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INSTRUMENTATION MAINTENANCE

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ABSTRACT

It is essential to any research activity that accurate and efficient measurements be made for the experimental parameters under consideration for each individual experiment or test. Satisfactory measurements in turn depend upon having the necessary instruments and the capability of ensuring that they are performing within their intended specifications. This latter requirement can only be achieved by providing an adequate maintenance facility, staffed with personnel competent to understand the problems associated with instrument adjustment and repair. The Instrument Repair Shop at the Lawrence Berkeley Laboratory is designed to achieve this end. The organization, staffing and operation of our system will be discussed

Maintenace policy should be based on studies of 1) preventive vs. catastrophic maintenance, 2) records indicating when equipment should be replaced rather than repaired and 3) priorities established to indicate the order in which equipment should be repaired. Upon establishing a workable maintenance policy, the staff should be instructed so that they may provide appropriate scheduled preventive maintenance, calibration and corrective procedures, and emergency repairs.

Apparatus may be reapired in situ, brought to the repair shop or returned to the manufacturer. The locale of instrument repair depends upon a number of factors including the fragility and size of the equipment, the ability to localize the problem in a distributed system, the seriousness of the reported malfunction, and any warranty provisions in effect at the time of failure.

The education, training and experience of the maintenance staff will be discussed along with the organization for an efficient operation.

The layout of the various repair shops will be described in the light of laboratory space and financial constraints.

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I. INTRODUCTION

A great deal of interest is reported in the scientific and technical literature concerning new instrumentation suitable for laboratory analysis. Almost any issue of a scientific or engineering journal will describe several research projects that have culminated in the development of a new instrument. Less information is available on training the technical staff on how to operate the apparatus; finally, there is even less information to be found in the literature on good maintenance procedures for laboratory instrumentation. Thus it is vitally important that users of scientific apparatus consider carefully the information that is available so that they may adequately invest the necessary personnel, test equipment and literature for the proper care of their instrumentation.

An evidence of the high cost of maintenance and the value placed on it may be drawn from a report that in 1961 25% of the operating budget of a large U.S. operatation went into maintenance.[1] This value would have represented equipment predating transistorized electronics, but the value today is still large.

It goes without saying that any research activity can operate only so long as its equipment performs as intended. This requirement can only be achieved by providing an adequate facility staffed with personnel who can handle the problems associated with the repair of their instruments.

The organization, staffing and operation of our Laboratory Instrument Repair Shop is described along with alternative methods for maintenance and repair.

II. MAINTENANCE POLICY

Instrumentation maintenance can be performed on several levels of priority depending upon the availability of personnel to provide these services. The most urgent requirement is for the repair of apparatus that has failed catastrophically and no longer operates. Less urgent is the need to maintain instruments that are still operating but known to be marginal in performance. Finally, the least urgent but perhaps the most fruitful in the long run is regularly scheduled preventive maintenance.

Most research institutions operate under the continual constraint of limited funding. This enhances the temptation to perform only the minimum repair required for day-to-day operation. Only those items that will not perform well enough to care for the immediate programs are fixed. No additional maintenance is undertaken. However, experience has shown that this is not the most economical way to operate a laboratory. Some balance between preventive maintenance and repair of actual breakdowns must be reached for most efficient operation of a research facility. This, of course, will differ with different types of laboratories.

The following arguments can be made in favor of conducting preventive maintenance in contrast to only doing emergency repair:

Scheduled maintenance can be done at a time when the equipment is less utilized in comparison with catastrophic repairs which often occur at the least opportune time. Scheduled maintenance will at times reveal conditions that if left unremedied will cause even greater need for replacement or repair. Preventive maintenance can be worked into an orderly schedule that minimizes the peak loads on the staff when several instruments are broken down and need repair simultaneously. Where several instruments with the same operating characteristics are in service, one spare unit can be reserved on a stand-by basis; it can be put into service when needed and the faulty unit repaired more leisurely.

Obviously some types of instruments are more amenable to scheduled inspection and repair than others. These include equipment with many mechanical parts and a somewhat uniform rate of wear, such as a magnetic tape transport. Another example is a spectrometer using a lamp source which has a known life time or a light transmitting window with a known rate of darkening with use. If instruments are continually used in a program with equal priority among experiments, then preventive maintenance loses much of its advantage.

The question of whether to replace or repair a defective instrument usually requires a fair degree of judgement. Occasionally a failure is so extensive that it is obvious that repair is out of the question; this might be the case where the apparatus employed a fragile glass or ceramic oven that has shattered and replacement parts are no longer available. More often the question of replacement vs. repair must be answered on the basis of whether 1) the instrument has become obsolete due to improved technology, e.g., electron valve equipment being replaced by solid state units, 2) the instrument is worn out and is constantly in need of repair, or 3) the cost of the apparatus approaches the annual cost of repair. (In an inflationary economy replacement costs rather than the original equipment price must be considered.) While no specific recommendations can be made, astute calibration and repair personnel can detect when an analyzer begins to require an undue amount of reconditioning and should be replaced.

Often when equipment needed in highest priority or most demanding experiments is replaced, the old equipment can be assigned to less demanding work or used by students to familiarize themselves with the operating principles of the apparatus.

The location of making repairs is usually self evident. Instrumentation may be fixed in situ, brought to the repair facility or returned to the manufacturer. We prefer to repair equipment on the site if it is fragile, too bulky or heavy to transport or part of a large system that would be difficult to simulate at the maintenance shop. Instruments are usually returned to the manufacturer as the last resort; however, there may be reasons which make this necessary including equipment still under warranty or apparatus requiring repair or calibration facilities that are beyond the scope of those available locally.

Maintenance can be undertaken by the same engineering and technician staff that ordinarily use the equipment. Let us call this "distributed maintenance", since it is distributed throughout the laboratory. On the other hand, maintenance can be done by a central facility. A combination of the two approaches described above is also a possibility.

There are some arguments in favor of distributed maintenance. When equipment breaks down, the staff are temporarily out of work, they might as well repair the broken-down unit immediately. Also, the equipment need not be transported; this avoids the possibility of damage in transit.

Arguments in favor of a central repair facility are that staff who continually maintain instruments can be much better trained in that aspect of the work. They become familiar with a class of instruments and are thus able to identify faults more rapidly than a person who only occasionally does repairs. It is also more efficient if spare parts, calibration and maintenance aids and the repair instruction manuals are all located at one site.

Arguments in favor of a combination distributed-centralized repair facility are that minor repairs such as broken control knobs or pilot lights can be taken care of locally with more extensive repairs being made at the central shop. Maintenance at our Laboratory follows the distributed-centralized repair concept.

III. MAINTENANCE FACILITIES

It is important that adequate working area be assigned for the maintenance of laboratory equipment. Using the facilities of our Laboratory as an example, Fig. 1 is a plan view of an area of approximately 272 m^2 assigned to the repair of equipment such as oscilloscopes, signal generators, power supplies and mobile radios. Fig. 2 shows an adjacent area of 114 m^2 in the same building used to recondition meters and chart recorders.

An adequate library is a crucial part of any maintenance organization. It should include several types of maintenance aids. Handbooks and texts supplying general maintenance information or suggested repair procedures are difficult to find. Reference 2 is an excellent treatment of the subject; although the principles of measurement are still in vogue, the instruments employed for making the measurements are being replaced by newer models with improved characteristics. Ref. 3 is a later handbook by the same author. The Instrument Society of America has a division concerned with the maintenance of industrial instruments. A number of their publications should be of interest to those maintaining analytical instrumentation.[4,5] Several manufacturers provide monographs and periodicals of general interest to maintenance technicians. Examples of these services are listed in Ref. 6, 7 and 8. In addition, several journals include frequent articles on operating characteristics of new instruments and occasionally ideas useful for upkeep and maintenance.[9,10,11] Specific instruments should only be serviced with the aid of the instruction manual supplied with that specific model of equipment.

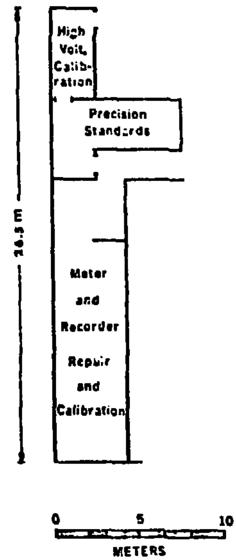

Fig. 1

STANDARDS AND METER SHOP

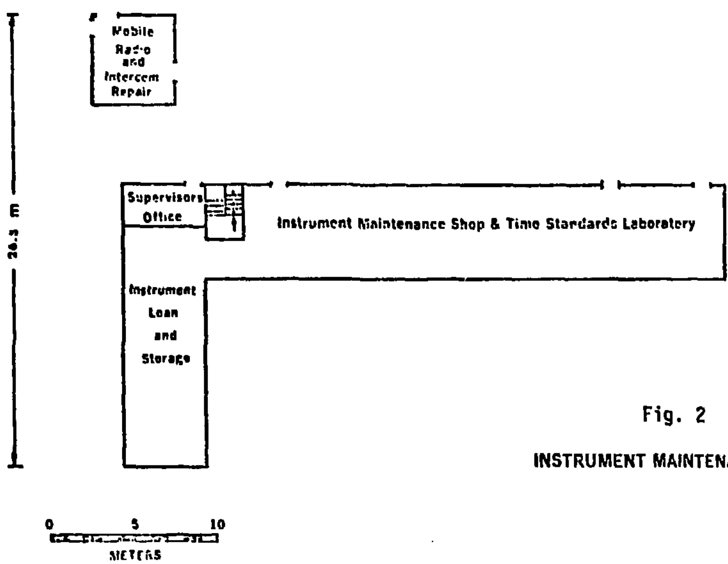

Fig. 2

INSTRUMENT MAINTENANCE SHOP

Finally, catalogs and component handbooks are useful to describe the operating characteristics of the individual components (such as integrated circuits) as an aid to finding substitute spare parts when a replacement for the original part is not available.

Cassette audio and video tapes are beginning to be a powerful new tool for maintenance instruction. See, for example, Ref. 12. The advantage of video tape instruction is that the lecture can be repeated many times until the student masters the concepts presented; a human teacher would soon tire of making an oft repeated delivery.

Fig. 10 shows a part of the library in our maintenance shop.

IV. MAINTENANCE STAFF

Now let us consider the qualities and experience needed for maintenance technicians. Good repair personnel require a particular temperament; they must be meticulous yet quick to grasp technical details. They should be more interested in repairing the apparatus than attempting to redesign it. (Good design technicians make poor repairmen; they continually try to modify the equipment in an attempt to up-grade it.)

As discussed in a related paper, our Laboratory technicians are selected on the basis of a combination of ability, education and experience.[13] On-the-job training is a vital component of improving the performance and capability of the maintenance staff.

Ref. 14 is an excellent discussion of the suggested curriculum, text books and training aids for a 2 year program to train those interested in becoming instrumentation specialists. This work, first published in 1964, is presently out of print and being revised; it is expected to be available as an Instrument Society of America report early in 1977. Management staff responsible for technician training are urged to refer to this new report or others of a similar nature.

The staff of our various maintenance facilities are organized into groups corresponding with the different types of equipment they repair. For example, small computers and their peripherals are maintained by a Real Time Computer Systems Group; nuclear instrumentation is repaired by the Measurement Techniques and the Physics Systems groups; oscilloscopes, signal generators and recorders are reconditioned in the Engineering Support Group. See Ref. 15 for an organization chart of the above groups in the Electronics Engineering Department.

V. MAINTENANCE PROCEDURES

It would be useful to consider a flow diagram of the procedures followed after instrumentation has been acquired by a research organization. What must be done to facilitate speedy maintenance when it becomes needed? See Fig. 3. It is an evidence of poor planning if the maintenance staff are suddenly confronted with an equipment malfunction in an instrument they have never seen before. In contrast, good planning requires that the staff have had an opportunity to examine each piece of new equipment to see if it is operating properly as well as order spare parts that may be peculiar to that unit. It is important that a second instruction and repair manual be ordered at this time if it was overlooked in the initial procurement. One manual should become a part of the maintenance library which has already been discussed.

The following discussion describes procedures followed in repairing an instrument at our Laboratory. Fig. 4 shows the record card which is filled out for each new instrument as it is acquired. This information is fed to a computer and bi-monthly property logs published of the equipment on hand at the Laboratory. See Fig. 5.

After an instrument has been in service it will sooner or later require recalibration or repair. Some instruments may be self-calibrated, i.e., the means for recalibration are designed into the unit; others must be sent to a central facility for this service. As has been mentioned earlier, minor repairs are expected to be made by the user himself. For more extensive up-keep and reconditioning most laboratory instrumentation is sent to the appropriate facility to be repaired. Fig. 6 and 7 show a Tektronix oscilloscope being brought to the maintenance shop and logged in. Fig. 8 is a copy of the repair form that is filled out for each instrument. By means of multiple copies this document serves three functions: one tag attached to the instrument indicates the work to be

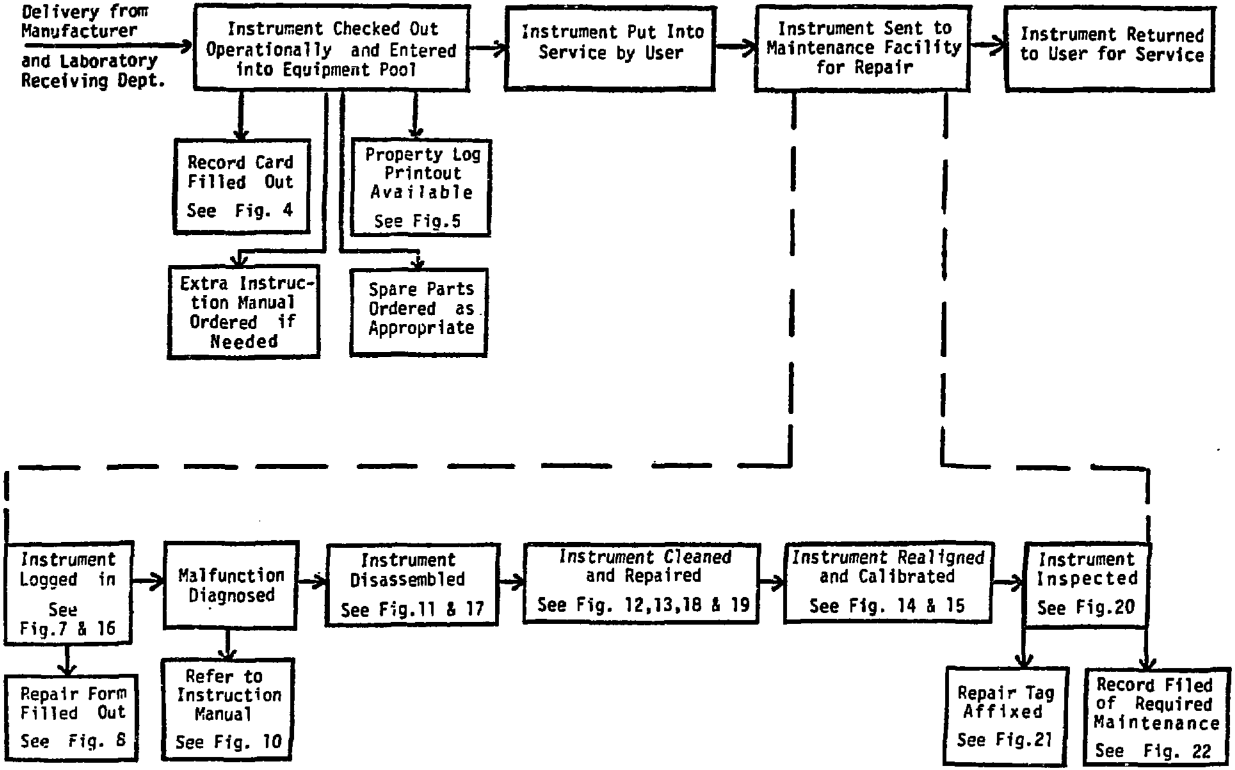

Fig. 3 Flow Diagram: Example of instrument maintenance procedure.

CAPITAL ASSETS RECORD CARD

DESCRIPTION: OSCILLOSCOPE AEC# 121364

P.O. # 9279406	REC. DATE 11-18-63		
PURCHASE ACCOUNT 7931-01	COST $570.00		SERIAL # 000559
I.L. REC. Yes	E.M.✓ No	MFR TEKTRONIX	MODEL # 567

ACCOUNT	BOOK & PAGE	NAME	LOCATION	DATE	RETURN TO STOCK BOOK & PAGE	RETURN TO STOCK DATE
4284-01	Code 22	Bill Smith	7-214	11-19-63		

LOCATION:

DATE:

LOCATION:

DATE:

Fig. 4 Information filed on each instrument as it is acquired.

PROP NO	NOMENCLATURE	ACQ	MANUFACTURER	MOD/TYPE	SERIAL NO	U ACCT	BLDG	ROOM	AREF	COST
00137001	PUMP VACUUM 21CFM	10-67	KINNEY VAC	KTC21	773L-P6511-2	5175-05	2341	MBN		712.95
00137002	SAW CIRCULAR	10-67	DEWALT	11633	537305	3321-01	2231	1203		846.55
00137003	DRILL PRESS BENCH	10-67	DELTA	15-491	1432974	3321-01	2151	1341		350.00
00137004	GRINDER	10-67	ROYAL MASTER	TG12	540	5429-11	2321	1437	ISS	8,351.00
00137006	LATHE METAL	10-67	HARDINGE	HLV-H	3209	3321-01	2261	1016		7,770.90
00137007	GENERATOR	10-67	ONAN DIV	5CCK-4RV	1070988426	5570-13	432	HHS2		848.00
00137008	TRANSFORMER STEPDOWN	10-67	JEFFERSON	75KVA	21867-3	9999-11	2131	1192		
00137010	CHILLER	08-55	TRANE	15CT	12266	9959-11	2121	1192	UTIL	
00137011	CHILLER	08-55	TRANE	40CT	1-2359	9999-11	2121	1192	UTIL	
00137012	POSITIONER WELDING	10-67	READ	UTP-30-T	162295	3321-01	2321	2411		1,555.00
00137014	PUMP VACUUM 118CFM	10-67	HERAEUS	DK180	180L6924	5175-05	2332	1361		1,730.00
00137015	POLISHER	10-67	BUEHLER	44-1502	NONE	5429-11	2412	1246	LOFT	
00137016	POLISHER	10-67	BUEHLER	44-1502	NONE	5429-11	2412	1240	LOFT	
00137039	FORMING MACHINE	10-67	AUTO-VAC	LABVAC	NC31067	5418-85	2404	G100		912.36
00137040	PUMP. VACUUM	10-67	HERAEUS	WS150	01201306	5570-35	2000	V143		1,621.83
00137041	REFRIGERATION UNIT	11-67	BENDIX WEST	BRL-113<	L6C706	5195-10	2222	OSSE		
00137042	PRESS	11-67	RES + IND	L30	0356R	5429-13	2231	1240		[illegible]
00137043	PUMP VACUUM 10CFM	11-67	WELCH	1376	681	5735-91	2131	2366		550.00
00137044	PUMP DIFFUSION	11-67	CON VACUUM	43	7041	5735-91	2131	2379		[illegible]
00137045	DRILL PRESS FLOOR	09-67	JOHANSSON I	MEL-914	31887	3321-01	2432	1200		4,356.00
00137049	PUMP VACUUM T/M 260 L/S	11-67	WELCH	31028	415	5735-91	2131	2283	A	3,850.00
00137050	CLEANER VACUUM	11-67	DANZIG FLOOR	V520	4333	3280-01	2511	0112		
00137051	CLEANER VACUUM	11-67	DANZIG FLOOR	V520	4334	3280-01	2511	0112		
00137052	TRAILER	11-67	MONTGOMERY	WEW30398	154213	3295-07	2321	OSH		1,610.08
00137063	COMPRESSOR HELIUM	11-67	PRESSURE PRO	3057	67-896	3370-01	840	OSE		4,250.00
00137066	GENERATOR	02-48	MASTER VIBR	PU254/U	386	5560-14	2515			2,138.00
00137067	PLATE SURFACE	11-67	CHALLENGE	F36844	NONE	5735-91	2131	2280		1,064.00
00137068	PLATE SURFACE	11-67	CHALLENGE	P36844	NONE	5735-91	2131	2280		1,064.00
00137071	AIR CONDITIONING UNIT	11-55	ELLIS + WATT	923	3721	5570-35	2166	OSE		[illegible]
00137072	AIR CONDITIONING UNIT	11-55	ELLIS + WATT	923	3722	5570-35	2141	OSN	AC122	[illegible]
00137073	LIFT	11-67	BIG JOE	1076SP	49831	5155-13	2234	OSH		802.50
00137074	LAPPING MACHINE	11-67	NORTON	28F	6V3246X	3321-01	2321	2348	B	13,894.00
00137075	MOTOR ELEC COMP	11-67	GEN ELECTRIC	5CD366E4	GE1303	3321-01	2321	2348	B	250.00
00137076	LATHE METAL	11-67	HARDINGE	HSL59	13120	5140-13	2231	2730		1,720.20
00137077	LATHE METAL	11-67	HARDINGE	HSL59	NONE	5680-11	2251	1225		1,731.30
00137078	LIFT	11-59	CLARK EQUIP	NR40	AE161	3230-03	2411	1600	ISS	7,539.00
00137079	APPARATUS ZONE MELTING	11-67	VARIAN	9281167	MEL943C	5680-11	602	R329	684733	45,885.00
00137081	PLATE SURFACE	12-67	CHALLENGE	P30602	NONE	5735-91	2131	2280		415.00
00137081	PLATE SURFACE	12-67	CHALLENGE	P30602	NONE	5735-91	2131	2281		415.00
00137082	PLATE SURFACE	12-67	CHALLENGE	P30602	NONE	5735-91	2131	2281		415.00
00137083	PLATE SURFACE	12-67	CHALLENGE	P30602	NONE	5735-91	2131	2281		415.00
00137084	TRANSFORMER POWR DIST	12-67	HILL MAGNET	105KVA	16696	5140-05	602	84	L81066	[illegible]
00137085	PUMP VACUUM 300CFM	12-67	KINNEY VAC	KD30	8451A1231	5570-35	2300	V007	OSN141	820.00
00137086	PUMP VACUUM 400CFM	12-67	KINNEY VAC	KPB0430	84511	5570-35	2300	V007	OSN141	2,830.05
00137089	LATHE METAL	12-67	MONARCH MACH	C	CK10083	3321-01	2321	1000	ISS	[illegible]
00137091	SAW BAND	12-67	POWERMATIC	678367.	MEL6420	3321-01	2343	1220	B	1,660.00
00137092	SAW BAND	12-67	POWERMATIC	676361	MEL642C	3321-01	400	0060		1,660.00
00137093	SAW BAND	12-67	POWERMATIC	678501	MEL642D	3321-01	8278	3101		1,699.00
00137094	SAW BAND	12-67	POWERMATIC	678672	MEL6420	3321-01	2151	1341		1,619.00
00137096	PUMP VACUUM 15.88CFM	12-67	CENCO	45	1185	3370-01	2243	1000	ISNW	429.00
00137097	PUMP VACUUM 15.88CFM	12-67	CENCO	45	1186	5652-10	2224	0110		429.00

Fig. 5 Computer printout of laboratory instruments

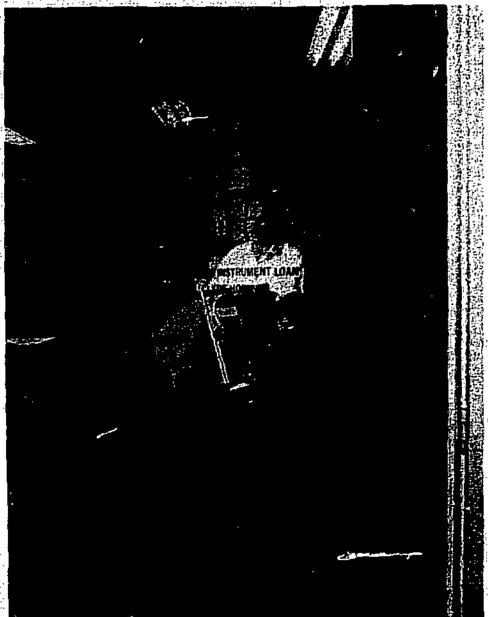

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Fig. 6 Oscilloscope being brought to maintenance facility for repair.

CBB 767-6809

Fig. 7 Instrument being logged in.

UNIVERSITY OF CALIFORNIA
LAWRENCE BERKELEY LABORATORY

ELECTRONIC MAINTENANCE
BLDG. 7 ROOM 214
EXT. 6181

NAME ______________________

BLDG. ________ ROOM ________ PHONE ________ GROUP ______________

NAME ______________________ WILL PICKUP

AEC NO. ________ BLDG. ________ ROOM ________ DATE ________
1 - 6   7 - 10   11 - 14   15 - 18

ITEM ________ MFG. ______________

JOB NO. ________ PHONE ________ DATE NEEDED ________

MODEL ________ SERIAL NO. ________ GROUP ________

DEFECT OR WORK TO BE DONE:

ACCESSORIES:

WORK DONE:

DATE ________ TOTAL HRS. ________ BY ________

RL-1098 (Rev. (9/73)

☆ GPO 792 846

Fig. 8 Repair form filled out for instrument brought in for maintenance.

done; upon repair it becomes a record of the remedial action taken; and it may be used as a shipping tag to return the equipment to the user.

Upon diagnosing the apparent malfunction or operating problem the equipment is usually disassembled, cleaned, realigned, calibrated, reassembled and given a final inspection before returning the unit to its user.

At most laboratories there is a perennial backlog of equipment awaiting attention. Fig. 9 is a photograph of the instruments in our repair facility in this condition. Normally, instruments receive attention on a first-come-first-served basis; however, priority is given to apparatus requiring special attention, e.g., a unique monitor at one of our computers.

Fig. 11, 12, 13, 14 and 15 illustrate the steps we typically take in the rehabilitation of a laboratory oscilloscope. It is of interest to note in Fig. 12 that the manufacturer recommends a water spray saturated with a detergent for removing the accumulated dust from its units. This is followed in Fig. 13 by an oven bake to remove all moisture.

Fig. 16, 17, 18, 19 and 20 show a similar procedure for meters and chart recorders that are undergoing repair.

VI. RECORD OF REPAIRS

Upon completion of these procedures a tag is affixed to the instrument as a reminder of the date of the last service. See Fig. 21.

Records are made of the location of each instrument and kept until the equipment is dismantled or sent to some other institution. The service records of instruments are filed for 3 years. See Fig. 22.

VII. SUMMARY

The role of the instrument repairman is often unappreciated until a vital piece of equipment malfunctions; at this point his services come into immediate demand and the equipment user insists that the unit be repaired without delay. With thorough training in maintenance procedures and planning ahead to procure instruction manuals and spare parts, the delay in returning a unit to service can be minimized.

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Fig. 9 Equipment tagged and awaiting repair.

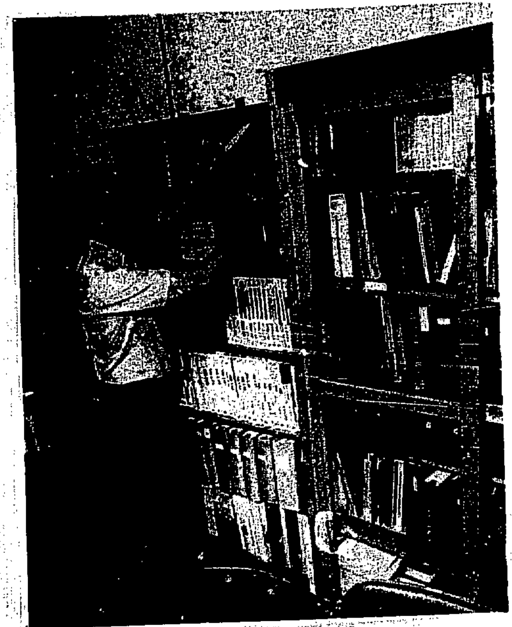

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Fig. 10 Maintenance staff referring to technical manual.

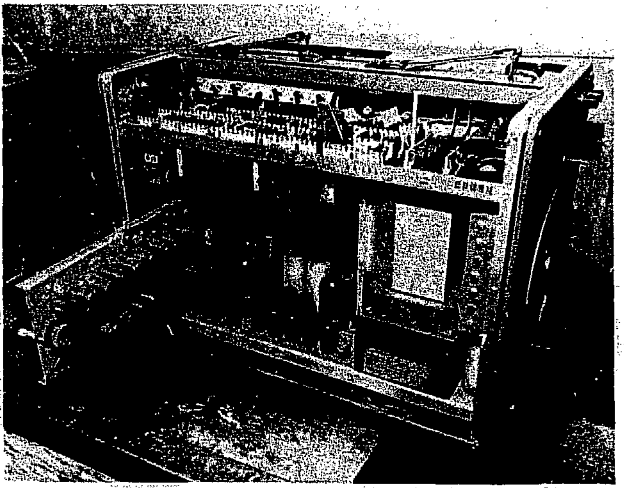

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Fig. 11 Initial disassembly. Note layer of dust on components.

CBB 767-6815

Fig. 12 Some instruments can be cleaned by water spray saturated with detergent.

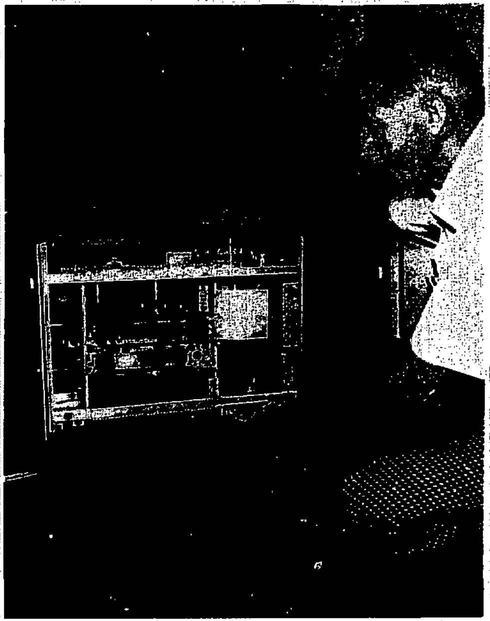

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Fig. 13 Oven bake following spray cleaning.

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Fig. 14 Circuit realignment.

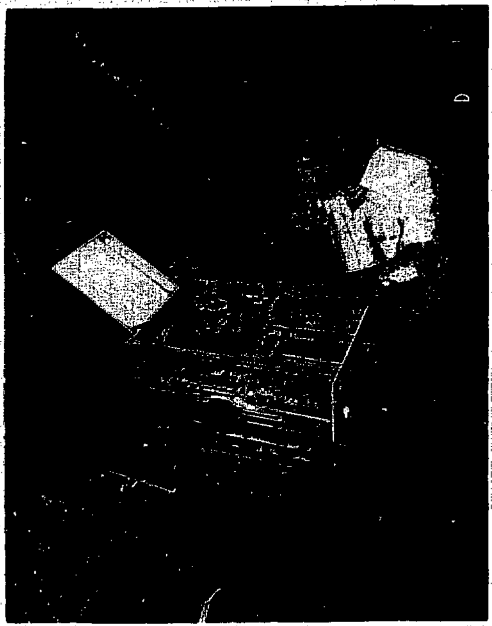

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Fig. 15 Reassembly of subcircuits.

CBB 767-6757

Fig. 16 Portable meters being returned for repair.

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Fig. 17 Disassembly of volt-ohm-milliammeter for repair.

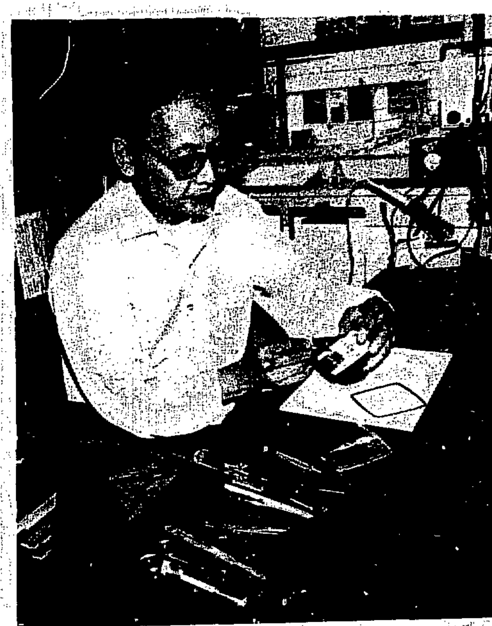

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Fig. 18 Repair of panel mounted meter.

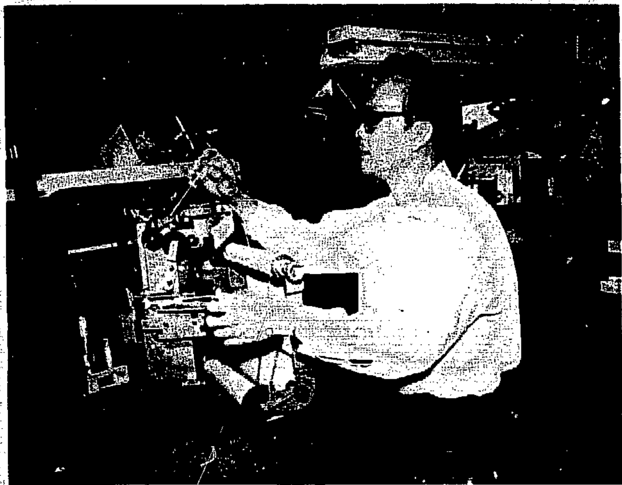

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Fig. 19 Repair of chart recorder.

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Fig. 20 Final inspection of chart recorder after repair.

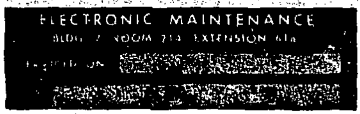

Fig. 21 Tag that is filled out and affixed to instrument after maintenance.

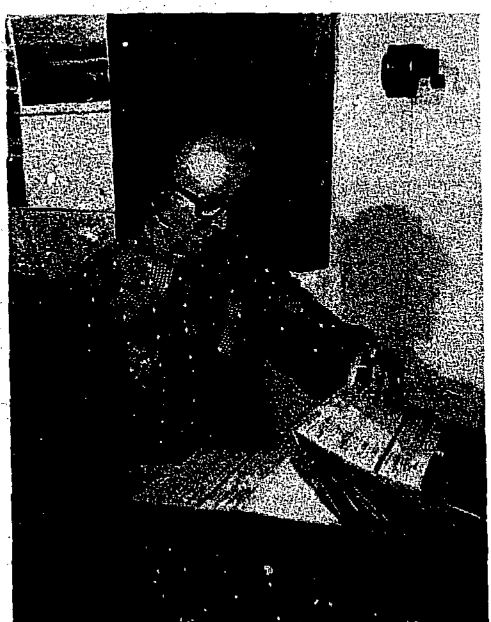

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Fig. 22 Records are kept for each instrument.

ACKNOWLEDGEMENT

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