AIRPLANE DOPES
DOPING AND DOPE ROOM REQUIREMENTS

(MATÉRIEL BRANCH REPORT)

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AIRPLANE DOPES, DOPING, AND DOPE ROOM REQUIREMENTS

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Wright Field, Dayton, Ohio, May 7, 1930

This paper has been prepared at the direction of the Chief of the Air Corps. It aims to cover the requirements for doping Air Corps equipment and the installations needed to insure a satisfactory and safe means of producing a lasting finish. It is intended more as a guide in securing the correct materials and equipment than as a specification to be followed. The specific requirements for the dopes, and other finishing materials, and the process requirements to be followed are given in Air Corps Specifications.

AIRPLANE DOPES

Airplane dopes are essentially colloidal solutions of cellulose acetate or cellulose nitrate, together with sufficient flexilizers to give a smooth, homogeneous, flexible film, produce tautness, and increase the length of service of the fabric to which they are applied.

A fabric-covered airfoil without the addition of a protective film would be very susceptible to humidity changes, becoming slack or taut with every change of atmospheric moisture. The fabric would also lose its strength quite rapidly with exposure and could not give the proper protection to the interior wing structure. Coating the fabric-covered airfoils with dopes render them waterproof and sunproof, and the tightening produced when the dopes dry causes the fabric to conform to the designed wing section.

Airplane dopes are of two types, clear and pigmented. The clear dopes are generally used only as undercoats, while pigmented dopes are used for the finishing coats over the clear dope, or in the semipigmented, as a complete finishing scheme in itself.

CLEAR DOPES

The essential constituents of a clear dope are five in number:

(a) The film-base compound.

(b) The flexilizers for producing a flexible film.

(c) The solvents for the film-base material.

(d) The diluents for thinning the solution.

(e) The slow dryers or antiblushing solvents.

The film-base compounds are cellulose acetate or cellulose nitrate. Cellulose acetate is the more expensive compound owing to the materials used in its preparation and the more involved method in its manufacture. It is much less flammable than cellulose nitrate and for this reason is used where the flammability of the film is of especial importance. Cellulose nitrate is most generally used for airplane dopes, the more suitable type being that manufactured to give a viscosity range of from 15 to 20 seconds. A lower viscosity has much less durability. The molecular structure is believed to be partially broken down, as compared with pure cellulose, in the process of manufacture.

Flexilizers are required in dopes to produce a film which will remain flexible for the required life of the finish. Triphenyl phosphate, tricresyl phosphate, triacetin, castor oil, camphor, and several other blown vegetable oils have been successfully used as flexilizers.

The solvents are the liquids which are used to dissolve the cellulose-base materials, to prepare them into such form that they may be applied to the fabric as a finish. Acetone, methyl acetate, ethyl acetate, and methyl-ethyl ketone are common solvents for cellulose acetate; butyl acetate and amyl acetate are common solvents for cellulose nitrate.

The diluents or thinners are liquids less expensive than the solvents, have little or no solvent action in themselves, and can be added to the dissolved base material without affecting its solubility. Diluents common to dopes are ethyl alcohol, toluol, xylol, mineral spirits, and butyl alcohol.

Benzol has been used, but its toxic action upon the human system has caused its replacement with other less toxic liquids.

When dope dries too rapidly, the cooling produced by the evaporation of the liquid causes moisture from the air to form on the wet dope film. This moisture will cause the cellulose base to precipitate from solution, forming white streaks and blotches in the film. To prevent this blushing, one of two methods must be used, either the humidity of the surrounding air must be kept low or solvents of slow evaporation rate must be added to the dope solution. When the humidity is not too excessive, it is customary to add slow-drying or antiblushing solvents to the dope. Ethyl lactate, diacetone alcohol, benzyl alcohol, cellulose, methyl cellulose, and cellulose acetate are all antiblushing solvents.

PIGMENTED DOPES

Pigmented dopes are of the same general composition as clear dopes, but with the addition of an inert pigment finely ground and mixed into the clear dope.
Pigmented dopes are used over the clear dopes for two purposes; i.e., to give the desired color to the finished surface, and to protect the fabric and clear dope from the actinic or ultra-violet ray of sunlight, which rapidly weakens the clear dope and fabric.

Normally four and sometimes more coats of clear dope are applied to the fabric, and when this is thoroughly dry, two coats of pigmented dope are applied by spray to give the desired finish.

The finish required by the Air Corps for military airplanes can be obtained by four coats of clear dope and two of pigmented dope, or by the use of four or five coats of semipigmented dope. Commercial airplanes very often have six or more coats of clear dope and two of pigmented. The addition of more clear dope adds only to the general smoothness and appearance of the finish.

Semipigmented dope is compounded so that it can be applied directly to fabric having no coats of clear dope, and a finish of four coats should produce the same degree of smoothness, tautness, and strength as four coats of clear dope. In addition, this finish should have the required pigment to protect the fabric from actinic light.

TESTING AND APPROVAL

All airplane dope used by the Air Corps or by contractors of airplanes for the Air Corps are thoroughly tested by the Matériel Division. Any new brand or formula must undergo chemical, physical, and weather-exposure tests as outlined in Government specifications. When found satisfactory for Air Corps use, they are placed upon an approved list, from which all purchases are made.

Each separate product is assigned a code number, which identifies the product while in storage and when used.

All clear dope for Government use is supplied in 110-gallon steel drums provided with two bungs, one in the head and the other in the side, to facilitate drawing the dope for use.

Pigmented and semipigmented dopes are supplied in 1 and 5 gallon large-opening cans to permit ease in mixing up any settled pigment. It may also be furnished in agitator-type drums, if so desired.

STORAGE

Dope should be stored in a dry warehouse where it is not subjected to direct sunlight and heat. The drums may be painted to prevent rusting, but care should be taken to see that the information stenciled on the drum is not effaced. Pigmented dopes stored for a period of months should be agitated periodically to prevent settling and caking of the pigments. Inverting the cans once a month would tend to prevent hard cakes of pigment from forming in the lower portion of the container.

CONDITIONS FOR DOPING

Doping is best accomplished in a warm dry room with plenty of ventilation. As previously stated, excessive moisture tends to make the dope bluish and retards the rate of drying. During the winter months, the room should be heated to about 70°, and the fresh air admitted through or over heated coils. The best method of heating the cold outside air is to draw it through a blower equipped with steam coils and then circulate it into the room in such a way as to avoid direct draughts on the work. During the summer months it is not necessary to heat the air and it can be drawn directly into the room either through ducts or windows. There should always be sufficient inlets to provide for the required amount of ventilation out through the exhaust fans. Most of the dopes used by the Government are sufficiently bluish resistant to give a satisfactory film even under adverse conditions.

When the relative humidity is more than 90 per cent, it is desirable to dehumidify the air. This can be done by chilling, which causes the excess moisture to precipitate out, or the relative humidity can be reduced by heating the air. However, this heating is undesirable in warm damp weather, as it produces disagreeable conditions for the workman.

APPLICATION OF DOPE TO FABRIC BY BRUSH

The first coat of dope should be applied the same day that the fabric is attached to the airfoil. The fabric is stretched during the covering and this tautness should be retained to secure a satisfactory tight-surface. If the stretched fabric is allowed to stand for several days before doping, the original tightness is lost by the fabric taking a permanent set.

The first two coats of dope should be applied by brush. The first coat should thoroughly wet the fabric but should not be rubbed in to give excessive penetration. It is with the first two coats that the nap of the fabric is laid and thereby tending to give a smooth finish. Finishing tapes and patches are applied with the second coat. The predoping of the tape has been found to give a little better adhesion with less rubbing down than if the tape has not been predoped. Tape can be predoped by submerging it in a bath of dope, passing it between rollers to squeeze out the excess, stretching it across the room, or draping it over supports, and allowing it to dry.

There has been some experimental work done in an attempt to secure a smooth finish by using spray guns for the first coats, but, until a satisfactory spray gun has been developed such practice is not recommended. A spray gun can be used after the first two coats and will greatly speed up the application of the dope.

Any oil or grease spots on the fabric must be washed out before doping. Dope thinner or acetone will remove these spots. If not removed, the areas will tend to blister and the dope peel.

The cans used for holding the dope during brushing should be of such size as can be conveniently handled and when not in use they should be emptied or kept covered. Brushes, when not in use, should be washed free from dope, with thinner, and then kept in an air-tight container with a little thinner.
APPLICATION OF DOPES AND LACQUERS BY SPRAY GUN

The application of finishing materials to the surfaces of aircraft by a spray gun, after the first two coats, is generally accepted as the most desirable method. The speed with which dope or lacquer can be applied and the rapidity with which these materials set or dry, make for a rate of production that cannot be approached by the brush method.

There are several different companies manufacturing spray equipment, which, if used as recommended by the manufacturer, should give entire satisfaction. The equipment used at the Material Division consists almost entirely of that from the DeVilbiss Co., and it is on the basis of this equipment that the following is written. The same general characteristics are found with other equipment, and the suggestions and troubles encountered with one type may also be found with other makes.

The DeVilbiss Co. have developed special guns and accessories designed especially for the handling of dope materials.

The necessary equipment for any particular dope room will depend upon the volume of work to be handled. The first of the actual spraying units to be considered is the spray gun.

The DeVilbiss Type BD Spray Gun has recently been developed and placed on the market as the latest in spray-gun construction for the application of heavy-clear and semipigmented dopes. Its construction differs from standard spray guns in that it has a flow of air both around and in the center of the dope material. Thus, the material is atomized both internally and externally, and complete atomization is insured. Dopes carrying little or no reduction can be satisfactorily applied with this type of gun. See Figure 1.

The DeVilbiss Type AV Spray Gun is recommended for the application of the finishing coats. This gun is designed to insure a good quality of work and high speed of application. Uniform, finely atomized coatings are the result. See Figure 2.

Both of the above spray guns operate from a pressure-feed material-container. In this type of material feed, the liquid is forced to the spray gun, under pressure, thus insuring uniform, steady, flow of material, making greatest speed possible commensurate with quality of work. (See fig. 3.)

The guns are so constructed that they will produce a round or a flat spray of variable width. Dope is released through the center of the core surrounded by an air blast which produces a round spray. Two tips at 180 degrees can be adjusted to release air from opposite sides to produce a flat spray. This tip is adjustable for either longitudinal or transverse spraying.

The Type AV Gun is also used with a suction-feed cup on finishing coats. This type of material feed is utilized where small quantities of finishing materials are used or where frequent color changes are involved. Figure 4 shows the Type AV Gun with a Type KR Cup attached.

In addition to the two guns just described, there should also be a smaller gun similar to the Type CH with 92-E Spray Head for small articles and touch-up work. This gun can be used with a pressure tank but it would most generally be used with a Type KS Suction Cup holding one or two pints of material. This type of spray gun is especially recommended for the application of insignia and the finishing of small parts of cowlings, etc. (See fig. 5.)

Separate tanks of the type and size required for each color of material used will eliminate the necessity of cleaning the entire equipment each time a different color is required. One 10 to 15-gallon tank is recommended for each base color, and one of smaller size for each of the other colors.

At least one air transformer will be necessary. This is for use in cleaning the air supplied to the spray guns and regulating atomizing-air pressure to guns when used with tanks or cups. When the pressure tanks are used, the regulator supplied as part of the tank assembly will act for control of material pressure. It is very important that a clean supply of air be furnished, as there is always a certain amount of water and oil in the air from a compressor, and such substances must be taken out to insure satisfactory work. (See figs. 6 and 7.)

A hose cleaner is required so that the material left in the hose can be readily washed from the line when desired. This is nothing more than a small container from which the solvent can be forced through the material lines, but the ease with which the lines can be cleaned with such a cleaner warrants its use. Any dope allowed to remain in the lines for a period of 10 hours or more is likely to cause the rubber of the line to soften and swell, thus obstructing the line and necessitating the replacement of the hose. (See fig. 8.)

The air for the supply of the spray equipment will most generally be available from some source about the shop other than the dope room. The line should be of sufficient capacity to continuously operate at least two spray guns and the air should be supplied at a pressure of at least 80 pounds. If there should be no supply that can be used for the spray equipment, then a separate compressor will be required.

This compressor should be capable of supplying at least 15 cubic feet of air at 60 pounds pressure for each spray gun. A compressor of about the following size is required to supply the air needed to operate one BD or two AV Guns: Two cylinders of 3-inch bore, 4½-inch stroke and operating at 900 revolutions per minute.

The size of the compressor depends upon the number and type of spray guns to be operated. The Type BD Spray Gun consumes 15 cubic feet at 60 pounds pressure; the Type AV Spray Gun consumes 6 to 10 cubic feet at 60 pounds, depending upon type of air cap being used; the Type CH Spray Gun consumes 4 cubic feet at 40 pounds.

The fittings for all spray equipment are not of the standard thread and a sufficient supply of connections, adapters, etc., should be available to make the neces-
sary line connections. Figure 9 shows a diagram of the complete spraying installation generally used in a well-equipped dope room.

CARE OF THE SPRAY EQUIPMENT

Spray Gun.—Do not dismantle the spray gun or other equipment unless necessary. Certain parts of the gun are removable for cleaning, but other parts should remain assembled.

Do not use greater air pressure than is necessary at the spray-gun nozzle. It creates an excessive mist about the main body of the spray and causes inefficient operation and poor results.

The holes in the air cap of the spray gun must be kept free from dried dope or other foreign material. When cleaning the air-cap holes, wash thoroughly with acetone or other solvent. Should this be insufficient, insert a broom bristle, pipe cleaner or other soft implement in the air-cap holes. A hard, sharp instrument will injure the air cap, causing an unbalanced spray.

Keep the packing in the fluid-needle packing-nut plant by an occasional oiling.

Air Transformer.—The air transformer removes oil and water from the compressed air, filters and regulates it, indicates both the main lines and the regulated pressure, and provides air outlets to the spray gun and pressure-feed container.

The moisture collects in the base of the transformer from which it is drained by opening the drain cock. This should be done each day before starting work and more frequently if necessary. When the Type HLB Transformer is used, the draining of moisture from the condensing chamber is automatically attended to.

The pressure regulator should be adjusted to zero pressure when not in use. The diaphragms of the pressure regulator are sometimes broken. A buzzing sound will then be heard in the valve. It is well to keep a supply of these diaphragms on hand for replacements. Releasing the air pressure and the valve when not operating the equipment will protect the diaphragm from distortion and cause them to last longer.

Pressure-Feed Tank.—The pressure-feed tank, after being regulated to the desired pressure, automatically maintains that pressure assuring a constant and uniform flow of material to the spray-gun nozzle. Always fasten the tank lid securely with the clamps before introducing pressure into the tank. Do not introduce the air too rapidly into the tank. The force with which the air strikes the material scatters it over the interior of the tank with the possibility of clogging the passages in the tank lid.

Always release air pressure from the tank before removing the lid.

Never permit the air-regulator protector on the under side of the tank lid to become clogged.

Do not allow the safety valve to become dirty or coated with dope.

Suction-Feed Cup.—Never allow the vent hole in the suction-feed cup to become clogged with dirt, dried dope, or other substances. This will cause a jerky or fluttering spray.

If loosened from the cup lid, the material tube will also cause a jerky or fluttering spray.

 Hose.—The material hose should be either black or gray, while that for the air pressure should be red. Material hose should be of special construction to withstand the action of solvents as used in doping materials.

The life of the hose depends upon the care given it. Always thoroughly clean the material hose after use. Do not allow kinks in the air hose during use. A sharp pull on the air hose when kinked and under pressure, greatly exaggerates the strain and pressure on the hose. To remove kinks in the air hose, loosen the connection nut on one end of the hose, and while under air-pressure turn the hose in such a way as to remove the kinks. When the kinks are removed, tighten the connections.

It may facilitate the handling of the spray gun and hose to tie the air and material hose together just below the spray gun.

Never use hose of smaller diameter than that supplied with the original equipment. The size required for the main air line is 3/16-inch inside diameter; that for the air line from the pressure tank to the spray gun is 1/4-inch inside diameter, and that for the material lines is 3/32-inch inside diameter.

Most troubles with the spray gun and equipment are due to improper cleaning of the parts.

The following is a list of the most common troubles encountered, their cause, and the remedies:

TROUBLE CHART

Most troubles may be avoided by thoroughly cleaning equipment after use

<table>
<thead>
<tr>
<th>Trouble</th>
<th>Possible cause</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jerky or fluttering spray</td>
<td>In general, caused by air leakage into material line.</td>
<td>Tighten material tip.</td>
</tr>
<tr>
<td></td>
<td>Loose material tip</td>
<td>Replace material tip gasket.</td>
</tr>
<tr>
<td></td>
<td>Defective material tip gasket</td>
<td>Tighten material tube.</td>
</tr>
<tr>
<td></td>
<td>Loose material tube in suction cup</td>
<td>Clean out vent hole.</td>
</tr>
<tr>
<td></td>
<td>Clogged venthole in cup lid</td>
<td>Reduce atomizing-air pressure for material flow or increase flow of material at spray-gun nozzle.</td>
</tr>
<tr>
<td>Excessive vapor</td>
<td>Too much atomizing-air pressure for material at spray-gun nozzle.</td>
<td>Reduce atomizing-air pressure or increase flow of material at spray-gun nozzle.</td>
</tr>
<tr>
<td>Trouble</td>
<td>Possible cause</td>
<td>Remedy</td>
</tr>
<tr>
<td>------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Spattering spray</td>
<td>Too much material for amount of air pressure at spray-gun nozzle.</td>
<td>Increase atomizing air-pressure or decrease flow of material to spray-gun nozzle. Clean air cap as instructed in “Care of Spray Gun.” Reduce air pressure at air transformer or spreader-adjustment valve. Increase material pressure. Clean air cap. Increase the pressure. Strain material and clean spray gun and hose line.</td>
</tr>
<tr>
<td>Form of spray unbalanced</td>
<td>Dried dope or dirt in center orifice or spreader-jet holes of air cap.</td>
<td>Slightly loosen packing nut.</td>
</tr>
<tr>
<td>Split spray</td>
<td>Too much air pressure.</td>
<td>Slightly loosen packing nut.</td>
</tr>
<tr>
<td>Spray too small</td>
<td>Insufficient material pressure.</td>
<td>Slightly loosen packing nut.</td>
</tr>
<tr>
<td></td>
<td>Dirty holes in air cap.</td>
<td>Slightly loosen packing nut.</td>
</tr>
<tr>
<td></td>
<td>Too low setting of spreader-adjustment valve.</td>
<td>Slightly loosen packing nut.</td>
</tr>
<tr>
<td></td>
<td>Lumpy material.</td>
<td>Slightly loosen packing nut.</td>
</tr>
<tr>
<td>Material leakage from nozzle</td>
<td>In general, improper seating of material needle. Material-needle packing nut too tight. An accumulation of dried material on inside of material tip.</td>
<td>Slightly loosen packing nut.</td>
</tr>
<tr>
<td>Air leakage</td>
<td>From spray-gun nozzle, caused by improper seating of air valve due to dirt or wear. From oil hole in top of spray-gun body or from worn valve stem. Loose material-needle packing nut.</td>
<td>Slightly loosen packing nut.</td>
</tr>
<tr>
<td>Material leakage from material-needle packing nut.</td>
<td>Dried packing.</td>
<td>Slightly loosen packing nut.</td>
</tr>
<tr>
<td>Excessive air-pressure drop when spray-gun trigger is pulled.</td>
<td>Too many spray guns or other items of equipment in simultaneous operation. Obstructed air passages.</td>
<td>Slightly loosen packing nut.</td>
</tr>
<tr>
<td>Gradual building up of pressure on pressure gage after adjustment.</td>
<td>Dirty baffles or waste sack. Improper seating of air-regulator-valve seat due to dirt accumulation on seat.</td>
<td>Slightly loosen packing nut.</td>
</tr>
<tr>
<td>Failure of air pressure to build up as rapidly as it should in dope tank.</td>
<td>Loose dope-tank lid. Dirt or dope-covered lid-passages or protector body on underside of lid. Improperly seated or broken diaphragm. Improper seating of air-regulator-valve seat due to dirt accumulation on seat.</td>
<td>Slightly loosen packing nut.</td>
</tr>
<tr>
<td>Insufficient removal of moisture from air.</td>
<td>Too many spray guns or other items of equipment in simultaneous operation. Obstructed air passages.</td>
<td>Slightly loosen packing nut.</td>
</tr>
<tr>
<td>Excessive air-pressure drop when spray-gun trigger is pulled.</td>
<td>Moisture-saturated waste sack.</td>
<td>Slightly loosen packing nut.</td>
</tr>
<tr>
<td>Gradual building up of air pressure in dope tank after adjustment.</td>
<td>Moisture-saturated waste sack.</td>
<td>Slightly loosen packing nut.</td>
</tr>
<tr>
<td>Too small spray</td>
<td>Not enough air pressure or material of too heavy consistency.</td>
<td>Slightly loosen packing nut.</td>
</tr>
<tr>
<td>Jerky or fluttering spray</td>
<td>Vent hole in cup cover closed or clogged with dope. Lack of material. Material tube loosened from cup lid. Loosened cup-coupling nut.</td>
<td>Slightly loosen packing nut. Slightly loosen packing nut.</td>
</tr>
<tr>
<td></td>
<td>Increase air pressure to spray gun. Thin or reduce material. Clean venthole of material.</td>
<td>Slightly loosen packing nut. Slightly loosen packing nut.</td>
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</table>

**SPRAY GUN**

- **Remedy**
  - Increase material pressure.
  - Clean air cap.
  - Increase the pressure.
  - Strain material and clean spray gun and hose line.

**AIR TRANSFORMER**

- **Remedy**
  - Slightly loosen packing nut.
  - Strain material. Clean gun and hose. Remove material tip and immerse in solvent. Blow out with compressed air. Snap trigger several times, and if trouble is not remedied, remove and clean or replace air valve. Replace air valve.

**PRESSURE-FEED TANK**

- **Remedy**
  - Slightly loosen packing nut.
  - Tighten lid.
  - Remove lid and examine passages. Remove and clean protector-body parts. Remove and reseat or replace regulator diaphragm.
  - Remove regulator-body cap and tap sharply on end of regulator valve. If this does not remedy conditions, remove valve and clean valve seat.

**SUCTION-FEED CUP**

- **Remedy**
  - Increase air pressure to spray gun. Thin or reduce material. Clean venthole of material.
  - Open cup and inspect amount of material in container. Tighten material tube against cup lid. Tighten coupling nut on material-inlet nipple of spray gun.
FINISHING METAL SURFACES

Metal surfaces were originally finished with an oil enamel but the development of quick-drying finishes has to a great extent displaced the use of such enamel.

The most important point with regard to the finishing of metal parts is the cleaning of the surfaces. If the surface is not thoroughly clean the finish will not adhere. The cleaning will depend upon the kind of metal. Steel parts can generally be cleaned by proper washing, or sand-blasting when necessary. Thin aluminum parts must be washed, not sand-blasted. There are several commercial cleaners which will give satisfaction. A caustic dip followed by an acid dip and washing in hot water is satisfactory for small parts.

There must be a suitable primer used over the metal before the color is applied. The overnight-dry, oil-base red-oxide primer is the one that is most highly recommended. The drying of this primer can be hastened by using a low-temperature oven. The temperature and time should be as recommended by the manufacturer whose products are being used. Where an unusually smooth finish is required, a surface that can be sanded is applied over the primer.

For the color coats, it is recommended that pigmented dope be used, and if the same material that is used on the fabric is applied to the other parts the entire airplane will have the same degree of smoothness and luster.

The materials for metal finishes should all be from the same manufacturer, as it is not recommended that one make of primer and another make of dope or lacquer be used together.

Some primers must be doped or lacquered the day following their application. If this is not done, they will tend to lift with the application of the finishing coats. The primer coat should not be applied too heavily. It is sufficient if a thin uniform coat is applied, even though it does not hide the metal. The pigment in the primer is generally of value only in determining whether the coat has been uniformly applied.

Two coats of color over the primer are all that is required to give a satisfactory finish to metal surfaces. More than this will only add unnecessary weight and require more time and material.

DOPE ROOMS AND SPRAY BOOTHs, THEIR REQUIREMENTS AND CONSTRUCTION

The dope room of any factory or repair depot should be an entirely separate unit from all other departments. There should be no work carried on in this room other than the application of the dope or other finishing material.

The construction should be preferably that of a separate 1-story building, but, if it is necessary that it be a part of another structure, it should be cut off from the rest by fireproof walls.

Care should be taken not to make the dope room so small as to increase the liability of explosive mixtures of vapors and air. The spraying should be confined to the booths, compartments, or section from which the vapors and residues can be readily exhausted. The spray booths, compartments, or section should be a part of the dope room. Figure 10 shows the part of the dope room containing the spray booth, at the Materiel Division. This booth is of sheet-metal construction and large enough to readily accommodate the average-size fuselage. The booth is equipped with three exhaust fans having a combined air-discharge of 54,000 cubic feet of air a minute. These exhaust fans are of the injector type shown in Figure 11, section E E.

This booth is equipped with automatic sprinklers, as shown at the top of the booth.

Figure 12 shows the booth side of the dope room at the Waco Aircraft Co., and Figure 13 shows a close-up view of one section of this booth.

Wing sections and smaller control surfaces are suspended from wires radiating out from the spray booth. This makes a very simple and satisfactory way to support the surfaces and they can be slid back out of the way while drying or awaiting another coat.

The exhaust system of this dope room is made up of ten separate units, each exhausting into the open air. These are motor-driven fans supported in a near vertical position. The fans are located at the top of the opening and driven by a long shaft from the motor which is located at the bottom outside of the duct. Figure 14 shows the outside arrangement of this system.

The dope room should have smooth ceilings, as it is difficult to thoroughly protect open-joist construction exposed to such severe fire hazards. It is advisable to sheath such joist construction over dope rooms and spray booths with cement plaster on metal lath or by an equivalent approved construction.

Fires in the dope rooms or spray booths are of such a nature as to require a large amount of water to extinguish them, hence the rules indicate that such work should not be done in locations above valuable articles subject to water damage, unless the floor is waterproofed and provided with adequate scuppers or drains.

Spray booths should be constructed of noncombustible materials. The use of wired-glass panels in part is satisfactory. If combustible, the floor within the booth and for an adequate distance outside should be protected with some noncombustible covering. Sheet metal from which a spark can not be struck is satisfactory.

Where baffle plates are necessary they should be of the removable type in order to facilitate cleaning. Baffle plates acting as catchers of residues inside of booths or vent ducts should be avoided. The baffle plates should be taken to a safe place for cleaning purposes.

EXHAUST SYSTEMS

The exhaust system should be of sufficient capacity to promptly remove all flammable vapors and residues.

Proper exhausts can be obtained only by strictly adhering to the following fundamental principles:
That the exhaust be sufficient to prevent spray residues and vapors from escaping other than by the means provided for the purpose.

The inclosures for the actual spraying operations may be in the form of single spray booths, double booths, spray tunnels, or spray rooms. Such inclosures are hereinafter referred to as booths. The necessary ventilating-air velocity in the spray booths will vary widely; in some cases a velocity as low as 60 linear feet per minute or lower is effective, and in other cases a velocity as high as 200 linear feet may be required. For these reasons the requirements for each installation should be carefully determined. Care should be exercised to insure that the air-exhausting equipment is sufficient to secure the desired results.

Where spraying operations are carried on in a room and not in the spray booth the provisions for exhausting the vapors from the room should be sufficient to effect a complete change of air every three minutes. The method of supplying this incoming air is a feature that also requires study.

It is preferable to have 10 to 20 per cent excess in the exhaust capacity over the supply of incoming air. The fresh-air supply should be distributed in such a way as to avoid back drafts. In some cases the best method may be to introduce the fresh air in or near the face of the booth. If windows adjacent to or in the side of the spray booths are opened or if high winds are allowed to enter the room through skylights, doors, or other openings, the drafts so created may nullify the benefit of the exhaust system and create a back draft of vapor into the room. Cool drafts allowed to blow on freshly-doped surfaces tend to cause blushing and should be avoided.

Where spray booths are provided, the management should take every precaution to insure that spraying processes are not carried on outside of the booth, as obviously the booth exhaust system is not designed for such conditions and a severe hazard will be set up. Articles being sprayed should be placed far enough within the booths so that the spray and fumes will not spread beyond the area in which the exhaust system is effective.

The general methods of exhausting from spray booths, as met with in practice, are as follows:

(a) Ejector-type fans and motors outside of the booths and ducts.
(b) Shaft-driven fans in duct with motor and main bearing outside.
(c) Belt-driven fan in duct with the belt bearing and pulley encased.

These are listed in the order of their preference.

Figure 15 shows typical dope-room and spray-booth exhaust systems.

Changes in direction of air flow should be avoided if possible. Necessary elbows or changes of direction of the exhaust pipe may cause heavy deposits of residue, and to facilitate cleaning, such pipe may need doors with strong fastenings, or otherwise installed and built to facilitate cleaning of the interior. It must be recognized that even with extreme cleanliness a fire may occur in these exhaust pipes, in which case they may get red hot. To prevent ignition of other parts of the plant, they should be treated as flues and kept free from contact with combustible materials.

Pipes should terminate in a location where the discharge will not endanger property.

Pipe outlets exposed to sparks or other sources of ignition should be protected from such hazards. Deflectors or wind breakers are desirable in all cases to prevent wind interfering with the efficacy of exhaust systems. As metal fan blades are a source of fire danger because of sparks from friction, fan blades should be made of rigid nonsparking metal, necessary allowance being made for the ordinary expansion and loading to prevent contact between moving parts and the fan housing.

Unless safely located away from the spray and fumes, fan motors should be of a type approved for hazardous atmospheres. Fans should be mounted on a shaft sufficiently heavy to maintain perfect alignment even when the blades of the fan are heavily loaded, the shaft preferably to have bearings outside the fan housing and booth. All bearings should be of the self-oiling type.

The stacks and vents should be of substantial construction. Joints should be riveted and soldered or otherwise made tight. All stacks and vents should extend as directly as possible to the outside air and not through other rooms.

Under no circumstances should a dust or refuse collection system be used for other purposes be used for the ventilation of spray booths.

Every large installation presents an individual problem requiring separate considerations. The necessary exhaust systems can not be obtained in a haphazard way nor by guesswork.

The reliable operation of exhaust systems will depend upon the maintaining of the conditions used as the basis for design. If this is not enforced the desired results will not be obtained, and hazardous conditions will be created. It is therefore obvious that frequent check-ups of these systems should be made by competent inspectors. A simple way to ascertain whether there is sufficient exhaust (aside from the direct evidence of accumulated deposits in the spray booth) is to stand off to one side with the booth opening between the light and the observer. If the vapors of residues spread beyond the booth opening, then there is not sufficient velocity across the face of the opening. If the spray can not be seen to spread out into the room, it is safe to assume that the exhaust system is adequate. If it is desired to obtain actual measurement of the velocity, anemometer readings should be taken across the face of the booth.

CLEANING OF EQUIPMENT

Spray booths, tubes, ducts, and stacks should be kept as free from deposits of residues as is practi-
can be somewhat as to their constituents, and fire-hazard cable by cleaning daily or as often as is necessary.

The materials used in the finishing of airplanes all contain volatile liquids which, under certain conditions of temperature, give off highly flammable vapors or gases. These materials, when discharged from a spray gun in a finely atomized form resembling a mist, are usually readily ignited. The residues or waste deposits, which collect as a result of the spraying, are highly flammable.

When dry and suspended in the air as a dust cloud, the particles present a high-flash fire hazard; or if present in large amounts offer conditions under which dust explosions may occur. These residues having a large cellulose-nitrate content may decompose under moderate heat, and this may result in the evolution of flammable gases, followed by fire.

Paints, varnish, oil-base primers, and similar oil-type finishing materials, as well as some of the dope and lacquer products, because of their oxidizing-oil content, create the hazard of spontaneous ignition when in contact with rags, waste, and other similar materials. It is apparent therefore that steam coils or other heated objects should be kept free of waste, dust, and residues from finishing materials.

While the paints, varnishes, enamels, and dopes differ somewhat as to their constituents, and fire-hazard properties when in liquid form, they all present a similar hazard when being applied by the spray method and they should be similarly protected.

CAUSES OF FIRES

The use of spray equipment has resulted in a considerable number of fires. Many of these fires have been of slight or moderate extent, but when structural and occupancy conditions have been unfavorable, or the proper protection has been lacking, losses have been heavy.

Regardless of the finishing materials employed, fires, as a rule, originate from four principal conditions in the spray booth:

1. Breaking of electric lamps and sparks from electrical defects.
2. Results of careless use of highly flammable solvents when cleaning the interior of the booths, pipes, tubes, fans, motors, etc.
3. Deposits of dust and sprayed material in the tubes and vent pipes resulting from neglecting to clean them frequently.
4. Improperly arranged or designed booths and booth equipment and the fans, motors, etc., used for removing the vapor-laden air.

Failure to maintain clean and orderly conditions in the vicinity of the booth has also facilitated the spread of many fires.

A feature of pronounced importance is the effectiveness in removing the vapors and residues from a designated area. The removal of the evaporating solvents of the dope is necessary not only to prevent the formation of explosive concentrations but also to improve the quality of the air breathed by the workman employed in the dope room.

Cellulose-acetate dopes are less flammable only in the dry conditions; the liquid dope is equally as flammable as the cellulose nitrate.

Assuming a direct means of ignition is eliminated, cleanliness and adequate ventilation are the features upon which rest the safe operation of the present spray equipment.

Of equal importance is adequate fire protection, supplemented by isolation of the dope room from other buildings or parts of buildings.

METHODS OF HANDLING SPRAY MATERIALS

There are now in use four methods of supplying the material to the spray gun: A fixed-pipe system, pressure feed from a pressure tank, gravity feed from elevated containers, and from a cup attached directly to the spray gun.

Where the fixed-pipe system is used, mixing tanks, filters, and pumps should be located in a separate mixing room. Motors and other electrical apparatus should comply with the requirements of the National Electrical Code for hazardous locations.

The National Fire Protection Association standards require that containers for gravity feed to the spray gun shall not exceed 10 gallons capacity and shall have noncombustible covers. Wire cables or those containing stranded-wire cores should be used to support gravity-feed containers. No open containers should be permitted.

The use of pressure tanks is recommended for all work where relatively large amounts of the same material are used.

Small cups attached directly to the spray gun may be of glass if not larger than 1-pint capacity; the metal cup of one quart is recommended for the small work where different colors are used.

SAFEGUARDING ELECTRICAL EQUIPMENT

The electrical installations of the dope room, spray booth, and dope storage should conform to the requirements of the National Electrical Code. All rooms, compartments, etc., in which dopes and other highly flammable gases, liquids, mixtures, or other substances are used or stored should be considered as hazardous locations and the electrical equipment installed accordingly. The National Fire Protection Association regulations for the above conditions require that no spark-producing cut-outs, switches, detachable plugs, or portable lamps shall be used. Lamps are prohibited inside spray booths and ducts and in any locations where there is possibility of the spray coming into direct contact with the lamp or fixture. Where spraying is carried on without a booth and in the dope rooms, the usual type of vapor-proof lamps, further guarded by extra glazing, may be used, or other provisions made to minimize the spray coming in contact with the lamp. Wiring must be installed in approved metal conduit. All electrical apparatus and equipment must be electrically grounded in an effective manner.
Figure 1.—Type BD spray gun

Figure 2.—Type AV spray gun
Figure 3.—Type QM pressure-feed material tank, 10-gallon

Figure 4.—Type AV spray gun with KK suction-feed material cup, 1 quart
FIGURE 5.—Type CH spray gun with type KS suction-feed material cup, 24-ounce.

FIGURE 6.—Type HL air transformer.
Figure 7.—Type HLB heavy-duty air transformer

Figure 8.—Cut of HD hose cleaner
Installation of Spraying Equipment—Pressure Material Feed

Figure 9.—Diagram of spraying-equipment installation
Figure 10.—Spray booth at Materiel Division

Figure 11.—Exhaust-duct detail
Figure 12.—Spray booth at a commercial plant. Courtesy of Waco Aircraft Co.

Figure 13.—Spraying at wing in production plant. Courtesy of Waco Aircraft Co.
FIGURE 14.—Outside view of exhaust system. Courtesy of Waco Aircraft Co.
ANS NOT ALL (IN THE MOLDING)

TYPICAL ARRANGEMENT OF SPRAYING DEPARTMENT.

Showing Storage and Mixing Room and five different spray booth installations

Figure 15.—Typical arrangement of exhaust system