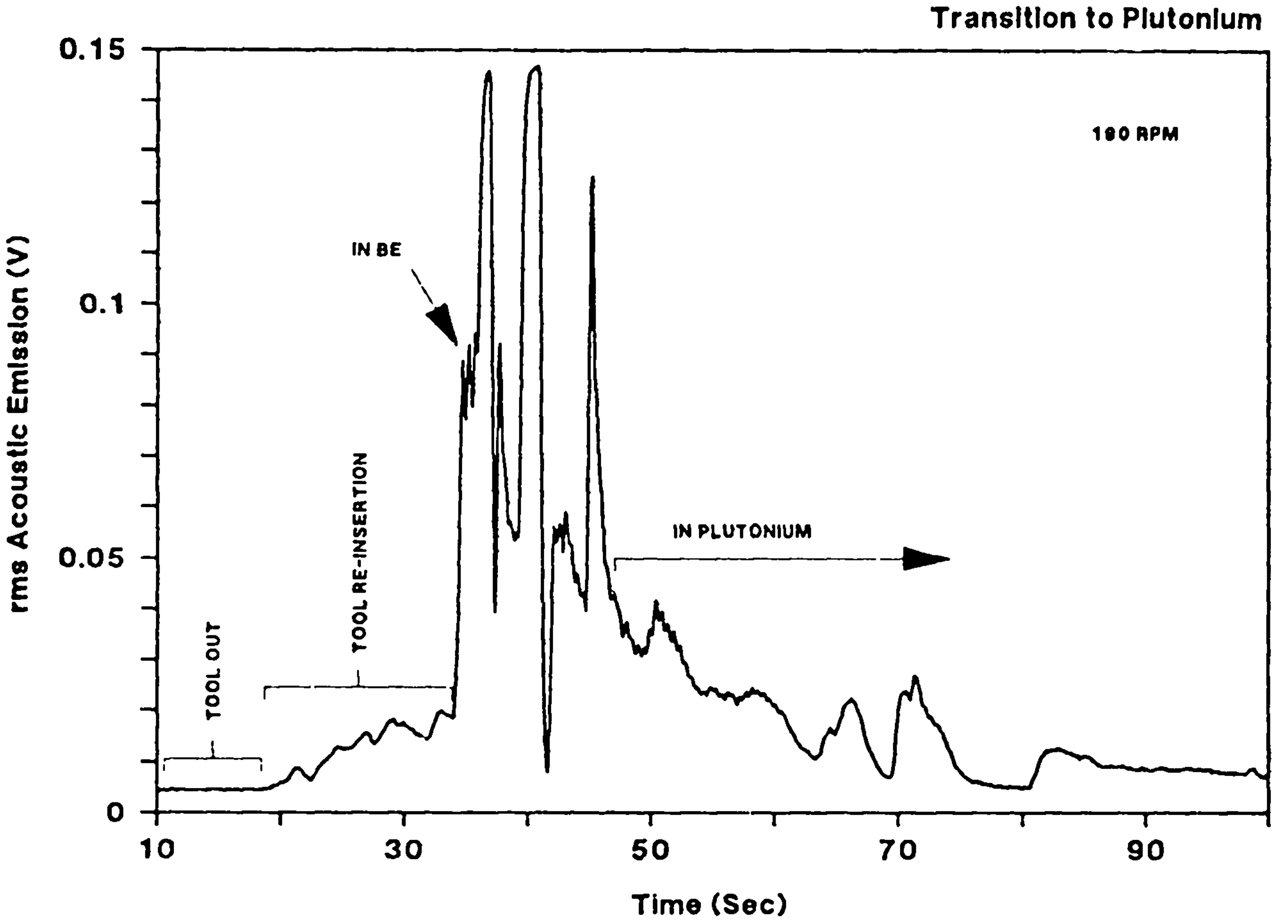

Figure 5. Change in AE rms voltage while cutting Unit 2 as the cutting tool cuts through the beryllium into plutonium. Carbide cut-off tool, manual feed. Voltmeter setting 0.1 volt full scale.

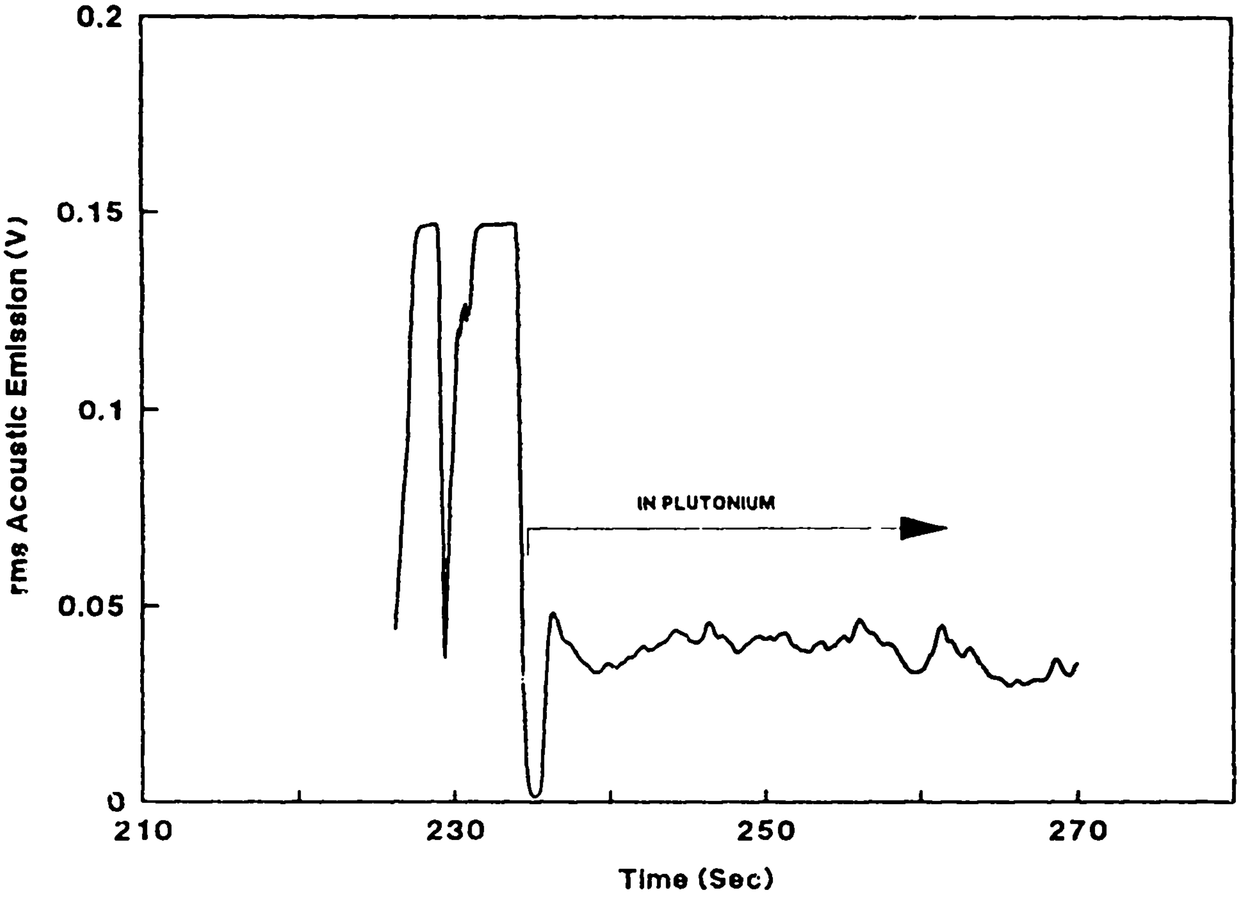

Figure 6. Change in AE rms voltage while cutting Unit 3 as the cutting tool cuts through the vanadium into plutonium. First cut. Carbide cut-off tool, manual feed. Voltmeter setting 0.1 volt full scale.

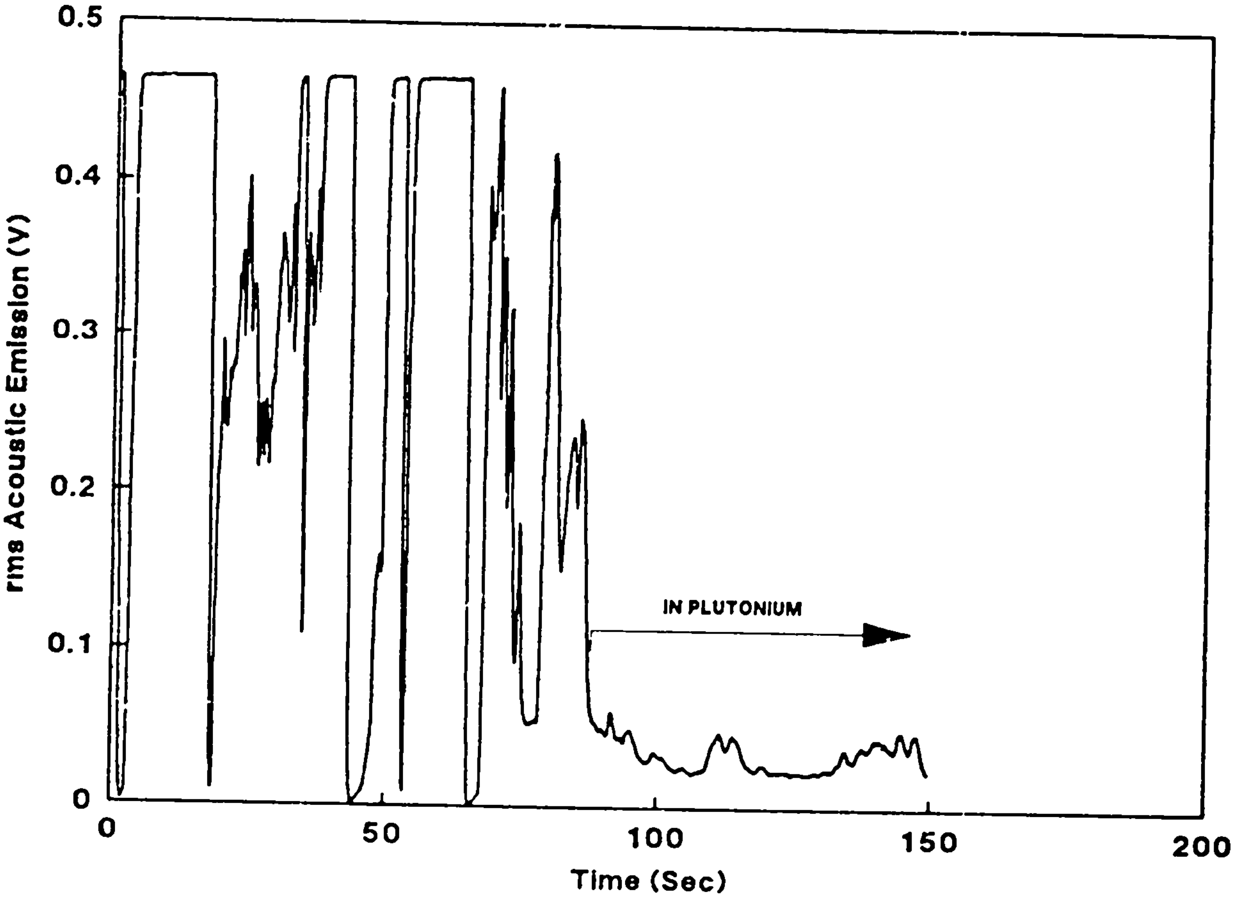

Figure 7. Change in AE rms voltage while cutting Unit 3 as the cutting tool cuts through the vanadium into plutonium. Second cut. Carbide cut-off tool, manual feed. Voltmeter setting 0.3 volt full scale.

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