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CHEMICAL SAFETY

CFSTI PRICES

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Abstract

Chemicals in any form can be safely stored and used if their physical and chemical properties are fully understood and the necessary precautions, including the use of proper safeguards and protective equipment, are observed. Physical and chemical explosions are discussed with emphasis on ether peroxides and hydrogen. The hazards and toxic properties of certain metals and organic compounds are briefly described. Finally, it is stated that the basic responsibility for safety remains with the individual and his supervision. They should fully understand the material properties and the precautions required in any set of chemical operations.

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1. Introduction (Outline)

In presenting the topic chemical safety I would like to follow a theme which is similar to that presented by the Manufacturing Chemist's Association. This is shown in Fig. 1, "Chemicals in any form can be safely stored, handled, and used if their hazardous physical and chemical properties are fully understood and the necessary precautions, including use of proper safeguards or protective equipment, are observed."

I recently had a conversation with an experienced chemist who said, "Why all this fuss about chemical safety? We work with dangerous materials every day. In working with these materials we use the hood area, wear gloves, and use tongs in handling samples. If we have a spill, it is washed up immediately." Such an experienced chemist does not need rules and regulations, because he knows what to do, can anticipate trouble, and rarely has a serious accident. This certainly emphasizes the quotation shown here: "If the hazardous physical and chemical properties are fully understood."

Accidents seldom happen to experienced key men. They do, however, often happen to an inexperienced worker, who is carrying out the actual physical manipulations in the experimental program. Thus, key men should: (1) bear full responsibility for maintaining the highest standards for working conditions, (2) provide safeguards against hazardous undertakings, (3) educate their staffs to be alert to all hazards. If each of you will keep these three items in mind, your co-workers will certainly lead a much happier life. No general set of rules ensures safety. Safety results from an attitude of the mind and depends upon the efforts of each individual.

Perhaps some of you are familiar with the design layout for munition factories. There are widely separated buildings for special processes.

There are barricades to protect the workers and because of the potential hazards involved, the number of operators per building is kept to a minimum. They are provided with escape hatches and doors through which operators can dive in case of emergency. In addition to all this, the building is purposely designed with one wall which will blow out first. In case of a severe explosion this saves the main building. Now, such explosions are rare, but can happen in spite of all safety precautions even when procedures are conducted with remote control equipment. (Fig. 2).

2.. Explosions

Explosions can result from a physical cause or a chemical cause. An explosion of a still with a plugged condenser is an example of a physical cause. A still containing an excessive amount of isopropyl peroxide is an example of a chemical cause.

All chemical reaction vessels should be: (1) properly vented or (2) equipped with rupture discs or relief valves, and (3) be manipulated behind safety screens.

2.1 Physical Explosions

Use common sense to avoid explosions from physical causes. For example: consider the freezing point of distillate materials together with the temperature of the coolant to avoid condenser freeze-ups. Inspect condensers and cold traps during distillations to make sure they have not become plugged. After stills have been shut down, take care that all liquid and vapor conduits are open before attempting to start up again. Insert glass tubing completely through rubber or cork stoppers so that the stopper will not swell and be closed by solvent action.

In general, leaking equipment operating under pressure should be shut down first and then tightened before restarting operations.

2.2 Chemical Explosions

Chemical explosions (Fig. 3) result from a rapid reaction or decomposition of compounds which suddenly yield gaseous products. Many explosions occur when mixing strong oxidizing agents with strong reducing agents. Some compounds that have particular explosive power are listed in Fig. 3. Acetylene, under certain conditions, forms highly explosive compounds with copper, silver, and mercury. Copper acetylides have caused many serious explosions, because they are easily detonated by heat or shock. Copper equipment that has been in contact with acetylene should be rinsed with hydrochloric acid before welding or heating to remove traces of acetylide. Silver acetylide deposits are explosive when dry. Consequently, the apparatus should be kept moist until ready for cleaning.

Mixtures of silver nitrate, nitric acid, and alcohol are known to form silver fulminate which is highly explosive. Iodine in contact with aqueous or alcoholic ammonia forms a black powder, nitrogen iodide monamine which, when dried, detonates spontaneously and violently when touched or slightly heated.

Among the peroxides are found some of the most highly explosive materials. Hazards with peroxides can be avoided by use of oxidation inhibitors or by careful temperature control.

Most of the other items on the list are familiar to you.

3. Hazards from Peroxides in Ethers

I would like to pay particular attention to the hazards from peroxides in ethers, because the danger is more common than most of us realize. Ethyl ether, isopropyl ether, dioxane, tetrahydrofuran, and other alkyl ethers tend to absorb and react with oxygen from the air to form unstable peroxides which may detonate with extreme violence when concentrated by evaporation or vacuum distillation of the ether.

3.1 University Laboratories

For example, there have been some narrow escapes from peroxides found in university laboratories. In sorting through some bottles of chemicals stored in a storeroom recently at one university, they found two 2-liter glass-stopper bottles labelled isopropyl ether, student preparation, which had been there more than 20 years. The bottles were nearly one-third full of camphor-like crystalline solid beneath the liquid upper layer. They very carefully transferred the bottles into a dump area and threw rocks at the bottles. There was a violent explosion which plastered mud and debris over the surrounding landscape.

At one university, they discovered a one-gallon bottle of ether which had gone to dryness leaving 40-50 g of large cubic crystals. They wrapped the bottle in towels, tiptoed out to a vacant lot, and threw rocks at it. There was a real shock wave and the police came to find out who had dynamited what.

Another university went through the same experience, but had the forethought to call in the police and army explosive experts beforehand.

3.2 Industrial Laboratory

An industrial laboratory experienced a fatality with isopropyl ether. The victim was fatally injured while trying to open a bottle of isopropyl ether. Dr. X, who had been with the company about three years, had apparently inherited some of the supplies from the storage room of his predecessor. How many of you have inherited storage cabinets full of chemicals? Needing some isopropyl ether, he found a pint glass bottle so labelled on the shelf and took it to the next room where he attempted to open it over a sink. The cap appeared to be stuck tightly and he grasped the bottle in one hand, pressed it to his stomach, and twisted the cap with

the other hand. Just as the cap broke loose, the bottle exploded and practically disemboweled the man and tore off several fingers.

It was concluded that this accident was caused by peroxides which formed in the ether while it sat on the storage shelf.

3.3 Preventive Measures

Isopropyl ether and anhydrous ether must be purchased in small quantities and in iron containers if possible (Fig. 4). The containers should be dated when they are placed in the storeroom and should be shielded from light and heat. All ethers used in the laboratory must be kept in cans rather than in bottles. Isopropyl, isoamyl, and anhydrous ethers should not be kept over six months, ethyl and other ethers not over one year. It should be noted that peroxides may form in distilled and unstabilized ether within less than two weeks.

4. Hydrogen Properties

The use of hydrogen has increased over the past few years. Let us look at some of the hydrogen properties (Fig. 5).

1. Hydrogen has a wide explosive range, 4 to 75% in air. The lower end of the range is relatively high compared to other gases and vapors; acetylene 2.5%, butane 1.6%, methane 5.5%, gasoline 1.3%, acetone 2.5%.
2. It is more difficult to reach the explosive range with hydrogen since its high dilution rate coupled with its somewhat high lower limit of combustibility makes the danger point harder to get to and harder to maintain.
3. Ignition temperature of hydrogen is 1085°F (ignition temperatures of gasoline range from 540 to 880°F).

4. The specific gravity of hydrogen is about 1/14 that of air, but it is capable of diffusing sideways as fast as upwards.
5. When hydrogen is vented, it sometimes ignites due to static electricity or due to spark caused by metal particles.
6. Hydrogen flame is invisible unless impurities color it.
7. Hydrogen is considered to have a weakening effect on metal containers (hydriding). Hydriding can occur at any temperature and pressure under flexing. The rate of hydriding increases with temperature and pressure, depending on the material.

4.1 Hydrogen Fires (Fig. 6)

If you get past the explosive stage and have only a fire, remember the following:

1. Remove everyone not needed for fire fighting or rescue.
2. If at all possible, shut off the flow of liquid or gaseous hydrogen.
3. It is usually not advisable to extinguish a hydrogen flame if the hydrogen supply cannot be shut off.
4. The continuing escape of unburned hydrogen can create an explosive mixture in any confined space which may be ignited by other burning material or hot surfaces.
5. It is better to allow the hydrogen supply to burn out and keep adjacent areas cool with water than to risk the possibility of an explosion. It will not be possible to extinguish fires of high pressure, large flow rates.
6. A "reach rod" (10-ft-long valve extension)(10 foot pole) is suggested for use in shutting off hydrogen valves in case of fire around the valve stems.

7. If electrical equipment is involved, disconnect the power remotely and use CO₂.
8. Use large amounts of water, preferably water spray, to cool adjacent exposures and to cool any burning material below the ignition point.

4.2 Liquid Hydrogen

Liquid hydrogen requires special precautions. A list of safety manuals for liquid hydrogen is shown in Fig. 7.

Nearly all specific safety rules are merely variations on the theme that in order to create a hydrogen accident, it is necessary that (1) hydrogen, (2) an oxidizing agent, usually air, and (3) an ignition source be present at the same time and in the same place. Existence of any one of these conditions should be regarded as potentially hazardous. Air can get into hydrogen storage containers by back-diffusion through over-large or improperly constructed vent lines. Vent tubes for small vessels or equipment should be arranged in a downward loop to prevent back-diffusion of air. Vent stacks from large systems should be equipped with check valves of the type suitable for pressure and flow rates applicable to the system.

In addition to the hazards created when oxygen condenses in liquid hydrogen, other dangerous situations can develop from solidification of air, carbon dioxide, or water vapor on the cold surfaces of the equipment. Such condensed vapors can form plugs in the vent and result in the physical rupture of the liquid hydrogen container. Anyone considering working with liquid hydrogen should carefully review some of the listed safety manuals on this subject. It is a very specialized type of investigation.

The proper room ventilation implies not only the number of air changes per hour but that the exhaust gases are not recirculated through the ventilation system and that there is no inverted dome structure existing in the room to trap hydrogen gas and permit its concentrations to build up to dangerous amounts.

5. Chemical Hazards and Toxic Materials

Toxic materials may enter the body through inhalation, ingestion, or through injured or intact skin. The most important means of entrance is by inhalation. Material entering the lungs can be immediately transferred into the blood stream and transported throughout the body. The surface area within the lungs is large, being some several hundred square yards for each individual. In addition, the volume of air breathed is extremely large, 8000 liters/eight hour day. Thus, even at low concentrations, a comparatively large amount of toxic material may enter the body during an eight-hour day. Most chemists are well aware of this situation and make good use of their chemical hood space. Acids and bases are familiar to chemists and ammonia, sulfur dioxide, hydrochloric acid, hydrofluoric acid are easily recognized and irritating enough so that very few people will expose themselves to toxic concentrations. Gases such as bromine, phosgene, nitrogen oxide and ozone are less soluble in water and produce their effects deep in the lungs and at first will produce little or no detectable effect in the upper respiratory tract. They may cause damage to the lungs without irritation to the nose and throat. Such materials are particularly hazardous since they have a delayed effect and a person who has been exposed may find his lungs filling with fluid as much as 12 hours after an exposure.

Cadmium is an irritant to respiratory systems and produces effects similar to those of phosgene and nitrogen oxide, that is, a chemical pneumonia can occur. Since cadmium is one of the principal elements in silver solder, this is the reason that good ventilation must be provided whenever extensive or prolonged silver-soldering operations are performed.

5.1 Metals

Beryllium, cadmium, lead, gallium, mercury, barium, bismuth, chromium, and alkali metals such as lithium produce toxic effects on the body under certain conditions. It is certainly advisable to use a hood system in vaporizing any of these materials. That mercury is poisonous is well known, but it may not be appreciated that mercury evaporates into air at room temperature if the material is subdivided into very fine droplets. Mercury spilled on the floor or in crevices in a closed room can readily produce significant concentrations of mercury vapor in the air. Air ventilation and prompt cleanup of spilled mercury are of high importance.

5.2 Organic Solvents (Fig. 8)

Carbon disulfide is a fire hazard and is highly toxic. It affects the central nervous system and its use should be avoided whenever possible. Benzene is another highly toxic material and affects the blood-forming organs. It is particularly hazardous in that it can penetrate intact skin. Carbon tetrachloride, the so-called safe solvent, will not burn, but it is highly toxic and affects both the liver and kidneys very severely. Its effect is cumulative in the sense that repeated inhalation of the solvent can cause irreversible changes in the liver. Hence, the gradual loss of function of the liver.

Practically all solvents will dissolve fat and oil from the skin, and as a result, the skin becomes dry, cracks, and easily becomes infected.

The skin should be protected from contact with solvents (Fig. 9). Indiscriminate washing of one's hands with gasoline, paint thinners, should be discouraged.

6. Personal Responsibilities

Every worker in the laboratory should recognize that he may be dealing with very powerful and treacherous forces everyday and that each individual is his own biggest hazard. The exercise of common sense, good judgement, careful manipulation with adequate information will reduce accidents to a minimum.

No set of rules, however, complete, can take the place of presence of mind. As a chemist goes about his daily work, he should constantly consider the nature of the substances being handled, whether flammable, volatile, explosive, corrosive, or toxic (Fig. 10). Will they react rapidly with some common substance such as water?

The chemist should think of other personnel as well as himself and should permit only qualified maintenance men to repair machinery and equipment. However, he should stand by and see that the maintenance man does not get into chemical troubles. It is generally agreed that a chemist should clean up his own mess if he creates a hazardous condition. An uninformed individual could easily get into trouble through lack of knowledge about the chemical hazards.

I would like to direct your attention to the Appendix which contains a group of cartoons and pictures which will remind you of certain safety situations. Pay particular attention to personal equipment and procedures. The cartoons are intended for your amusement. Laugh if you wish, but the medical reports over a two-year period show the following:

Cuts, abrasions, lacerations	513
Sprains, strains	96
Eye complaints	54
Burns	43

STOP!

Take time to outline your operational procedures in advance.

LOOK!

Wear your safety glasses.

LISTEN!

It may save you time, pain, and personal embarrassment.

Fig. 1

Manufacturing Chemist's Association

Chemicals in any form can be safely stored, handled, and used if their hazardous physical and chemical properties are fully understood and the necessary precautions, including use of proper safeguards or protective equipment, are observed.

Key men should: (1) bear full responsibility for maintaining the highest standards for working conditions, (2) provide safeguards against hazardous undertakings, (3) educate their staffs to be alert to all hazards.

Fig. 2

Fig. 3. Explosive Power

Acetylides

Silver fulminate

Other nitrogen-containing compounds

Peroxides

Peracetic acid

Organic nitrogen compounds

Polymerization

Liquid oxygen

Oxygen and combustibles

Chlorine and ethylene

Sodium metal

Calcium carbide

Perchlorates

Fig. 4. Formation of Peroxides

1. Peroxides may form in freshly distilled and unstabilized ethers within less than two weeks.
2. Ethyl ethers, isopropyl ether, dioxane, tetrahydrofuran, and other alkyl ethers tend to absorb and react with oxygen from the air to form unstable peroxides which may detonate with extreme violence when concentrated by evaporation or distillation of the ether.

Preventive Measures

1. Isopropyl ether and anhydrous ether must be purchased in small quantities and in iron containers if possible. The containers will be dated when placed in the storeroom and will be shielded from light and heat.
2. All ethers used in the laboratories must be kept in cans rather than in bottles.
3. Isopropyl, isoamyl, and anhydrous ethers will not be kept over six months, ethyl and other ethers not over one year.

Fig. 5. Hydrogen Properties

1. Hydrogen has a wide explosive range, 4 to 75% in air, The lower end of the range is relatively high compared to other gases and vapors: acetylene 2.5%, butane 1.6%, methane 5.3%, gasoline 1.3%, acetone 2.5%.
2. It is more difficult to reach the explosive range with hydrogen since its high dilution rate coupled with its limit of combustibility makes the danger point harder to get to and harder to maintain.
3. Ignition temperature of hydrogen is 1085°F.
4. The specific gravity of hydrogen is about 1/14 that of air, but it is capable of diffusing sideways as fast as upwards.
5. When hydrogen is vented, it sometimes ignites due to static electricity or sparks caused by metal particles.
6. Hydrogen flame is invisible unless impurities color it.
7. Hydrogen is considered to have a weakening effect on metal containers (hydriding). Hydriding can occur at any temperature and pressure under flexing. The rate of hydriding increases with temperature and pressure, depending on the material.

Fig. 6. Hydrogen Fires

1. Remove everyone not needed for fire fighting or rescue.
2. If at all possible, shut off the flow of liquid or gaseous hydrogen.
3. It is usually not advisable to extinguish a hydrogen flame if the hydrogen supply can create an explosive mixture in any confined space which may be ignited by other burning material or hot surfaces.
4. It is better to allow the hydrogen supply to burn out and keep adjacent areas cool with water than to risk the possibility of an explosion. It will not be possible to extinguish fires of high pressure, large flow rates.
5. A "reach-rod" (10-ft-long valve extension) is suggested for use in shutting off hydrogen valves in case of fire around the valve stems.
6. Use large amounts of water, preferably water spray, to cool adjacent exposures and to cool any burning material below the ignition point.
7. If electrical equipment is involved, disconnect the power remotely and use CO₂.

Fig. 7. Safety Manuals

1. Rover Safety Procedures, LASL-NRDS, May 1, 1964.
2. Safety in the Rover Project, Reider, LASL, October 1961.
3. Limits of Flammability of Gases and Vapors, Coward and Jones, Bureau of Mines Bulletin No. 503.
4. Electrostatic Hazards Associated with the Transfer and Storage of Liquid Hydrogen, A. D. Little, Inc., Cambridge, Mass., May 15, 1961.
5. NASA - Lewis Safety Manual, Dec. 10, 1959.
6. The Protection of Closed Vessels Against Internal Explosions, Cousins and Cotton, Process Industries Conference (ASME) April 1951.
7. Hydrogen, Safety and Fire Protection, AEC Technical Bulletin No. 5 (1956).
8. Designing for Safety in Hydrogen Bubble Chambers, UCRL-3508, Hernandez, Mark, and Watt, Univ. of Calif. Rad. Lab., Berkeley, California.
9. NBS Safety Instruction and Safety Guide for Handling Gaseous and Liquid Hydrogen at the Boulder Laboratories, Memorandum Report No. CM-4, January 1960.
10. Research on the Hazards Associated with the Production and Handling of Liquid Hydrogen, Zabetakis and Burgess, Bureau of Mines Report WADD-TR-60-141 (1960).
11. Final Report on an Investigation of Hazards Associated with the Storage and Handling of Liquid Hydrogen, Arthur D. Little, Inc., March 22, 1960.

Fig. 8. Some Hazardous Chemicals Absorbed Through Intact Skin

Alkyl alcohols	Dinitrobenzene	Almost all halogen
Carbon disulfide	Ethylene chlorohydrin	compounds, including carbon
Carbon monoxide	Phenols	tetrachloride, the most
Cresols	Tetryl	hazardous of the common
Cyanides	TNT	solvents
Dimethylaniline	Almost all nitro	compounds
Dimethyl sulfoxide		
$(\text{CH}_3)_2\text{S} = \text{O}$		

Fig. 9. Compounds Which Sensitize or Cause Reactions to the Skin

Epoxide monomers and catalysts	Aliphatic mono- and polyamines
Aromatic amines	Aromatic hydrazines
Aromatic isocyanates	Aromatic nitro compounds (some)
Chlorinated biphenyls	Tolylene diisocyanate (TDI)

Adhesive	Chemical of Concern	Hazards and Effects		
		Inhalation	Skin	Eye and Nose
Duco cement	Methyl ethyl ketone and unsaturated organic	Irritant; nausea	Drying	Temporary burning; irritant
Eastman 910	Methyl-2-cyano-acrylate	Lung irritant		Lachrymator
Epoxy formulations	Amine (hardener)	Sensitizer	Sensitizer	Irritant
CM hardener	Chloromaleic anhydride	Severe irritant	Burns	Severe burns; lachrymator; eye protection required
Elvanol	Polyvinyl alcohol	Slight	None	Irritant

APPENDIX I. ADDITIONAL FIGURES

Cartoons from Guelich: Chemical Safety Supervision, New York,
Reinhold Publishing Corporation, 1956.

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ORNL DWG. 66-8732

Janitors Aren't Chemists! The careful chemist should do most of his own housekeeping.

“From Guelich: CHEMICAL SAFETY SUPERVISION, New York, Reinhold Publishing Corporation, 1956.”

PHOTO 84698

ORNL DWG. 66-8731

Use a Towel! Pushing glass tubing through rubber stoppers is tricky. Use a towel and you won't cut your hands. Fire polish ends, and use a lubricant too.

"From Guelich: CHEMICAL SAFETY SUPERVISION, New York, Reinhold Publishing Corporation, 1956."

PHOTO 84711

PHOTO 84709

ORNL DWG. 66-8735

Smart chemists use shields. Hot reaction? Keep wired glass between you and the apparatus.

"From Guelich: CHEMICAL SAFETY SUPERVISION, New York, Reinhold Publishing Corporation, 1956."

PHOTO 84701

PHOTO 84703

ORNL DWG. 66-8736

Keep carboys upright!

“From Guelich: CHEMICAL SAFETY SUPERVISION, New York,
Reinhold Publishing Corporation, 1956.”

Pouring corrosive liquids. Man is risking a burned foot and a back strain. Use approved transfer methods.

"From Guelich: CHEMICAL SAFETY SUPERVISION, New York, Reinhold Publishing Corporation, 1956."

ORNL DWG. 66-8737

Use a carrier! Whether you fall, or just drop the bottle, acid splashes . . . unless it's in a carrier.

"From Guelich: CHEMICAL SAFETY SUPERVISION, New York, Reinhold Publishing Corporation, 1956."

PHOTO 84707

PHOTO 84712

ORNL DWG. 66-8734

Safety cans for flammable solvents. Good ones can't spill, nor can fire enter them.

"From Guelich: CHEMICAL SAFETY SUPERVISION, New York, Reinhold Publishing Corporation, 1956."

ORNL DWG. 66-8729

Tame those cylinders! Use a cart, and keep caps in place.

“From Guelich: CHEMICAL SAFETY SUPERVISION, New York,
Reinhold Publishing Corporation, 1956.”

ORNL DWG. 66-8733

**Don't "Neutralize." For chemicals in eyes, use water only,
and call the doctor.**

"From Guelich: CHEMICAL SAFETY SUPERVISION, New York,
Reinhold Publishing Corporation, 1956."

ORNL DWG. 66-8727

**Are Chemicals on the Menu? The dirty man makes his food dirty.
Send him back to the washroom.**

"From Guelich: CHEMICAL SAFETY SUPERVISION, New York,
Reinhold Publishing Corporation, 1956."

ORNL DWG. 66-8728

Color code them? Here's a man that isn't confused in this pipe jungle. Colors of lines tell him what is in each pipe.

"From Guelich: CHEMICAL SAFETY SUPERVISION, New York, Reinhold Publishing Corporation, 1956."

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- 136. R. A. Strehlow
- 137. B. J. Sturm
- 138. A. L. Sutton, Jr.
- 139. F. H. Sweeton
- 140. W. P. Teichert
- 141. R. E. Thoma, Jr.
- 142. R. L. Towns
- 143. J. Truitt
- 144. R. M. Waller
- 145. W. T. Ward
- 146. G. C. Warlick
- 147. G. M. Watson
- 148. C. F. Seaver
- 149. J. F. Winesette
- 150. L. B. Yeatts
- 151. W. D. Yuille

Division Safety Officers and Radiation Control Officers

- 152. C. L. Burros
- 153. D. C. Doherty
- 154. J. B. Ruch
- 155. J. W. Boyle
- 156. C. E. Higgins
- 157. C. B. Fulmer
- 158. T. F. Wagner
- 159. N. E. Bolton
- 160. H. C. Hoy
- 161. E. C. Parrish
- 162. G. S. Salowski
- 163. C. V. Ketron
- 164. L. P. Riordan
- 165. L. E. Banker
- 166. L. B. Holland
- 167. E. M. King
- 168. J. C. Dougherty
- 169. J. K. Bair
- 170. R. H. Winget
- 171. A. J. Miller
- 172. J. T. Howe
- 173. H. M. Sartelle
- 174. R. S. Edwards

- 175. M. L. Randolph
- 176. A. R. Olsen
- 177. B. E. Foster
- 178. F. R. Bruce
- 179. T. A. Arehart
- 180. T. W. Hungerford
- 181. R. G. Affel
- 182. W. B. Cottrell
- 183. D. M. Davis

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- 184. Nuclear Safety Information Center
- 185-187. Central Research Library
- 188-189. ORNL Y-12 Technical Library, Document Reference Section
- 190-192. Laboratory Records Department
- 193. Laboratory Records, ORNL R. C.
- 194. Patent Office
- 195-196 Nita Henkle, Reinhold Book Division, 430 Park Ave., New York, N. Y.
- 197-211. Division of Technical Information Extension, Oak Ridge
- 212. Research and Development Div., AEC, ORO