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COMPUTER CONTROL FOR A CLADDING THICKNESS TESTER

R. J. SAND

DECEMBER 1979

E. I. du Pont de Nemours & Co. (Inc.)
Savannah River Laboratory
Aiken, South Carolina 29801

PREPARED FOR THE U. S. DEPARTMENT OF ENERGY UNDER CONTRACT DE-AC09-76SR00001

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ABSTRACT

A cladding thickness tester for extruded reactor fuel tubes has been automated to provide reduced operator interaction. The cladding thickness tester, which uses an x-ray fluorescence analyzer, has been interfaced with an SRL/6800 microcomputer to control fuel tube orientation, operate the analyzer, calculate cladding thickness, and give pertinent data in hardcopy tabular form.

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COMPUTER CONTROL FOR A CLADDING THICKNESS TESTER

INTRODUCTION

The Nuclear Engineering Division has a cladding thickness tester (CTT) for nondestructive thickness determination of experimental and production fuel tubes. As designed, the CTT did not allow precise position control of the tubes and required three analyses to be performed by the operator. A Savannah River Laboratory (SRL)/6800 microcomputer has been included in the CTT to precisely position the tubes and automatically make the analyses, thereby reducing any human errors in measuring techniques.

The CTT uses a Kevex® (Registered trademark of the Kevex Corporation) x-ray fluorescence spectrometer as a front end to a Canberra counter-scaler system to analyze the spectrum produced by a radioactive cadmium-109 source when the fuel tube wall is placed at the detector.[1]

Previously, a preset indexer and stepping motor were used to rotate the tubes to a specific position. The index has been replaced with a computer-controlled translator. A manual control for a synchronous induction motor was used to position the tubes longitudinally. The control and synchronous motor were replaced with a stepping motor and translator.

The Canberra counter and scalers, and the Kevex® ratemeter used in the measuring analyses were connected to the microcomputer so it could read the data directly for calculations. The cadmium-109 source probe, which rides a controlled vertical elevator, was also integrated with the computer to allow the probe to be raised while the fuel tubes were rotated.

CLADDING THICKNESS TESTER - SRL/6800 MICROCOMPUTER

The photograph in Figure 1 shows the CTT on the floor of the Fabrication Development Laboratory. The SRL/6800 microcomputer and Kevex® x-ray fluorescence spectrometer are in the rack beside the middle of the CTT bed. The probe elevator raises and lowers the liquid nitrogen Dewar at the left end of the CTT bed. The cadmium-109 probe source is in the plastic cage at the CTT bed's mid-section. The CTT chuck cart positions the fuel tube that is being analyzed.

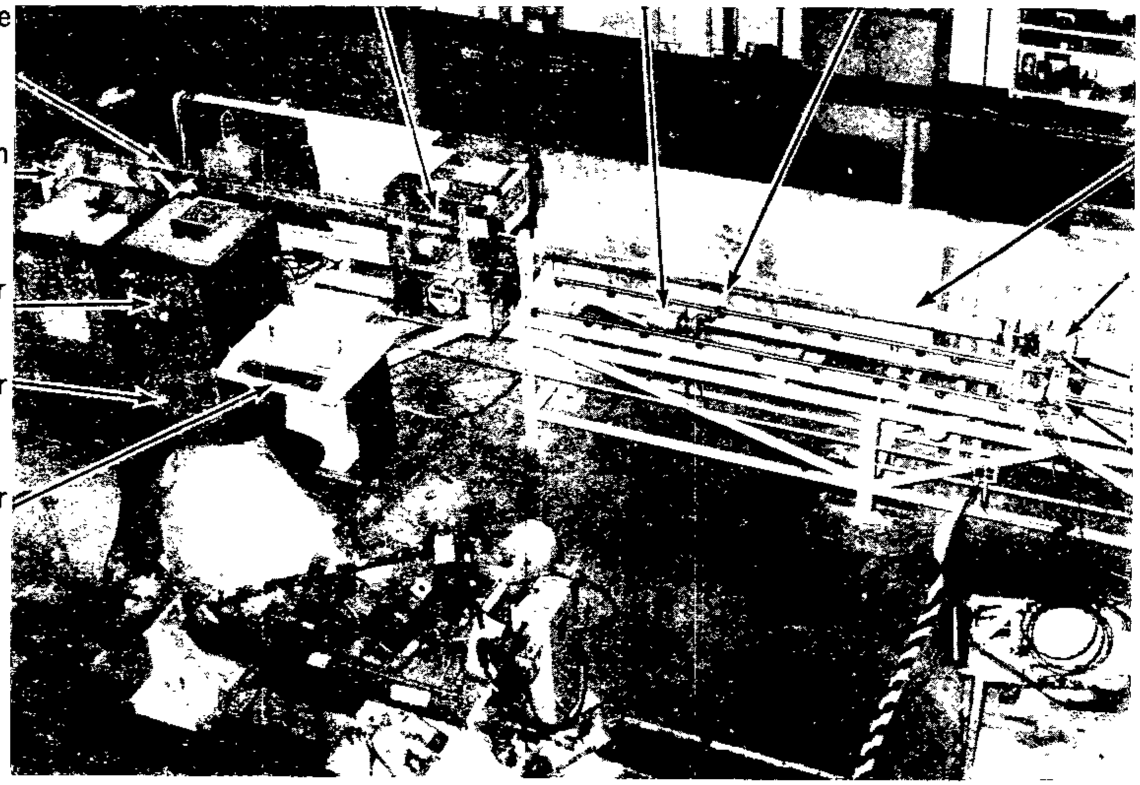

FIGURE 1. Cladding Thickness Tester

Software

The characteristics of the CTT-SRL/6800 microcomputer[2] are defined by its software. Four types of analyses are available in this system:

Type 1 - The core end analysis is a rather extensive routine which can search an area to find a minimum cladding thickness point. It requires nine orientation specifications to define the search details. The first step in the analysis is to determine the starting position of the search with respect to an area of nominal cladding thickness. The fuel tube is then searched longitudinally for a thin cladding area using a coarse scan grid, and a fine scan grid is used to pinpoint the minimum cladding thickness. The coarse grid scan is then resumed, and after a specified length of nominal thickness cladding is scanned, the fuel tube is rotated and the process repeated.

Type 2 - The ring section analysis simply rotates the fuel tube in increments, taking cladding thickness measurements at specified intervals.

Type 3 - The spot analysis allows the detector to be centered over a spot on the fuel tube, where cladding thickness measurements are taken from a grid surrounding the center point.

Type 4 - Manual control software allows the fuel tube to be positioned at the operator's discretion. Cladding thickness measurements can be taken as desired. Manual control is also used to input orientation specifications for the first three analyses, and also to input constants for calculating the cladding thickness. Figure 2 is a sample of a specification entry page. Manual control software allows the option to use constants and specifications previously entered or to enter new constants and orientation specifications, reducing unnecessary variable entry.

The data that the microcomputer receives from the analyses are used in an equation to determine the cladding thickness (CT equation, Figure 1). For three ranges of weight percent radioactive material in aluminum alloy, three different sets of constants are also used.

$10 \leq \% \leq 30$	Constants A
$30 < \% < 50$	Constants B
$50 \leq \% \leq 80$	Constants C

Data are displayed in tabular form, providing coordinate information with respect to the analysis starting point, raw spectrometer data, and calculated cladding thickness (Figure 3). If the difference of count minus background for either the L_α

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SRL/6800μC CLADDING THICKNESS TESTER
NUCLEAR ENGINEERING DIVISION
SAVANNAH RIVER LABORATORY
VERSION I    1979 MAY 4
DATE 1979 MAY 14
OPERATOR RICK SAND
RUN IDENTIFICATION 1
DO YOU WANT NEW EQUATION CONSTANTS? NO
```

$$CT = CONSTANT\ 1 \times \ln \frac{L_\beta - BG_\beta \times CONSTANT\ 4}{L_\alpha - BG_\alpha} + CONSTANT\ 2 \times WT\ \%\ ALLOY + CONSTANT\ 3$$

```
THREE CONSTANT SETS
A CONSTANT 1 = 27.571
B CONSTANT 1 = 27.571
C CONSTANT 1 = 27.571
A CONSTANT 2 = 0.02564
B CONSTANT 2 = 0.02564
C CONSTANT 2 = 0.02564
A CONSTANT 3 = 2.293
B CONSTANT 3 = 2.293
C CONSTANT 3 = 2.293
A CONSTANT 4 = 1
B CONSTANT 4 = 1
C CONSTANT 4 = 1
CONSTANT INTERVAL BREAKPOINT 1 = 40
CONSTANT INTERVAL BREAKPOINT 2 = 80
MINIMUM ALPHA PEAK = 500
MINIMUM BETA PEAK = 1000
FOUR TYPES OF ANALYSES AVAILABLE
    1. CORE END ANALYSIS
    2. RING SECTION ANALYSIS
    3. SPOT ANALYSIS
    4. MANUAL CONTROL
1. CORE END ANALYSIS
DO YOU WANT NEW ORIENTATION SPECIFICATIONS? YES
NOMINAL CLADDING THICKNESS = 40
WITHDRAW STEP   -1  (-0.9935015)
STEP LENGTH = 2 (+2.0019056)
THIN CLADDING = 30
SMALL STEP LENGTH = .5  (+0.5017182)
MINIMUM LENGTH = 10 (+9.9995932)
MINIMUM NOMINAL CORE END LENGTH = 4 (+3.9988438)
TUBE ROTATION = 20  (+20.019431)
TOTAL ROTATION = 60 (+59.975226)
2. RING SECTION ANALYSIS
DO YOU WANT NEW ORIENTATION SPECIFICATIONS? YES
TUBE ROTATION = 20  (+20.019431)
TOTAL ROTATION = 60 (+59.975226)
3. SPOT ANALYSIS
DO YOU WANT NEW ORIENTATION SPECIFICATIONS? NO
BACKOFF ROTATION = +29.987613
BACKOFF LENGTH = +5.0022803
TUBE ROTATION = +20.019431
TOTAL ROTATION = +59.975226
STEP LENGTH = +2.0019056
MINIMUM LENGTH = +9.9995932
```

DISTANCE INCHES	ROTATION DEGREES	AVERAGE TOTAL COUNT	ALPHA COUNT	ALPHA BACKGROUND	BETA COUNT	BETA BACKGROUND	CLADDING THICKNESS

FIGURE 2. Specification Entry

WEIGHT % ALLOY 70
WHICH TYPE ANALYSIS? 1

DISTANCE INCHES	ROTATION DEGREES	AVERAGE TOTAL COUNT	ALPHA COUNT	ALPHA BACKGROUND	BETA COUNT	BETA BACKGROUND	CLADDING THICKNESS
+0.00"	+0.0°	2000	2668	568	8224	2247	+32.7
0.99"	+0.0°	1892	506	489	2630	2300	1000
+2.00"	+0.0°	2032	2978	532	9120	2174	+32.9
+4.00"	+0.0°	1996	3031	540	8591	2239	+29.8
+3.50"	+0.0°	1970	2825	497	8815	2214	+32.8
+4.00"	+0.0°	2024	2898	544	8859	2133	+33.0
+6.00"	+0.0°	2021	3109	566	9038	2201	+31.3
+8.00"	+0.0°	2013	2961	563	9140	2200	+33.3
+10.00"	+0.0°	2024	2984	548	9006	2223	+32.5
+0.00"	+20.0°	1974	2136	515	7575	2230	+36.9
0.99"	+20.0°	1858	501	489	2629	2324	1000
+2.00"	+20.0°	2027	3375	598	9599	2176	+31.1
+4.00"	+20.0°	2012	3240	593	9544	2191	+32.2
+6.00"	+20.0°	2014	2962	562	9062	2118	+33.3
+8.00"	+20.0°	1994	2847	523	8673	2221	+32.2
+10.00"	+20.0°	2027	3005	543	9088	2213	+32.1
+0.00"	+40.0°	1915	711	505	3627	2213	1000
+2.00"	+40.0°	2056	3222	505	9393	2176	+31.0
+4.00"	+40.0°	2022	3211	545	9387	2220	+31.3
+6.00"	+40.0°	2031	3060	557	9146	2164	+32.3
+8.00"	+40.0°	1984	2663	551	8599	2134	+34.9
+10.00"	+40.0°	2025	2704	509	8507	2143	+33.1
+0.00"	+60.0°	1817	667	482	3566	2278	1000
+2.00"	+60.0°	2047	3257	569	9711	2205	+32.1
+4.00"	+60.0°	2032	3396	536	9563	2172	+30.2
+6.00"	+60.0°	2002	2765	513	8867	2112	+34.3
+8.00"	+60.0°	1981	2746	542	8619	2201	+33.5
+10.00"	+60.0°	1990	2723	583	8467	2140	+33.9

1. CORE END ANALYSIS RUN COMPLETE
WEIGHT % ALLOY 70
WHICH TYPE ANALYSIS? 2

DISTANCE INCHES	ROTATION DEGREES	AVERAGE TOTAL COUNT	ALPHA COUNT	ALPHA BACKGROUND	BETA COUNT	BETA BACKGROUND	CLADDING THICKNESS
+0.00"	+0.0°	1981	2823	553	8598	2183	+32.7
+0.00"	+20.0°	1973	2599	520	8361	2217	+33.9
+0.00"	+40.0°	2022	2908	547	8862	2212	+32.6
+0.00"	+60.0°	2020	3080	594	9077	2133	+32.4

2. RING SECTION ANALYSIS RUN COMPLETE
WEIGHT % ALLOY = 70
WHICH TYPE ANALYSIS? 3

DISTANCE INCHES	ROTATION DEGREES	AVERAGE TOTAL COUNT	ALPHA COUNT	ALPHA BACKGROUND	BETA COUNT	BETA BACKGROUND	CLADDING THICKNESS
+0.00"	+0.0°	2000	2937	564	9058	2211	+33.3
+0.00"	+20.0°	2005	3281	571	9304	2150	+30.8
+0.00"	+40.0°	2003	3284	529	9485	2101	+31.2
+0.00"	+60.0°	2002	3059	517	9122	2115	+32.0
+2.00"	+0.0°	1985	2577	530	8271	2141	+34.3
+2.00"	+20.0°	1967	2849	550	8957	2183	+33.8
+2.00"	+40.0°	1986	3085	508	9214	2177	+31.7
+2.00"	+60.0°	1953	2863	523	8973	2253	+33.1
+4.00"	+0.0°	1948	2471	495	8262	2195	+35.0
+4.00"	+20.0°	2008	3030	548	9350	2191	+33.2
+4.00"	+40.0°	2001	2908	550	8879	2206	+32.7
+4.00"	+60.0°	1991	3232	532	9584	2185	+31.8
+6.00"	+0.0°	2001	2814	536	8655	2071	+33.3
+6.00"	+20.0°	1981	2711	531	8562	2184	+33.6
+6.00"	+40.0°	1981	2685	562	8439	2170	+33.9
+6.00"	+60.0°	1996	2908	545	8673	2070	+32.4
+8.00"	+0.0°	1990	2900	516	8713	2186	+31.8
+8.00"	+20.0°	1983	2741	617	8582	2224	+34.3
+8.00"	+40.0°	1987	2725	526	8473	2127	+33.3
+8.00"	+60.0°	1947	2998	588	9078	2187	+33.0
+10.00"	+0.0°	2007	2944	539	8919	2210	+32.3
+10.00"	+20.0°	1940	2649	560	8374	2132	+34.2
+10.00"	+40.0°	1965	2926	565	8781	2179	+32.4
+10.00"	+60.0°	1953	3060	519	9018	2243	+31.1

3. SPOT ANALYSIS RUN COMPLETE
WEIGHT % ALLOY = 70
WHICH TYPE ANALYSIS? 4
4. MANUAL CONTROL

DISTANCE INCHES	ROTATION DEGREES	AVERAGE TOTAL COUNT	ALPHA COUNT	ALPHA BACKGROUND	BETA COUNT	BETA BACKGROUND	CLADDING THICKNESS

* C

FIGURE 3. Data Output

peak or the L_β peak of the detected x-rays is below a given value, the cladding thickness value is forced to 1000 mils in order to flag an invalid result and to allow proper program functioning.

CTT Program Structure

The CTT program structure is centered around three analyses and the manual control option (see Figure 4) with numerical operations based on variables represented by ASCII coded characters. This allows operator-oriented input and output to be stored in immediately useable form. The only binary operation performed is for the stepping motor handler routine, which requires a 16-bit binary number to indicate the number of steps to move the stepping motor.

Interface and terminal initializations are actuated by a button on the CTT panel. The CTT routine then requests the alloy weight percent and the analysis that is to be run.

General practice after a power up start is to run Type 4 manual control to permit entry of equation constants and orientation specifications.

Longitudinal position sensors are actuated if the CTT chuck cart holding the fuel tube reaches either end of the CTT bed. This action forces the microcomputer to restart the program, thus halting any computer-initiated motion directives.

Hardware

The microcomputer interfaced with the CTT uses three 4K EPROM modules to hold the program and messages. One 4K RAM is used for variable storage. One 4-port serial interface is used to drive the stepping motor translators, and one serial interface is used to communicate with a DEC® writer II terminal. One 4K EPROM module is used for the 1K monitor, and one 1K RAM module is used for monitor scratch and diagnostic programs. One MPU module and one status indicator module also are used. Numerical processing is performed by a Number Cruncher module. Interfacing to the Kevex® ratemeter, Canberra scaler-counters, tube handler position sensors, and probe elevator is through a Parallel Interface module.

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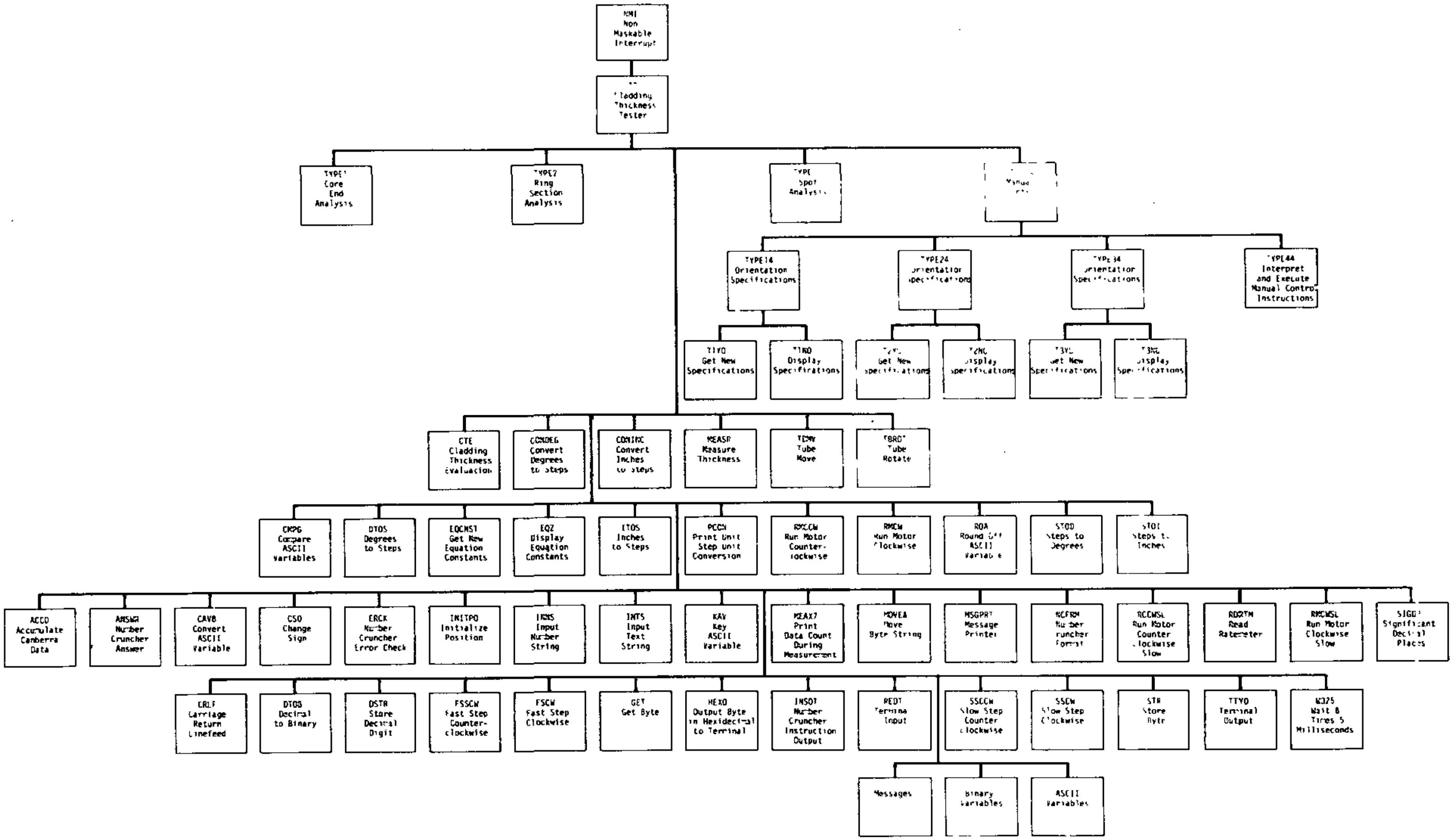

FIGURE 4. Program Structure

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2. R. J. Sand, Savannah River Laboratory/6800 Microcomputer Hardware Manual, DPSTM-DC-1, Savannah River Laboratory, Aiken, SC (1979).