PRODUCT ASSURANCE FOR SPACEFLIGHT HARDWARE

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ABSTRACT

This report contains information about the tasks I have completed and the valuable experience I have gained at NASA. The report is divided into two different sections followed by a program summary sheet. The first section describes the two reports I have completed for the Office of Mission Assurance (OMA). I describe the approach and the resources and facilities used to complete each report. The second section describes my experience working in the Receipt Inspection/Quality Assurance Lab (RI/QA).

The first report described is a Product Assurance Plan for the Gas Permeable Polymer Materials (GPPM) mission. The purpose of the Product Assurance Plan is to define the various requirements which are to be met through completion of the GPPM mission. The GPPM experiment is a space payload which will be flown in the shuttle's SPACEHAB module. The experiment will use microgravity to enable production of complex polymeric gas permeable materials.

The second report described in the first section is a Fracture Analysis for the Mir Environmental Effects Payload (MEEP). The Fracture Analysis report is a summary of the fracture control classifications for all structural elements of the MEEP. The MEEP hardware consists of four experiment carriers, each of which contains an experiment container holding a passive experiment. The MEEP hardware will be attached to the cargo bay of the space shuttle. It will be transferred by Extravehicular Activity and mounted on the Mir space station.

The second section of this report describes my experiences in the RI/QA lab. I listed the different equipment I used at the lab and their functions. I described the extensive inspection process that must be completed for spaceflight hardware. Included, at the end of this section, are pictures of most of the equipment used in the lab.

There is a summary sheet located at the end of this report. It briefly describes the valuable experience I have gained at NASA this summer and what I will be able to take with me as I return to college. I briefly discuss the experiences I mentioned in the previous three paragraphs along with training classes I attended and courses I completed at the Learning Lab.

OFFICE OF MISSION ASSURANCE (OMA)

Product Assurance Plan

My first project consisted of preparing a Product Assurance (PA) Plan for the Gas Permeable Polymer Materials (GPPM) mission. The purpose of the Product Assurance Plan is to define the requirements for configuration management, reliability, quality assurance, parts, materials, processes, and system safety which are applicable for design, procurement, fabrication, assembly/disassembly, and test operations for Langley Research Center deliverables through completion of the GPPM mission.

The purpose of the GPPM experiment is to use microgravity to enable production of complex polymeric gas permeable materials. This experiment will be put aboard the SPACEHAB module which is integrated into the Orbiter cargo bay. SPACEHAB provides a shirtsleeve environment for performance of multiple experiments.

The material resources I used to accomplish this task were the manual (LHB 5300.1), the handbooks NHB 5300.4(1B) and 5300/4(1A-1), and a PA Plan for a previously completed experiment. The human resources I took advantage of, in the Office of Mission Assurance, to complete the plan were the program assurance manager, GPPM project personnel, payload safety engineer, and the reliability engineer.

The first section of the Product Assurance Plan includes the classification of the payload, the mission success criteria and a list of the Office of Mission Assurance's Product Assurance Services. GPPM is a "Class D" payload. This means that this payload has objectives worth achieving at a cost not to exceed the amount required for a single low cost attempt where single failure points are acceptable and formal verification requirements are limited to those necessary for safety and compatibility. The mission success criteria for the GPPM experiment will be met if it maintains mechanical and electrical integrity from launch through landing and has the capability to enable a variety of sample tube monomer mixtures to polymerize. I worked with the program assurance manager to determine all of the items to be furnished to the Project Leader at appropriate times.

The second section of the PA plan states where the GPPM Project Team Organization can be found and describes the responsibilities of the Product Assurance Engineer. The Product Assurance Engineer is responsible for assuring the overall implementation of the requirements of the PA plan consistent with the intent of the Product Assurance Instruction 5300.1 "Program Assurance: General Policy, Responsibility, Authority, and Implementation."

The reliability assessment and design specifications for the GPPM are included in the third section of the PA plan. I found out, from the reliability engineer, the type of reliability analysis that will be done on GPPM. The GPPM had been flown on previous missions successfully without a reliability analysis being done. Therefore, a reliability analysis does not need to be done for the current experiment. Design data will be reviewed to ensure that quality, reliability, and safety considerations have been factored into the flight hardware design.

The fourth section of the PA plan establishes a Configuration Management System for the control of the GPPM experiment. This section cites the way design changes are dealt with and how parts, materials, and processes are to be accounted. The GPPM Project Manager shall be responsible for providing and implementing a GPPM Configuration Management Plan prior to fabrication of flight hardware. The plan should identify the configuration management system to accurately define and control the configuration of flight hardware, spares, and ground support equipment.

Procurement Program Assurance is covered in the fifth section of the PA plan. The purchase request review, receiving and inspection, the acceptance/rejection of received articles, receipt inspection and supplier documentation requirements are contained in this section.

The sixth section covers parts, material selection, and process control. Parts shall be selected which optimize design and performance to certain extents specified. The Electrical, Electronic, and Electromechanical (EEE) Parts Manager shall approve all EEE parts in the GPPM hardware and is responsible for qualification, screening, testing, and failure analysis as required. The EEE Parts Engineer shall develop the GPPM Parts list and show lot/date codes as appropriate. Fasteners received at Langley Aerospace Research Center will be verified by the Receiving and Inspection Lab per GPPM specifications (I was able to do this task of verifying fasteners at the Receiving and Inspection lab as I will describe under the topic heading "Receipt Inspection/Quality Assurance Lab"). A materials and limited life items list shall be prepared. Metals will be selected using MSFC 522B "Design Criteria for Controlling Stress Corrosion Cracking," as a reference and all GPPM hardware will satisfy outgassing constraints in accordance with JSC 09604F/MSFC-HDBK-527F.

Quality control requirements are contained in the seventh section of the PA plan. Electrostatic Discharge Control (ESD), fabrication control, inspection and testing, assembly and integration, nonconforming articles and material control, bonded stores, metrology control, QA stamp control, the end-item data package and handling preservation and shipping all have requirements included under quality control. Most of these topics' requirements are defined in certain cited handbooks. The end-item data package provides cognizance of the functional characteristics, and flight worthiness of the hardware to be shipped and subsequently maintains configuration accountability.

The eighth and final section describes what will be done for system safety of the GPPM experiment. A reflown assessment will be developed and documented based on the Safety Analysis presented to the Safety Review Panel for previous flights. All safety reviews shall be held in accordance with the phased system as defined in NSTS 13830B.

Fracture Analysis

My second project consisted of preparing a fracture analysis report on the Mir Environmental Effects Payload (MEEP). The MEEP hardware consists of a sidewall carrier and four Passive Experiment Carriers (PEC), each of which contains an experiment container holding a passive experiment. The PEC's will be attached to the cargo bay of the space shuttle. They will be transferred by Extravehicular Activity and then mounted on the Mir space station.

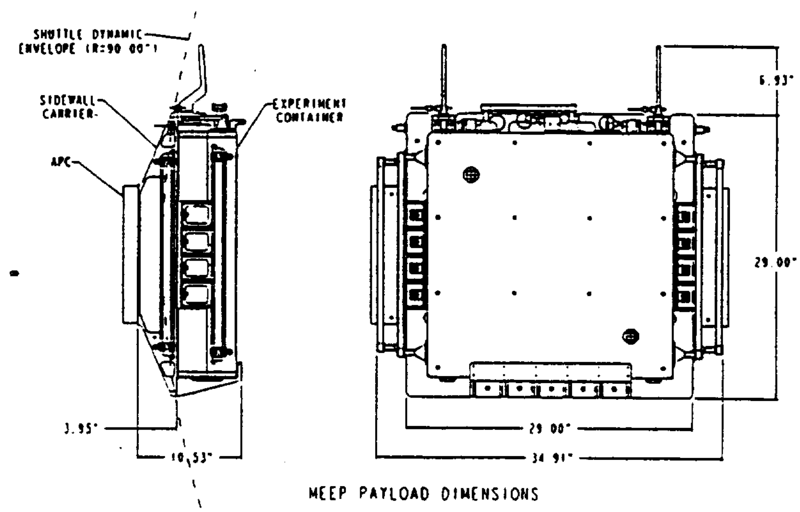
The fracture analysis report is required for the flight certification of Shuttle payloads by NHB 8071.1. The fracture analysis report is a summary of the fracture control classifications for all structural elements of the MEEP. Each component may fit under one of five categories: contained, fail-safe, low risk fracture, low released mass, or fracture critical. The structural elements have been fabricated from materials that have high resistance to stress corrosion cracking (SCC). For each part, the material is listed along with its SCC classification.

The first step that needed to be taken, in order for me to be able to determine the information needed to complete the requirements stated in the paragraph above, was to obtain the drawings for the hardware under consideration. I obtained the drawings from the aerospace system engineers who drew them. These drawings of the individual structures of the MEEP show the material of which each component is made. I then listed, in my report, the components of the MEEP, followed by the material they are made of and the stress corrosion cracking (SCC) classification of the material. The SCC classification for each material was obtained from the booklet "Design Criteria for Controlling Stress Corrosion Cracking." A classification of 1 indicates high resistance to SCC, 2 indicates moderate resistance, and 3 indicates low resistance.

I then studied the drawings of each component very carefully to determine their fracture classifications. A full-scale model of the MEEP was also available, in the systems engineering building, to study in order to get a better picture of its components. In order to classify each component, I determined fractures that could occur in each component that would cause a worst case scenario. If a component is classified as being contained, it can fracture and not be a threat to the payload of the shuttle, due to it being contained by a surrounding structure. A fail-safe component is designed with redundancy, which means if one part of its structure failed there would still be another structure holding the part in place. Low released mass is a classification given to a structure which does not have the potential to do damage to the shuttle payload if it fails, due to its light weight (Mass < 2.5 lb.). The classification "fracture critical," raises the most concern of all the possible classifications a structure can be labeled. If a structure is fracture critical, it may cause damage to the shuttle if it fails (catastrophic failure). Engineers try to design the structures to contain a minimal number of fracture critical parts. Low risk fracture is a classification which permits hardware which would ordinarily be defined as "fracture critical" to be classified as "non-fracture critical" when the possibility of failure due to a crack-like flaw can be shown to be extremely remote.

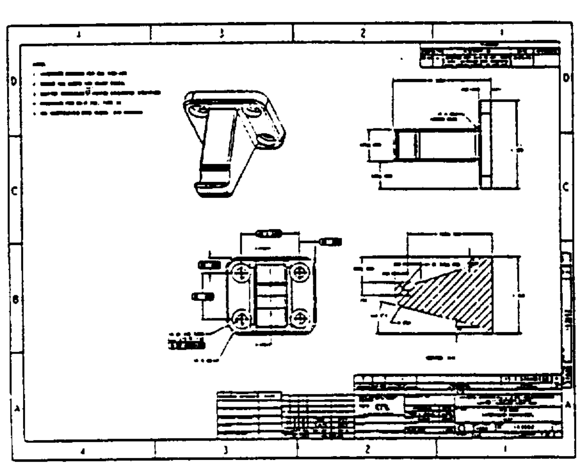
Every component of the MEEP was made of either 6061-T6 AL, 7075-T73 AL, A286 SST, or 300 series SST. These are all materials which have high resistance to stress corrosion cracking and therefore, in the analysis, each component was given a SCC classification of 1. Most of the components of the MEEP were identified during the analysis as being either fail-safe or a low released mass. The attention should be drawn to the two components which were found to be fracture critical. These components are the hook latches located on top of the experiment container and on the sidewall carrier and the latch plate pins which join the latches to the sidewall carrier (drawings of these components along with the entire MEEP structure are shown below). If a crack propagated at the bottom of the hook latch, above where it is bolted on to the structure, causing the component to fail, it would become a projectile. This projectile would weigh more than .25 pounds and has potential to do damage to the shuttle payload (if it weighed less than .25 pounds, it would be considered a low release mass as stated earlier). The latch plate pins are also considered fracture critical since if one failed, the entire latch assembly would become a projectile which weighs much more than .25 pounds. Stricter and more numerous inspections will be done on these fracture critical components.

MEEP Payload Drawing

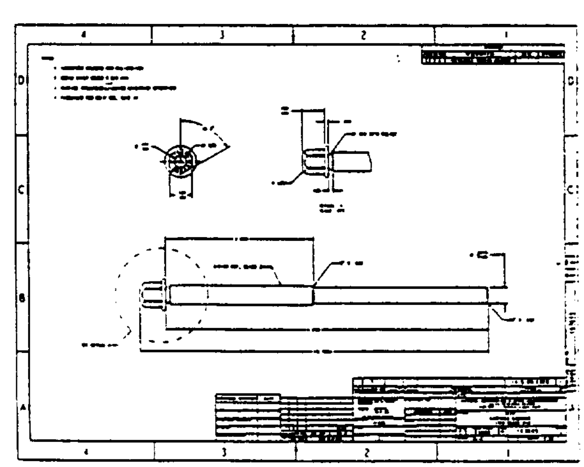


Fracture Critical Components

Hook Latch



Latch Plate Pin



Receipt Inspection / Quality Assurance (RI/QA) Lab

I was fortunate enough to be able to spend some time working with the inspectors at the Receipt Inspection/Quality Assurance (RI/QA) Lab. The inspectors are employed by Mason & Hanger who are contractors at NASA. I conducted various quality inspections and verification tests of incoming stock and spaceflight hardware. I gained experience on the equipment used in the inspection process. The following list shows the equipment I used. There are pictures of most of these machines at the end of this section.

- Cutting Saw - cuts a section of material to be mounted by the mounting processing system.
- Mounting Press - encapsulates specimens to be metallographically prepared and examined.
- Grinder - prepares samples for metallographic examination by using progressively smaller abrasive materials to remove distorted surface material from the sample so it can be studied under a microscope.
- Stereoscope/Microscope Video package - allows low and high magnification of prepared samples to view surface coatings and to determine surface discontinuities.
- Measurement System - video measurement system which measures coating thickness and non-conformities.
- EDAX (energy dispersive X-ray fluorescence) system - Spectra chemical microanalysis system which uses X-ray energy to excite unknown elements causing them to give off their own specific energy which allows each element to be identified in a test specimen.
- Magnaflux F.P.I. Processing System - uses florescent penetrant inspection to detect discontinuities exposed to a specimens surface.
- Hardness Tester - performs the Rockwell Hardness Test to determine the hardness of a specimen.
- Micro-hardness Tester - performs the Rockwell Hardness Test on very small and thin samples.
- Tensile Tester - determines the mechanical properties of a specimen, such as, ultimate tensile strength and reduction of area.
- Laser Thread Measurement System - non-contact thread measurement system used for determining root radius, flank angles, functional diameter, etc.

In the inspection process, there is a chart that is followed in the lab which specifies the number of samples that must be tested from a certain lot, depending on the number of pieces contained in the lot. The most ideal method would be to test every part in a lot, but this takes too much time and money to be effective. The idea is to choose samples which represent the entire population. NASA follows the "zero-defect" policy. This policy states that if one of the pieces in the lot does not meet its' specifications, the whole lot is rejected. This strict rejection policy gets the manufacturer's attention providing an extra incentive to make parts strict to their specifications.

During my time at the lab, screws were the main items being tested. First, every inspection machine must be calibrated. Then I would pick a designated number of samples out of the lot, referring to a chart. Then I would perform a variety of tests on the samples.

The first test I would perform on these samples is a visual test. This would consist of seeing if they would properly screw into a pre-tapped hole of the screws specified measurement, and simply looking at the screw to see if there were any noticeable defects. Then one sample from each lot would be tested for its proper thread dimensions using the Laser Thread Measurement System. This is a very precise non-destructive test, which virtually eliminates human error. NASA is one of the few places to have purchased one of these devices.

Then a chemical test is performed to see if the sample was made of the material specified. Many times manufacturers have sold zinc coated screws to NASA, while telling NASA they were coated with cadmium. This is because it is cheaper and easier for the manufacturers to coat screws with zinc, and they could still charge cadmium coating prices, if this went undetected. The EDAX machine keeps manufacturers from getting away with delivering pieces made with material other than what was specified in the contract. The EDAX is an X-ray device which can determine the percentage of each element present in a sample.

A tensile test or hardness test should then be done on the sample. A tensile test can be done on most screws and is done to see if it meets or exceeds the minimum tensile strength stated in the specifications. The screw's length and width must be measured before and after the test in order for the elongation and reduction of area to be calculated. This is a destructive test which literally pulls the screw until it breaks apart in order to find it's ultimate tensile strength.

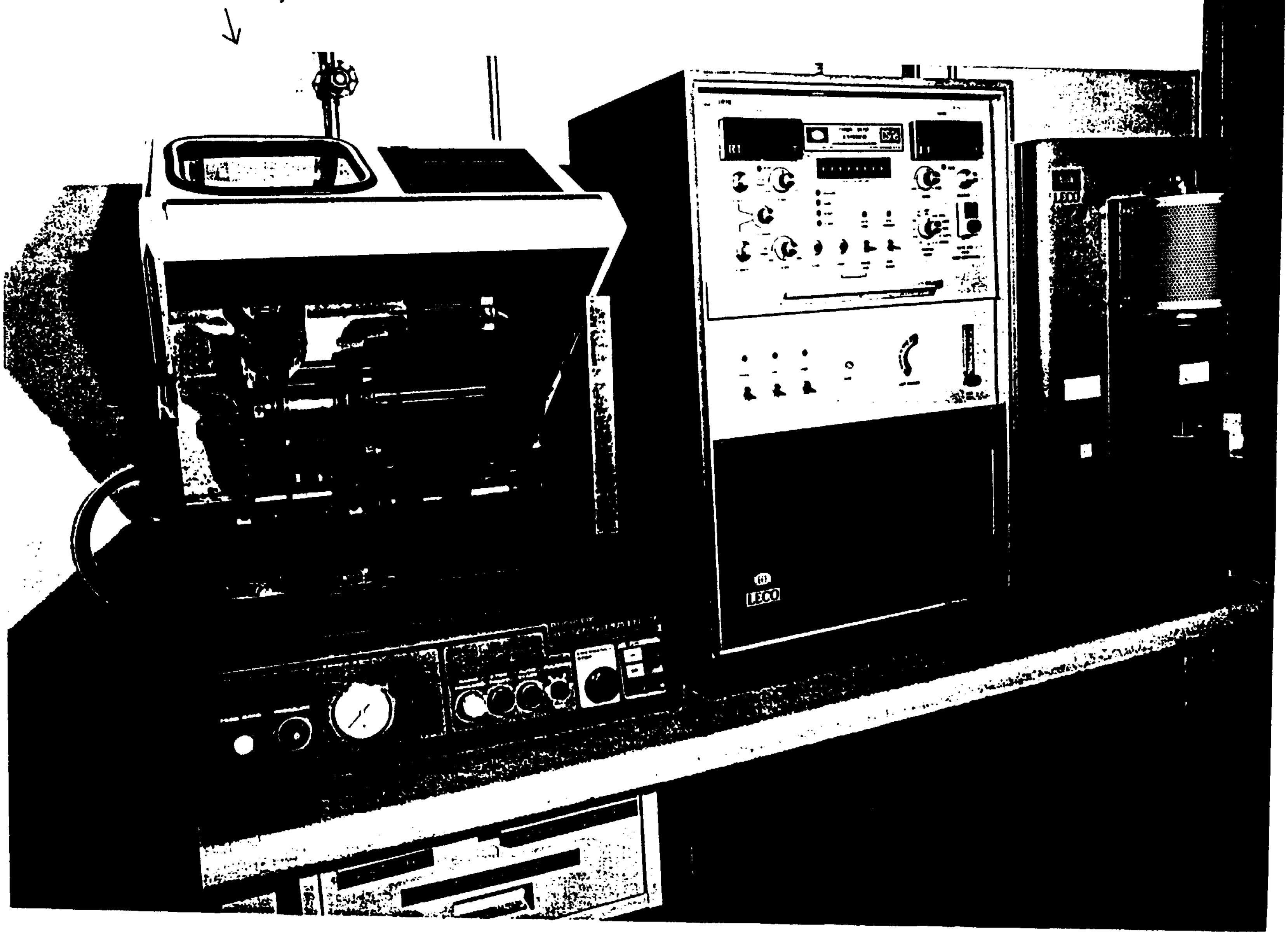
If the screw can not be placed in the tensile test machine, it must be prepared for a Rockwell Hardness test to be executed with either the Hardness Tester or the Micro-hardness tester, depending on the specimen's size. The preparation phase is a rather long process for this test. First the specimen should be cut, using the cutting saw, to about one centimeter long. Then, the specimen is mounted using the Mounting Press. A flat, polished surface, free from obstructions must be exposed in order to do the hardness test. Therefore, a grinder is used to achieve this purpose, using progressively smaller abrasive materials to remove distorted surface material. After this process is finished, the sample can then be tested for hardness. A test for coating thickness can also be done to the specimen after it has been prepared in the way stated.

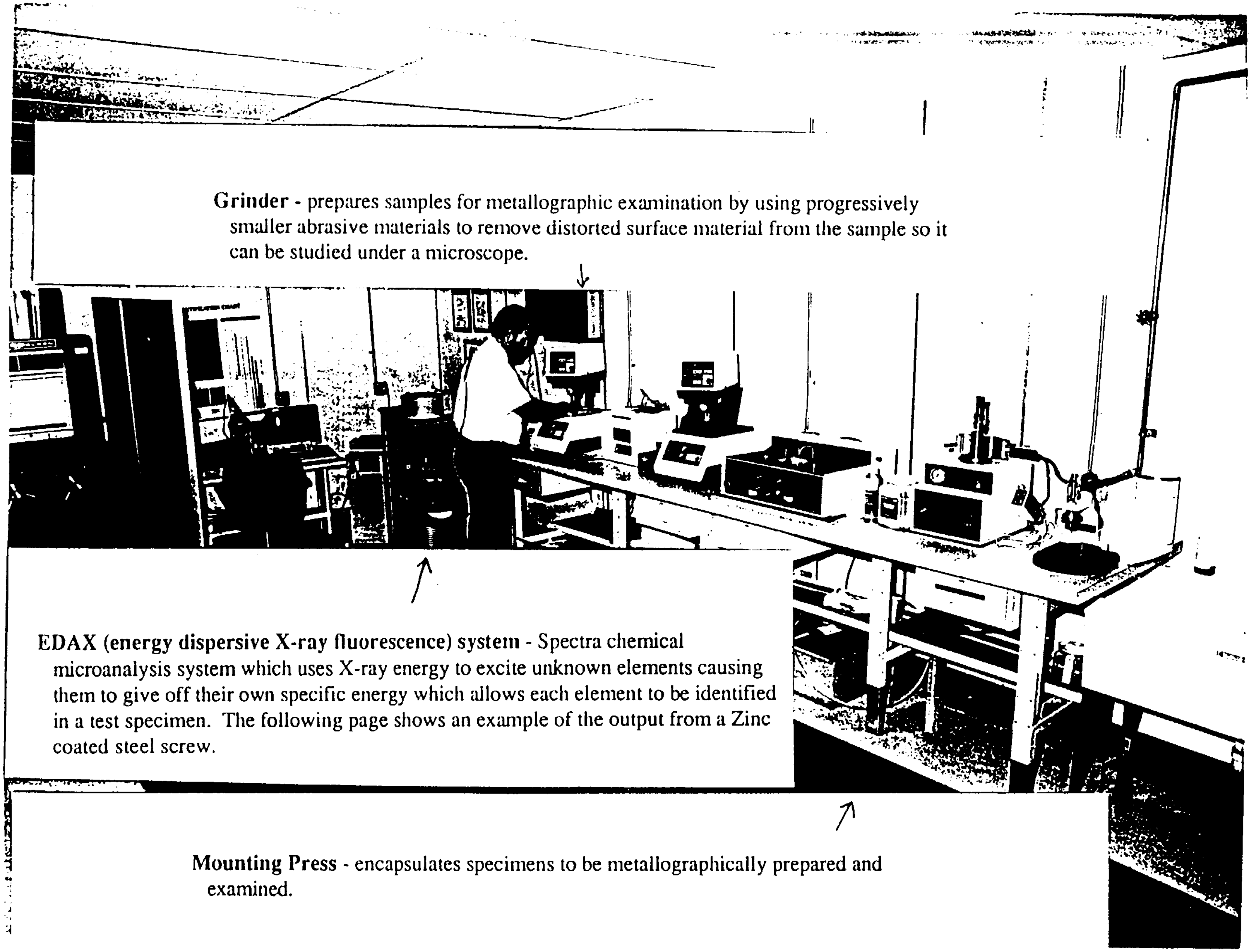
In order to see if a specimen has been coated with the specified amount of material, the Stereoscope/Microscope Video package is used along with the video Measurement system. The specimen is magnified many times with this system. The image of the specimen is shown on a monitor. Pointers can then be toggled around the coating layer of the specimen on the video screen. The system automatically measures the distance between the two pointers, determining the coating thickness of the specimen. This entire system can also be used to show irregularities in the material. The system can print a picture of the image displayed on the monitor to be used for the sake of argument when dealing with manufacturers of faulty components.

The Magnaflux F.P.I. Processing System is used mainly for pressure fittings to see if there are discontinuities on the surface of the specimen. One must be a level III inspector in order to do diagnose faults in specimens, using this test.

With NASA's zero defect policy, if any of the tests mentioned above, shows a result which does not agree with the specifications of the part being examined, all of the parts are rejected. During my stay, only one of the lots I worked with was rejected. It was rejected because there were bolts contained in this same lot made by two different manufacturers. This was made illegal, since the parts lose their tractability causing it to be impossible, at times, to hold a specific manufacturer accountable for the quality of their products.

Cutting Saw - cuts a section of material to be mounted by the mounting processing system.

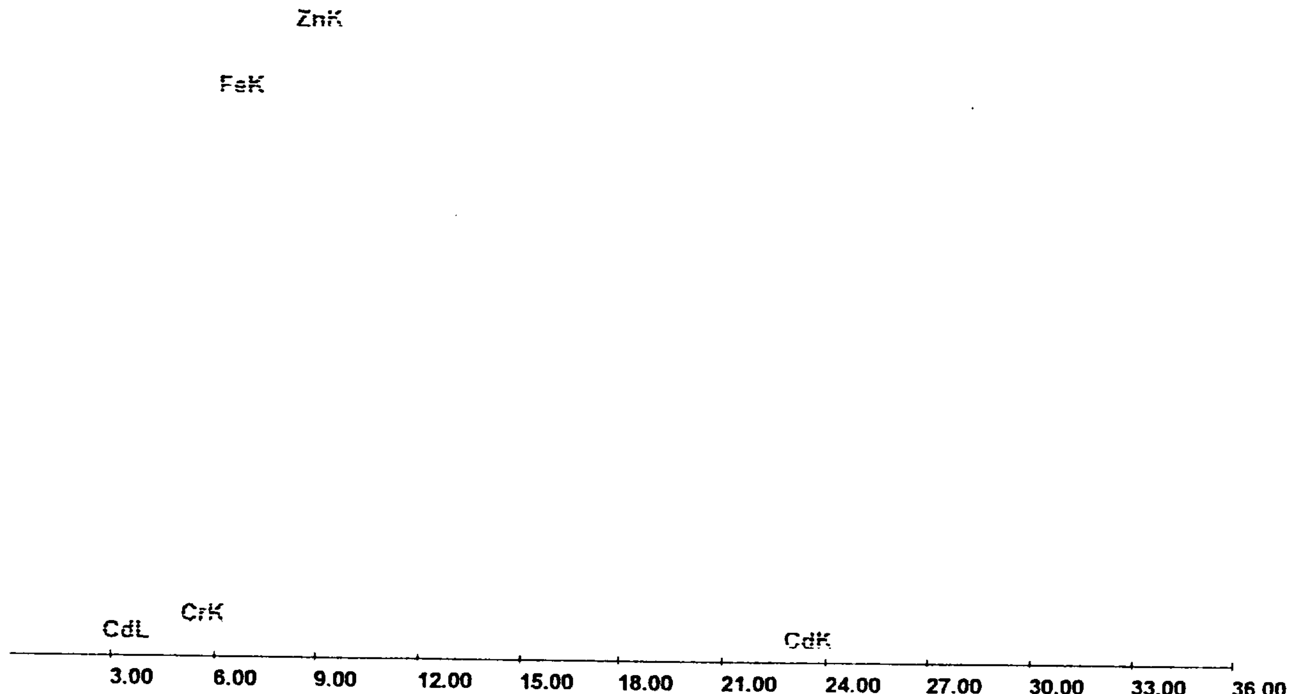



Grinder - prepares samples for metallographic examination by using progressively smaller abrasive materials to remove distorted surface material from the sample so it can be studied under a microscope.
EDAX (energy dispersive X-ray fluorescence) system - Spectra chemical microanalysis system which uses X-ray energy to excite unknown elements causing them to give off their own specific energy which allows each element to be identified in a test specimen. The following page shows an example of the output from a Zinc coated steel screw.
Mounting Press - encapsulates specimens to be metallographically prepared and examined.

c:\dx4\xrf\4294.spc

Label:TEST

Prst:200L Lsec:200 11:25:14 7-13-95

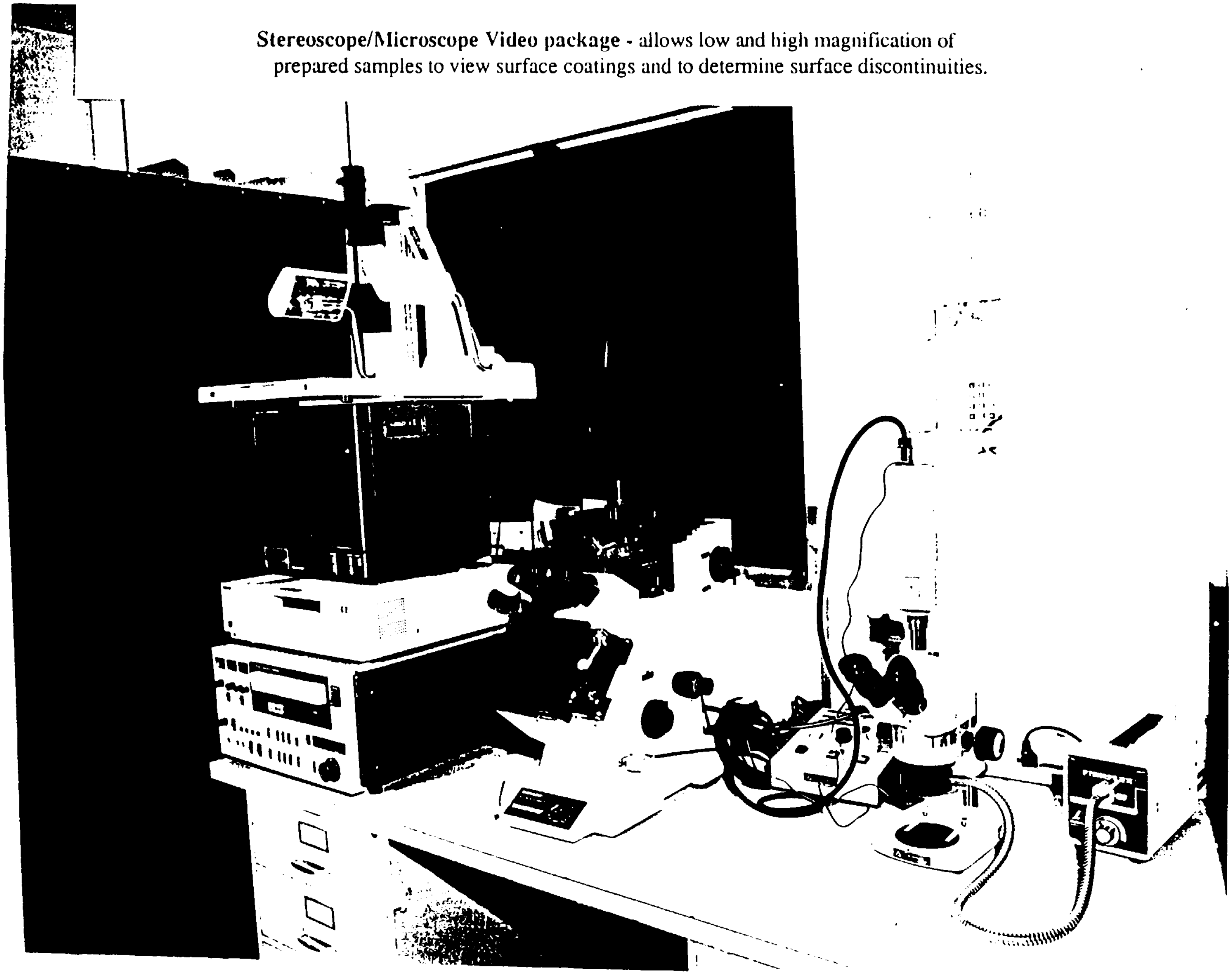


FS : 1380 CPS : 260 Cnts : 2 KeV : 10.58

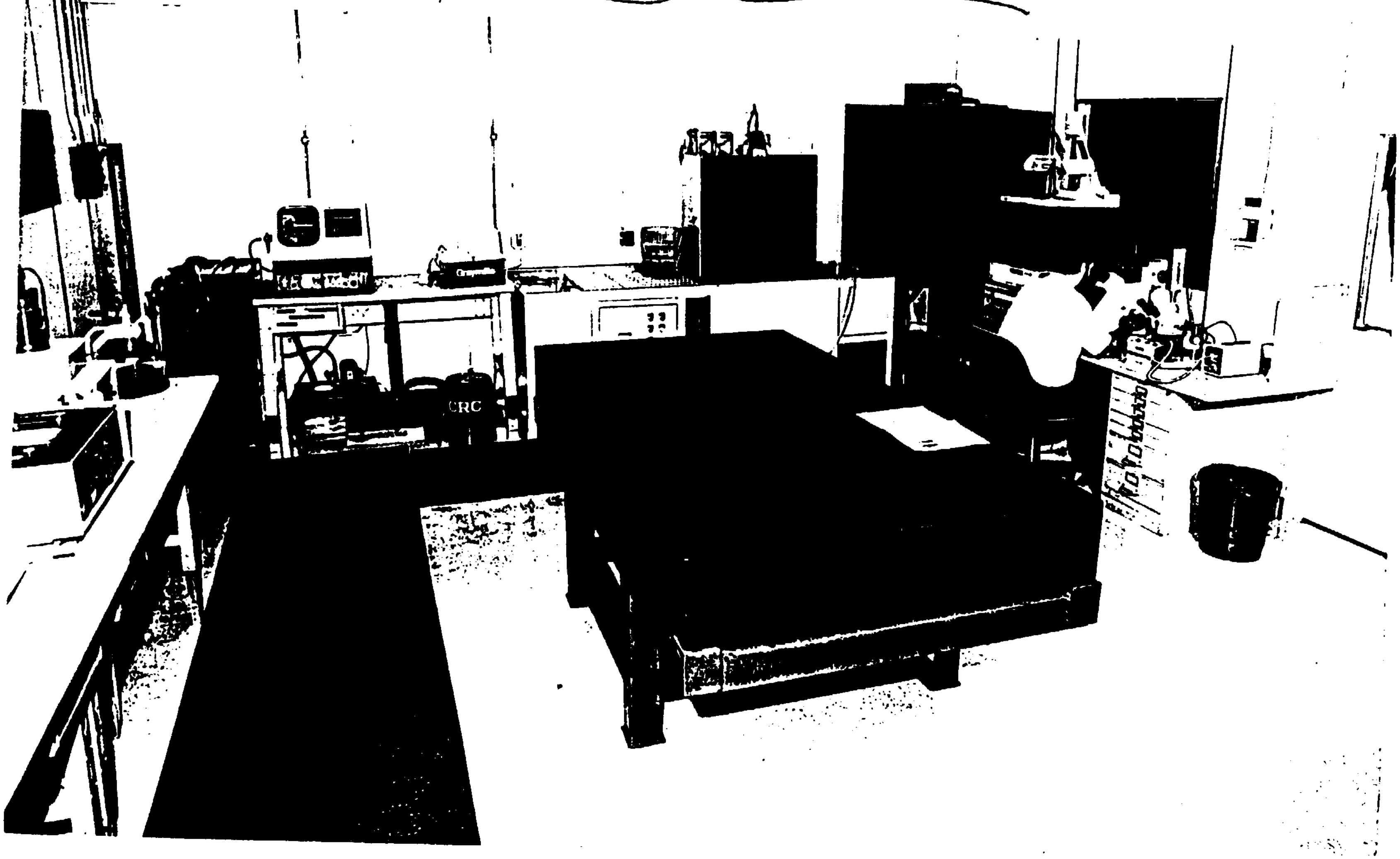
Element	Gross Inten	Inten Error
CdL	0.49	10.15
CrK	3.17	3.97
FeK	94.35	0.73
ZnK	126.19	0.63
CdK	0.20	15.81

This is an example of output from the **EDAX (energy dispersive X-ray fluorescence) system** which is a spectra chemical microanalysis system that uses X-ray energy to excite unknown elements causing them to give off their own specific energy which allows each element to be identified in a test specimen. The purpose of this specific inspection test was to determine if a screw was coated with zinc as stated in its specifications. The screw was, in fact, coated by zinc as shown by the graph on this page.

Stereoscope/Microscope Video package - allows low and high magnification of prepared samples to view surface coatings and to determine surface discontinuities.



Magnaflux F.P.I. Processing System - uses florescent penetrant inspection to detect discontinuities exposed to a specimens surface.



NASA

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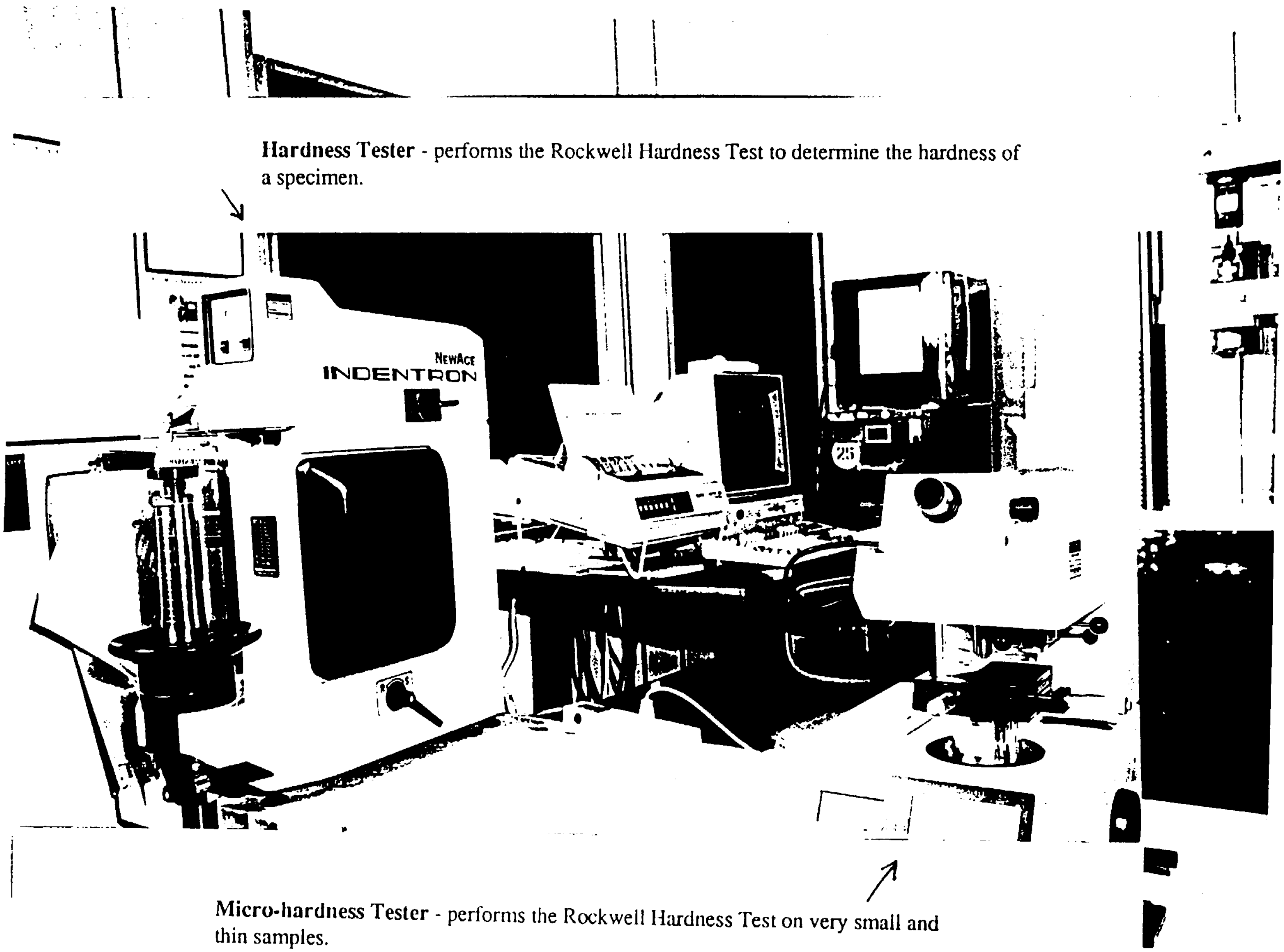
Hardness Tester - performs the Rockwell Hardness Test to determine the hardness of a specimen.



Micro-hardness Tester - performs the Rockwell Hardness Test on very small and thin samples.

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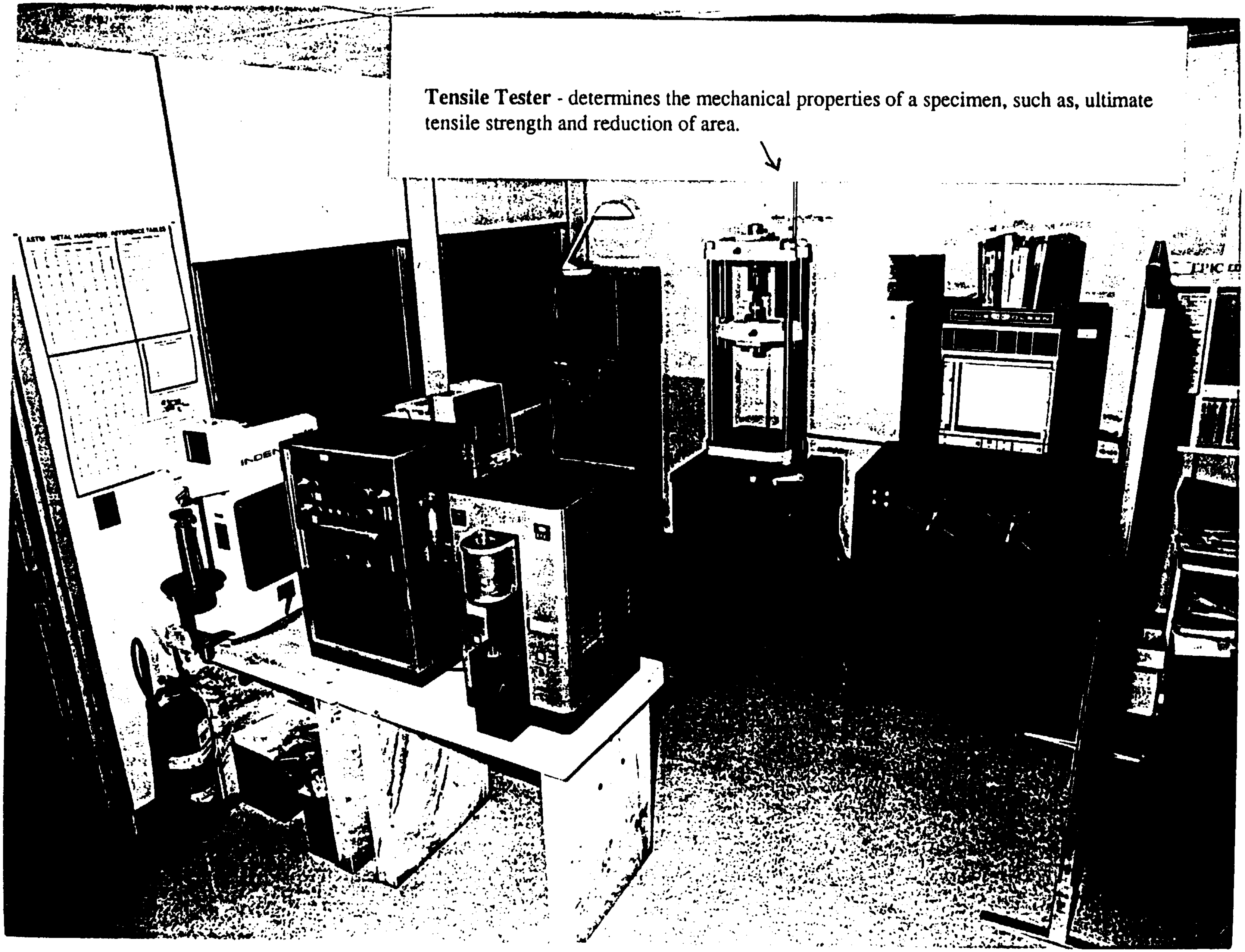

Tensile Tester - determines the mechanical properties of a specimen, such as, ultimate tensile strength and reduction of area.