# Safety Practices in Chemical Laboratories

By JOSEPH B. FICKLEN III

THE practice of safety in a chemical laboratory is not essentially different from that in an industrial plant. However, much has been overlooked in many chemical laboratories with regard to an adequate safety program. It is worth while to point out the following accident figures for chemical laboratories as reported by the National Safety Council for the period 1939 to 1942, inclusive. For every 89 injuries reported there was one fatality. Furthermore, for every six injuries reported there was one accident causing permanent partial disability. Also there was a 35 per cent increase in the total number of injuries during the year 1942 over the number of injuries reported in 1941. It is unfortunate that later accident figures are not now available; but if general accident trends in regard to both accident frequency* and accident severity** in the nation be any criterion, it is safe to say that there has been a substantial increase in both frequency and severity of accidents in chemical laboratories during 1943 and 1944 over 1942.

Generally speaking, the drive for increased production is associated with increased accident frequency and severity in normal industrial operations. On this score alone, it would appear that chemical laboratories should not have such an unfavorable accident record as that cited above, inasmuch as in many laboratories speed is not of the essence as in the manufacturing plant proper. It appears that the unfavorable experience in chemical laboratories is largely due to the lack of proper instruction and supervisory control over the laboratory worker. It has long been an established fact in accident prevention work that a guard placed in the worker's mind is worth many tangible protective devices. In other words, if the worker is taught to think safely so as normally to perform operations with care, the best accident prevention results are obtained. Obviously, proper instruction is essential to such a program.

There are many ways of providing and following up such instruction, some of which are not nearly as effective as others. This question of effectiveness, or whether a safety program, to use a slang phrase, "has teeth in it," is the crux of the more important portion of an entire safety program for a chemical laboratory.

### MANAGEMENT'S ATTITUDE

The most effective and easiest way to achieve the desired result, whether it be from the professorial viewpoint in the case of high school, junior college, or seat of a higher education, or the directorial, as in a commercial plant laboratory or a consulting laboratory, is for top management to convince the student or the employee that management is definitely interested in safety and intends to see operations carried out in a reasonably careful manner. Some readers of this article may recall from student days, a certain incident wherein a professor brought home a definite point by individual instruction, and realize that this point is remembered through the years on account of that particular incident. Similar conditions apply to the instillation in the individual of safety practices. It is not enough for top management to sign a few notices to be placed on the bulletin board once in a while with regard to safety. This action may relieve management's conscience, but all too often the reader of the bulletins is making the mental reservation, "I don't believe the old man would do it that way himself, and why should I?" What does achieve results is top management's visiting the workers' table, and, if something is wrong or unsafe, calling attention to it and having it corrected then and there. Such incidents, even if infrequent, carry the most weight in driving home a safety program, and the news of their occurrence spreads rapidly among other workers. Workers begin to realize that safety practices in their laboratory are worth while and are not to be taken lightly. The following example will accent this important point.

A certain large company, which bas had an enviable safety record, was called upon to operate a shell loading plant. The particular shell to be loaded was regarded as being in tbe more bazardous category. The operation

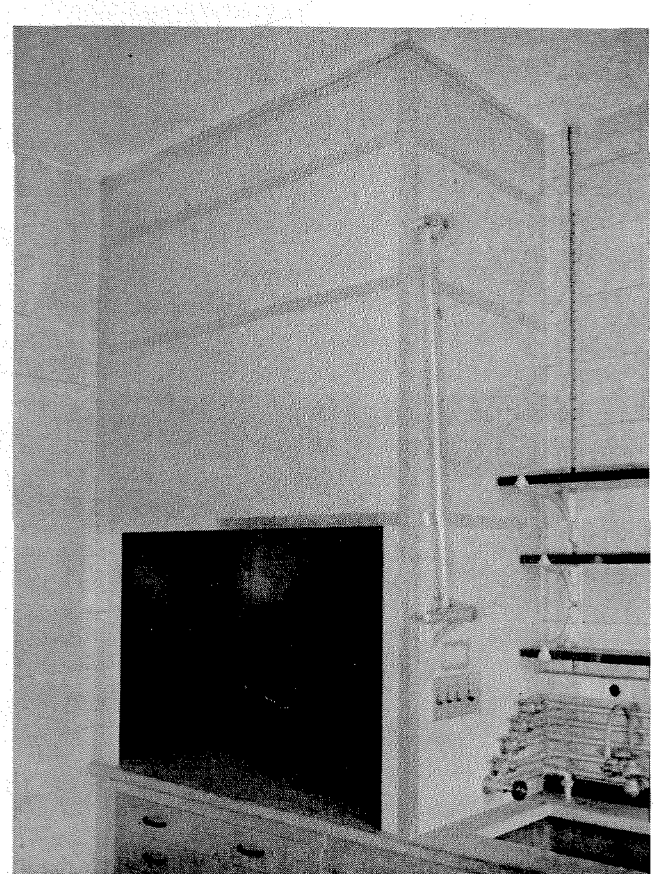


FIG. 1*. Hood provided with exhaust system. Note that water, gas, oxygen, air, and vacuum lines are aranged so that connections can all be made inside hood.

*(Illustrations courtesy National Safety Council.)

*Accident frequency: The accident frequency rate is the number of lost time injuries per one million man hours of exposure. A lost time injury is defined as occurring when an employee stays away from work on his next normal shift after the accident. Also, where a permanent partial disability is involved, even though no actual lost time occurs, this is counted as a lost time injury.

**Accident severity: Accident severity is defined as total lost time, including both actual lost time and also time charges, where death or permanent partial disability is involved, times one thousand divided by the number of man hours of exposure.

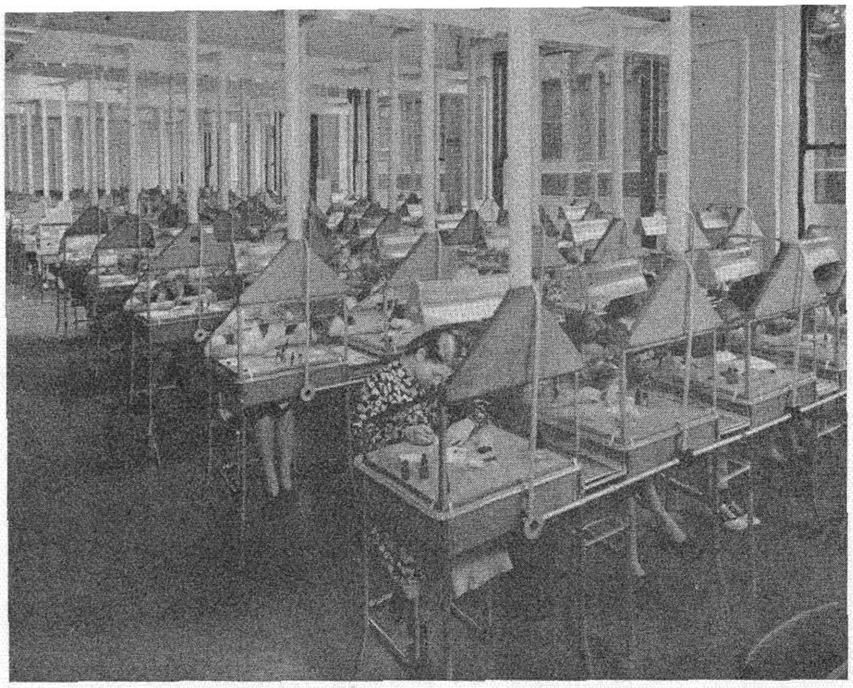


FIG. 2. Illustration of an ideal layout for a radium painting laboratory.

was new to this company. Although the company had operated other munition plants in a different manner, the lines of plant management at this location had been set up in such a way that the safety director had equal rank with the production manager, the chief engineer and the technical director. Furthermore, although the latter three were directly responsible to the factory manager, the safety director was not responsible entirely to the factory manager but more directly to his superior, the division manager. This was one of the numerous steps taken to see that the plant functioned in as safe a manner as possible.

Just after the plant had started, an incident happened which also had a great bearing on convincing all the workers in the plant that the management was sincerely interested, as it had often stated, first, in safety; second, in quality; and third, in quantity of production. The chairman of the Board of Directors of this company paid a visit to the plant. After the visit, he himself advised the safety director that he believed too much powder was being allowed in certain portions of the plant. Obviously, such a happening provided the safety department with the most potent means of convincing all employees in the plant of the sincerity of management's regard for their welfare, and, since this was so, of making it clear that they as employees must cooperate in every way possible to see that through no careless act any hazardous condition was allowed to exist.

As a result of this attitude, the Army and Navy Production "E" was obtained in relatively short order, and this was followed in another very short period by a second "E" award. Also, during 20 months of intensive operation no one was killed at the plant; whereas in another plant, making the same number of similar shells and employing approximately the same number of people over the same period of time, in the neighborhood of 40 persons were killed and many others were maimed.

Forgetting for the moment any humanitarian consideration, obviously the economic saving alone was well worth the effort involved.

Concomitant with top management's interest in safety in the laboratory must go its own example in safety matters. In other words if the laboratory director or supervisor conducts laboratory experiments, he "must practice what he preaches." Many seasoned safety engineers can estimate almost precisely just how carefully a plant will be run by observing the behavior of top management in regard to a safety program, and the conditions which management allows to exist in its own immediate office or laboratory.

A considerable portion of this article has been focused on the supervisory control of accidents, as experience has shown that most can be done from this angle with the least expenditure of effort. Many insurance men have stated that they would rather insure a plant where the executives are safety-minded, even if the plant processed hazardous materials with relatively poor physical safeguards, than a plant where the best physical protection was provided but where the executives, and naturally in turn the employees, were not safety-minded. However, in general what happens is that if safety-mindedness permeates top management, precautionary measures of a physical nature become apparent throughout the entire laboratory area, and the whole becomes cleaner and more businesslike, and hence the physical attributes which are guards from a safety point of view are obtained subconsciously.

### SPECIFIC RECOMMENDATIONS

With regard to the betterment of these physical conditions, certain definite safety ideas have been developed in chemical laboratory buildings which are worth enumerating. The buildings in general should be of fire-resistant construction. Locations where flash fires or explosions are likely to occur preferably should be on the ground floor. Also, apparatus in connection with which such accidents are most likely to happen should

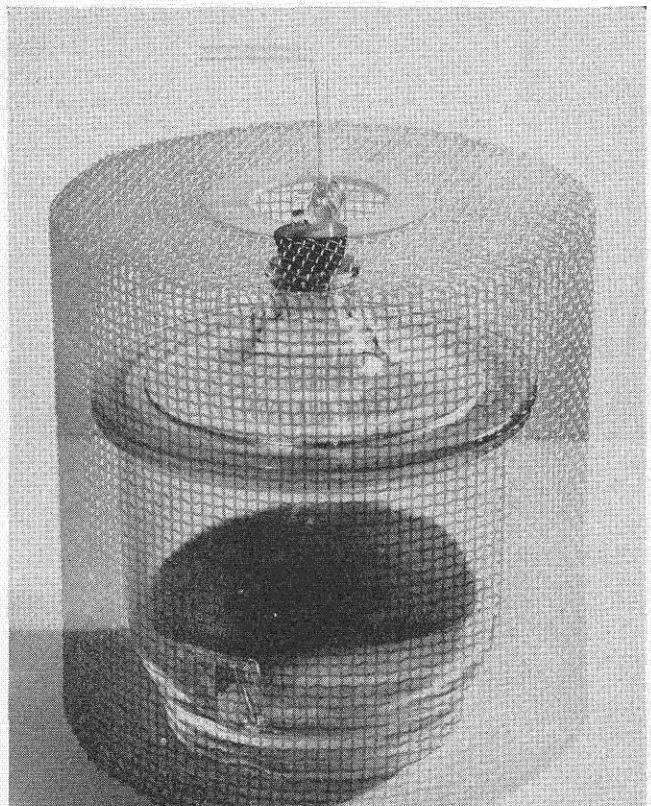


FIG. 3. Illustration of a vacuum desiccator, provided with an asbestos cushion for sulfuric acid as well as an over-all protective screen.

be placed as far as possible from exits. There should be two exits for each floor, located on opposite sides of the building. Exit doors should open outwardly and should be provided with a clear wire glass in the upper panel.

Laboratory exhaust ventilation system requirements may vary a great deal, dependent upon the use to which the laboratory is put. For example, small laboratories in which analyses of simple solutions are made may require exhaust ventilation only where hydrogen sulfide is handled; while in large industrial laboratories the complexity of the ventilation problem approaches that of a chemical manufacturing plant. Ventilation systems should meet local and state requirements. If there are no requirements, then those of the American Standards Association Code for ventilation, where they apply, should be followed. It is advisable to have inlets and outlets at both top and bottom of laboratory rooms, so as to take care of gases both heavier and lighter than air. A sufficient number of air changes per hour should be provided to hold any toxic air contaminants down below the generally accepted maximum permissible limits. Exhaust hoods should be arranged so that a face velocity of at least 60 linear feet per minute is available at all times. A well arranged hood is shown in *Fig. 1.*

All ventilating equipment should be arranged so that there is no possibility of the effluent air from one system contaminating the incoming air either in the same system or in other systems. Provision should be made for the periodic checking of systems to see that they are actually functioning as designed. One interesting case of the improper use of adequate ventilation came to light recently in a laboratory in a synthetic rubber plant. Here titration work on synthetic rubber was conducted, using hot benzene as the medium. After titrating, the entire contents of the flasks was dumped into a metal garbage can, which was located in such a way that the fumes of the can were drawn by the suction of the exhaust hood in which the titration was conducted directly past the breathing zone of the titrator.

The bearing that correct illumination has on safety is important. Noteworthy is the fact that over the past 20 years the minimum standards in lighting have been raised continually and now levels higher than 50 foot candles are often recommended for laboratory work. The periodic cleaning of skylights, windows and artificial lighting units is a point which is too often overlooked in chemical laboratories.

## GOOD HOUSEKEEPING

Under the heading of good housekeeping there are several important points. The first is that the laboratory should be kept clean. There is no reason why a chemical laboratory cannot be kept as clean as an ordinary office. Every collection of residues or other dirt which is allowed to remain at a chemical laboratory is a potential source of trouble.

A second requirement to observe is that operations be carried on with minimal amounts of material, and that other chemicals be not allowed to remain in the work place when they are not needed. Too often one sees in a chemical laboratory, for example, a can of ether which has been allowed to remain near the worker. Yet, from the deposit of dust on the cork of the ether can, it would appear doubtful whether that particular can has been used for months.

Another point is the disposal of waste materials, especially such items as volatile solvents and broken glassware. The dumping of volatile solvent residues down usual drains cannot be condoned. There are too many cases where serious fires and accidents have occurred through such a practice. Separate closed containers should be provided for the disposal of this material. Where there is any extensive hazard involved in its disposition, the ordinary janitor service should not be relied upon but someone conversant with the hazard involved should be assigned to the handling of this material.

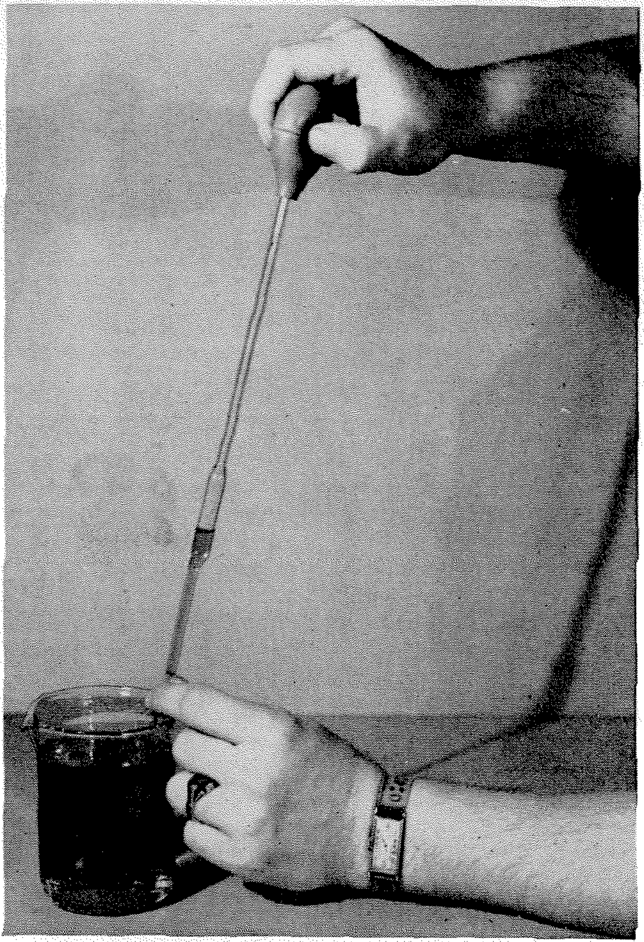


FIG. 4. A suction bulb used for the filling of a pipette.

*Fig. 2* shows a laboratory engaged in painting radium dials. Just recently such a laboratory was found upon inspection to conform satisfactorily to standard ventilation and illumination conditions, as shown in this picture. However, a wastepaper container, like the one shown in the picture, was used for the disposal of small pieces of wiping paper with which the employees cleaned traces of radium paint from objects. Readings taken on this wastepaper basket with a radium evaluation instrument showed an exposure equivalent to 250 micrograms of radium in the paint accumulations on the side of the basket. Furthermore, it was found that the contents of this basket was given from time to time to the ordinary janitor, and that he was permitted to dispose of this waste in a backyard incinerator. Such conditions as these bring out the great importance of following through on waste disposals from a chemical laboratory.

The segregation in the laboratory of broken glassware from other waste materials often will protect the janitors from needless cuts.

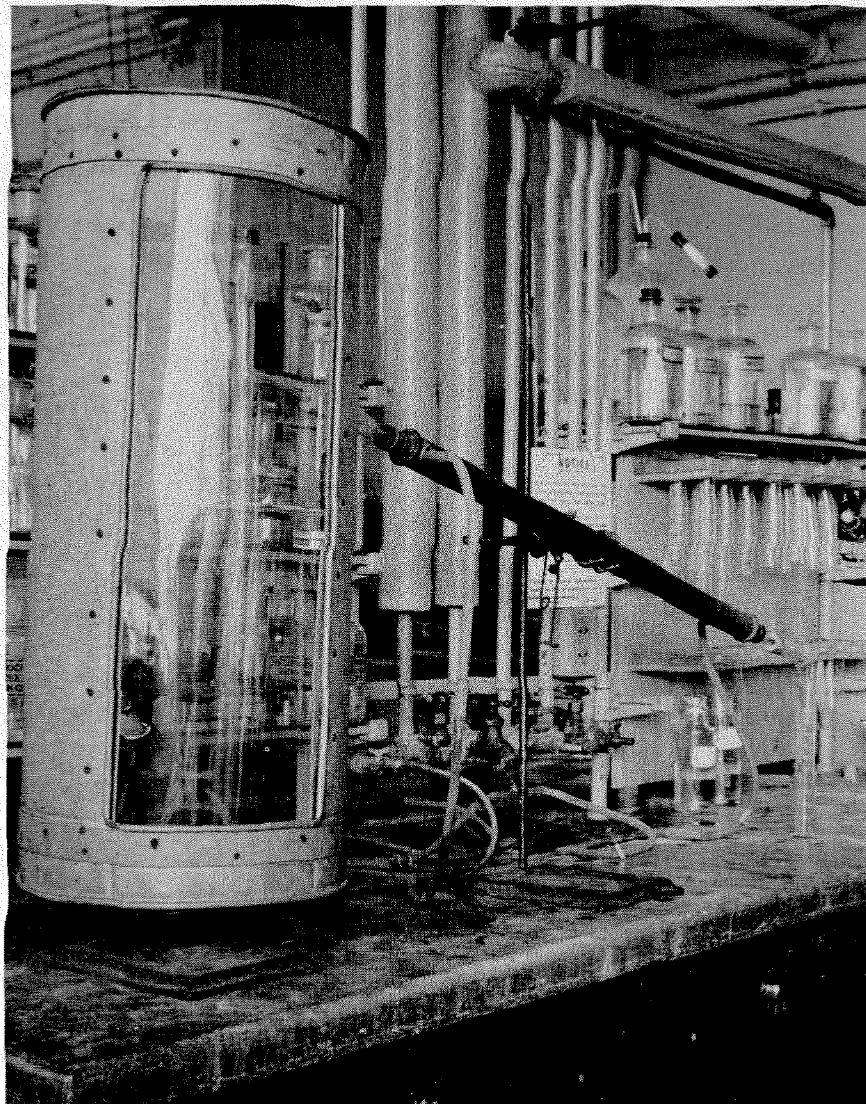


FIG. 5. A well-designed guard for a laboratory distillation process.

It is often desirable, because of the importance of this general subject of housekeeping, to have work in the laboratory arranged so that the last 15 minutes of the day are available for each worker to clean up the area in which he has been working.

The storage of chemicals and apparatus in a separate storeroom should come in for close scrutiny. Heavy articles should be stored as near the floor as possible. Glass apparatus should be stored so that ends do not project beyond the shelves. Glass tubing should be stored horizontally and kept off the floors. Shelves should be provided with copings to prevent chemicals and apparatus from sliding or rolling off. Chemicals which might react together to give off dangerous fumes or cause fire or explosion or accidental breakage should be stored remote from one another. Many points regarding certain hazardous chemicals cannot be covered in this article. However, information on good practice in the storage of these materials can be obtained from such sources as the National Safety Council, Safe Practices Pamphlet No. 60, titled "Chemical Laboratories."

Fire protection requires that protective equipment be provided to meet the needs shown by an actual survey of the particular laboratory. In general, extinguishing equipment should be placed in the hall room. If placed in the laboratory proper, it should be near the door and away from the principal fire hazard. It is very important that employees be trained in the proper handling of fire extinguishing equipment. The proper handling of a fire extinguisher or fire hose has been found to be considerably different from the usual employee's conception of what he would do with it if he had to use it. Actual use of the equipment at periodic intervals by the workers is most desirable. All fire protection equipment should be examined at regular intervals to see that it is in good working order, and portable extinguishing equipment should bear tags showing inspection dates.

Close supervision to see that bottles are adequately labeled and that they are opened correctly will more than adequately pay for time spent. The fire polishing of glass tubing before use should be insisted upon as well as safe methods of inserting glass tubes in stoppers, as through the use of a cork borer.

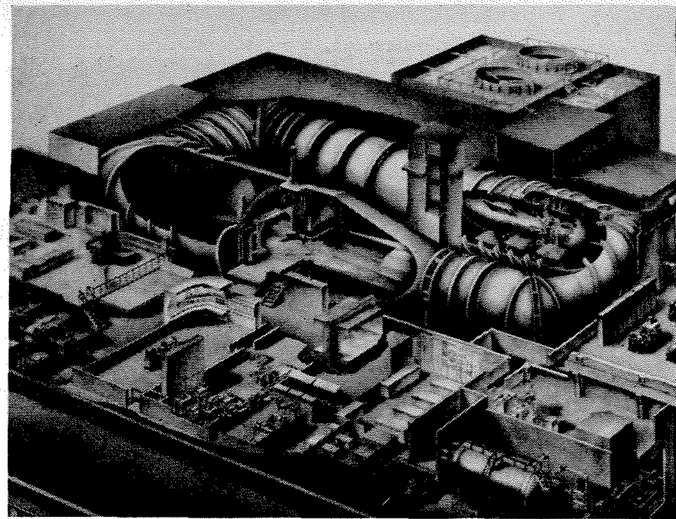
One or more drinking fountains should be installed. The practice of drinking from beakers is dangerous and has caused fatal accidents. The bubbler type of fountain, equipped with a control valve, is preferred because it has proved ideal for irrigating the eyes in case of burns from an acid splash.

Wells of desiccators may be more adequately protected by being incased in a metal guard. If sulfuric acid is used as a drying agent, an asbestos cushion in the well can be used to advantage. Vacuum desiccators, as well as other glassware in which a vacuum is created, should be tested for use under a higher vacuum than is normally used.

The customary use of pipettes is hazardous; most pipetting of common corrosive liquids is done by using the lips at the top of the pipette. *Fig. 4* shows one of the simplest substitute methods by which this operation may be freed from the principal risk. More aspirator lines provided with convenient taps may also be employed. Considerable attention can be given to designing protective equipment around distilling operations. A well-designed protective equipment for such an operation is shown in *Fig. 5*.

This article has sketched a rough outline of some of the more important ways of ameliorating the potential hazards in and around a chemical laboratory. However, after all is said and done, the over-all successful attack on the safety problem in the chemical laboratory depends largely upon the effective selling of the program by top management to the individual worker. Once this is done, then through cooperation there easily follows the adaptation and use of proper laboratory precautionary technics. Broadly speaking, the two most important elements involving these technics are:

1. Good housekeeping;
2. Cutting down to the minimum the amount of hazardous materials around the worker.



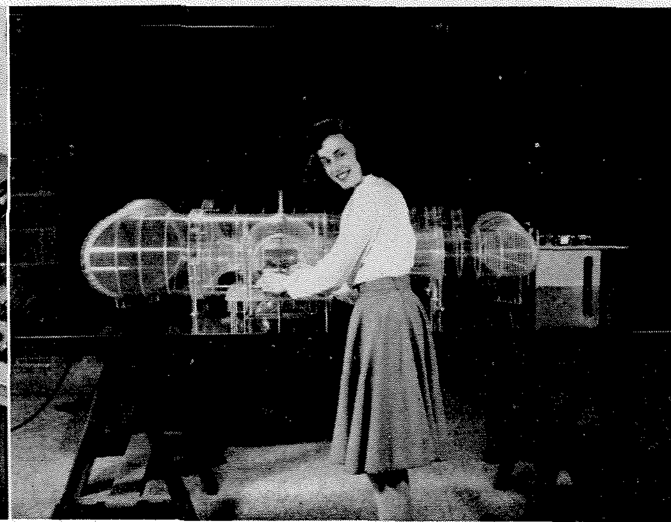


FIG. 1 (at left). Model of Curtiss-Wright Wind Tunnel, Buffalo, New York. FIG. 2 (at right). Working model, made of *lucite*, *Curtiss-Wright Wind Tunnel (one-thirtieth scale)*.

## THE CURTISS-WRIGHT WIND TUNNEL

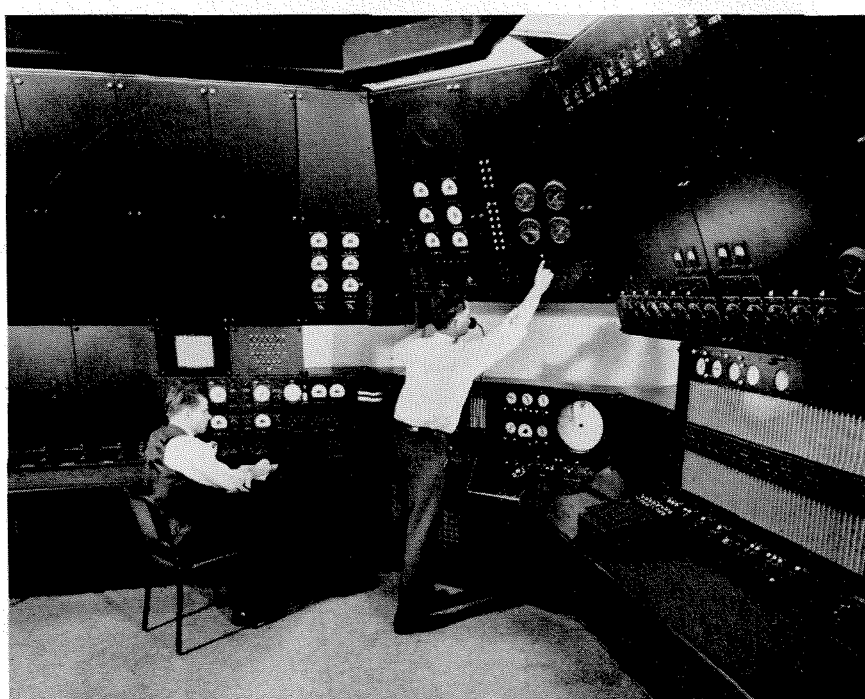
A NEW WIND TUNNEL, basically of the same design as that of the Southern California Cooperative Wind Tunnel, has been constructed at Buffalo, New York, by the Curtiss-Wright Corporation and is expected to be in operation soon. The design costs for this tunnel and the Southern California Tunnel were divided between the Curtiss-Wright Corporation and the Southern California group. In view of the similarity of the basic design, the two tunnels are essentially the same, differing in a few respects.

The arrangement of the Curtiss-Wright Tunnel is shown in *Fig. 1*. The model shop is shown at the left in the photograph. An exact working replica of the tunnel, made of lucite, is shown in *Fig. 2*. The model, built to one-thirtieth scale of the tunnel, duplicates in every detail the operation of its prototype, even to the operation of the air locks. The console from which the Curtiss-Wright Tunnel is controlled is shown in *Fig. 3*.

The new tunnel is housed in the Research Laboratory with complete facilities for aeronautical research. The laboratory also houses altitude chambers which make it possible to simulate the pressure and temperatures encountered at any altitude. In order to care for the many problems associated with aeronautical research, there are wood and machine shops, a hydraulic laboratory, a metallurgical laboratory complete with controlled-atmosphere furnaces, a physics laboratory, a completely equipped chemical laboratory, wood and plastics laboratories, as well as a technical library.

This laboratory is under the direction of Dr. C. C. Furnas, formerly associate professor of chemical engineering at Yale University. The testing and initial operation of the new wind tunnel are under the direction of Marc A. de Ferranti, formerly associated with the General Electric Company at Schenectady.

The new tunnel not only will serve as a "proving ground" for the Curtiss-Wright Corporation, but it will also be in a position to serve as a testing laboratory for other eastern airplane manufacturers.



AT RIGHT:

FIG. 3. Console of control room, Curtiss-Wright Wind Tunnel, Buffalo, New York.