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LOS ALAMOS SCIENTIFIC LABORATORY
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ROUTINE DECONTAMINATION PROCEDURES AND FORMULAS FOR PLUTONIUM CONTAMINATION

by

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HEALTH AND SAFETY

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ABSTRACT

This report consists of a list of methods, equipment, and formulas which have been used routinely in removal of plutonium contamination. The methods include manual cleaning, mechanical agitation, degreasing, and blast cleaning. Formulas are given for general cleaners and for cleaners for some metals, skin, cloth, floors, or rubber. Pictures of the laboratory layout and some of the procedures and equipment are included.

PREFACE

The following material is an accumulation of ideas from many sources; all ideas, however, have been tried on numerous occasions and have proved successful in some application. In this type of work each item to be decontaminated presents, in itself, a different problem. No "cut and dried" rules can be established; therefore, the procedures and formulas listed herein are general and should be looked upon as guides rather than rules.

ACKNOWLEDGEMENT

The authors wish to express their appreciation to the many persons who have given assistance and advice in developing the procedures listed in this report, and, in particular to William R. Kennedy who supervised the organizing of this phase of decontamination and the procuring of the equipment, and Joe Bill Webber who carried on the work during a leave of absence taken by one of the authors.

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DECONTAMINATION PROCEDURES

All cleaning operations require different degrees of manual manipulation. In specific cases mechanical aides are employed, not only to ease the manual operation, but, more frequently, to handle objects that are highly contaminated and would otherwise present a health hazard to the operator. Mechanical aides are also used in cases where large quantities of similar apparatus have to be handled in short periods of time.

Listed below are the four major methods used, either individually or in combination, to solve most decontamination problems.

1. Simple manual cleaning. The operator, with the use of small hand equipment (scrub brushes, rags, etc.), actually scrubs the object by hand, using various solutions. This type of attack should be tried, in most cases, before seeking mechanical aides. The method has as many variations as the number of personalities involved and requires no elaborate equipment.

2. Mechanical agitation. There are two general methods of mechanical agitation: One--the use of some type of mechanical shaker or agitator on which the objects can be placed in sealed containers with the cleaning solutions and agitated for various lengths of time. The only practical application is to small objects such as pieces of precious metals. Two--air and steam agitation. In this case either air or steam is introduced into the cleaning solution, producing a bubbling of the decontaminant. It differs from the first method in that the container is stationary during the operation. For this reason, containers, 50-gallon drums and such, can be used, thereby providing a method for cleaning larger items and greater quantities of equipment. This system is particularly applicable to cleaning rubber objects and large numbers of metal pieces, such as tools, etc. The steampot (Figs. 7 and 8) is a special piece of equipment used in the second method. It is so constructed that the item or items can be cleaned without undue handling by the operator.

3. Degreasing. This method utilizes some type of commercial degreaser. Its only practical application is to contamination of such a nature that the degreasing action of the solvent is of value. Special caution should be exercised in its use because the cleaning solvent reaches rather high temperatures (e.g., 150°C) and could cause damage to electrical wires, insulators, etc.

4. Impact or blast cleaning. This is the only known efficient method for cleaning highly contaminated objects (over 20,000 d/m/100 cm^2).* However, it requires expensive blasting equipment and an elaborate air filtering system. Proper operation can be carried out only in

* d/m/100 cm^2 = disintegrations per minute for an area of one-hundred square centimeters.

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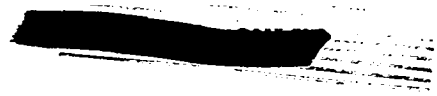
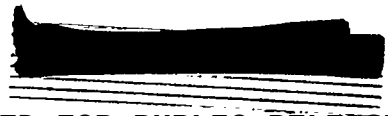
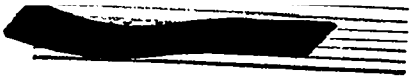


a fixed installation. The nozzle blast method, using some type of mineral abrasive, is the only phase of this cleaning process that has been tried. Any metallic surface that will not be unduly damaged by the abrasive action of the blasting material can be so cleaned. The desired action can be obtained with an impact velocity of the abrasive of 254 feet per second. This velocity can be reached with a properly working blast unit under 80 pounds per square inch air pressure. Special precautions should be taken if the abrasive is to be recirculated, because it has been found that for the first two impacts the abrasive is too highly contaminated to be handled in the routine manner. During the entire operation the possibility of large amounts of air-borne contamination is present, and either an adequate exhaust system should be used or personnel respiratory equipment should be worn. For jobs so small that the installation of blasting equipment is impractical, hand sanding machines have been used with some success. Both of the above systems result in the removal of the surface of the object.

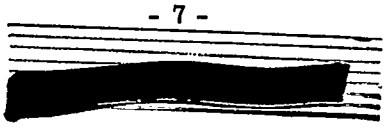




DECONTAMINATION FORMULAS

On the following pages are listed cleaning solutions, solvents, and commercial products that can either be found or made in the laboratory, usually with the material on hand, or which are readily available from commercial sources. For convenience, different formulas have been listed under a particular heading (metal cleaners, skin cleaners, etc.). This, however, does not mean that they are used exclusively for that purpose, but that they have been found to produce generally better results on that type of surface. If the need arises, the solutions can be changed to fit the particular conditions.

Consideration should be given to the fact that, for example, even if a solution is listed as good for cleaning of cloth, it might prove satisfactory for cotton but might harm a plastic type of cloth. Problems of this nature are present throughout, and, if possible, when the construction of the object in question is unknown, only small areas should be handled, and milder cleaners should be used at first.



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GENERAL CLEANERS

A number of general cleaners have been devised and have been used as the name implies. They give the Laboratory a universal cleaner which in most cases will handle all low-level, dust-borne contamination. They also eliminate the necessity for having on hand large quantities of different cleaning solutions. The general cleaners can be used as standards and should be tried first on most equipment. Their use may eliminate the need for stronger or undesirable cleaning agents.

1. K-W Solution (Mild)

   Citric acid: 5.76 grams

   Igepal (C.A. Extra): 1 cc*

   Versene (Fe_3 Specific): 2 cc

   Add distilled water to make 1 liter of solution.

2. Standard Cleaning Solution (Stronger)

   Sodium citrate: 135 grams

   Igepal (C.A. Extra): 10 cc

   Hydrochloric acid (Sp. gr. 1.19):** 150 cc

   Mixing procedure: Mix sodium citrate and Igepal thoroughly with about 400 cc of water. Add acid. Add distilled water to make 1 liter of solution.

3. Acid Cleaning Solution (Strongest)

   Hydrochloric acid (Sp. gr. 1.19): 1 liter

   Citric acid: 150 grams

   Igepal (C.A. Extra): 20 cc

   Add distilled water to make 2 liters of solution.

CAUTION: Direct skin contact with any agent which contains Versene should be avoided because of the probable absorption of the Versene through the skin.

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* cc: cubic centimeters or milliliters.

**Sp. gr.: specific gravity.

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METAL CLEANERS

1. General Cleaners for All Metals
   - A. Mild cleaners
     - 1) K-W solution
     - 2) Weak acid solution (1 or 2 N*)
     - 3) Commercial detergents (Dutch Cleanser, Dreft, etc.)
   - B. Medium cleaners
     - 1) Stronger general solutions (standard cleaner)
     - 2) Acid solutions (6 to 8 N)
   - C. Heavily contaminated material cleaners
     - 1) Concentrated acids
     - 2) Aqua Regia (1 part HNO_3 to 3 parts HCl)
     - 3) Impact cleaning
2. Specific Cleaners for Various Metals
   - A. Aluminum
     - 1) Citric acid bath (1 gallon water, 50 cc Igepal, 150 grams citric acid)
   - B. Brass
     - 1) Sodium hydroxide (20%) or citric acid (10%)
   - C. Copper
     - 1) Citric acid and ammonium hydroxide solution (1 gallon water, 400 grams citric acid, 85 cc ammonium hydroxide. Sp. Gr. 0.90.)
   - D. Duriron
     - 1) Saturated chromic acid solution
   - E. Iron
     - 1) Saturated potassium permanganate solution followed by 15% sodium acid sulfite.
     - 2) Saturated tartaric acid solution
   - F. Galvanized iron
     - 1) Commercial detergent: Tergitol P-28
   - G. Lead
     - 1) Emery cloth or sandpaper

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*N: normal. A normal solution contains one gram molecular weight of the dissolved substance divided by the hydrogen equivalent of the substance (that is, one gram equivalent) per liter of solution.

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H. Nickel

1) (See copper)

I. Steels (In some instances the particular type of steel is not known and a certain amount of caution should be exercised)

1) Nitric acid (2 N) followed by Calgon (50% to saturated)

2) Calgon and Versene solution (1 gallon water, 100 grams Calgon, 20 cc Versene, 20 cc Igepal. Adjust pH to 8 by adding potassium hydroxide.)

3) Saturated potassium permanganate followed by 10% sodium bisulfite.

J. Precious metals (platinum)

1) Aqua Regia (1 to 2 N, with mechanical agitation)

K. Chromium

1) (See aluminum)

NOTE: In the decontamination of metals, any one of the four major methods can be used, depending on the construction of the item to be cleaned.

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SKIN CLEANERS

1. General Cleaners for All Parts of the Body

   Commercial detergents such as:

   A. Dreft

   B. Ivory

   C. Sulfa-soap

   D. Any olive base soap

2. Extremities Cleaners

   A. Sodium tartrate and tartaric acid powders (1 to 1)

   B. Ammonium citrate solution (5%)

   C. Citric acid solution (5% solution to paste)

   D. Citric acid and tartaric acid mixture (1 to 1)

   E. Potassium permanganate (4%). (Stain may be removed by using 4% sodium bisulfite.)

   F. Titanium paste

   NOTE: Several methods may be employed for cleaning the extremities. Either scrub brushes or soaking may be used. The above solutions should be followed by use of lanolin cream or glycerol. Some types of skin will redden and become chapped after scrubbing or soaking and further attempts at decontamination should be made only under a doctor's supervision.

3. Other parts of the body (e.g., the head) should be treated only with mild soaps. Again extreme care should be taken to eliminate chapping.

4. A general plan for cleaning moderately contaminated hands (2,000 d/m/100 cm^2 to 10,000 d/m/100 cm^2) is given below.

   Step 1. If the person has made no attempt to clean his hands, proceed down the list. If a commercial soap has been used previously, the best policy is to continue using that soap.

   Step 2. Fill receptacle half full of lukewarm water. Add 50 to 75 grams of citric acid and soak the hands for 5 to 10 minutes.

   Step 3. Use commercial soap to scrub the area for 3 minutes.

   Step 4. Repeat Step 3.

   Step 5. From this point on, the condition of the skin will determine whether repeated cleaning should be attempted.

   Step 6. If the hands are still contaminated, continuous wearing of rubber gloves will usually 'sweat out' the contaminant.

   NOTE: Monitoring between steps has been purposely omitted because it may not be

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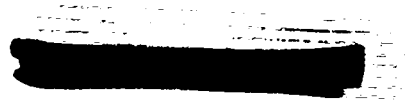
available at the time. It is highly desirable to have a check between each step. If suspected contamination is present, it is better to wash immediately to reduce spreading. Some system, such as the above plan, should be sufficient for lower contamination levels.



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CLOTH CLEANERS

1. Dry Cleaning
   - A. Detroit solvent (70% Stoddard solvent, 25% trichloroethylene, 5% methylene dichloride)
   - B. Stoddard solvent: commercial
   - C. Trichloroethylene: commercial
   - D. Carbon tetrachloride: commercial. Trichloroethylene is preferred because of the high toxicity of carbon tetrachloride.
   - E. Dry cleaning fluid (987 parts Detroit solvent, 5 parts dry cleaning soap, 4 parts distilled water, 4 parts butyl Cellosolve)
   - F. Dry cleaning soap (dissolve 56 grams potassium hydroxide in 100 cc distilled water. Add this solution to a mixture of 340 grams oleic acid in 100 cc isopropyl alcohol and 400 cc of Stoddard solvent. This is enough cleaning soap to use in 5 liters of dry cleaning fluid "E".)

   NOTE: In dry cleaning material one should use a large, properly ventilated receptacle enough cleaning solution to cover the article completely. It is desirable to have some sort of mechanical agitation of the solution, such as bubbling air; however the agitation may be done by hand.

2. Wet Cleaning
   - A. Commercial laundry soaps
   - B. Mild cleaning solutions (skin cleaners)
   - C. K-W solution
   - D. Citric acid (3%) (highly recommended)
   - E. Typical approach for less expensive materials
     1) First wash: submerge article in suds (Ivory soap, sodium carbonate, sodium pyrophosphate-- pH 10.5). Agitate for 5 to 10 minutes. Desirable temperature of solution: 160°F.
     2) Hot rinse (160°F)
     3) Suds (Ivory, 150°F)
     4) Hot rinse (150°F)
     5) Sour rinse (add ammonium silicofluoride to reduce pH to from 6 to 6.5) (140°F)
     6) Cold rinse (tap water)

   NOTE: The above procedure may prove too extensive for occasional cleaning. Certain steps can be eliminated and, by using several small containers, one or two pieces of clothing can be handled conveniently.

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FLOOR CLEANERS

1. General Consideration for All Types of Floor Surfaces
   - A. Commercial detergents
     - 1) Zoleo
     - 2) Neutralave
     - 3) Any available liquid or powdered soap (i.e., Ivory)
   - B. Ammonium citrate solution (500 cc water, 325 grams citric acid, 230 grams ammonium hydroxide)
   - C. Sodium pyrophosphate solution (8 liters water, 170 grams sodium pyrophosphate, 170 grams sodium citrate, 3 grams Duponol M. E.)
   - D. K-W solution
   - E. Versene solutions (50 to 1, small amounts of Igepal)
2. Specific Types of Flooring and Cleaning Methods
   - A. Painted surfaces (all)
     - 1) Mild acids (2 or 3 N)
     - 2) Remove surface paint with commercial paint remover and repaint
   - B. Concrete surfaces
     - 1) Acids (chromic and nitric)
     - 2) Sodium bicarbonate (25% solution or stronger)
     - 3) Remove surface
   - C. Linoleum surfaces
     - 1) Dilute acids (1 or 2 N)
     - 2) Commercial solvents for small areas
   - D. Wooden surfaces
     - 1) K-W solution
     - 2) Dilute acids
     - 3) Remove surface
   - E. Commercial tile (asbestos tile, cork tile, Armstrong tile, etc.)
     - 1) Standard cleaning solution
     - 2) Small areas, commercial solvents
     - 3) Remove and replace

   NOTE: Whenever practical, floors should have some type of protective coating (house paint, shellac, etc.). In the case of concrete, it is of great importance to have some type of coating (e.g., Amercoat). For routine cleaning the use of any acceptable type of commercial soap (e.g., Neutralave) has proved satisfactory.

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RUBBER CLEANERS

One of the most successful methods of cleaning rubber is the steam agitation method. The solutions listed below can be used.

A. Citric acid soap bath (25 gallons water, 2 pounds citric acid, 1/2 pound sodium citrate, 300 cc hydrochloric acid, 200 cc Igepal). Let steam bubble through solution from 1 to 2 hours. Rinse thoroughly.

B. Versene solutions (20 to 1 or greater)

With small quantities, the following manual methods may be used:

A. Igepal and water (using scrub brushes)

B. Citric acid solution (4%)

C. Citric acid standard cleaner (1/4 pound citric acid, 3 gallons water, 1 pint standard cleaning solution)

D. K-W solution

NOTE: The use of clear plastic paints to cover rubber surfaces and aid later in decontamination have met with little success.

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MISCELLANEOUS CLEANERS

1. Plastics
   - A. Standard cleaning solution
   - B. Calgon (50% to saturated solution) following nitric acid (2 N)
   - C. Solvents (use caution when applying)
   - D. Dilute acids
2. Glass
   - A. Concentrated acids (hydrochloric, nitric, chromic acids)
   - B. Boiling Calgon
   - C. Laboratory cleaning solution (35 cc sodium bichromate, 1 liter concentrated sulfuric acid. Avoid contact with flesh or clothing.)
3. Porcelain
   - A. (See glass)
   - B. Saturated ammonium carbonate solution (boiling)
4. Wood, other than floors
   - A. General cleaners
   - B. Remove surface coat (shellac, varnish, etc.) and repaint
   - C. Dilute acids
   - D. Spindle oil (low-level contamination)
5. Asbestos
   - A. General cleaners
6. Leather
   - A. Commercial soaps
   - B. Saddle soap
   - C. Dilute acid (1 N)
   - D. Citric acid solution (4%)
   - E. Sandpaper (remove surface)
7. Paper (books)
   - A. Spray with clear coating (e.g., Krylon) to cover up low-level contamination
   - B. Art gum erasers (low-level contamination)

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The following information is of general interest:

1. The advantages of paint removing and painting.

Throughout this work, one of the quickest and easiest methods of cleaning moderately contaminated articles, is to remove the painted surfaces with any good commercial paint remover and then repaint. Paints used can be any good enamel, synthetic paint, Zapon, Tygon, Pruf-coat, etc. It has been found that the fast drying coats are of great advantage. New surfaces that have been coated prove easier to decontaminate later. If a particular surface is known to be subject to contamination, the practice of coating it before use should be observed.

2. Treatment of contaminated cuts.

Allow the cut to bleed freely. Wash with water for at least 5 or 10 minutes. Always report as soon as possible to the nearest aid station.

3. Acid burns.

Always have available some mild base (e.g., sodium bicarbonate) to apply directly to a burned surface. If the acid solution was contaminated, rinse burned surface thoroughly and report to the nearest aid station.

4. Personnel protection.

Throughout this work, use of complete protective clothing (safety glasses, gloves, booties, coveralls, or smocks) should be emphasized. When little is known about the contaminant, respiratory equipment should be used until the object has been cleaned to established safe levels.

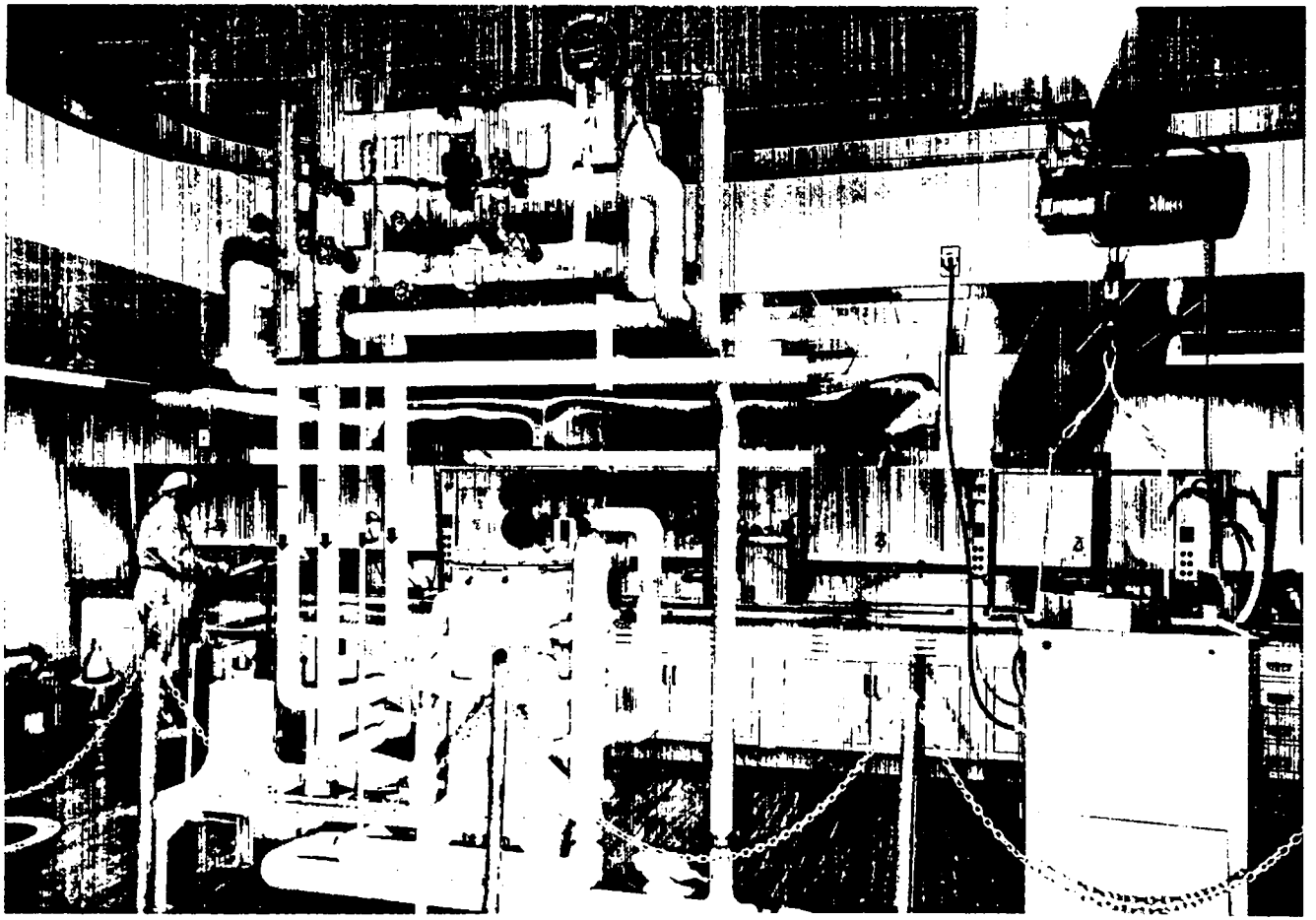

Fig. 1. General layout of decontamination laboratory. Left front: rear view of steam pot showing incoming utilities. Lower right front: rear view of degreaser. Upper right front: crane on continuous overhead monorail. Background: hood and sink arrangement. Sliding doors allow a constant air flow in any position. In this arrangement there are 2 lead and 3 stainless steel sinks to take care of the various types of cleaning solutions. The utilities for each hood include distilled water, hot and cold running water, steam, air, gas, 110- and 220-volt electrical outlets. The cabinets under the sinks are used for storage of chemicals and miscellaneous equipment.

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Fig. 2. Protective clothing. General: coveralls, cap, booties, rubber gloves, safety glasses, and a respirator or supplied air equipment for unknown or high contamination levels. The instruments used include portable meters: the Pee Wee, proportional alpha counter, and the Victoreen 263, a Geiger-Mueller beta-gamma detector.

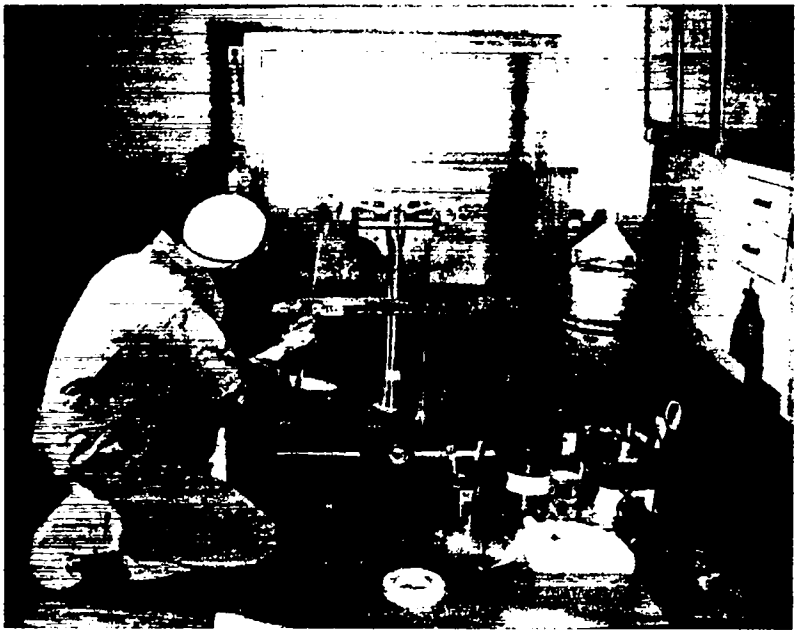

Fig. 3. Careful disassembly of laboratory equipment is of great importance. The different components (glass, metal, etc.) can then be handled separately, depending on their material structure. Manual decontamination is the only practical method for equipment of this type.

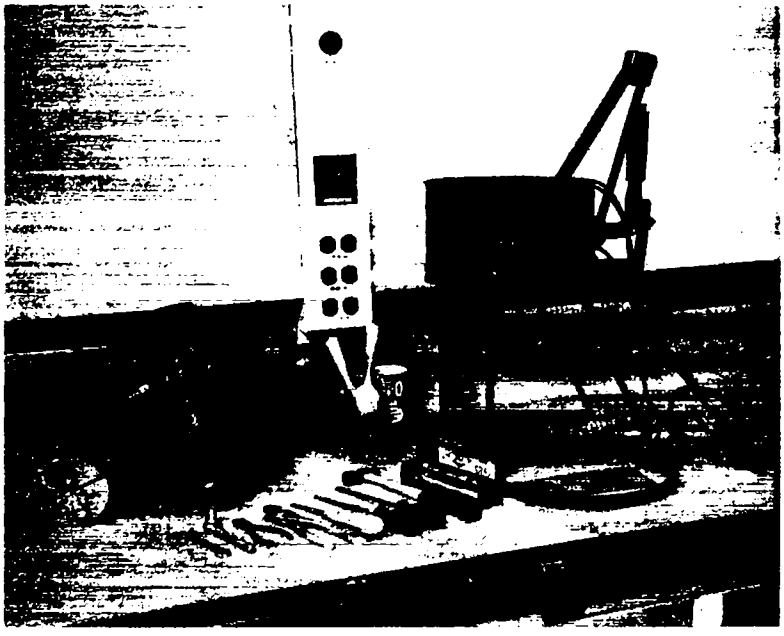

Fig. 4. Layout of equipment. Most items can be disassembled for easier cleaning without elaborate or expensive equipment.

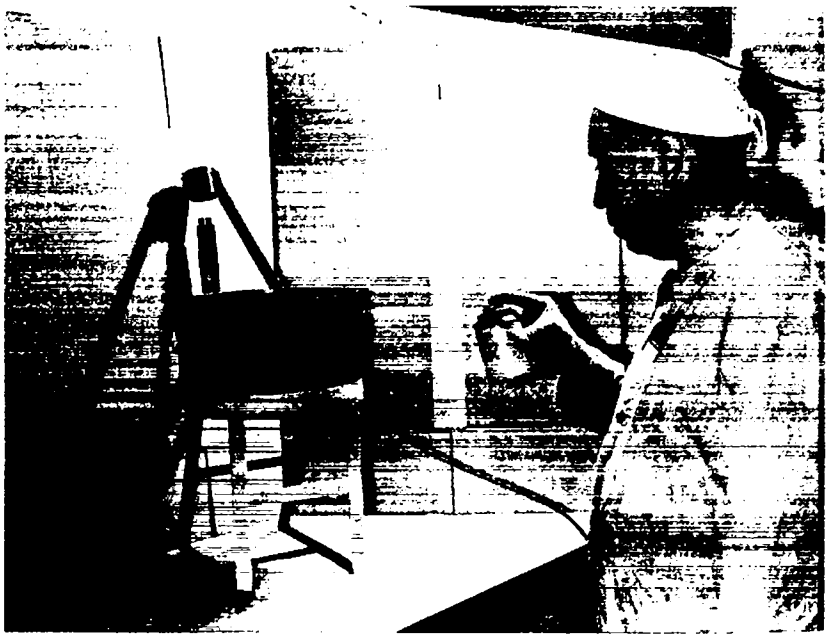

Fig. 5. The repainting of equipment known to be subject to recontamination should not be underemphasized. 90% of the contamination of the lower levels will be removed with the paint. An unpainted surface will require considerable time to decontaminate and strong acid solutions will probably have to be used before decontamination is complete.

Fig. 6. Shop-made decontamination tank. When the steam or the air bubbling method is to be used, any convenient container can be used (a G.I. can is shown).

Fig. 7. Front view of steam pot showing the various control valves.

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A PARTIAL LIST OF AGENTS MENTIONED IN THE TEXT AND THEIR MANUFACTURERS

Trade Name	Manufacturer
Amercoat (Paint)	Amercoat Corp., Firestone Blvd., South Gate, Calif.
Calgon (Sodium Hexametaphosphate)	Calgon, Inc., 1943 Hagan Bldg., Pittsburgh, Pa.
Cellosolve, Butyl (Solvents)	Union Carbide & Carbon Corp., 30 E. 42nd St., New York, N.Y.
Duponol, M.E., dry (Fatty Alcohol Sulfate)	E. I. du Pont de Nemours & Co., Wilmington 98, Delaware
Igepal (C.A. Extra)	General Dyestuff Corp., 435 Hudson, New York, N.Y.
Krylon (Plastic Spray)	Krylon, Inc., 2601 N. Broad St. Philadelphia 32, Pa.
Neutralave (Tile, Linoleum, & Asphalt Cleaner)	The DuBois Co., Cincinnati, Ohio
Pruf-coat (Protective Coating)	Prufcoat Laboratories, Inc., 61 Main, Cambridge, Mass.
Stoddard Solvent	Shell Oil Co., 50 W. 50th St., New York, N.Y.
Tergitol (P-28) (Surface Active Agents)	Union Carbide & Carbon Corp., 30 E. 42nd St., New York, N.Y.
Tygon (Plastic)	U.S. Stoneware Co., 5300 E. Tallmadge Ave., Akron, Ohio
Versene (Fe_3 Specific)	Bersworth Chemical Co. Framingham, Mass.
Zapon (Lacquers & Enamels)	Atlas Powder Co., Ludlow St., Stamford, Connecticut
Zoleo (Liquid Cleaning Soap)	West Disinfecting Co., Orchard & West Sts., Long Island City, N.Y.

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