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Some Health Hazards Associated with the Manufacture of Commercial Jet Aircraft*

M. CHAIN ROBBINS

Aero-Space Division, Boeing Airplane Company, Seattle, Washington

THE development and production of the 707 airplane has presented some interesting industrial hygiene problems which have required the application of engineering control measures, utilization of personal protective devices and continued medical surveillance to preclude industrial disease and injury. These problems have been related to the following manufacturing operations:

(1) Integral wing fuel tank cleaning and sealing.
(2) Hydraulic system testing and installation.
(3) Spray painting with epoxy resin paint formulations.

Each of these operations will be considered with a brief discussion on their related industrial hygiene problems.

Integral Wing Fuel Tank Cleaning and Sealing

The development of an integral or "wet" wing has presented health and safety problems in the cleaning and sealing operations necessary to make the wing fuel tight. An integral wing is defined as one in which the raw fuel is in direct contact with the structural members of the wing itself. Sealing to prevent the loss of fuel is necessary around fasteners, rivets, lockbolts, and the periphery of the entire wing structure.

In order to accomplish the seals, the metal surfaces are cleaned with methyl ethyl ketone in the confined space of the wing cavity. Subsequent to this cleaning operation a sealing material is manually applied to the desired locations. This sealer is composed of a polysulfide base material mixed with an accelerator which contains calcium dichromate and the solvent dimethyl formamide. Following this a topcoating material is brushed over the seal and the bare metal on the bottom wing panel to preclude softening of the seal and corrosion of the metal by the fuel. This topcoating material is a phenolic base with a mixture of methyl isobutyl ketone and butyl acetate as the solvent medium. It is to be remembered that these entire operations are performed manually and the estimated time spent cleaning and sealing an airplane wing (both right and left-hand sections) is about 3000 manhours. The wing cavities are small confined spaces and many of the sealing locations are such that the employees must literally sit or lie down to perform the job, as illustrated in Figure 1.

An engineering solution to the problem of wing ventilation during these operations resulted in providing exhaust systems in the sealing shops, with each system having a capacity of two air changes per minute per wing. These systems are shown in Figure 2. The ventilation has proved adequate to keep solvent vapors below threshold levels, even with several persons cleaning in a wing at one time.

For operations out of manufacturing sequence (*i.e.* out of the regular wing sealing shop) portable exhaust or blower units are utilized. Determinations of solvent vapor concentrations have generally been made with a Davis Vapotester. It is felt that the use of a properly calibrated direct-reading instrument, such as this, is more practical for day to day operating conditions than chemical determinations. This is especially true when the solvents involved are ketones or aliphatic naphtha.

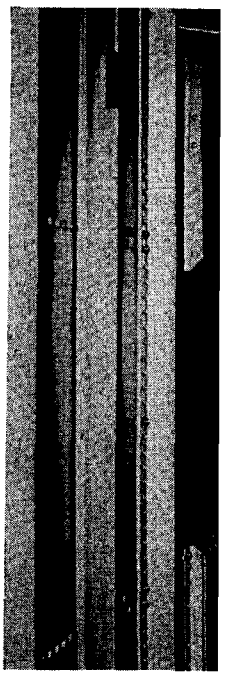
Mixing of the sealants is carried out in a central shop location provided with local exhaust ventilation.

Fortunately, quality control measures demand that skin contact with the sealant be avoided. Although personal protective devices are provided, control of skin contact with the solvents such as methyl ethyl ketone, acetone, etc., is difficult, and a number of dispensary calls have been made by employees suffering from dermatitis as a result of solvent defatting of the skin. The possible fire hazards are obvious; for this reason air-driven and explosion-proof electrical equipment is used. Cleaning rags (small gauze squares) are collected in paper bags outside the wings.

Personnel cleaning and sealing are given physical examinations to screen out persons suffering from epilepsy, cardiac, lung, or skin diseases.

Hydraulic System Testing and Installation

The manufacture of multi-million dollar aircraft, which will be carrying over 100 passengers



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FIGURE 2. Wing clean

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FIGURE 1. Employee cleaning and sealing 707 wing.

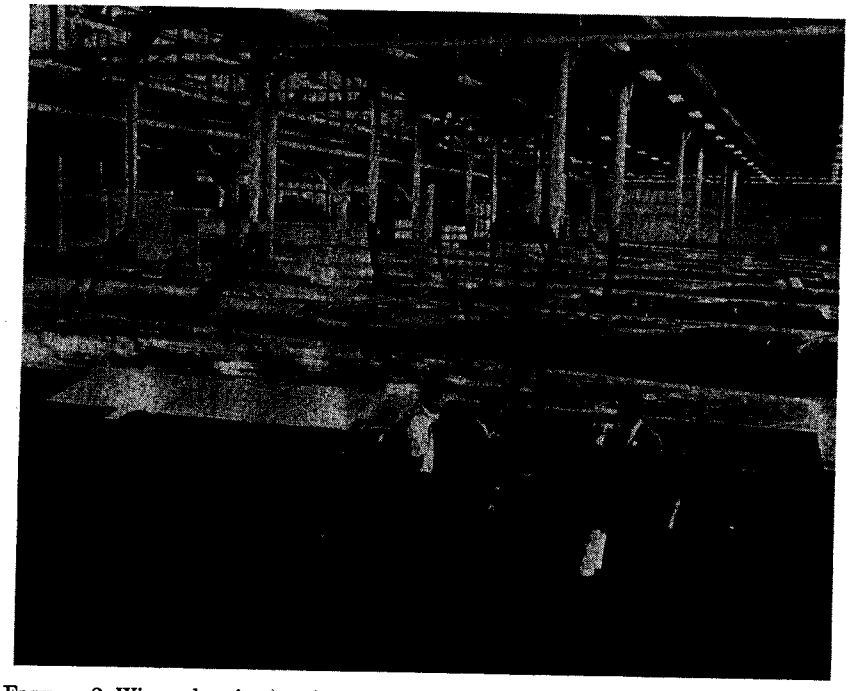


FIGURE 2. Wing cleaning and sealing shop showing local exhaust ventilation.

at altitudes of 30–40 thousand feet, has necessitated the development of a fire resistant hydraulic fluid which will operate at temperatures from minus 40° to plus 200°F. This fluid, marketed by Monsanto Chemical Company, under the trade name of Skydrol 500 has presented equipment and personnel problems in its handling.

Skydrol 500 is a phosphate-ester type synthetic fluid. It contains a corrosion inhibitor, viscosity improver, and dye. Equipment-wise the fluid has a stripping effect on standard aircraft finishes and plasticizing effect on many organic materials including common rubbers. As a consequence, hydraulic system materials in contact with the fluid must be fabricated from Skydrol resistant compounds such as silicone, butyl rubber polymers, nylon, Teflon, and/or epoxy resins. Areas where leaks and spills are liable to occur must be painted with a finish which will not soften under these conditions. This paint and its application will be discussed later.

Hydraulic system components undergo routine pressure testing by mechanics working at test benches where the fluid is supplied at the desired pressure to the component. It is necessary for the mechanic to perform manual operations in attaching and disconnecting the parts from the test bench and draining hydraulic fluid back into the bench reservoir. This operation is repeated many times in an eight-hour shift.

Preliminary toxicological tests by Monsanto indicated that no serious problems would be encountered by personnel handling the fluid beyond the transient irritant effects upon the eyes and upper respiratory tract from direct contact with the fluid or its mist from a high pressure leak.

Patch testing of mechanics and Medical Section staff proved the material was not a primary irritant. No special personnel precautions were instituted beyond recommendations to avoid eye and unnecessary skin contact and to shut off any high pressure leak which might occur then to leave the area until the mist dispersed. Occasional cases of skin reactions appeared but it was felt that these were due to simple defatting of the skin as a result of prolonged or repeated contact with the fluid. Tests on various kinds of rubber and plastic gloves indicated that latex surgical or industrial gloves would last up to a week of continuous work in the fluid providing they were not punctured sooner by lock wires or sharp edges of equipment being tested. Understandably, there was some employee resentment to continuous wearing of rubber gloves. Employees were rotated in other areas for a time in an effort to minimize exposures until it was observed that more than 50 percent of the personnel were exhibiting varying degrees of skin reactions, even among employees who were most conscientious about wearing the rubber gloves. At this point patch testing was again undertaken and it showed those having the most severe skin reactions had indeed become sensitized to the fluid.

With the assistance of Monsanto an extensive patch testing program was undertaken by the Boeing Medical Section using the individual components of the hydraulic fluid in known non-sensitizing, non-irritating diluents. Fortunately the base fluid was not implicated, but the corrosion inhibitor was proved to be the sensitizing agent. Monsanto has not divulged the chemical composition of the corrosion inhibitor, however a new formulation has been developed in which this offending agent is not used.

While tests were underway by Monsanto to determine if the corrosion inhibitor could be eliminated or replaced we were able to substitute in the system component testing program another hydraulic fluid, Skydrol 7000, which does not contain the sensitizer. Mechanics installing and testing the hydraulic system with Skydrol 500 in the factory and on the flight line thereafter took precautions previously unheard of by airplane mechanics. These precautions included the use of protective creams, rubber gloves, and special emphasis on personal hygiene using a sulfonated liquid hand soap to wash off contaminated skin. A safer fluid, Skydrol 500A, has now completely replaced Skydrol 500, and these extreme precautions are no longer required.

Spray Painting with Epoxy Resin Paints

As mentioned earlier, the Skydrol hydraulic fluid has necessitated the development of a paint which will be chemically resistant to the fluid under spill and leak conditions. Such a finish was found in a paint which contains an epoxy resin formulation. Many portions of the airplane are ordinarily painted as parts in sub-assembly areas, but when specifications require that an entire airplane exterior be painted, then the industrial hygiene and safety problems become magnified.

It was realized that the resin paint formulation contained an amine hardener which would probably act as a sensitizing agent on certain individuals, and that spraying the paint would greatly increase the chances for both skin and inhalation exposures.

The painting is performed in a building where the airplanes are painted one at a time. The building has approximately six air changes per hour. The airplane is moved in under a hanging scaffold which is enclosed over the airplane fuselage. Tempered supplied air is brought in at the top of this enclosure and blown down over the

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fuselage at the rate of 100 to 150 feet per minute. The overspray-laden air is discharged onto the floor and exhausted through a water-wash curtain at one side of the building. The main purpose of this tempered air is to remove quickly the overspray for quality control reasons and to provide a satisfactorily constant curing temperature. During cleaning operations prior to painting solvent vapor concentrations measured in the breathing zone are below threshold limits. When the spray painting is being performed, all employees in the building are provided with chemical cartridge respirators. Painters and their helpers are required to wear respirators, gloves, cotton hoods, goggles and coveralls. Exposed skin surfaces are covered with protective creams. Even with these precautions at least one case of sensitization has been observed among employees who have been in the area during the spraying.

Point-Source Gamma-Ray Standards

THE NATIONAL BUREAU OF STANDARDS is making available for the first time point-source standards of radioactivity. These standards are gamma-ray emitters and will be useful to research workers in approximating "ideal" conditions when calibrating scintillation counters and other beam-detecting devices.

Five of these standards are being issued under the Bureau's program to supply standards in all areas of physical sciences. The five are sodium-22, zinc-65, niobium-95, strontium-85, and mercury-203. Each standard consists of radioactive material deposited between two layers of a thin polyester tape.

The activity of each of the nuclides distributed in this form is approximately 5×10^4 gamma rays per second. Sodium-22, which has a half-life of 2.6 years, emits a gamma-ray of 1.28 Mev energy, an annihilation gamma ray of 0.511 Mev energy, and x-radiation characteristic of neon. Zinc-65, with a 45-day half-life, gives off a 1.11-Mev gamma-ray, an annihilation gamma-ray of 0.511 Mev, and x-rays characteristic of copper. Strontium-85 emits a gamma ray with an energy of 0.513 Mev and x-radiation characteristic of rubidium. Its half-life is 65 days. Niobium-95, which has a half-life of 35 days, emits a 0.768-Mev gamma ray. Mercury-203 emits a 0.279-Mev gamma-ray and x-radiation characteristic of thallium. Mercury-203 has a half-life of 46.5 days.

Further information is contained in *Standard Materials*, NBS Circular 552 (third edition), which may be obtained by writing to the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. (35 cents).

Tungsten for High-Temperature Coatings

High-purity tungsten can now be easily plated on metal surfaces by using a vapor deposition process which the National Bureau of Standards has developed for the Navy. The method, devised by W. E. Reid and Dr. A. Brenner of the Bureau's electrodeposition group, involves reducing gaseous tungsten hexafluoride with hydrogen by passing it over the heated object to be plated. At temperatures above 300°C, tungsten is deposited on the hot surface, and the only other reaction product, hydrogen fluoride, passes out with the excess of hydrogen.

By this method, it is possible to coat numerous simple and complex surfaces such as rocket and missile nozzles and jet engine parts. The technique also lends itself to the fabrication of tungsten articles, and may be the only way that complicated shapes of tungsten can be formed. Simple tungsten shapes for use in vacuum tubes have already been fabricated.

Tungsten is one of the few metals that possess structural strength at temperatures above 2000°C. Its extremely high melting point (3140°C), hardness, and corrosion resistance make it a desirable material for high-temperature equipment. However, until lately, the high-temperature properties of tungsten could not be effectively utilized. Its brittleness and hardness prevented it from being machined by conventional methods while its weight restricted its uses in aeronautical equipment.