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BDX-613-2102 (Rev.)

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DEVELOPMENT OF A SEMI-AUTOMATIC
BETA-BACKSCATTER THICKNESS-MEASURING
SYSTEM

By R. V. Heckman

Published June 1979

Final Report

Prepared for the United States Department of Energy
Under Contract Number DE-AC04-76-DP00613.

**Kansas City
Division**

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Printed in the United States of America

Available From the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

Price:	Microfiche	\$3.00
	Paper Copy	\$6.00

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**Final Report
R. V. Heckman, Project Leader**

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The semi-automated beta-backscatter system was evaluated to determine the overall system capability. The capability studies performed on the system indicate that the system can measure aluminum nominally $11.33 \mu\text{m}$ ($450 \mu\text{in.}$) thick on a Kapton substrate to a precision of better than 0.72 percent (one standard deviation = $\pm 0.0816 \mu\text{m}$) in a time interval of 10 seconds. The report also covers various fail safe devices installed in the positioning fixture, and changes made in the system's software to facilitate operation of the system and storage of data.

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The Bendix Corporation
Kansas City Division
P. O. Box 1159
Kansas City, Missouri 64141

A prime contractor with the United States
Department of Energy under Contract Number
DE-AC04-76-DP00613

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SUMMARY

This is the final report summarizing the work conducted to determine the overall system capability, a detailed statistical study was conducted to determine the nature and magnitude of the various sources of system error. These results were compared to those obtained from similar studies conducted on the older Geiger-Muller based system. The results of these endeavors indicate that the semi-automatic system achieved its primary design goals of:

- Reducing measurement time.
- Improving measurement precision.

The measurement time was reduced from 100 to 10 seconds and the measurement precision was reduced from 1.0 to less than 0.72 percent.

The report also covers various improvements made in the positioning fixture to prevent an accidental run away of the system; and includes the operating procedure required for system operation. A long term data storage system is also discussed.

DISCUSSION

SCOPE AND PURPOSE

This report summarizes the work previously reported^{1,2} and contains the results of the final evaluation of the completed semi-automated beta-backscatter system. The purpose of this project was to reduce measurement time to a time interval of 15 seconds or less while improving the system accuracy to less than ± 0.5 percent.

To achieve these goals, a probe using a higher activity source (7.4 GBq, or 200 millicuries) and a detector which is capable of accepting count rates in the order of 100 to 200 kHz was developed. In addition, a high precision dual-axis fixture controlled by a minicomputer was built. This report, while restating the results of previous reports, covers the statistical evaluation of the completed system. Two evaluations were conducted to determine the overall error of the system, and to measure the magnitude of the individual components of this overall error.

ACTIVITY

Scintillation Detector/Counting Electronics

As previously reported, a scintillation detector using a high activity (7.4 GBq; 200 millicuries) Pm-147 source was designed, built, and evaluated (Figure 1). The detector was evaluated using (1) a standard nuclear pulse counting system and (2) a current-mode system which measures the anode current directly. It was reported that the current-mode system was superior to the standard nuclear pulse counting system. As the result of work performed since this report was distributed, the instability in the nuclear counting system was found to have been the result of over-saturation of the linear amplifier by the preamplifier and not a result of variations in the discriminator level as previously reported. At present the nuclear counting system is being used without any preamplifier and it has proven to be as stable as the current-mode system.

The scintillation detector has been in operation now for over one year; and aside from a failure of the power supply, the detector system has performed without any problems.

Dual-Axis Automated Fixture

The dual-axis fixture was transferred to the production department. The system is essentially the same as was reported previously (Figure 2).

Figure 1. Disassembled Scintillation Probe Assembly

Initially the system was wired so that the table could be moved only when the control solenoid on the pneumatic system controlling probe position was activated. The problem with this arrangement was if the air supply failed, the control solenoid could successfully switch and the probe would not be retracted. Consequently, the part or standard on which it rested would be scratched. To rectify this problem, a microswitch was installed as shown in Figure 3. With this arrangement, before either table can move, the probe must be physically retracted. Therefore, even if the air supply should fail, no table motion would be possible until the probe is retracted. Additional microswitches were installed on the two rotating tables to limit the rotation of the tables so that even in a computer "crash" or other malfunction in the motor translator system the system would shut down when these limit switches were activated. The revised schematic of the Motor Control Interface showing these microswitches and the other logic changes is shown in Figure 4. The resistor and capacitor values for the open-collector interface are given in Table 1.

Figure 2. Dual Axis Locating Fixture

The software for the system was rewritten to make the system as self-explanatory as possible, and a detailed operating procedure was written to facilitate system operation. A copy of this procedure is given in Appendix A of this report. To operate the system, all the operator must do is type in the designation R BETA.

From this point all that is required are Y (yes) or N (no) responses to the instruction produced by the program. A listing named MENU (see Figure A-4) details the various options available in the program. Less than four hours training was required to train the first operator.

Figure 3. Microswitch to Prevent Movement of the Horizontal and Vertical Tables When Probe is Extended

First Capability Study

The format for this study was the same one used in evaluating the original Geiger-Muller System. The same units used in the evaluation of the manual Geiger-Muller System were also used for this evaluation.

The format of the capability study was as follows:

- System calibrated.
- First unit ran five times with a closure after each run.
- Second unit ran five times with a closure after each run.

Figure 4. Revised Schematic of the Motor Control Interface

This procedure was repeated five times so that each unit was run 25 times with five different calibrations. The system calibration consisted of running each of five standards for three time intervals (the time interval was 10 seconds), running a linear regression

Table 1. Resistor and Capacitor Values for the Open-Collector Interface

Resistor Designation	Resistor Value (k Ω)	Capacitor Designation	Capacitor Value (μ F)
R-1	1.0	C-1	0.022
R-2	0.680	C-2	0.047
R-3	10.0	C-3	16.0
R-4	1.0	C-4	2.2
R-5	3.3	C-5	0.022
R-6	10.0	C-6	0.047
R-7	0.100	C-7	16.0
R-8	8.2	C-8	2.2
R-9	1.8	C-9	1.0
R-10	20.0	C-10	1.0
R-11	34.0	C-11	50
R-12	20.0	C-12	50
R-13	2.7		
R-14	0.220		
R-15	0.470		
R-16	0.470		
R-17	1.0		
R-18	0.680		
R-19	10.0		
R-20	1.0		
R-21	3.3		
R-22	10.0		
R-23	0.100		
R-24	8.2		
R-25	1.8		
R-26	20.0		
R-27	3.9		
R-28	20.0		

Table 1 Continued. Resistor and Capacitor Values for
the Open-Collector Interface

Resistor Designation	Resistor Value (k Ω)	Capacitor Designation	Capacitor Value (μ F)
R-29	2.2		
R-30	0.220		
R-31	1.0		
R-32	0.220		
R-33	2.2		
R-34	0.470		
R-35	0.470		
R-36	1.0		
R-37	1.0		
R-38	1.0		
R-39	0.390		
R-40	1.0		
R-41	0.390		
R-42	0.390		
R-43	0.390		
R-44	0.470		
R-45	0.470		
R-46	1.0		
R-47	1.0		
R-48	1.0		
R-49	2.0		
R-50	1.0		
R-51	0.220		
R-52	0.220		
R-53	0.390		

of the data, and then verifying the constants obtained from the calibration by rerunning each standard and making sure it was within 0.5 percent of the known standard thickness value. A part consisted of running 30 points on each unit then calculating the average thickness and standard deviation of the thickness for each unit. The closure consisted of rerunning the same standards used in the calibration to ensure that no system drift had occurred.

The data was sent to Quality Engineering Services and Reporting. It was analyzed to determine the magnitude of each error component. A copy of their report is included as Appendix B of this report. As seen in Table B-1, the average total measurement error (one standard deviation) over all positions was estimated to be $0.09712\text{ }\mu\text{m}$ ($3.82\text{ }\mu\text{in.}$); the average calibration error (one standard deviation) was $0.06081\text{ }\mu\text{m}$ ($2.39\text{ }\mu\text{in.}$); and the repeat measurement error was $0.07572\text{ }\mu\text{m}$ ($2.98\text{ }\mu\text{in.}$). Table B-2 (Appendix B) shows a comparison of these estimates with similar estimates from previous studies. The overall system error was reduced 13 percent from the best values obtained in previous studies; the repeat measurement component remained essentially the same, while the calibration component was reduced 32 percent. In the previous studies, the time interval for each measurement was 100 seconds whereas a 10 second interval was used with this system. The improvements in system error were obtained while the measurement time for each measurement was decreased by a factor of 10.

An examination of Figures B-1 and B-2 (Appendix B) reveals a definite cyclic behavior to the data. The symmetry of the unit is such that each set of 5 test points should have the same thickness value since they are located the same distance from the center of the part and receive the same amount of material during the PVD process. As seen in Figures B-1 and B-2 rather than having the same thickness within each set of 5 there is a definite thin-thick-thin trend. Since essentially the same trend was present in both parts, it was concluded that this cyclic behavior was the result of some type of fixture misalignment or another source of systematic error.

A thorough examination of the fixture components revealed that the vertical table had a wobble of approximately 1.5 degrees and that the probe was off center by approximately 0.0508 cm (.020 in.). To remedy these problems, the fixture was reworked and aligned.

Second Capability Study

The system, having been extensively reworked and realigned, was shipped to its final location and set up for production operation.

A second capability study, exactly the same as the first was repeated using the same two test units. The results of this study were again analyzed and the report is Appendix C of this report.

As seen in this report, the alignment of the fixture significantly improved the system error. The total measurement error (one standard deviation) was reduced to $0.0816\text{ }\mu\text{m}$ ($3.21\text{ }\mu\text{in.}$) from the value of $0.0971\text{ }\mu\text{m}$ ($3.82\text{ }\mu\text{in.}$) previously obtained or an improvement of 16 percent over the previous study. The most improved error component was the calibration component which was reduced from $0.06081\text{ }\mu\text{m}$ ($2.39\text{ }\mu\text{in.}$) to $0.0344\text{ }\mu\text{m}$ ($1.36\text{ }\mu\text{in.}$). The repeatability component was the least affected being reduced from $0.0757\text{ }\mu\text{m}$ ($2.98\text{ }\mu\text{in.}$) to $0.0739\text{ }\mu\text{m}$ ($2.91\text{ }\mu\text{in.}$). The measurement error was no longer significantly different for the various part positions. The cyclic behavior that was so noticeable in the first capability study was virtually eliminated.

Overall System Operation and Performance

The system has successfully measured over 300 laminates since beginning operation and has experienced less than one day total down time. A long term data storage system has been included as part of the system software (Figure 5). This program automatically stores a copy of each data run under the part serial number on a magnetic disk. The operator can obtain at any time a copy of each part run, or if desired, a summary consisting of the part serial number, the date when the run was made, the average thickness, the standard deviation, and the standard deviation expressed as a percentage of the average part thickness. The documentation of this software is included as Appendix D of this report.

ACCOMPLISHMENTS

The semi-automated beta-backscatter system has reduced the part measurement time by better than a factor of 6. This system can measure over 18 units in 8 hours whereas the old system could measure on the average only 3 units per 8 hour shift. Not only has the measurement time been drastically reduced but the precision of the measurements has been improved 27 percent (from $4.4\text{ }\mu\text{in}$ to $3.21\text{ }\mu\text{in}$).

The finished system has proven to be extremely reliable requiring little maintenance and the software is designed so that a minimum of training is required to qualify the operator.

The long term data storage capability represents a savings in time and can provide a summary of all units within a given time frame. The necessity for maintaining hard copies of data runs has been virtually eliminated.

FILENAME	SERIAL NUMBER	RUN NUMBER	PART RUN NUMBER	RUN DATE	RUN TIME	MINIMUM THICKNESS	MAXIMUM THICKNESS	AVERAGE THICKNESS	STANDARD DEVIATION
78A297.BBD	X-1	298	1	06/19/78	13:04	12.9922	13.4705	13.2353	0.1469
78A004.BBD	TEST	5	1	03/02/78	14:06	10.0252	10.4048	10.2344	0.0894
78A005.BBD	TEST	6	1	03/02/78	14:16	10.1279	10.3557	10.2317	0.0655
78A006.BBD	TEST	7	1	03/02/78	14:29	8.2345	10.4550	9.1956	0.6723
78A007.BBD	TEST	8	1	03/03/78	08:29	10.2688	10.5386	10.3879	0.0806
78A008.BBD	TEST	9	1	03/03/78	08:48	10.0541	10.5059	10.2922	0.0947
78A009.BBD	TEST	10	1	03/03/78	12:38	10.1785	10.4920	10.3204	0.0807
78A010.BBD	TEST	11	1	03/03/78	13:41	17.6393	18.2242	17.8866	0.1646
78A011.BBD	TEST	11	1	03/03/78	13:41	17.6393	18.2242	17.8866	0.1646
78A012.BBD	TEST	13	1	03/06/78	12:04	10.1893	10.3885	10.2984	0.0607
78A013.BBD	TEST	14	1	03/06/78	12:30	10.1964	10.4781	10.3297	0.0660
78A014.BBD	TEST	15	1	03/06/78	12:40	9.6330	9.2143	9.1178	0.0566
78A015.BBD	TEST	16	1	03/06/78	12:54	9.0527	9.2288	9.1399	0.0511
78A016.BBD	TEST	17	1	03/07/78	13:17	10.4489	10.7283	10.5711	0.0825
78A017.BBD	TEST	18	1	03/07/78	13:58	10.1487	10.3922	10.2819	0.0702
78A019.BBD	TEST	20	1	03/08/78	08:13	10.2482	10.4703	10.3803	0.0667
78A034.BBD	TEST	35	1	03/08/78	18:59	10.2900	10.5405	10.4000	0.0646
78A050.BBD	TE--	51	1	03/14/78	13:04	9.9249	10.1377	10.0463	0.0539
78A105.BBD	D-393	106	1	03/28/78	09:05	9.2916	9.6885	9.5277	0.0990
78A018.BBD	D-443	19	1	03/07/78	14:36	9.2022	9.8017	9.5708	0.1458
78A020.BBD	D-443	21	1	03/08/78	08:54	9.8131	10.1474	9.9673	0.0746
78A021.BBD	D-443	22	1	03/08/78	09:10	9.7543	10.0944	9.9275	0.0890
78A150.BBD	D-453	151	1	05/11/78	08:08	9.3074	9.7720	9.4478	0.1079
78A156.BBD	D-453	157	1	05/11/78	10:49	9.4038	9.9798	9.5723	0.1202
78A152.BBD	D-454	153	1	05/11/78	08:50	9.4372	9.8048	9.6421	0.0957
78A151.BBD	D-455	152	1	05/11/78	08:31	9.3841	9.7543	9.5648	0.1150
78A145.BBD	D-458	146	1	05/10/78	13:03	9.6737	9.9626	9.8105	0.0808
78A177.BBD	D-458	178	1	05/16/78	10:54	9.7677	10.1557	9.9594	0.0925
78A180.BBD	D-458	181	1	05/17/78	07:49	9.8257	10.0669	9.9456	0.0701
78A187.BBD	D-458	188	1	05/18/78	09:13	9.7846	10.1012	9.9436	0.0797
78A189.BBD	D-458	190	1	05/18/78	12:08	9.9367	10.1867	10.0701	0.0690
78A190.BBD	D-458	191	1	05/18/78	13:07	9.8281	10.1056	9.9595	0.0664
78A191.BBD	D-458	192	1	05/19/78	07:53	9.7284	10.0032	9.8514	0.0726
78A192.BBD	D-458	193	1	05/19/78	08:20	8.6046	10.0069	9.8490	0.1784
78A136.BBD	D-459	137	1	05/05/78	07:50	9.5579	9.9122	9.6972	0.0878
78A135.BBD	D-460	136	1	05/05/78	07:29	9.8508	10.0538	9.9738	0.0600
78A157.BBD	D-461	158	1	05/11/78	11:13	9.8327	10.1227	9.9594	0.0851
78A159.BBD	D-462	160	1	05/11/78	13:06	9.9451	10.3793	10.1334	0.1088
78A132.BBD	D-463	133	1	05/04/78	09:50	9.7043	10.0774	9.8929	0.0859
78A133.BBD	D-463	134	1	05/04/78	10:44	9.8387	10.1090	9.9534	0.0708
78A134.BBD	D-463	135	1	05/04/78	11:08	9.7749	10.0629	9.8994	0.0702
78A158.BBD	D-464	159	1	05/11/78	11:33	9.8665	10.1445	10.0155	0.0705
78A137.BBD	D-465	138	1	05/05/78	08:13	9.4808	9.9535	9.6918	0.1146
78A138.BBD	D-465	139	1	05/05/78	09:03	9.6680	9.9176	9.7814	0.0652
78A140.BBD	D-466	141	1	05/05/78	09:00	9.6701	9.9608	9.7124	0.0919
78A148.BBD	D-466	149	1	05/10/78	14:20	9.6986	9.9621	9.7408	0.1049
78A141.BBD	D-467	142	1	05/05/78	09:40	9.7161	9.9400	9.8302	0.0546
78A142.BBD	D-468	143	1	05/09/78	07:00	9.5296	9.9103	9.6970	0.1003
78A143.BBD	D-468	144	1	05/09/78	08:19	8.8059	9.8558	9.4424	0.3866
78A147.BBD	D-468	148	1	05/10/78	13:44	9.6153	10.0392	9.7851	0.1064
78A144.BBD	D-469	145	1	05/09/78	10:05	8.8151	9.8652	9.3927	0.3753
78A146.BBD	D-469	147	1	05/10/78	13:25	9.6175	10.0083	9.7887	0.1013
78A175.BBD	D-470	176	1	05/16/78	10:16	9.1520	9.4354	9.2795	0.0782
78A176.BBD	D-471	177	1	05/16/78	10:36	9.1641	9.4873	9.3227	0.0731
78A179.BBD	D-472	180	1	05/16/78	13:33	9.4957	9.8450	9.6720	0.0883
78A178.BBD	D-473	179	1	05/16/78	13:11	9.5748	9.8426	9.7056	0.0829

Figure 5. Summary of Data Files in Directory

FUTURE WORK

This is the final report to be issued under this project. Future development is currently under way to develop an eddy current system to measure insulator uniformity, and to make independent measurements of the individual layers in the laminar composite.

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Appendix A

SEMI-AUTOMATIC BETA-BACKSCATTER
OPERATING PROCEDURE

Appendix A

SEMI-AUTOMATIC BETA-BACKSCATTER OPERATING PROCEDURE

This procedure describes the steps necessary for operating the semi-automatic beta backscatter system. This procedure is intended to be self-contained and no previous experience with the minicomputer is required in order to comprehend and perform the operations described.

The system includes five pieces of equipment:

- Positioning fixture and probe (Figure A-1).
- Probe control and nuclear counting console (Figure A-2).
- Minicomputer (Figure A-1).
- Line printer (Figure A-1).
- Keyboard (Figure A-1).

BASIC SYSTEM PREPARATION

1. Instrument settings for the nuclear counting console.
 - a. Time/counts switch in "counts" position.
 - b. Cycle/recycle in "cycle" position.
 - c. Pos/neg in "neg" position.
 - d. Set threshold to 1.0.
 - e. Set preset to 13.
2. Instrument settings for discriminator.
 - a. Set threshold to 7.70.
 - b. Set dead time to minimum.
3. Instrument settings for spectroscopy amplifier.
 - a. Course gain to 1K.
 - b. Fine gain to 0.0.

Figure A-1. Pictorial View of the Dual Axis Fixture for the Semi-Automatic Beta-Backscatter System

- c. Shaping to 0.25 seconds.
- d. Restorer to off.
- e. Threshold to 100 mv.
- f. Polarity input to neg.
- g. Unipolarity output to neg.

Figure A-2. Control Console Showing Nuclear Package, Power Supply, and Motor Controls

4. Instrument settings for regulated high voltage power supply.

- a. Standby switch up.
- b. HV switch up.
- c. Set high voltage to 800 V.
- d. NIM BIN - Turn on power switch.

NOTE: High voltage is to be on probe for a minimum of 24 hours before measuring a part.

5. System start up.

- a. Minicomputer key switch on.
- b. Disk unit.
- c. Place switch in load position.
- d. Wait for load light.
- e. Open door.
- f. Load disk pack.
- g. Close door and place in run position.

Disk pack designated beta-backscatter 1 goes in "0" position; disk pack designated beta-backscatter 2 goes in "1" position.

- h. Insert cassette for unit under test in decassette 0 drive unit.
- i. Printer - power switch down.
Remote switch down.
- j. Teletypewriter - power switch on.
-Local/line on line.
-Baud rate set to 300.

- k. Magnetic Tape - power switch on.
- l. Driver/Translator - power switch on.
- m. Probe Controller - power switch on.
 - Probe switch - activate.
 - Speed - fast.
- n. Air Supply - Turn on air supply.

6. Computer Program Implementation and Operation.

The software has been designed to be basically self-explanatory. At the end of each operation the operator is asked to verify that the input is correct or to decide which operation should be conducted next. These responses will take the form of either a

YES (type a Y followed by a carriage return).

NO (type a N followed by a carriage return).

7. Bootstrapping computer.

- a. Place ENABLE/HALT key to HALT.
- b. Load initial address into computer (See Figure A-3a).
- c. After the switches have been placed in their proper position, depress the LOAD ADDRESS KEY.
- d. Enter the second address as shown in Figure A-3b, place the ENABLE/HALT key to ENABLE and depress START.

At this point, the teletypewriter should respond with Volume I.D. listing.

8. Program initiation.

- a. The date and time must first be entered.
- b. The operator types DAT space and the date:
(First 3 letters of the month).
Example: DAT 16-JAN-78

- c. The operator types TIM space then the time of day (24 hour clock).
Example: TIM 10:45
 - d. To initiate the basic program, the operator types R space BETA then a carriage return;
Example: R BETA (carriage return).
 - e. In response to this command the printout shown in Figure 4 should be obtained.
 - f. The MENU program gives a listing of the fixture set up procedure and various part programs available as well as calibration procedures (Figure A-4a).
 - g. Set up fixture by typing SETUP, carriage return, and follow instructions. (Figure A-4b)
9. Instrument settings to initiate the CAL program.
- a. The operator types CAL carriage return (Figure A-4c).
 - b. While the probe is centered over the first standard, the probe should be moved in until it touches the standard with approximately 1/8" of preloading.
 - c. The CAL program runs on all the standards then rechecks the standards. After these operations have been completed, the operator is asked whether they should be written to file or not. If the test has been performed to the operator's satisfaction, he answers YES, a NO response ends the calibration test.
 - d. The operator is then asked if the calibration test is completed. A NO response restarts the calibration. A YES response should be given if calibration has been successfully written to file.
 - e. At this point, the operator selects from MENU the program required for the part being measured.
 - f. When one of these programs is run, the tables zero themselves then the probe moves out of position to enable loading the unit under test. LOAD THE UNIT UNDER TEST AT THIS POINT.
 - g. From this point on the program is self-explanatory.

R BETA

J300.5 - 2/3/78 - BETA BACKSCATTER

a. MENU

DATE:05/26/78 TIME:13:40:53

MENU.DAT - PROGRAM LISTING - HEP 4/78
DO YOU WANT THE MENU PRINTED?Y

SETUP = SETUP THE VACUUM DISH AND STANDARD FIXTURES

CAL = CALIBRATION FILE

DRUN = RUN 30 POINT TEST 1350-D PARTS

WRUN = RUN 30 POINT TEST 1370-D PARTS

KRUN = RUN 30 POINTS ON 'K' PARTS

RRUN = RUN 30 POINTS ON 'R' PARTS

DRUN60 = RUN 60 POINT TEST ON 1350-D PARTS

WRUN60 = RUN 60 POINT TEST ON 1370-D PARTS

KRUN60 = RUN 60 POINT TEST ON 'K' PARTS

RRUN60 = RUN 60 POINT TEST ON 'R' PARTS

RCLOS = RUN CLOSURE TEST ON STANDARDS

*** END-OF-TEST ***

TYPE 'MENU' OR A NAME FROM MENU:*

Figure A-4. Listing of Various Computer Programs
Available for Thickness Measurement

• B BETA

J300.5 - 2/3/78 - BETA BACKSCATTER

b. SETUP

DATE:05/26/78 TIME:13:42:55

MENU.DAT - PROGRAM LISTING - HEP 4/78

DO YOU WANT THE MENU PRINTED?N

*** END-OF-TEST ***

TYPE "MENU" OR A NAME FROM MENU:*SETUP

SET UP THE FIXTURE FOR TESTING PARTS HEP 5/78

*****CAUTION*****

MAKE SURE THAT THE SOURCE IS COVERED WITH THE
MANUAL BEAM STOP BEFORE DOING ANY WORK ON THE
FIXTURE

*****NOTE*****

ADJUST PROBE ALL THE WAY BACK BEFORE CHANGING FIXTURES.

DO YOU WANT TO INSTALL A DIFFERENT FIXTURE?Y

VACUUM DISH INSTALLATION.

Figure A-4 Continued. Listing of Various Computer Programs
Available for Thickness Measurement

REMOVE EXISTING VACUUM DISH IF ANY AND
INSTALL PROPER DISH

WHEN COMPLETED TYPE YES:Y

DO YOU WISH TO INSTALL A DIFFERENT
STANDARD HOLDER?

INSTALL PROPER STANDARD HOLDER

*****NOTE*****

PART NUMBER MARKED ON HOLDER

WHEN COMPLETED TYPE YES:Y

PRELIMINARY SETUP IS NOW COMPLETE

*** END-OF-TEST ***

WILL MORE UNITS BE RUN WITH SAME TEST?N

J300.5 - 2/3/78 - BETA BACKSCATTER

DATE:05/26/78 TIME:13:44:30

Figure A-4 Continued. Listing of Various Computer Programs
Available for Thickness Measurement

R BETA

J300.5 - 2/3/78 - BETA BACKSCATTER

c. CAL

DATE:05/26/78 TIME:13:46:14

MENU.DAT - PROGRAM LISTING - HEP 4/78

DO YOU WANT THE MENU PRINTED?N

*** END-OF-TEST ***

TYPE "MENU" OR A NAME FROM MENU:*CAL

CAL.DAT - CONTROL FILE FOR CALIBRATION

WALDRY 2/3/78

STANDARDS CALIBRATION DATE: 05/26/78 TIME: 13:46:28

STDS.DAT - 1/78 - LOCATIONS FOR STANDARDS - UNCLASSIFIED

ADJUST PROBE TO CORRECT DISTANCE FOR MEASUREMENT.

READY FOR MEASUREMENT?Y

STANDARD NUMBER	TIMES	THICKNESS (UM)	COUNTS	
1	3	8.1000	402562.	30.0
2	3	8.2300	403858.	30.0
3	3	9.5800	415217.	30.0
4	3	10.1600	421385.	30.0
5	3	10.9200	427681.	30.0

MODEL: THICKNESS = (COUNTS - A)/B

WITH A = 330264.53 & B = 8924.868 BASED ON 5 STANDARDS.

FIT = R² = 0.9988

Figure A-4 Continued. Listing of Various Computer Programs
Available for Thickness Measurement

CALIBRATION CLOSURE MEASUREMENTS

STANDARD NUMBER	THICKNESS (UM)	COUNTS	COMPUTED THICKNESS	ERROR
1	8.1000	403204.	8.1726	-0.072610
2	8.2300	404783.	8.3495	-0.119532
2	8.2300	404059.	8.2684	-0.038410
3	9.5800	416020.	9.6086	-0.028598
4	10.1600	420599.	10.1217	0.038342
5	10.9200	427426.	10.8866	0.033401

SHALL STANDARDS DATA BE WRITTEN TO FILE? Y

IS THE CALIBRATION TEST COMPLETED? Y

*** END-OF-TEST ***

WILL MORE UNITS BE RUN WITH SAME TEST? N

J300.5 - 2/3/78 - BETA BACKSCATTER

DATE:05/26/78 TIME:13:52:39

TYPE "MENU" OR A NAME FROM MENU:*

Figure A-4 Continued. Listing of Various Computer Programs
Available for Thickness Measurement

At the end of testing, the question "Is testing complete on this unit?" is printed. A NO response will put the program in "keyboard" mode.

At this time, one can exit the program by typing QUIT and two carriage returns.

A YES response will lead to the question "Will more units be run with same test?" A YES response will start a test for another unit of the same type. A NO response will cause the program to ask for another name from the MENU.

Whenever the low paper level light or any servicing of the printer is required, the following procedure should be followed:

1. Hit C, while CTRL key is depressed, twice.
2. Switch disks to off.
3. Turn off power switch.
4. Clean heads and rollers with alcohol as well as the sensor in upper cover.
5. Remove old paper, if any, and load new paper.

The black square on the paper should face up and be on the left side.

6. Position paper straight on rollers and close cover.
7. Turn on power, put the remote switch up.
8. Hit paper feed two or three times to ensure that it feeds properly.
9. Put remote switch down.
10. Turn on disks and reboot the system.

To print matrix at any time:

1. First type: R BETA
2. When it asks for MENU type KEYBD.
3. It will return with an arrow.

4. Type MATRIX

-on D's type 9, 11

-on R's type 10, 12

Repeat this as many times as you want matrix printed.

5. Type ASSIGN, space 6, carriage return, carriage return.

6. It will ask for file name. The file name must be the same as unit required, i.e. RK1:78A116.BBD

Type carriage return.

7. Then after printing, type QUIT, carriage return, carriage return.

Appendix B
BETA-BACKSCATTER CAPABILITY STUDY NO. 5

Appendix B

BETA-BACKSCATTER CAPABILITY STUDY NO. 5

A number of studies were conducted to establish the capability of the beta-backscatter equipment. Recent modifications of the equipment have made the current study necessary in order to evaluate the capability of the modified equipment.

The modified equipment has a higher flux source, approximately 200 millicuries, as compared with 0.05 millicuries for the old equipment. The old equipment utilized a Geiger tube detector which was operating at maximum flux with a dead time of 300,000 counts per (μ s). The modified equipment has a much smaller dead time of 300,000 counts per (ns). The modified equipment has an automatic fixture and is computer controlled which reduces the operator's influence.

The beta-backscatter equipment was used to measure two parts at thirty positions with five calibration occasions. Each measurement was repeated five times. This test design provided 1500 data points for analysis.

The analysis provided estimates of the total measurement error, the corresponding calibration, and repeat measurement error components at each part position. These estimates are shown in Table B-1 reported in μ m.

The total measurement error differed significantly among the part positions. The average total measurement error (one standard deviation) over all positions was estimated to be 3.82 μ in. (0.09712 μ m). The estimated average calibration error (one standard deviation) was 2.39 μ in. (0.06081 μ m) and the repeat measurement error was 2.98 μ in. (0.07572 μ m). These estimated averages were used in Table B-2 to reflect a comparison of these estimates with similar estimates from previous studies. The comparison of these estimates with previous estimates did not indicate a significant reduction in the total measurement error. The total measurement error remained approximately the same.

Table B-3 provides a summary of the data for each test condition, i.e., the mean and standard deviation for each combination of positions, calibrations and parts. Figures B-1 and B-2 provide a visual comparison of the average measurements for positions on different calibration occasions. Figures B-3 and B-4 are similar comparisons for the standard deviations.

Table B-1. Estimates of Measurement Error Components

Position Number	Measurement Error Components				
	Calibration		Repeats		Total
	Δ σ (μm)	% of Total Error	Δ σ (μm)	% of Total Error	Δ σ (μm)
1	0.05475	32.9	0.07824	67.1	0.09549
2	0.05773	41.6	0.06841	58.4	0.08952
3	0.04608	18.7	0.09598	81.3	0.10647
4	0.06228	45.6	0.06807	54.4	0.09226
5	0.05255	29.6	0.08100	70.4	0.09656
6	0.05851	44.8	0.06502	55.2	0.08747
7	0.01238	5.8	0.08594	94.2	0.08560
8	0.05054	22.0	0.09520	78.0	0.10779
9	0.03906	13.8	0.09782	86.2	0.10533
10	0.04981	30.6	0.07506	69.4	0.09011
11	0.05444	40.3	0.06628	59.7	0.08578
12	0.07834	52.6	0.07438	47.4	0.10802
13	0.04751	28.1	0.07607	71.9	0.08969
14	0.05164	30.5	0.07795	69.5	0.09350
15	0.04386	23.8	0.07856	76.2	0.08997
16	0.04512	34.2	0.06259	65.8	0.07716
17	0.05580	30.7	0.06877	69.3	0.08856
18	0.05943	44.6	0.06628	55.4	0.08902
19	0.06631	41.5	0.07871	58.5	0.10292
20	0.05947	49.3	0.06028	50.7	0.08468
21	0.16176	83.5	0.07203	16.5	0.17707
22	0.04345	35.2	0.05897	64.8	0.07324
23	0.03658	15.3	0.08617	84.7	0.09361
24	0.06746	44.6	0.07523	55.4	0.10105
25	0.05174	34.7	0.07094	65.3	0.08780
26	0.08164	51.2	0.07969	48.8	0.11408
27	0.05039	30.9	0.07531	69.1	0.09061
28	0.06022	56.3	0.05302	43.7	0.08024
29	0.03477	13.3	0.08867	86.7	0.09524
30	0.04993	35.1	0.06793	64.9	0.08430
Average	0.06081	39.2	0.07572	60.8	0.09712

Table B-2. Comparison of Measurement Error and Standard Deviations

Source of Variation	Dec. 1975 Log Model 1 (μ in.)	March 1976 Log Model 1A (μ in.)	Dec. 1976 Log Model 1 (μ in.)	Current Study (μ in.)
Repeats	2.4	2.7	2.9	2.98
Setups	.6	.0		
Operators	.9			
Calibrations	3.5	3.6		2.39
Total	4.4	4.5	4.5	3.82

Table B-3. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
1	1	891	10.71480	0.06433
		890	10.67284	0.01390
	2	891	10.73456	0.14807
		890	10.53842	0.04335
	3	891	10.74896	0.07200
		890	10.61216	0.05301
	4	891	10.84638	0.07620
		890	10.68928	0.04712
	5	891	10.72624	0.06423
		890	10.52518	0.04829
2	1	891	10.86942	0.05925
		890	10.81512	0.07273
	2	891	10.85198	0.07247
		890	10.67208	0.07276
	3	891	10.83532	0.02620
		890	10.86350	0.04017
	4	891	10.96604	0.08463
		890	10.86350	0.07949
	5	891	10.87046	0.05761
		890	10.71316	0.07101
3	1	891	11.16148	0.12835
		890	11.09868	0.06757
	2	891	11.12514	0.17074
		890	11.00720	0.09292
	3	891	11.22066	0.5585
		890	11.03280	0.12473
	4	891	11.23024	0.04621
		890	11.15468	0.03771
	5	891	11.13380	0.09262
		890	11.00172	0.04992

Table B-3 Continued. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
4	1	891	11.15220	0.08850
		890	11.17154	0.04079
	2	891	11.11908	0.06100
		890	10.95770	0.09067
	3	891	11.16432	0.06154
		890	11.03912	0.03487
	4	891	11.20598	0.07214
		890	11.09680	0.06466
	5	891	11.14492	0.01511
		890	10.95534	0.10140
5	1	891	10.99880	0.05774
		890	10.95094	0.03497
	2	891	10.94294	0.14855
		890	10.77502	0.12462
	3	891	10.97734	0.04536
		890	10.82710	0.04739
	4	891	11.05382	0.06279
		890	10.92960	0.10335
	5	891	10.92754	0.05279
		890	10.84304	0.04180
6	1	891	10.81152	0.08696
		890	10.82260	0.07159
	2	891	10.84690	0.12090
		890	10.6445	0.05875
	3	891	10.85240	0.04128
		890	10.69360	0.03022
	4	891	10.92240	0.05407
		890	10.83378	0.02216
	5	891	10.84604	0.04877
		890	10.71364	0.05572

Table B-3 Continued. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
7	1	891	11.06378	0.09382
		890	10.99342	0.05318
	2	891	11.06022	0.15533
		890	10.90252	0.09678
	3	891	11.12510	0.04468
		890	10.91512	0.08428
	4	891	11.11710	0.05772
		890	11.02522	0.10502
	5	891	11.07292	0.05364
		890	10.92410	0.04897
8	1	891	11.35784	0.07100
		890	11.19386	0.10906
	2	891	11.24498	0.21601
		890	11.05982	0.03096
	3	891	11.28962	0.03353
		890	11.21464	0.09726
	4	891	11.36540	0.01793
		890	11.21468	0.09112
	5	891	11.30624	0.03997
		890	11.11630	0.07266
9	1	891	11.19758	0.10572
		890	11.18232	0.10753
	2	891	11.20666	0.18765
		890	11.04124	0.11320
	3	891	11.23842	0.04770
		890	11.07948	0.09108
	4	891	11.26780	0.04660
		890	11.23084	0.09746
	5	891	11.22404	0.04665
		890	11.09558	0.02246

Table B-3 Continued. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
10	1	891	11.02252	0.08094
		890	11.00020	0.05483
	2	891	11.03668	0.11850
		890	10.85556	0.07301
	3	891	11.08442	0.04265
		890	10.91738	0.3484
	4	891	11.14324	0.11964
		890	11.03476	0.05318
	5	891	11.05522	0.05434
		890	10.95466	0.06089
11	1	891	11.00094	0.07088
		890	10.95916	0.5244
	2	891	11.02286	0.11625
		890	10.75726	0.06575
	3	891	11.04574	0.07467
		890	10.86250	0.03684
	4	891	11.08078	0.03467
		890	10.95276	0.01581
	5	891	11.01726	0.03202
		890	10.87770	0.09441
12	1	891	11.16592	0.09490
		890	11.22794	0.06702
	2	891	11.23996	0.15726
		890	10.98658	0.06805
	3	891	11.24384	0.06007
		890	11.09440	0.03996
	4	891	11.33626	0.0471
		890	11.14796	0.02863
	5	891	11.18570	0.06500
		890	11.10458	0.04278

Table B-3 Continued. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
13	1	891	11.16492	0.07361
		890	11.08212	0.08896
	2	891	11.25940	0.14369
		890	11.06944	0.05209
	3	891	11.24096	0.04034
		890	11.09672	0.07999
	4	891	11.30560	0.03645
		890	11.22776	0.08008
	5	891	11.25272	0.05192
		890	11.13236	0.05211
14	1	891	11.11906	0.08242
		890	11.07196	0.05445
	2	891	11.12548	0.18375
		890	10.93046	0.04723
	3	891	11.12610	0.03828
		890	11.0184	0.046821
	4	891	11.21154	0.05920
		890	11.12872	0.06679
	5	891	11.09686	0.04940
		890	11.08742	0.03072
15	1	891	10.95800	0.08757
		890	10.94706	0.06864
	2	891	10.98352	0.06985
		890	10.80364	0.10292
	3	891	10.99480	0.05843
		890	10.86188	0.06157
	4	891	11.08202	0.12653
		890	10.95604	0.03464
	5	891	10.97530	0.05376
		890	10.90290	0.08099

Table B-3 Continued. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
16	1	891	10.97198	0.05067
		890	10.89400	0.06843
	2	891	10.99280	0.09297
		890	10.77814	0.07594
	3	891	11.03164	0.03731
		890	10.90978	0.05306
	4	891	11.06786	0.03188
		890	10.92892	0.03104
	5	891	10.95178	0.05806
		890	10.88024	0.08919
17	1	891	11.09288	0.04279
		890	11.01098	0.05962
	2	891	11.29162	0.13246
		890	10.97289	0.08194
	3	891	11.16270	0.01485
		890	10.98178	0.03096
	4	891	11.28766	0.03446
		890	11.02682	0.06153
	5	891	11.10268	0.05467
		890	10.95688	0.05584
18	1	891	11.28664	0.04631
		890	11.20716	0.04184
	2	891	11.33092	0.13080
		890	11.09596	0.05251
	3	891	11.37410	0.03491
		890	11.18052	0.05262
	4	891	11.46168	0.04513
		890	11.25398	0.07808
	5	891	11.33476	0.05416
		890	11.10766	0.07148

Table B-3 Continued. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
19	1	891	11.14470	0.08738
		890	11.03496	0.09480
	2	891	11.14284	0.11535
		890	10.98814	0.09241
	3	891	11.13178	0.07946
		890	11.03758	0.04991
	4	891	11.28932	0.07799
		890	11.17846	0.04906
	5	891	11.11060	0.02516
		890	11.05924	0.07456
20	1	891	11.02472	0.05356
		890	10.96734	0.05980
	2	891	11.09460	0.10441
		890	10.87632	0.06688
	3	891	11.06010	0.02200
		890	11.01004	0.02685
	4	891	11.17592	0.06739
		890	11.06294	0.07169
	5	891	11.03698	0.02923
		890	10.94994	0.05276
21	1	891	10.97470	0.06335
		890	10.38400	0.04568
	2	891	11.04112	0.11957
		890	10.80160	0.09511
	3	891	10.93246	0.06332
		890	10.88992	0.06602
	4	891	10.99152	0.03532
		890	10.97142	0.06403
	5	891	10.95426	0.06017
		890	10.83358	0.07169

Table B-3 Continued. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
22	1	891	10.97914	0.05589
		890	10.83280	0.05350
	2	891	11.01450	0.04878
		890	10.77204	0.11646
	3	891	11.09358	0.01564
		890	10.79094	0.09906
	4	891	11.09768	0.05692
		890	10.90274	0.01713
	5	891	11.03510	0.07387
		890	10.81350	0.03448
23	1	891	11.16158	0.06592
		890	11.02112	0.05476
	2	891	11.16172	0.16221
		890	10.87534	0.10720
	3	891	11.15266	0.08689
		890	11.02570	0.06572
	4	891	11.22148	0.06431
		890	11.05342	0.04329
	5	891	11.19032	0.07470
		890	10.99032	0.07768
24	1	891	11.00080	0.07523
		890	10.87058	0.06684
	2	891	11.04146	0.10017
		890	10.78566	0.05962
	3	891	10.87814	0.07441
		890	10.7975	0.08478
	4	891	10.94644	0.05995
		890	10.95588	0.07068
	5	891	10.86422	0.04739
		890	10.85448	0.09655

Figure B-1. Comparison of Average Readings (μm) and Part Position for Beta-Backscatter Part Number 891

Figure B-2. Comparison of Average Readings (μm) and Part Position for Beta-Backscatter Part Number 890

Figure B-3. Comparison of Standard Deviation (μm) and Part Position for Beta-Backscatter Part Number 891

Figure B-4. Comparison of Standard Deviation (μm) and Part Position for Beta-Backscatter Part Number 890

Appendix C
BETA-BACKSCATTER CAPABILITY STUDY NO. 6

Appendix C

BETA-BACKSCATTER CAPABILITY STUDY NO. 6

Additional modifications were made to the beta-backscatter equipment since the results determined from capability study No. 5. A study to evaluate the equipment's measuring capability after the modifications was conducted in the same manner as described in Capability Study Number 5.

The estimated total measurement error (one standard deviation) for the equipment was 3.21 μ in. (.0816 μ m). This value indicates a significant improvement over the previous value of 3.82 μ in. The estimated calibration component (one standard deviation) was 1.36 μ in. (.0344 μ m) which is also significantly smaller than the previous estimate of 2.39 μ in. The repeat measurement error of 2.91 μ in. (.0739 μ m) did not improve significantly the previous estimate of 2.98 μ in.

The estimated total measurement error and corresponding calibration and repeatability components at each part position are shown in table C-1. These results are reported in μ m. These estimates are also plotted in Figure C-1 in μ in. There were no significant differences between the total measurement error among the modification. The inability of the equipment to repeat a measurement is the largest source of error.

Table C-2 provides a summary of the data for each test condition, i.e., the mean and standard deviation for each combination part position, and calibration and part. Figures C-2 and C-3 provide a visual comparison of the average measurements for positions for each calibration occasion.

Figures C-4 and C-5 provide a visual comparison of the standard deviation estimates for part positions.

Table C-1. Estimates of Measurement Error Components

Position Number	Measurement Error Components				
	Calibration		Repeats		Total
	Δ α (μm)	% of Total Error	Δ α (μm)	% of Total Error	Δ α (μm)
1	0.03169	14.35	0.07742	85.65	0.08365
2	0.02118	9.28	0.06624	90.72	0.06954
3	0.03421	24.29	0.06040	75.71	0.06941
4	0.06156	43.13	0.07070	56.87	0.09375
5	0.03187	18.63	0.06660	81.37	0.07383
6	0.02451	11.68	0.06740	88.32	0.07172
7	0.00306	0.23	0.06404	99.77	0.06411
8	0.03503	15.85	0.08073	84.15	0.08801
9	0.02171	7.82	0.07456	92.18	0.07766
10	0.04539	20.16	0.09031	79.84	0.10108
11	0.02976	16.24	0.06757	83.76	0.07383
12	0.04099	21.73	0.07779	78.27	0.08793
13	0.04027	23.26	0.07315	76.74	0.08350
14	0.04198	20.21	0.08342	79.79	0.09338
15	0.03629	17.84	0.07788	82.16	0.08592
16	0.04016	26.76	0.06644	73.24	0.07763
17	0.01838	6.51	0.06966	93.49	0.07205
18	0.02527	11.55	0.06995	88.45	0.07437
19	0.02723	12.01	0.07370	87.99	0.07857
20	0.02691	8.47	0.08848	91.53	0.09248
21	0.02582	13.67	0.06490	86.33	0.06985
22	0.04884	34.99	0.06657	65.01	0.08257
23	0.03022	12.75	0.07906	87.25	0.08463
24	0.04123	26.38	0.06888	73.62	0.08027
25	0.03873	18.77	0.08056	81.23	0.08938
26	0.02801	11.58	0.07740	88.42	0.08232
27	0.01994	5.75	0.08072	94.25	0.08315
28	0.01623	4.70	0.07309	95.30	0.07487
29	0.01496	3.36	0.08024	96.64	0.08162
30	0.03514	21.54	0.06705	78.46	0.07570
Average	0.03442	17.96	0.07386	82.04	0.08155

Figure C-1. Estimates of Measurement Error (Total Error and Components)

Table C-2. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
1	1	891	11.0310	0.0857
		890	10.8729	0.0656
	2	891	11.0749	0.0729
		890	10.8915	0.0651
	3	891	11.0024	0.0706
		890	10.8410	0.0612
	4	891	11.0213	0.0413
		890	10.9839	0.0943
	5	891	10.9905	0.1056
		890	10.8462	0.0907
2	1	891	10.9502	0.0375
		890	10.8398	0.0556
	2	891	11.0414	0.0706
		890	10.8832	0.0619
	3	891	10.9849	0.1020
		890	10.8181	0.0811
	4	891	10.9864	0.0594
		890	10.9085	0.0308
	5	891	11.0103	0.0268
		890	10.8269	0.0917
3	1	891	10.9697	0.0644
		890	10.8560	0.0373
	2	891	11.0915	0.0271
		890	10.8763	0.0460
	3	891	10.9718	0.0867
		890	10.8317	0.0587
	4	891	10.9743	0.1052
		890	10.9214	0.0178
	5	891	10.9927	0.0612
		890	10.8794	0.0448

Table C-2 Continued. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
4	1	891	11.0532	0.0728
		890	10.8851	0.0759
	2	891	11.1002	0.0498
		890	10.8903	0.0516
	3	891	11.0259	0.1302
		890	10.8187	0.0514
	4	891	10.9688	0.0527
		890	10.9945	0.0267
	5	891	11.0283	0.0870
		890	10.9179	0.0558
5	1	891	11.0664	0.0767
		890	10.8840	0.0187
	2	891	11.1201	0.0244
		890	10.9226	0.0846
	3	891	11.0298	0.1101
		890	10.8781	0.0633
	4	891	11.0405	0.0726
		890	10.9980	0.0406
	5	891	11.0686	0.0424
		890	10.8995	0.0744
6	1	891	10.9304	0.0494
		890	10.7680	0.0658
	2	891	10.9687	0.1008
		890	10.8170	0.0268
	3	891	10.8988	0.0804
		890	10.7522	0.0378
	4	891	10.8550	0.0912
		890	10.8216	0.0538
	5	891	10.9471	0.0757
		890	10.7861	0.0542

Table C-2 Continued. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
7	1	891	10.8958	0.0508
		890	10.8011	0.0618
	2	891	10.9339	0.0513
		890	10.8046	0.0506
	3	891	10.9165	0.0925
		890	10.7311	0.0489
	4	891	10.9137	0.0612
		890	10.7830	0.0663
	5	891	10.9076	0.0754
		890	10.7704	0.0681
8	1	891	10.9295	0.1082
		890	10.7941	0.0520
	2	891	10.9424	0.0576
		890	10.8547	0.0453
	3	891	10.8778	0.1326
		890	10.7307	0.1051
	4	891	10.9306	0.0839
		890	10.8392	0.0594
	5	891	10.7405	0.0746
		890	10.8299	0.0249
9	1	891	10.9109	0.0767
		890	10.8365	0.0317
	2	891	10.9427	0.0896
		890	10.8222	0.0561
	3	891	10.8849	0.0826
		890	10.7677	0.1133
	4	891	10.8434	0.0630
		890	10.8011	0.0776
	5	891	10.9167	0.0452
		890	10.8061	0.0763

Table C-2 Continued. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
10	1	891	10.9478	0.1338
		890	10.8611	0.0430
	2	891	10.9933	0.0747
		890	10.8729	0.0504
	3	891	10.8871	0.1494
		890	10.7740	0.0919
	4	891	10.8377	0.0326
		890	10.7991	0.0914
	5	891	10.9226	0.0440
		890	10.8045	0.0770
11	1	891	10.9127	0.0912
		890	10.7853	0.0389
	2	891	10.9679	0.0523
		890	10.8128	0.0375
	3	891	10.8971	0.0684
		890	10.6932	0.0719
	4	891	10.9046	0.0654
		890	10.8239	0.0694
	5	891	10.8999	0.0735
		890	10.7569	0.0853
12	1	891	10.9711	0.0992
		890	10.7418	0.0576
	2	891	10.0127	0.1051
		890	10.8042	0.0690
	3	891	10.8841	0.0960
		890	10.6964	0.0759
	4	891	10.8149	0.0793
		890	10.8304	0.0647
	5	891	10.9401	0.0639
		890	10.7388	0.0448

Table C-2 Continued. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
13	1	891	10.8817	0.0753
		890	10.7754	0.0616
	2	891	10.9792	0.0561
		890	10.8449	0.0644
	3	891	10.9339	0.1394
		890	10.7031	0.0542
	4	891	10.9018	0.0360
		890	10.8604	0.0493
	5	891	10.9445	0.0833
		890	10.7809	0.0609
14	1	891	11.0025	0.0821
		890	10.8366	0.0496
	2	891	11.0325	0.0476
		890	10.8802	0.0486
	3	891	10.8813	0.1709
		890	10.7909	0.0290
	4	891	10.9444	0.0499
		890	10.8357	0.0790
	5	891	10.9710	0.0820
		890	10.8915	0.1012
15	1	891	10.9340	0.0832
		890	10.8514	0.0358
	2	891	11.0080	0.0947
		890	10.8140	0.0574
	3	891	10.9532	0.1290
		890	10.7769	0.0478
	4	891	10.9419	0.0644
		890	10.9229	0.0343
	5	891	10.9096	0.1070
		890	10.8503	0.0669

Table C-2 Continued. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
16	1	891	10.8007	0.0738
		890	10.7507	0.0481
	2	891	10.9030	0.0661
		890	10.6978	0.0681
	3	891	10.8603	0.0788
		890	10.6654	0.0633
	4	891	10.8367	0.0420
		890	10.7489	0.0498
	5	891	10.8814	0.1072
		890	10.6968	0.0369
17	1	891	10.9139	0.0292
		890	10.6697	0.0382
	2	891	10.8960	0.0210
		890	10.6830	0.1015
	3	891	10.8440	0.1250
		890	10.6059	0.0635
	4	891	10.8261	0.0665
		890	10.6878	0.0491
	5	891	10.9049	0.0811
		890	10.6593	0.0490
18	1	891	10.8234	0.0973
		890	10.7401	0.0088
	2	891	10.9142	0.0921
		890	10.7322	0.0488
	3	891	10.8066	0.1029
		890	10.6696	0.0282
	4	891	10.8175	0.0596
		890	10.7076	0.0805
	5	891	10.8317	0.0514
		890	10.7076	0.0668

Table C-2 Continued. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
19	1	891	10.0944	0.0635
		890	10.7453	0.0873
	2	891	10.9383	0.0319
		890	10.7666	0.0917
	3	891	10.8709	0.0855
		890	10.7004	0.0636
	4	891	10.8163	0.0610
		890	10.7859	0.1077
	5	891	10.9080	0.0768
		890	10.7614	0.0260
20	1	891	10.8613	0.0831
		890	10.7471	0.1043
	2	891	10.9398	0.0544
		890	10.7979	0.0722
	3	891	10.8342	0.1436
		890	10.7237	0.0737
	4	891	10.8306	0.1109
		890	10.7769	0.0693
	5	891	10.8894	0.0835
		890	10.7342	0.0473
21	1	891	10.8294	0.0697
		890	10.6331	0.0607
	2	891	10.8073	0.0528
		890	10.6442	0.0417
	3	891	10.7393	0.1262
		890	10.5745	0.0354
	4	891	10.7268	0.0406
		890	10.6457	0.0096
	5	891	10.7802	0.0950
		890	10.6605	0.0333

Table C-2 Continued. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
22	1	891	10.7754	0.0498
		890	10.5797	0.0733
	2	891	10.8219	0.0360
		890	10.6335	0.0611
	3	891	10.7047	0.1020
		890	10.4882	0.0683
	4	891	10.7372	0.0505
		890	10.6629	0.0431
	5	891	10.7922	0.0571
		890	10.5867	0.0932
23	1	891	10.7809	0.1271
		890	10.5421	0.0418
	2	891	10.8246	0.1057
		890	10.5587	0.1550
	3	891	10.8025	0.1133
		890	10.5095	0.0463
	4	891	10.7841	0.0408
		890	10.6337	0.0428
	5	891	10.7195	0.0893
		890	10.5683	0.0627
24	1	891	10.7729	0.0622
		890	10.5718	0.0365
	2	891	10.8019	0.0543
		890	10.6221	0.0571
	3	891	10.6845	0.1056
		890	10.5604	0.0514
	4	891	10.6689	0.0578
		890	10.6467	0.0834
	5	891	10.7913	0.0819
		890	10.6093	0.0723

Table C-2 Continued. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
25	1	891	10.5494	0.1170
		890	10.6191	0.0371
	2	891	10.8900	0.0565
		890	10.6983	0.0523
	3	891	10.7739	0.1485
		890	10.5553	0.0627
	4	891	10.8105	0.0466
		890	10.6883	0.0504
	5	891	10.8075	0.0512
		890	10.6819	0.1029
26	1	891	10.8031	0.0722
		890	10.4959	0.0396
	2	891	10.8468	0.1038
		890	10.5591	0.0522
	3	891	10.7867	0.1363
		890	10.4290	0.0282
	4	891	10.7661	0.0747
		890	10.5425	0.0461
	5	891	10.7572	0.0912
		890	10.5351	0.0650
27	1	891	10.7488	0.1152
		890	10.4994	0.0673
	2	891	10.7834	0.0576
		890	10.4294	0.0674
	3	891	10.7363	0.1140
		890	10.3868	0.0894
	4	891	10.7195	0.0732
		890	10.4877	0.0817
	5	891	10.8018	0.0660
		890	10.4252	0.0462

Table C-2 Continued. Capability Study - Raw Data (μm)

Position	Calibration Attempt	Part	Average	Standard Deviation
28	1	891	10.9775	0.0585
		890	10.5136	0.0335
	2	891	10.7929	0.0441
		890	10.5041	0.0519
	3	891	10.7505	0.1116
		890	10.4532	0.0842
	4	891	10.7780	0.0633
		890	10.5593	0.0962
	5	891	10.8003	0.0719
		890	10.4885	0.0791
29	1	891	10.7494	0.0927
		890	10.6059	0.0251
	2	891	10.7926	0.0332
		890	10.6203	0.0818
	3	891	10.7490	0.1166
		890	10.5144	0.0239
	4	891	10.7533	0.0674
		890	10.6447	0.0732
	5	891	10.7872	0.0404
		890	10.5791	0.1472
30	1	891	10.8235	0.1141
		890	10.6303	0.0634
	2	891	10.8415	0.0939
		890	10.5997	0.0552
	3	891	10.8306	0.0628
		890	10.4961	0.0127
	4	891	10.7918	0.0382
		890	10.6283	0.0402
	5	891	10.8084	0.0561
		890	10.5935	0.0757

Figure C-2. Comparison of the Average Measurements for Each Position and Calibration for Beta-Backscatter Part Number 890

Figure C-3. Comparison of the Average Measurements for Each Position and Calibration for Beta-Backscatter Part Number 891

Figure C-4. Comparison of the Standard Deviation Estimates for Each Part Position for Beta-Backscatter Part Number 891

Figure C-5. Comparison of the Standard Deviation Estimates for Each Part Position for Beta-Backscatter Part Number 890

Appendix D
DOCUMENTATION FOR J500/FILE MANAGER ROUTINES

Appendix D

DOCUMENTATION FOR J500/FILE MANAGER ROUTINES

The following routines written by J. Waldby, D/744, were added to the Beta Backscatter software.

500 Series Programs

J520	Main Program	The data file manager
J525	- FILGET	Gets the user's data from a data file
J530	- FILPUT	- Puts the user's data in a data file
J535	- FILNEX	- Creates the next data filename
J540	- FILINS	- Handles the insertion of items in the directory
J545	- FILPRI	- Prints out the entries in the data file directory
J550	- FILSRC	- Searches the directory for a given filename
J555	- DIRINS	- Inserts an entry in the data file directory
J560	- GETDAT	- Gets a data file and prints a summary of its data

These routines are used to handle the data files generated by the Beta Backscatter part runs. Whenever a part is run, 'FILPUT' creates a data file for it containing any necessary data associated with the run. Whenever 'FILMGR' is run, it makes entries in the data file directory for any data files just created and are not yet in the directory. Therefore, the necessary data is in a data file and the data is catalogued in the data file directory.

Variable Definitions For J500/File Manager Programs

BASEYR	-	The base year for all the parts run, used to compute the run date.
DIRSIZ	-	The current size (in blocks) of the directory NOTE: This counts block 0.
ICHAN	-	The I/O channel used to access the directory; obtained by a call to IGETC.
INXTPG		Index of the page pointer, in an item. The page pointed to contains entries that immediately follow this item.
IYEARN	-	Index of the part's run number for that year, in an item.

IRUNDT	-	Index of the part's run date, in an item.
ISERIU	-	Index of the part's serial number, in an item.
IFILNM	-	Index of the part's filename, in an item.
INITEM	-	Index of the number of items on a page, in a page.
IPAGPT	-	Index of the page pointer, in a page. The page pointed to contains items that precede those on this page.
LEVEL	-	Tells which level of the directory to search; used for the recursion.
LITEM(9,5)		The item to search for in a page on the current level.
LLAST(5)	-	The index, in the current page, of the previous filename on the current level.
LPTR(5)	-	The block number of the page to search for the item on, on this level search.
MNITEM	-	The minimum number of items per page in the directory, under ideal conditions.
MXITEM	-	The maximum number of items per page, in the directory.
NEWPAG(256)		A buffer used when forming a new page.
NWORDS	-	Number of words in block 0 that contain valid information regarding the directory.
NCHARI	-	The number of characters in an item.
NWDSI	-	The number of words in an item.
PAGSIZ	-	The page size, in words.
ROOT(256)		A buffer to hold the root page of the directory.
COPY	-	A flag used to update the directory number. Copy is used to create at most one new directory for each 'FILMGR' run.

SRCBUF(256)	The current page to search for the item on. It may be equal to the root page.
SUBTRE	A flag which tells when an item needs to be placed in a new page, J a subtree is needed.
RKODIR(4)	The RAD50 filename of the directory.
RKOBAK(4)	The RAD50 filename of the directory backup. This is created whenever a new directory is written.
SRCBLK	The current block number of the search buffer.
TOTLEV	The total number of levels down in the direc- tory the item should be inserted.
FILREC(10,2)	Two 5 word data file names <ol style="list-style-type: none"> 1. The first filename is the last data file that 'FILPUT' J530 has processed this year. 2. The second filename is the last data file that 'FILMGR' J520 has processed this year.
FILCNT(3)	Three integer values <ol style="list-style-type: none"> 1. The number of data files 'FILPUT' has processed this year. 2. The number of data files 'FILMGR' has processed this year. 3. The number of data files 'FILPUT' pro- cessed last year.
DIRNUM	The directory version number now being used. This changes whenever splitting occurs.
ROOTPG	The block number of the directory's root page.
FILNAM(14)	The complete data file name, including the device specified, and the extension.
SERIFL(10)	The part's serial number.

PARTRN The part's run number.

Program Functions and Requirements

J520 FILMGR MAIN ROUTINE

CALLING ROUTINES: None

CALLED ROUTINES: None

CALLED ROUTINES: J315DATEOK, J540FILINS, J545FILPRI

LANGUAGE: FORTRAN

LENGTH: 114 Lines

FUNCTION:

The file manager does three main tasks:

1. It prepares the data file directory for subsequent use by assigning a channel number to a device handler. It then reads in block 0 and the root page.
2. It requests an output file for the data written by 'FILPRI' and for the summary data written by 'FILINS'. 'FILMGR' then prints the appropriate header for the output.
3. It determines which function is to be conducted; either the insertion of an item in the directory, or the printing of data items. 'FILMGR' then calls either 'FILINS' or 'FILPRI' depending on the function desired.

J525FILGET GET A DATA FILE

CALLING ROUTINES: J355ELTS

CALLED ROUTINES: J535FILNEX

LANGUAGE: FORTRAN

LENGTH: 47 Lines

FUNCTION:

The 'FILE GET' routine locates a data file given a serial number and an optional part run number. If the part run number is not given, the latest data file for the given serial number is found. 'FILSRC' is then called to search the directory for the given file. Once the data file is found, it is read into core and some of its contents are printed.

J530FILPUT PUT DATA IN A DATA FILE

CALLING ROUTINES: J355ELTS

CALLED ROUTINES: J535FILNEX

LANGUAGE: FORTRAN

LENGTH: 47 Lines

FUNCTION:

This routine puts some data in a data file. The data filename is created by calling 'FILNEX'. Once the name is formed, 'FILPUT' writes the data to the new file.

J535FILNEX CREATES THE NEXT DATA FILENAME

CALLING ROUTINES: J530FILPUT, J540FILINS

CALLED ROUTINES: J435MOVA

LANGUAGE: FORTRAN

LENGTH: 37 Lines

FUNCTION:

'FILNEX' forms a file name for the data files. The routine first determines whether 'FILPUT' or 'FILINS' called it, via a parameter. Next, it looks up the last filename produced for that calling routine, in block 0. It then produces the next sequential filename, and finally, updates the data in block 0 of the directory. The filenames produced are in the form YYANN.BBD, where 'YY' is the year (e.g. 78), 'A' is a letter (e.g. 'C'), and 'NNN' is a number in the range 000-999. A typical filename might be 78C123.BBD. The 'BBD' extension stands for Beta Backscatter Data.

J540FILINS INSERTS ITEMS IN THE DIRECTORY

CALLING ROUTINES: J520FILMGR

CALLED ROUTINES: J535FILNEX, J435MOVA, J550FILSRC

LANGUAGE: FORTRAN

LENGTH: 93 Lines

FUNCTION:

This routine inserts an item into the directory. It calls 'FILNEX' to get the filename of the next data file to be included in the directory. It then reads the data file, prints a short data summary, and uses some of the data to form the directory entry, or item. Having formed the item, 'FILINS' calls 'FILSRC' to be sure the item is not already in the directory. If it is not, then it inserts the item by calling 'FILSRC' again, which this time calls 'DIRINS' to do the actual inserting. 'FILINS' processes all the data files produced since the last file manager run. NOTE: 'FILINS' disables any control C abort while entries are being made in the directory. The abort action be conducted, only when a complete entry is made.

J545FILPRI PRINT THE DIRECTORY CONTENTS

CALLING ROUTINES: J520FILMGR

CALLED ROUTINES: J435MOVA, J545FILPRI

LANGUAGE: FORTRAN

LENGTH: 91 Lines

FUNCTION:

This routine prints the contents of the data file directory using recursion. There are two methods of printing available. In the first, or short method, the routing scans down the directory tree in order to print the files in order. The second method searches the directory in the same manner, but in this case a summary of the data in the data files is printed. Recursion is used to simplify the process of scanning up and down a tree.

J550FILSRC SEARCH THE DIRECTORY FOR A FILENAME

CALLING ROUTINES: J525FILGET, J540FILINS

CALLED ROUTINES: J435MOVA, J550FILSRC, J555DIRINS

LANGUAGE: FORTRAN

LENGTH: 69 Lines

FUNCTION:

This routine searches the directory for the item specified. The search proceeds from one page to another until the item, or the location of where the item should be, is found. If

an insertion was not specified, control is then returned to whichever routine called it. However, if an insertion was specified by 'FILINS' then 'DIRINS' is called, with the necessary information in Common, to insert the item. Again recursion is used to scan up and down the Bayer Tree.

J555DIRINS INSERT AN ITEM INTO THE DIRECTORY

CALLING ROUTINES: J550FILSRC

CALLED ROUTINES: J435MOVA, J555DIRINS

LANGUAGE: FORTRAN

LENGTH: 166 Lines

FUNCTION:

'DIRINS' inserts an item into the directory. There are two cases of interest concerning the insertions. The first occurs when the page is not full and the item can be inserted onto it directly. The second case occurs when a page where insertion is to take place is already full, causing a split. In the latter case, some of the entries remain on the page, some are transferred to a new page, and one item is inserted on a page one level higher, that will point to the newly created page.

When the split is the first one of a 'FILMGR' run, a copy of the old directory is also made. This allows easy recovery in case of subsequent errors. Recursion is used here to handle the splitting case. When the one item to be moved up a level is isolated, it is inserted via a call to 'DIRINS'. Therefore, there may be more than one split during the insertion of only one item.

J560GETDAT GET A DATA FILE AND PRINT A SUMMARY

CALLING ROUTINES: J540FILINS, J545FILPRI

CALLED ROUTINES: None

LANGUAGE: FORTRAN

LENGTH: 49 Lines

FUNCTION:

'GETDAT' reads the data file specified by the variable 'FILNAM'. It then computes the maximum thickness, minimum thickness, average thickness, and standard deviation. These

items and other identification data are then printed. After printing a summary, 'GETDAT' returns to the calling routine.

J521MAIN SETS UP THE DIRECTORY

CALLING ROUTINES: None

CALLED ROUTINES: J435MOVA

LANGUAGE: FORTRAN

LENGTH: 56 Lines

FUNCTION:

This is the initialization routine for the data file directory. It requests certain initial conditions, then creates blocks 0 and 1 of the directory. Any old directory with the same name (BBDDIR.DAT) is deleted.

Two other routines used by J500 series programs are:

J435MOVA Transfers character strings from one location to another.

J315DATEOK Sets up the date and time by reading the system clock. A date and time must be entered for the file manager series to run.

Operating Procedures

1. Computer Start Up

2. Running J520

3. Running J521

4. Using .DIR

1. Computer Start Procedure

A. Turn on power to computer, terminal, and printer

B. Load in disk(s) and press run switches

C. Depress halt switch on computer console

D. Raise register switches to display 173100

- E. Depress load switch
- F. Set register switches to 177406
- G. Raise the halt switch
- H. Depress the start switch

The disk should now boot and some lines will print on the terminal. At this point enter the date and time by typing:

```
.DAT DDMMYY  
.TIM HH:MM
```

Where 'DD' is the day of the month, 'MMM' are the first three characters of this month's name, 'YY' is the year, 'HH' is the hour (24 hour clock), and 'MM' is the minutes. For example:

```
.DAT 23FEB78  
.TIM 14:28
```

2. Running J520 The File Manager

- A. Type .R J520
- B. The program will respond with:

PRINT DEVICE (CR=TT:):

Respond by entering the device you want summary data to appear on. A carriage return will default the device to TT:. Examples of responses are: LP:, GD:, FS:.

- C. The program then prints:

FUNCTION:

To this, enter either "PRINT" or "INSERT". These responses

can be shortened to "P" and "I". The "PRINT" option will print all the data files in the directory in the manner specified (see D.). The "INSERT" option will insert in the directory, any data files not already there. For example:

FUNCTION:PRINT

- D. If the option specified was "INSERT", the program does the insertion and prints a summary of the data files inserted, on the print device specified in part B. However, if "PRINT" was the choice, the program types:

DO YOU WANT THE SUMMARY FORM?

Typing a "Y" will produce the summary form. Any other response defaults to the short form. The short form is a list of the directory's structure, while the summary form reads the data file and prints some data contained in it.

- E. Whichever option was requested, the program will terminate with the message:

STOP END FILE MANAGER RUN

The requirements needed to run the file manager series of programs are:

1. A data file directory must exist on device RK0:. When it is initialized it must contain the proper data in block 0 and have block 1 allocated. NOTE: J521.SAV may be used to initialize the directory.
2. Data files should be present on device RK1:. This device can be changed permanently by a data statement change in J305.FOR, or temporarily by an:

.ASSIGN XXX RD1:

where XXX is some other device, e.g., CT1: or RK0:.

3. Device LP:, or equivalent, must be available. If the Gould 5010 is not used, the following statements must be entered; if LP: has been assigned to GD:.

.DEASSIGN LP
.ASSIGN XX LP

The second statement above is needed only if the printing device LP: should be device XX. Example:

.DEASSIGN LP
.ASSIGN TT LP

This would direct all printing to the terminal.

2. Running J521

A. Type .R J521

B. The program will print:

LAST DATA FILE CREATED (WITH EXT.):

Respond by entering the filename of the last data file created. Omit the device, but include the extension, as shown below.

LAST DATA FILE CREATED (WITH EXT.):

78A000.BBD

LAST DATA FILE CREATED (WITH EXT.):

770127.BBD

LAST DATA FILE CREATED (WITH EXT.):

78F986.BBD

C. The program next types:

LAST DATA FILE INSERTED IN DIRECTORY (WITH EXT.):

Answer by typing the filename of the last data file inserted in the directory. The form is the same as in the above stem.

D. Next, the following is printed:

NUMBER OF DATA FILES CREATED THIS YEAR,
NUMBER OF DATA FILES INSERTED IN THE DIRECTORY
THIS YEAR, NUMBER OF DATA FILES CREATED LAST YEAR

Respond by typing three integer numbers, separated by commas, such as:

NUMBER OF DATA FILES CREATED THIS YEAR,
NUMBER OF DATA FILES INSERTED IN THE DIRECTORY
THIS YEAR, NUMBER OF DATA FILES CREATED LAST YEAR

49,36,512

1. The first number is the total number of data files created this year. This can be obtained from the following formula, using the filename entered in part B.

of files = (Three digits of data filename + 1) +
(position in alphabet of the letter in the
data filename - 1)*1000

For instance, if the last data file created was 78A127.BBD the total number of data files would be $(127+1)+(11)*1000$ or 128. If the filename was 78C237.BBD the number would be $(237+1)+(31)*1000=2238$.

2. The second number is the number of files inserted in the directory this year. This can be computed from the same formula as in step 1, using the data filename entered in part C.
3. The program will then create the directory and print the message:

DIRECTORY BLOCKS 0 AND 1 INITIALIZED STOP -

To initialize the directory for the first time, enter the same filename in parts B and C. The filename must have been created a year earlier than the current one. For example, if the directory is to be initialized in 1978, an appropriate filename would be 77M372.BBD. The three numbers can be all zeroes, but irregardless, the second and third numbers must be the same. For instance, 0,100,100.

The directory will then be set up to produce data files starting with YYA000.BBD, where 'YY' is the current year.

4. Using .DIR

The monitor command .DIR (short for .Directory) is used to list files on a device. The general form of the command is:

DIR(/SWITCHES) DEVICE:FILENAME

Some of the more common switches are:

/PR Directs output to the printer (the terminal is default)

/BAD Scans the device specified for any bad blocks

/ALP Will alphabetize the files before printing them

/COL:N Allows specification of the number (N) of columns to print the files in. N can range from 1 to 9.

/DATE:DD:MMM:YY Will list any files created on the date specified

/BEFORE:DD:MMM:YY Will list any files created before the date specified.

/SINCE:DD:MMM:YY Will list any files created on or after the date specified.

Compatible switches may be combined.

'DEVICE' is any system device which has a directory, e.g., RK1:, or CT1:.

The filename can include the wildcard characters * and %. The * accepts any character or group of characters that are located in the position shown. The % accepts any character in the position specified.

Examples:

To get a listing of all the data files created with the .BBD extension, residing on RK0:. The following statement can be typed:

```
.DIR *.BBD
```

To produce the same listing on the printer, alphabetized, and in three columns, type:

```
.DIR/PR/ALP/COL:3 *.BBD
```

To list all the data files created in 1978 type:

```
.DIR 78*.BBD
```

To list all the data files created since 1978 type:

```
.DIR/SINCE:1:JAN:78 *.BBD
```

The command

```
.DIR/PR RK1:7 %A000.BBD
```

Will list on the printer the first data file created each year that resides on device RK1:. For instance, 76A000.BBD, 77A000.BBD, 78A000.BBD.

Directory Structure File BBDDIR.DAT

The data structure chosen for the directory is the Bayer Tree as described in "Algorithms + Data Structures = Programs" by Niklaus Wirth, 1976, pages 245-252. Quoting from page 245 "... Every page (except one) contains between N and 2N nodes for a given constant N. Hence in a tree with M items and a maximum page size of 2N nodes per page, the worst case requires $\log_2 M$ page accesses, and

page accesses clearly dominate the entire search effort. The important factor of store utilization is at least 50 percent since pages are always at least half full."

"The underlying data structures are called B-Trees and have the following characteristics; N is said to be the order of the B-Tree.

1. Every page contains at most $2N$ items (keys).
2. Every page, except the root page, contains at least N items.
3. Every page is either a leaf page, i.e., has no descendents, or it has $M+1$ descendents, where M is its number of keys.
4. All leaf pages appear at the same level."

Simply stated, the tree is set up so that every page except the root page, always contains at least N items, and at most $2N$ items. Whenever a page is full and another item must go on it, a split occurs and the following steps are conducted. First, a new page, or node, is created. Next, items are taken out of the full page and put in the new page until the new page contains at least the minimum number N . Finally, one item is sent to the page one level up, with a pointer to the newly created page. Multiple splits can occur; in which case one item is always sent a level higher until a page is found that is not full, or a new root page is needed.

The basic structure just described has been modified somewhat for this series of programs. Since the data files to be inserted are expected to be in essentially alphabetical order, the need for half filled pages that contain earlier filenames, is gone. Consequently, rather than guaranteeing between N and $2N$ entries per page, the setup here guarantees between a minimum and a maximum number, where the minimum has been set to $3/4$ of the maximum. This ratio can be easily changed by modifying one data statement.

This new approach allows for a better storage capability, cuts down on the number of pages needed, and requires less search time to locate the entries. With the current structure of between 21 and 28 entries per page, the Bayer Tree structure guarantees no more than three accesses are needed to locate around 10,000 entries. With the root page core resident, this reduces to two accesses per 10,000 entries. Over 230,000 entries can be stored and still require at most three accesses, if the root is core resident. This structure will allow fast lookup and will have a high storage density.

Block 0 Structure

Block 0 of the directory contains information vital to the operation of the file manager routines. Currently there are 15 words of useful data which can be broken down as follows:

WORDS	CONTENTS
1 to 5 the	The last data filename produced this year. It is in form YYANN.BBD and stored as LOGICAL*1 DATA. Whenever a new data file needs to be created, the file manager uses this filename to produce the next one. Data filenames are produced by incrementing 'NNN' until 999 is reached, and then incrementing the letter 'A'. I.e., they go from A000,...,A999,B000,B001,..., Z999. Thus a maximum of 26,000 different data names can be produced each year. 'YY' is the current year.
6 to 10	The last filename that was inserted in the directory. The file manager uses this name whenever an insertion is requested, to locate the proper data file and enter the necessary data in the directory. As in the above filename, this gets updated by the file manager whenever it is used. The form is the same as that above.
11	The number of data files produced this year.
12	The number of data files inserted in the directory this year. When an insertion is called for, the program checks the years of the filenames in words 11 and 10. If they are the same, the file manager compares the numbers in words 11 and 12, and if they indicate that more data files have been produced than have been inserted, the insertion is performed. These numbers likewise, are updated as operations are performed.
13	The number of data files produced last year. This is used in the event that dates of words 1 to 5 and 6 to 10 differ. This number is then compared to that in word 12 and if they are the same, the file manager knows it has inserted all of last year's files in the directory. The insertion of data files produced last year continues until words 12 and 13 are equal. Word 12 is zeroed and insertion continues until word 12 equals word 11.
14	The directory version number. This starts at 0 and increases whenever a copy of the directory is made. Copies are made when the first split of a file manager

run occurs. This number is then incremented and used as the extension of the copied directory. For instance, the first copy of the directory is called BBDDIR.001. NOTE: The copy is made before the splitting is actually carried out.

- 15 The block number of the directory's root page. This is important because of the structure of the directory. The root page is where the directory originates, and is core resident at all times.

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