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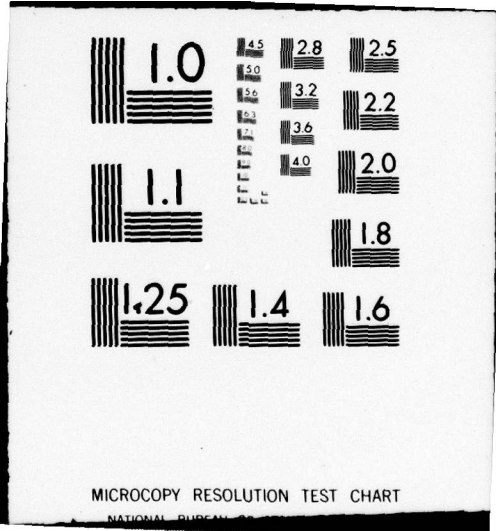
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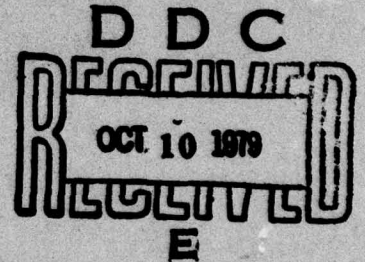
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NRL Memorandum Report 4090

**Report of Cyclotron Facility Operations
October 1, 1978 through June 30, 1979**

ROLLON O. BONDELID

*Cyclotron Applications Branch
Radiation Technology Division*



September 28, 1979

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Washington, D.C.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This is the seventh in a series of quarterly reports summarizing the use of the Naval Research Laboratory Cyclotron Facility. During the nine month period ending June 30, 1979 the cyclotron was used in support of eight research programs for a total 1325 hours of beam on target. These research programs are summarized in this report together with the details of beam time usage and facility engineering. No major operational problems have been encountered this year. Lwone		

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10. Program Element, Project, Task Area & Work Unit Numbers (Continued)

**NRL Problem H00-01
H01-57
H01-79
H01-83
H01-94
H11-01
H11-07
H11-08**

19. Key Words (Continued)

**Neutron beams
Nuclear reactor
Neutron production
Non-military application
Cancer treatment**

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I. Introduction

The Naval Research Laboratory Cyclotron Facility began operations as a cost center on October 1, 1977 and completed the first year of such operation on September 30, 1978. For fiscal year 1979 an estimate was made of the projected cost of operating the cyclotron facility and the number of hours users would require the cyclotron beam. These estimates are \$273,200 and 2024 hours respectively, leading to a charge of \$135 per hour. This report is the seventh in the current series of quarterly reports covering operation of the NRL Cyclotron Facility as a cost center from October 1, 1978 through June 30, 1979.

II. Beam Time Records

A. The Daily Record

Beam time charge accounting is accomplished using a simple method of coding information. At the end of each week the information is recorded in card images and stored on the disc file of the Systems 32/55 data acquisition computer located in the Cyclotron Facility for later recall and summarization. Figure 1 in the first report of this series is a sample of a beam time code sheet. The method of using this form was also described in the first report.

B. Computer Readout

Tables 1 through 4 show the collated data from the beam time card images.

Table 1 shows the beam time use by program and month. Outage is listed as a point of interest. This table is submitted to the NRL budget branch at the end of each month. Proper charges can then be recorded against the using program and credited to the cyclotron cost center.

Table 2 shows the summary by program and particle. The lowest and highest energies for that particle used are also shown.

Table 3 shows the beam time summaries in various ways. Firstly, by program, secondly, by month and thirdly, by particle. Clearly, the table shows that the greatest user has been the MANTA program.

Table 4 is an overall summary of beam time which lists primarily the reasons for unscheduled outages. From this table we see the major problem source continues to be the power supplies of the cyclotron. However, the R. F. system of the cyclotron has developed problems which has caused some significant down time. Outage number 8, "Experimenters Equipment," is included in total beam-on time, but it is not included as cyclotron down time. The item, "Total Hours Available to Date," is the number of hours from 0000 hours October 1 through 2400

Note: Manuscript submitted August 7, 1979

hours June 30. The NRL cyclotron schedule had originally been planned for operating two 8-hour shifts per day for six days per week, holidays and scheduled engineering periods excluded. The utilization factor is the total scheduled time divided by this planned schedule.

III. Engineering and Maintenance

A. Cyclotron

A remotely operable particle detector positioner was installed at the terminal end of Beam-Line 1C. The device has an adjustable, reversible speed drive. It allows precision horizontal positioning of detectors in straight-line motion along the ion-beam-line axis in two directions, with negligible wobble, within a range of 10 cm to 150 cm from the target being irradiated. Initial alignment is done using a laser beam. Read-outs and controls are located in the data acquisition room at the physicists' work station.

An updated phase sensing and control circuit to electronically stabilize the cyclotron's magnetic field has been bread boarded and tested using three NIM bins for amplification and detection. Work is continuing on debugging and improving the prototype. The pending acquisition of a fast detector to pick up the capacitive, beam-probe signal will eliminate the need for the NIM bins.

For the type of operation conducted in the cyclotron facility, it is essential that equipment be shut down and overhauled in the shortest possible time. To permit continuous operation of the cyclotron while concurrently doing maintenance, the transistor banks (an average of 10 banks each having 29 power transistors) were bypassed by shorting across the common emitter and collector busses and disconnecting the transistor drive signal. A small, regulated dc Kepco power supply was substituted for the transistor banks to drive the SCR's, thus controlling the output current. To provide remote control of the supply from the Cyclotron Control Room, a circuit, using a Zener diode for protection, was designed and installed between the small power supply and the SCR firing circuit. Although some slow drift of a few dc amps occurred (3500 amps is average operating current), it can be operator-corrected without noticeable ion-beam degradation.

IV. Summary of Facility Use

A. MANTA

Six patients were in various stages of treatment during this reporting period. See the previous reports in this series for a further discussion of the neutron therapy program. The National Cancer Institute terminated the MANTA program effective June 30, 1979.

A'. MANTA Dosimetry

Clinical research continued on whole-body dosimetry for open and wedged fields. These measurements are taken in a Rando-anthropomorphic phantom and in tissue-equivalent liquid phantoms by means of diodes, ion chambers, foil activation and thermoluminescent dosimeters. These four types of dosimeters are used in an attempt to separate whole-body dose into fast-neutron, thermal-neutron and gamma components.

During this period two runs were made on a collaborative experiment with Dr. Richard Miller of Columbia University to compare the relative biological effectiveness of neutrons with x-rays for the induction of oncogenic cell transformations.

Two one-week runs were made in continuation of an experiment involving mouse tumor systems performed in collaboration with Professor Herman Suit of Massachusetts General Hospital and Harvard University. Each run is a set of five-fraction treatments, one per day for five days. The object is to compare tumor response and normal tissue reactions for neutron treatment, x-ray treatment, and x-ray treatment in conjunction with hypoxic sensitizers or hyperbaric oxygen.

B. Advanced Microdosimetry

As indicated under the Neutron Spectrometer Section of this report, the recently discovered light-ion flux associated with collimated neutron beams can influence the results obtained in the advanced microdosimetry program. Accordingly, some time was spent studying the light-ion flux under this work unit.

At the end of this reporting period the stainless-steel Rossi counter and some associated equipment were received, and preparatory work has begun for using this novel instrument.

Progress has been made during this reporting period in developing Systems computer software and hardware for acquiring and analyzing the Rossi-counter data. The implementation of the needed live-time correction feature on the Systems computer awaits final check out.

C. Radiation Interactions

Dynamic 16K random access memories (RAMs) have been irradiated with neutrons having mean energies of 6.5, 9 and 14 MeV and with 32 MeV protons and have been found to undergo single-event upset. For both particles, one upset is expected for approximately 10^8 particles/cm². The upsets are statistical and the affected cells can be reset and continue normal operation. Both HIGH and LOW storage elements are upset, though at different rates. The cause of the upsets is most

probably a multi-MeV alpha particle created by (n, alpha), (p, alpha) or similar nuclear reactions. The alpha particle discharges either the storage capacitor, the floating bit line, or the reference capacitor used by the sense amplifier.

A total of 15 dynamic RAMs from five vendors were irradiated, namely, Intel C2117-2, Motorola MCM4116L20, Texas Instrument TMS4116-200L, Hitachi HM4716A-3 and NEC PD416D. All were tested at a cyclotron mean neutron energy of 14 MeV. Selected ones were also irradiated at cyclotron neutron energies of 9 MeV and 6.5 MeV or d-t neutrons of 14-MeV energy. Two chips were irradiated with 32-MeV protons. In each case both the '0' and '1' memory states were tested.

The numbers given for upset levels are the mean fluence for a single upset in one 16K RAM. A moderate size computer memory of 64K bytes requires 32 of the 16K RAMs. The mean fluence for one upset in the memory then drops from say 2×10^8 n/cm² to 6×10^6 n/cm². If a 90% confidence of no upset is required, the acceptable neutron fluence drops to 6×10^5 n/cm². These levels for upset are many orders of magnitude below the thresholds for commonly tested neutron damage.

D. Neutron Damage

A set of commercial LED devices previously selected by Deep Level Transient Spectroscopy (DLTS) to have similar pre-irradiation characteristics have been irradiated by a 14-MeV neutron beam. These devices are being analyzed by DLTS to see the effects of the neutron beam.

E. Neutron Spectrometer

During this reporting period measurements were made that showed there is a significant energetic, light-ion flux produced by collimated neutron beams in air. Work is continuing on quantifying this light-ion flux since it can have a significant impact on work done in this program as well as others. A good deal of effort will be required to adequately parameterize this light-ion flux. Our results on this light-ion flux are to be presented at the APS Meeting to be held in Knoxville, Tennessee in October 1979.

F. Neutron Spectra

Some data were acquired for the (n, charged particle) spectrum produced by the neutron beam in air. A strong peak due to deuterons passing through feed-throughs in the Beryllium target assembly was identified and eliminated with shielding. A remotely controlled assembly for locating the detector at distances of 10 cm to 110 cm from the target

was installed. This assembly enables the identification of fluxes from the A1 end plate of the target assembly to be followed in air and separated from the flux produced in air.

The Systems Computer software support systems were changed to RTM 7.0 and TSS 3.0. These systems have a number of valuable enhancements. The data transmission rate to the terminals was increased during this installation. The data acquisition system was modified to run with the new support system.

F. Heavy Ion Acceleration

A few computer runs, using the program DIAL, have been made for the heavy ions $^{14}\text{N}^{4+}$ and $^{14}\text{N}^{5+}$. For calculations under the present running conditions (trim coils 1 and 3 = 0, and no harmonic coils), the RMS field errors are quite large, though they decrease with increasing ion energy. Possibly the isochronous field for a 100.5 MeV $^{14}\text{N}^{5+}$ beam could be obtained under present conditions. With optimum running conditions (maximum of all trim coils = 800 amps and harmonic coils working) there should be no trouble in obtaining the isochronous fields needed for the heavy-ion beams.

V. Accounting

Estimates made at the beginning of the fiscal year were for a total beam time of 2024 hours in support of the various programs. The total budget required to support this beam time is estimated to be \$273,200. On a straight line extrapolation this would lead to 1518 hours of beam time and a budget of \$204,900 for the nine month period ending June 30. The actual beam time use during this period was 1325 hours which represents a cost transfer of \$178,900. The job order status report through 30 June showed total costs of \$199,300. At this time the cost center is running about \$20,000 dollars behind income. Although the MANTA program is no longer active and providing income to the cost center, other programs have increased in activity and it is expected that cyclotron use will not drop significantly. Current cost projections indicate that the total budget will be less than that estimated at the beginning of the year by 15 to 20 k\$.

Table 5 shows a list of purchases required for Cyclotron Facility operation. The table is self explanatory.

VI. Conclusion

The NRL Cyclotron Facility continues to operate effectively as a cost center. Costs will come close to matching income and the use of the facility will not be far from that which was predicted at the start of the fiscal year.

Report Assembled by R. Bondelid

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Table 1

Beam time summary by program and month

CYCLOTRON APPLICATIONS BRANCH SUMMARY OF BEAM TIME
FY-79 JUNE 30, 1979

PROGRAM	MONTH	BEAM TIME	HT COST	OUTAGE
MANTA 66H01-23A	OCTOBER	154.6 HOURS	\$ 21411	9.4 HOURS
	NOVEMBER	113.1 HOURS	\$ 15269	10.5 HOURS
	DECEMBER	124.6 HOURS	\$ 17361	10.3 HOURS
	JANUARY	124.7 HOURS	\$ 17510	1.9 HOURS
	FEBRUARY	104.9 HOURS	\$ 14702	2.5 HOURS
	MARCH	109.3 HOURS	\$ 14756	17.5 HOURS
	APRIL	120.1 HOURS	\$ 16214	25.3 HOURS
	MAY	95.9 HOURS	\$ 12947	7.7 HOURS
	JUNE	54.1 HOURS	\$ 7444	2.3 HOURS
	SUBTOTAL	1022.3 HOURS	\$136014	87.4 HOURS
RADIATION INTER. 66H01-57	JANUARY	6.0 HOURS	\$ 810	0.0 HOURS
	FEBRUARY	27.0 HOURS	\$ 3645	3.0 HOURS
	MARCH	5.5 HOURS	\$ 743	9.6 HOURS
	APRIL	15.5 HOURS	\$ 2093	0.5 HOURS
	MAY	21.6 HOURS	\$ 2916	7.6 HOURS
	JUNE	36.1 HOURS	\$ 4874	0.0 HOURS
	SUBTOTAL	111.7 HOURS	\$ 15081	20.9 HOURS
NEUTRON SPECTROM. 66H01-79	NOVEMBER	6.0 HOURS	\$ 810	2.0 HOURS
	DECEMBER	14.5 HOURS	\$ 1954	0.0 HOURS
	MARCH	10.0 HOURS	\$ 1350	0.0 HOURS
	JUNE	1.5 HOURS	\$ 203	0.0 HOURS
	SUBTOTAL	32.0 HOURS	\$ 4321	2.0 HOURS
H + HE IN METALS 66H01-83	OCTOBER	4.0 HOURS	\$ 1080	0.0 HOURS
WEAPONS MONITORS 66H01-94	OCTOBER	0.5 HOURS	\$ 66	0.0 HOURS
	NOVEMBER	2.3 HOURS	\$ 311	0.0 HOURS
	DECEMBER	4.2 HOURS	\$ 567	0.0 HOURS
	FEBRUARY	4.3 HOURS	\$ 581	0.0 HOURS
	SUBTOTAL	11.3 HOURS	\$ 1527	0.0 HOURS
NEUTRON DAMAGE 66H11-01	OCTOBER	1.0 HOURS	\$ 135	0.0 HOURS
	DECEMBER	16.7 HOURS	\$ 2255	0.0 HOURS
	JANUARY	12.2 HOURS	\$ 1647	0.0 HOURS
	MARCH	30.1 HOURS	\$ 4064	0.0 HOURS
	MAY	32.0 HOURS	\$ 4320	0.0 HOURS
	JUNE	7.9 HOURS	\$ 1067	0.0 HOURS
	SUBTOTAL	99.9 HOURS	\$ 13488	0.0 HOURS
ADVANCED MICRODOS. 66H11-07	JUNE	7.0 HOURS	\$ 945	0.5 HOURS
NEUTRON EFFECTS 66H11-08	OCTOBER	1.0 HOURS	\$ 135	0.0 HOURS
	NOVEMBER	4.5 HOURS	\$ 607	0.0 HOURS
	JANUARY	27.7 HOURS	\$ 3740	0.0 HOURS
	SUBTOTAL	33.2 HOURS	\$ 4483	0.0 HOURS
	TOTAL	1325.4 HOURS	\$176934	110.8 HOURS

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Table 2

Beam time summary by program and particle

CYCLOTRON APPLICATIONS BRANCH SUMMARY OF BEAM TIME
FY-79 JUNE 30, 1979

PROGRAM	PARTICLE	BEAM TIME	ENERGY RANGE-MEV	
MANTA 66M01-23A	DEUTERON	1022.3 HOURS	35	35
RADIATION INTER. 66M01-57	PROTON	15.0 HOURS	35	36
	DEUTERON	72.7 HOURS	16	35
	HELIUM-3	26.0 HOURS	22	22
	SUBTOTAL	111.7 HOURS		
NEUTRON SPECTRUM. 66M01-79	DEUTERON	32.0 HOURS	16	35
H + HE IN METALS 66M01-83	ALPHA	8.0 HOURS	36	36
WEAPONS MONITORS 66M01-94	DEUTERON	11.3 HOURS	16	35
NEUTRON DAMAGE 66M11-01	DEUTERON	99.9 HOURS	22	35
ADVANCED MICRODOS. 66M11-07	DEUTERON	7.0 HOURS	35	35
NEUTRON EFFECTS 66M11-08	PROTON	27.7 HOURS	16	18
	DEUTERON	5.5 HOURS	35	35
	SUBTOTAL	33.2 HOURS		
	TOTAL	1325.4 HOURS		

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Table 3

Beam time totals by program, month and particle

PROGRAM	START UP TIME		BEAM ON TARGET		TOTAL TIME		COST	OUTAGE		SCHEDULED TIME		% ON
	HOURS	MIN	HOURS	MIN	HOURS	MIN		HOURS	MIN	HOURS	MIN	
PHYSICS												
ADDITIONAL PIPES	259.4		792.4		1022.4		\$ 15011	67.8		1109.7		92.1
BEAM LOSS SPECTRA	23.0		99.1		111.7		\$ 15060	20.9		132.6		64.2
BEAM LOSS SPECTRA	4.0		27.2		32.0		\$ 4320	0.0		34.0		100.0
BEAM LOSS SPECTRA	1.0		7.0		8.0		\$ 1050	0.0		8.0		100.0
BEAM LOSS SPECTRA	2.9		8.4		11.3		\$ 1520	0.0		11.3		100.0
BEAM LOSS SPECTRA	13.0		66.1		99.9		\$ 13467	0.0		99.9		100.0
BEAM LOSS SPECTRA	0.5		2.5		3.0		\$ 405	0.0		3.0		100.0
BEAM LOSS SPECTRA	0.0		0.0		0.0		\$ 0	0.0		0.0		100.0
TOTALS	274.0		1041.4		1325.4		\$ 178931	110.8		1436.2		92.3
PHYSICS												
BEAM LOSS SPECTRA	169.1		9.4		178.5		\$ 94.7	0.0		178.5		94.7
BEAM LOSS SPECTRA	162.4		12.3		174.7		\$ 91.0	0.0		174.7		91.0
BEAM LOSS SPECTRA	175.0		1.9		176.9		\$ 98.9	0.0		176.9		98.9
BEAM LOSS SPECTRA	140.2		5.5		145.7		\$ 96.2	0.0		145.7		96.2
BEAM LOSS SPECTRA	134.4		27.1		161.5		\$ 85.1	0.0		161.5		85.1
BEAM LOSS SPECTRA	135.6		25.8		161.4		\$ 84.0	0.0		161.4		84.0
BEAM LOSS SPECTRA	149.5		12.8		162.3		\$ 90.5	0.0		162.3		90.5
BEAM LOSS SPECTRA	110.6		12.8		123.4		\$ 97.5	0.0		123.4		97.5
TOTALS	1325.4		110.8		1436.2		\$ 92.3	0.0		1436.2		92.3
PHYSICS												
BEAM LOSS SPECTRA	40.7		16		56.7		\$ 40.7	0.0		56.7		100.0
BEAM LOSS SPECTRA	1250.7		16		1266.7		\$ 92.0	0.0		1266.7		92.0
BEAM LOSS SPECTRA	26.0		22		48.0		\$ 70.0	0.0		48.0		100.0
BEAM LOSS SPECTRA	8.0		36		44.0		\$ 100.0	0.0		44.0		100.0
TOTALS	1325.4		110.8		1436.2		\$ 92.3	0.0		1436.2		92.3

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Table 4

Beam time summary to show cyclotron performance

CYCLOTRON APPLICATIONS BRANCH SUMMARY OF BEAM TIME
 FY-79 JUNE 30, 1979

CYCLOTRON OPERATIVE	HOURS	HOURS
CYCLOTRON START-UP	284.0	
BEAM ON TARGET	1041.4	
TOTAL BEAM-ON TIME		1325.4
UNSCHEDULED OUTAGE		
1 ION SOURCE	10.4	
2 VACUUM SYSTEM	6.6	
3 DEMINERALIZED WATER	1.7	
4 POWER SUPPLIES	48.9	
5 R. F. SYSTEM	29.5	
6 ELECTRICAL COMPONENTS	2.0	
7 MECHANICAL COMPONENTS	10.9	
8 EXPERIMENTERS EQUIPMENT	3.7	
9 RADIOLOGICAL SAFETY	0.8	
TOTAL OUTAGE	114.5	
TOTAL SCHEDULED TIME		1436.2
PERCENT BEAM AVAILABLE (ITEM 8 INCLUDED IN BEAM-ON TIME)		92.3
TOTAL HOURS AVAILABLE TO DATE		6552.0
POSSIBLE SCHEDULED HOURS (2-SHIFTS 6-DAYS PER WEEK)		3632.0
UTILIZATION FACTOR, PERCENT		39.5

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Table 5
A listing of purchases required for cyclotron facility operation

CONTRACTS AND PROGRAM OPERATIONS	MONTH ALL	PRICE	CATEGORY A ALL	MONTH	CARD	STUM NO.	CATEGORY A
ITEM	COST	PROGRAM					
ITEM REPAIRS	1632	OPERATIONS		OCTOBER	1	13	DATA SYSTEM
TYPE C	691	OPERATIONS		OCTOBER	2	14	DATA SYSTEM
SEAL SHUTTER	635	OPERATIONS		OCTOBER	3	15	DATA SYSTEM
STATION FILTER	3492	OPERATIONS		OCTOBER	5	16	DATA SYSTEM
PLASTIC TOP	5	OPERATIONS		OCTOBER	6	17	DATA SYSTEM
DISC CAMERAS	142	OPERATIONS		OCTOBER	7	18	DATA SYSTEM
GASKET MATERIAL	50	OPERATIONS		OCTOBER	8	19	DATA SYSTEM
APPROX TRANSPARENTS	64	OPERATIONS		OCTOBER	9	20	DATA SYSTEM
DISPATCH CASE	10	OPERATIONS		NOVEMBER	10	21	DATA SYSTEM
OPERATION	257	OPERATIONS		NOVEMBER	11	22	DATA SYSTEM
POWER SUPPLIES	1804	OPERATIONS		NOVEMBER	12	23	DATA SYSTEM
CAMERAS REGENERATION	1204	OPERATIONS		NOVEMBER	13	24	DATA SYSTEM
FILM REPAIR	1276	OPERATIONS		DECEMBER	14	25	DATA SYSTEM
CAPACITANCE REGENERATION	66	OPERATIONS		DECEMBER	15	26	DATA SYSTEM
VIDEO TRANSPARENTS	66	OPERATIONS		JANUARY	16	27	DATA SYSTEM
ALUMINUM TUBE	256	OPERATIONS		FEBRUARY	17	28	DATA SYSTEM
SLIP BEARING	240	OPERATIONS		FEBRUARY	18	29	DATA SYSTEM
CAMERA REPAIR	255	OPERATIONS		MARCH	19	30	DATA SYSTEM
VACUUM REPAIR KIT	50	OPERATIONS		MARCH	20	31	DATA SYSTEM
IONIZATION TUBES	420	OPERATIONS		MARCH	21	32	DATA SYSTEM
VACUUM REPAIR KIT	50	OPERATIONS		APRIL	22	33	DATA SYSTEM
INSTRUMENT TUBE	240	OPERATIONS		APRIL	23	34	DATA SYSTEM
MULTIPLAST REGENERATION	1224	OPERATIONS		APRIL	24	35	DATA SYSTEM
CAMERA	206	OPERATIONS		MAY	25	36	DATA SYSTEM
CHROMIUM REPAIR	307	OPERATIONS		JUNE	26	37	DATA SYSTEM
UPPER PART FOR REPAIR	9	OPERATIONS			27	38	DATA SYSTEM
TOTAL	21626						

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