TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 537

FIRE PREVENTION ON AIRPLANES

By J. Sabatier

PART II

From Bulletin Technique No. 56, of the Service Technique
et Industriel de l'Aéronautique, Jan., 1929

Washington
October, 1929

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

TECHNICAL MEMORANDUM NO. 537.

FIRE PREVENTION ON AIRPLANES.*

By J. Sabatier.

PART II.

Chapter III.

Sparks and Hot Points

Electric sparks.- The main sources of dangerous sparks on airplanes are the magnetos, the engine ignition circuits, the radio, electric light and power wires with their accessories. No difficulty in principle is encountered in taking the proper safety measures regarding them. They will, in general, give satisfactory results, provided they are carefully applied. One of the principal measures is the removal of the magnetos as far as possible from the carburetors and fuel pipes, in order to prevent the electric insulating materials from being damaged by possible leaks, and the fuel vapors from coming into contact with magneto sparks, in spite of the protection afforded by the metal casings. The installation, seen in July, 1928, at Orly, on a well-known foreign touring airplane, the magneto of which was placed close to the carburetor, just behind the joint of the air-intake pipe (a pipe which, moreover, opens practically inside

---

*"Etude sur les Moyens d'Eviter les Incendies á Bord des Avions" from Bulletin Technique (Service Technique et Industriel de l'Aéronautique) No. 56, January, 1929. Reproduced by permission of the author. For Part I, see N.A.C.A. Technical Memorandum No. 536.

the cowling), is subject to criticism.

Of course, the electric wires should not run under the fuel and oil pipes, since they would thus be exposed to drippings harmful to the insulating materials. Switches and other accessories (especially those belonging to the radio equipment), which may produce sparks, should be enclosed in metal casings. Lastly, the safety fuses should not, in melting, be able to project incandescent metal into the fuselage.

The terminals of different polarity should be sufficiently separated to prevent the possibility of a short circuit. The connections should be proof against being loosened by accidental shocks and vibrations. Moreover, it is very desirable that provision be made for comparatively easy access and inspection of the back sides of the switchboards. A fire in 1924 was attributed to the bad condition of the connections on the back of a switchboard which, not being readily accessible, could not be adequately inspected and repaired.

The engine ignition wires require special precautions, owing to their importance for the functioning of the engine, and to their proximity to the latter, to the fuel pipes and even to the tanks. There is recommended the use of protective battens, grouping all the ignition wires over the common portion of their length and guarding them against impacts, friction and fuel and oil splashes. The results and the degree of safety thus achieved are remarkable. It should not be possible for the connections of the wires to the spark plugs to unfasten or slacken in flight. Moreover, when using storage batteries, protective measures should be adopted not only against the danger of short circuits presented by the exterior terminals, but also against the detonating gases escaping during the charging period. Thus, a battery explosion, followed by fire, the consequences of which were fortunately limited, occurred in 1927 on an airplane which had an insufficiently ventilated battery compartment. These precautions should render it possible to avoid dangerous electric sparks under normal conditions of operation. They may, nevertheless, occur if the airplane is seriously damaged, its installations dislodged and bare portions of live wires brought into accidental contact. This may occur, but should do so only rarely. It is difficult to establish general regulations which will completely prevent this possibility.

Exhaust Gases, Fire Screens and Mufflers

The danger presented by the exhaust gases, valves and corresponding pipes is more imminent than that due to electric sparks. In addition to their inherent heat, these gases contain flames and particles of incandescent carbon due to incomplete combustion of the fuel, or rust scales due to oxidation of the pipes. Flames and sparks are produced chiefly when the engine speed is changed suddenly.

The most obvious means of avoiding these troubles is to lengthen the exhaust pipes by means of expansion chambers in which the gases can expand and cool sufficiently to extinguish any flames or sparks before they reach the outside. A narrow-meshed screen can also be placed at the point of exit of the gases, which will remove the incandescent particles without stopping the gases themselves. When these expansion chambers are conveniently arranged, they muffle the exhaust noise of the engine and thus serve the double role of mufflers and fire screens. As a matter of fact, designers have hitherto chiefly sought to make good mufflers, since engines with direct exhausts soon render the stay on airplanes unbearable. Fire prevention has received some attention only as a matter of minor importance.

It has also been endeavored to reduce the glare of the flames from the engine rather than to suppress them completely. These flames greatly disturb the pilot during night flights, especially in landing. Although it is rather easy to reduce the glare of the flames, it is much more difficult to suppress them completely, especially when the engine speed is suddenly changed. However, the efficacy of the desired fire-prevention device depends principally on the latter condition. Particularly, in the case of capsizing or of a rough landing, the engine may pass directly from a high speed to a complete stop, and the absolute absence of dangerous flames is then of paramount importance.

The conditions outlined above and the difficulty of the problem fully account for the fact that the fire screens thus far tested have not yet given satisfactory results as regards fire protection. Since, however, the problem has been stated, it should be possible to solve it at the cost of some effort.

Assuming that satisfactory fire screens will be made shortly, the question arises as to whether their use should be made compulsory in order to reduce the fire hazards. In this connection some doubt has been expressed by several authorities. They have called attention to the fact that in lengthening the exhaust pipes by means of tubes or expansion chambers, the valves and adjacent sheet-metal parts are prevented from cooling as quickly and thoroughly as would be possible if they were in direct contact with the open air. The heating of the valves, if excessive, causes serious trouble in the functioning of the engine (seizing of the rods, breaking of the valve stems, impairment of the tightness, etc.). This is not the greatest danger, however. It is revealed in the case of a bad landing. If the impact of the airplane is sufficient to burst the tank or break a pipe, the fuel flows out and fills the air with its vapors. They gradually penetrate into the muffler and enter into contact with the hot points. If the temperature of the latter is still high enough to cause the carbureted air to take fire, there is an immediate explosion. Tests made in 1924-26 in the United States, where obsolete airplanes were made to crash against obstacles, are indicative in this connection. They reveal the incendiary effect of hot spots in the exhaust pipes in landing accidents. Hence, in estimating the efficacy of a fire screen, it is not enough merely to verify its cooling action on the gases and the low temperature of its outer envelope, but it is also necessary to make sure that the temperature of its inner portions is sufficiently low to avoid the risk of setting fire to the fuel vapors with which it is brought in contact in the case of an accident.

Before issuing regulations regarding the precautions to be taken in this connection, the S.T.I.Aé. made the following tests, in an attempt to determine the admissible limiting temperature. Different fuels were poured drop by drop on an electrically heated metal plate and the temperature was measured, above which each fuel ignited on contact with the plate. Under these conditions, gasoline took fire at a temperature of the plate of 580°C (1076°F), gas oil at 560°C (1040°F), mineral lubricating oil at 500°C (932°F), and the safety fuels referred to above, at 620 to 650°C (1148 to 1202°F). The same fuels were also projected against the plate in the form of vapors, after passing through a suitably heated tube. The vapors were found to take fire at the same temperatures as the liquid, without appearing to be affected by the heating temperature in the tube.

The results merit consideration. They show, in the first place, that according to the assumed hypothesis (i.e., the projection of fuel against a muffler after a hard landing) oil is as dangerous as gasoline, since it takes fire at a lower temperature of the plate. Hence, oil tanks must be separated from engine compartments by bulkheads, the same as fuel tanks, so as to prevent, as completely as possible, leaking oil from coming in contact with the mufflers. It is also seen that, although there is an actual superiority of safety fuels over gasoline (according to the above hypothesis), it is not so great that we can neglect, in using them, the precautions regarding mufflers which have been found necessary in the case of gasoline.

Besides, these considerations were confirmed by the following tests, made at the end of 1928, by Chief Engineer Caillol of the S.T.I.Aé. Fuel, in drops and in a sheet, was poured on the outside of a muffler of a recently approved type. The muffler had been heated by prolonged running of the engine. The engine itself was placed on a bench, in an air flow of approximately 100 km/h (62.1 mi./hr.). The engine was suddenly stopped and gasoline was dropped on the muffler a few seconds later. No fire occurred, which was quite natural, since the temperature of the sprinkled walls was not over 400°C (752°F). The test was then repeated, but the fuel was injected inside the muffler. The gasoline took fire immediately. This also occurred with the safety fuels, but only within a few seconds after the injection. The phenomena are self-explanatory. The internal portions of the muffler had local hot spots, the temperature of which exceeded the critical value indicated above. The fire took place as soon as the fuel or its vapors came into contact with these hot spots, the quickness of the contact depending on the volatility of the liquid injected.

These data can be used in an attempt to produce efficient mufflers and fire screens, without increasing the danger of fire. In this connection, experimental indication is given by the airplane crash tests made in the United States (Fig. 4 - see Technical Memorandum No. 536, Part I of this report). They comprise, in particular, a comparative test, during which sixteen airplanes were crashed. Ten were provided with aluminum mufflers, arranged so as to be well cooled by the relative wind. Five exhausted directly into the air. The last airplane was equipped with a steel muffler of the so-called "saxophone" type. A single fire occurred in the course of the sixteen tests. This was on the airplane with the steel muffler, which was cooled the least.

Independently of the American results, the previously mentioned hot-plate tests indicate the goal which must be pursued in order to improve mufflers from the viewpoint of fire prevention. It consists primarily in reducing the temperature of the hottest portions of exhaust manifolds below the burning point - 580°C (1076°F) for gasoline. After this result has been achieved, it will be possible, if necessary, to lengthen the exhaust pipe by means of sound or flame-reducing devices. But as long as the cooling at the origin is not assured, any prolongation of the exhaust will cause the heat to be retained at the origin and hence retain the fire hazard instead of removing it. Of course, the cooling system must act immediately at the outlet of the engine cylinders. It may consist of aluminum, as in the American tests, or of thin steel with fins, tubular wire gauze, or any other equivalent device.

The above considerations assume that the hot spots are red-hot metal portions of the exhaust pipes. However, it often happens that gases, incompletely burned in the cylinders, contain carbon particles which are deposited in the exhaust pipes. In the first place, the accumulations of coke and soot cause a reduction in the cooling capacity of the walls coated by them. The chief trouble, however, is that they may contain incandescent particles of coke. From our viewpoint, these particles, owing to their high temperature, form particularly dangerous hot points. It is rather difficult to make general suggestions for their complete elimination. We can say, however, that improved original cooling of the exhaust manifolds reduces the danger from the coke deposits. In designing a new type of muffler, one can then determine experimentally whether it has a tendency to accumulating soot at its hottest points and how to combat it. It is only necessary to make, as certain designers already do, test models which are cut by a longitudinal plane and which can be easily opened for inspection after being used for some time.

Tests recently made by the S.T.Aé. show that it is possible, on the basis of these observations, to make efficient mufflers which do not involve so great fire hazards. It has been found possible to inject gasoline and safety fuels into one of these mufflers, immediately after stopping the engine, without producing fire. Following the experiments of 1924-26, the Americans have suggested the application of similar tests to every new fire screen submitted for approval.

The tests begun in France will be continued, especially by systematic temperature measurements of internal portions of the exhaust manifolds under normal conditions of flight. Pending the final results, the particular attention of muffler designers is called to the foregoing considerations, the importance of which is often not understood. It is probably because their application has been neglected, that serious fires have so often occurred after partial crashes.

Lastly, even a good muffler is not sufficient in itself, but much depends on its correct installation. Two factors which greatly affect the fire hazard in the case of fuel leaks should be considered in this connection. They are the rapidity with which the hottest portions of the exhaust pipes and valves cool after the engine stops and the time elapsing before the fuel and oil come in contact with them. If this time is increased, there is more time for the heat accumulated in the exhaust to disperse in the air.

Measures for retarding the progress of the fuel toward the engines will be described later. As to the measures for the quick cooling of the manifolds after stopping the engine, each case must be studied by itself. As a matter of fact, these measures do not simply vary for different mufflers, but also for the same muffler when used on different engines. Thus, a muffler located in the V formed by the two rows of cylinders, may be sufficiently cooled as long as the air is circulated in flight, but will remain hot long after the engine stops, since it is directly affected by the intense heat radiation of the surrounding parts. The same muffler, placed on the side, will cool much faster. This leads to the conclusion that one should avoid, if possible, placing exhaust pipes and mufflers in the V of the engines.

To sum up, the presence of a fire-screen muffler increases the safety against fire, as long as the conditions of flight remain normal. If, on the other hand, fuel is spilled after a bad landing, the situation is reversed and the presence of an inadequate device may greatly increase the danger it was designed to remove.

Obviously, in addition to the fundamental qualities discussed above, fire-screen mufflers must satisfy the following conditions: relative lightness and low aerodynamic resistance; low absorption of engine power; insulation of their walls from combustible parts of the airplane; good resistance to vibrations, impacts and oxidation by gases at high temperatures.

Heating the intake air.- The question of heating the carburetors and intake air is closely related to the exhaust problem considered above.* The intake pipes and carburetors of powerful engines collect frost in cold, damp weather. On certain engines,

---

*I am indebted for many of the data in this treatise to the courtesy of Chief Engineer Hardy, of the S.T.I.Aé.

this phenomenon may occur even at relatively high temperatures of 10 to 15°C (50 to 59°F). It is accompanied by a rapid decrease in the engine speed. Sometimes, the decrease may last, and in some cases it may be followed by a jerky running of the engine, with periodical rises and falls in the number of revolutions. When the cold is intense and protracted, the ice which forms inside the carburetor may obstruct the carburetor jet and block the controls. It then causes serious engine trouble. On the other hand, it was seen in Chapter II (Technical Memorandum No. 536 - Part I of this report) that extending the air intake pipes to the outside of the cowling, deemed necessary as a protection against fire, increased the tendency of the carburetors to collect frost.

The heating of the carburetors and their intake pipes is not only a means of improving the regularity of the engine, but is also a direct consequence of the measures taken to avoid conflagrations due to back fires. It was also seen that safety fuels could not be used without thoroughly heating the carburetors. This fact increases the importance of the devices proposed for this purpose. Whatever fuels are used, it is important that heaters introduce no additional fire hazard.

In order to combat frost, we may heat either the air before it reaches the carburetor, or the carburetor itself, or else the carbureted air as it leaves the carburetor.

1. On many old engines the air was heated before it reached

the carburetor, by locating the ends of the air-intake pipes inside the cowling on the hot portions of the engine. We have, however, pointed out the danger of fire involved in this arrangement, which is no longer authorized in principle. Under these conditions we must use either water or oil radiators in the intake pipe, or we must use a special exhaust-gas pipe running through the intake pipe. Of course, water radiators cannot be used on air-cooled engines. Besides, both water and oil radiators are relatively heavy and not easily adjustable to the temperature variations of the surrounding air. If the radiator gets too hot, the quantity of air per cylinder volume may be reduced and a considerable fraction of the engine power lost. Moreover, in attempting to start in cold weather or to pick up after a long dive with engine stopped, the water or oil may get cold and fail to heat just when it is most needed.

Preheating, by means of exhaust gases, does not cause the same troubles, but it involves a serious danger of fire in the two following cases:

a) The pipe which runs through the air intake is not perfectly gas-tight, either due to joint leakage or to the perforation of the walls by oxidation. In this case, hot gases, flames or incandescent particles may be introduced directly into the carburetor.

b) The hard impact of a bad landing tears off or dislodges the heating pipe at the point where it enters the air-intake pipe. Direct communication is thus established between the exhaust and intake pipes, which may immediately result in a fire if the engine is still running.

In principle, no difficulty is encountered in preventing the first case. Thick pipes, with strong and well-protected connections, answer the purpose. Unfortunately, quite different conditions are encountered in the second case, because the damage from an abnormal impact is too diversified to enable the necessary precautions against all its possible effects.

It is important, however, to take at least one precaution, namely, to place the air intake and its heating pipe where they will not be the first parts of the engine to strike the obstacle. Thus, for example, the air intake should be located rather high and well aft, so that a cylinder would have to be torn off first, or a large portion of the crank case knocked in, before it would be reached. Under these conditions, one would be almost certain that the feared communication between intake and exhaust would not be established before the engine would be completely stopped and its incendiary action suppressed. However, in spite of the good results which may be achieved by this precaution, it is better to avoid, if possible, heating the air by means of the exhaust gases and to heat the carburetor instead, as explained below.

2. One can heat the body and the float chamber of a carburetor either by a water or oil by-pass or by an exhaust-gas

by-pass. Water and oil are naturally open to the objection which has already been encountered in connection with the question of heating the intake air. They are ill adapted to cold starts and to picking up in flight after a long stoppage of the engine. Aside from this, however, experience shows that heating by means of the radiator water is very satisfactory and easy to regulate.

Unfortunately, it cannot be used on air-cooled engines. For these we must resort to the oil or exhaust gases. Heating by oil is possible on light airplanes, the relatively small oil reserve of which rises quickly to the required temperature level after the engine is started. This, however, does not apply to large airplanes, the great oil mass of which heats very slowly. On such airplanes, the oil seldom raises the temperature of the carburetor sufficiently.

In order to remedy the disadvantages resulting from heating with the water or oil at the take-off and to provide the additional heat required when oil is used, it has been proposed to supplement these methods by using the exhaust gases. The method of heating by the exhaust gases would then be used only in emergencies, such as starting, picking up and flying in very cold weather, being cut out under normal conditions. The fire hazards involved in this system are thus greatly reduced. On the other hand, we may criticise this combination for its relative complexity of installation and of operation.

It remains to examine the question of heating the carburetors by means of the exhaust gases. It is to be feared that, as far as fire hazards are concerned, this method be open to objections similar to those mentioned above in connection with the intake air. These objections, however, are greatly weakened by the following considerations. When air is to be heated, its poor conductivity calls for a high temperature of the heating gas, a great output and large radiating surfaces. The direct exhaust flow of one or several cylinders must therefore be used in most cases, always with large pipes, provided with a highly developed system of fins. On the other hand, the carburetor and the fuel which it contains have a high degree of conductivity. Hence, a rather small quantity of gas at a relatively low temperature will provide the requisite heat.

Experience shows that good heating is generally obtained by sending a small portion of the main exhaust flow into the carburetor jacket. The amount can be regulated by a throttle placed at the origin, in such a manner that the temperature of the delivered gases remains below the value, beyond which there is danger of igniting the fuel in case of rupture or leakage of the pipes. In this connection, a maximum temperature of 350°C (662°F) for the carburetor envelope and of approximately 450°C (842°F) for the heating gas seems to be about right. Besides, the following test shows, without making accurate temperature measurements, whether the requisite safety conditions are satisfied for any given engine type. After interrupting the gas by-pass below its throttle valve and letting the gases escape into the open air, we can make sure that a pad-soaked with gasoline and exposed to these gases, is not ignited by them. Besides, as an additional precaution, the by-pass pipe can be placed in a region where it will be protected from destructive impacts. Its small size and the proximity of the carburetor will facilitate the achievement of this additional guaranty.

3. We have just seen how the intake air or the carburetor and its accessories are heated. The carbureted air should, moreover, be kept hot until it enters the engine. The coldest spot of the carburetor is usually near the Venturi tubes. Hence, fuel condensation and irregular carburetion may be feared if, after heating the air before or in the carburetor, it is left to cool immediately afterward. In most cases, the proper temperature can be satisfactorily maintained by the circulation of water or oil, or simply by recourse to the conductivity of the hot portions of the engine. The corresponding devices present no special difficulty nor require any particular precaution.

All the above considerations show the importance of heating the air before its admission into the engine. They also show the necessity of carefully designing the heating devices, in order to avoid serious fire hazards. When heating by the radiator water is possible, it is the simplest and safest means. Otherwise, and especially in the case of air-cooled engines, one should, in principle, resort to the heating of the carburetor by a by-pass from the exhaust pipe. It is possible to use exhaust gases without danger of fire, only by taking very complete precautions. These precautions, however, can be easily taken, except in very special cases.

Chapter IV

Precautions to be Taken in Anticipation of Hard Landings

The regulations in Chapters II (Technical Memorandum No. 536 - Part I of this report) and III should suffice to eliminate most possibilities of fire in flight, as long as no serious engine trouble develops. Besides, their efficacy is confirmed by experience. They do not suffice, however, in the case of major engine troubles or when the airplane lands on its nose. The latter case is by far the most dangerous one. Its consequences reproduce, on a larger scale, those resulting from engine troubles. It is better for us to consider the case of fire produced by a bad landing. This phenomenon develops along well-known lines somewhat as follows. The airplane strikes the ground, the impact dislodges the engine and its accessories. The pipe connections spring aleak or separate, while the pipes break. In the most serious cases the fuel tank bursts open, the carburetor float chamber is knocked in or torn off. Eventually the fuel leaks and forms a dangerous explosive mixture.

If the pilot, for want of time or attention, does not cut the ignition, the engine strikes the obstacle while still running.* The immediate stop caused by the ground, starts fire in the exhaust manifold and back fires at the intake. A spark due to a broken ignition circuit or electric distribution wire, or a contact of the fuel vapors with the hot spots of the manifold may also occur. They all cause the ignition of the carbureted air, which explodes. It is particularly difficult to combat the ensuing general conflagration since it is fed by vapors which are spread everywhere.

If the fuel tanks cannot be isolated at the very beginning of the accident from the field of the conflagration, either by a stopcock or by means of a tank-dumping device, and especially if the tanks are broken open by the impact, their contents will feed the fire and increase its violence.

Precautions of a general character.- The order of the phenomena analyzed above, indicates the means of stopping or delaying their progress. The first and most common means is to enable the pilot to cut the ignition as soon as a crash becomes inevitable. Besides, the switch is usually placed within easy reach of the pilot, and its installation involves no difficulty unless the airplane is of the multi-engine type. In this case, the pilot should be able, at will and according to circumstances, either to cut the ignition of any engine separately or to cut

---

*Engines with a high compression ratio sometimes continue to run, under the action of auto-ignition phenomena, even after their normal ignition is cut. In this respect they involve serious danger and hence require even more than an ordinary engine, anti-fire precautions in the case of a bad landing.

the ignition of all the engines together by means of a single switch. The feeling of safety which this arrangement will give him, will greatly compensate for the relative complexity of the electric circuits.

Certain inventors, impressed by the accidents which happen when the pilot fails to cut the ignition in time, have suggested devices which break the ignition circuit as soon as the airplane encounters difficulties, especially during stalls. The danger entailed by the untimely functioning of such devices, has always rightly prevented their use.

We have already considered the devices which make it possible to avoid back-firing at the air inlet and flames in the exhaust pipe. Hence, there is no occasion to revert to them here. We will only call attention to the fact that, in order to play their part, the fire screens and devices for preventing back fires, must not be damaged too soon, when the engine strikes an obstacle. It is therefore highly advisable to place them in a portion of the cowling where they will be relatively well protected and where, in any case, they will not be struck before the vital parts of the engine. The mufflers, intake pipes and carburetors are often located at the front end of the engine, so that they are the first accessories to be torn off or crushed by the obstacle. Under these conditions, the engine may continue to rotate for a fraction of a second, with the valves exhausting into the open air, the carburetor being broken and the air flowing back toward the inlet. This is all that is necessary to start a fire, which might have been prevented, if the heavy parts of the engine had been the first to be broken, thus causing it to stop before the emission of dangerous flames.

Besides, we may ask whether it would not be advisable to add to the above precautions. In the bows of ships there are shock compartments which are crushed and which damp the effect of collisions, before the vital parts of the hull are reached. The first and last cars on passenger trains likewise act as buffers. There is no such arrangement on airplanes. On single-engine airplanes the impact is primarily received by the propeller shaft and the engine, with which the destruction begins. Since the engine, crank shaft and crank case form a rigid mass, it has the effect of a veritable ram which drives everything behind it.

It would seem possible, at least in certain cases (e.g., for engines with reduction gear, where the distance between the propeller and the crank case is greater than on direct-drive engines) to protect the engine by surrounding its front portion with a truss or cage of angle irons, strongly attached to the fuselage. This truss would be crushed by the impact, before the engine and its principal accessories would be damaged. Even if we admit that this protecting cage can only partially damp violent impacts and does not suffice to prevent the dislodging of the engine, it will nevertheless increase the interval of time between the stopping of the engine and the destruction of the fuel pipes and fire-prevention devices. It is of capital importance to gain time in such cases.

In addition to landing impacts, conflagrations are often caused by back fires at the inlet, even when the above-mentioned precautions have been taken. This occurs when the rupture of a connecting rod, in the neighborhood of the carburetor, causes the latter to be torn off and lays open the inlet to the cylinders.

If the pilot cuts the fuel supply, as he ought to, the quantity of ignited fuel is reduced to the gasoline contained in the carburetor and in the adjacent pipes. The fire will not be so intense as to render extinction impossible, provided the airplane is adequately equipped for this purpose. It is nevertheless advisable, in order to avoid such risks, to place backfire prevention devices as closely as possible to the cylinders, and to separate the carburetors from the splash area of the connecting rods, in so far as the other general arrangements of the engine will permit.

In this connection, attention is again called to the paramount importance of draining fuel and oil leakages outside of the fuselage in the most direct way possible, whether they are due to an injury to the engine, the breaking of a pipe or to any other cause.

Isolation of the Engine Compartment and Tanks

The engine compartment is a hot chamber where the slightest accident can start a fire. One should therefore reduce to a minimum the combustible elements which it contains. Besides, it should be isolated from the airplane proper so as to prevent the spreading of incipient fires. All agree on the necessity of a fireproof bulkhead (fire wall) between the engine and the rest of the airplane. No large fuel or oil receptacle (except the carburetor) should be placed on the same side of the fire wall as the engine. Means should be provided for the immediate isolation of the main fuel and oil tanks (especially the fuel tanks) from the pipes leading to the engine and passing through the fire wall. The isolation should be effected by means of a quick-closing cock operated by the pilot. Each stopcock must be placed as close as possible to the tank which it is designed to protect. If, after a certain length of time, it is feared that a quick-closing cock is no longer perfectly tight, it should be supplemented by a slow-motion cock. The former would be used by the pilot only in case of emergency, but the latter would be used under normal conditions of operation. The fireproof bulkhead serves a double purpose. It is designed to prevent the flames, originating in the engine compartment, from spreading to the body of the airplane. It is also intended to prevent external fuel leakage from getting into the engine compartment. In order to stop the flames, the bulkhead must be metal and provided, if possible, with a heat-resistant lining. It often consists of two metal sheets with an intermediate sheet of asbestos. The fire wall should not be strictly confined to the transverse section of the fuselage, but should be prolonged at right angles to the transverse section in both directions.

Flames stopped by the transverse bulkhead actually tend to burst through the sides of the engine compartment. They are then swept back on the airplane by the relative wind, if the fire breaks out during flight, or by normal draft, if it occurs on the ground after a landing on the nose. We cannot prevent the flames from bursting forth, especially through the ports provided in the cowling for the ventilation of the engine, but we can separate the ports from the bulkheads and render the intermediate cowling sufficiently gas-tight, so as to increase the distance traversed by the flames materially, thus reducing their harmful effect. The fire wall should also be extended along the sides of the fuselage in the direction opposite to the engine compartment. Otherwise, the fuel escaping from the tanks or pipes, broken by a landing impact, will flow on and around the bulkhead, without encountering any obstacle, and soon reach the possible location of the fire. When, however, the fire wall is extended laterally by sufficiently long metal walls (e.g., 20 to 30 cm - 7.9 to 11.8 in.), the fuel will be stopped by the relatively tight basin thus formed. It will not pass this barrier unless the leakage is very large. Besides, the flooding would not be immediate. Thus, the safety is increased by simultaneously reducing the danger of fire and increasing the time it will take to break forth. The extension of the fire wall, by metal elements, is generally adequate in the direction of the engine, but not in the opposite direction. Thus, we often see the wood planking of the fuselage enter into direct contact with the metal of the fire wall, as though it sought to get as close as possible to the eventual location of a fire. This arrangement, for which no adequate reason can be given, greatly reduces the efficacy of the barrier.

Of course, the points where pipes and controls pass through the bulkhead must be perfectly fuel-tight and fireproof. In general, it will be possible to satisfy these conditions by using stuffing boxes. One may also have recourse to special ball and socket joints which will reduce the danger of jamming and change of level especially in the case of rigid controls. On examining the fire walls with which most airplanes are provided, we are struck by the carelessness of their installation, characterized by the absence of joints or stuffing boxes and by the existence of wide openings on the sides and at the upper portion.

Still, everybody agrees on the necessity of opposing complete and resistent barriers to the fire. For those who still remain skeptical, we will merely remind them of the accident which happened at the beginning of 1928, on an observation airplane in Syria. Fire had broken out, following an engine breakdown due to faulty lubrication. The fire wall retained the main mass of flames long enough to enable the two men of the crew to save themselves by jumping with their parachutes but, owing to the poor design of the barrier, they were badly burned by the hot gases and tongues of flame which it allowed to pass, thus preventing them from successfully combating the fire.

The above considerations apply particularly to the case of an airplane with its engine located in the axis of the fuselage, with the fuel tank behind it. The precautions will vary if the engines are of the lateral type or if the tanks are located in the wings, but the principles to be observed remain the same.

Although a carefully designed fire wall affords real protection against conflagrations in flight, it is unfortunately less satisfactory in the case of a fire following a landing on the nose. The engine, thrust backward by the ground, acts like a ram on the fire wall, which it knocks in. In some cases, the latter is struck by the tank, inadequately secured by its attachment fittings. Finally, in some cases, the engine after forcing the fire wall, hits the tank which it also knocks in. This condition is particularly dangerous since it creates a fuel leakage and simultaneously facilitates its direct access to the engine compartment.

We considered in Chapter II (Technical Memorandum No. 536, Part I of this report), the conditions which the tanks and their fittings must satisfy, in order to withstand direct landing impacts. We need not revert to the subject here. As regards the crushing of the fire wall by the engine, we must in most cases confine ourselves to reducing its effects, without absolutely removing the possibility. We can, in particular, either protect the engine proper against landing impacts, or place it farther from the fire wall (if permitted by the weight distribution of the airplane), or else reinforce the fire wall itself.

It will be observed in this connection that present-day fire walls are not designed to withstand even slight impacts. Their function is confined to stopping fuel and flames (more or less well, as seen above). It would, however, be easy in many cases to reinforce at least the portion directly opposite to the projecting part of the engine, without greatly increasing the weight.

Lastly, it is necessary to prevent the engine from striking the tank after passing through the fire wall. The measures to be taken in this connection are too closely related to local conditions to be specified in advance. We shall therefore confine ourselves to the following suggestions:

a) Place the fuel tanks at a certain distance - 10 to 15 cm (3.94 to 5.9 in.) - from the fire wall, so as to allow for a considerable deformation of the latter before it comes in contact with the tanks.

b) Avoid locating the tanks exactly in the axis of the engine. It is usually possible to place them on either side of the axis, so that the projecting parts of the engine, which first strike the bulkhead, will not immediately afterward come in contact with the tanks.

c) Protect the tanks by a special elastic covering, designed to keep it tight even after deformation or rupture. Some of these coverings are quite efficacious against machine-gun bullet holes and may also be used in the present case. However, most of them finally become saturated with fuel, especially when a tank springs a leak. If the leak is not immediately discovered (which is difficult, since the protective covering conceals the walls and their seams), the covering becomes a veritable sponge soaked with a combustible liquid. Under these conditions the remedy is worse than the danger which it is designed to avoid.

The best means of preventing the engine from striking the tank consists in placing them well apart. This is achieved by placing the fuel tanks in the wings, above and behind the engine compartment. This disposition is most advantageous from the viewpoint of fire protection and is highly advisable whenever the general arrangement of the airplane permits.

Lastly, the question as to whether arrangements should be made for quickly dropping or emptying the fuel tanks in flight has been much discussed. This would enable the pilot to eliminate the main explosive mass as soon as there should be danger of fire reaching it, thus greatly reducing the violence of the calamity.

The tank-emptying devices hitherto used on airplanes generally have their disadvantages. They drain off in a few seconds all the fuel desired, but do not render it possible to control the path of the liquid after it has left the tank. Thus, it may come in contact with the fuselage (especially at the end of the operation when the expulsive pressure is low) or simply create a dangerous carbureted atmosphere about the airplane. Besides, it is rather paradoxical to seek safety by scattering fuel, even at some distance from a fire. The rapid emptying of the tanks should therefore be authorized only in particular cases, e.g., on certain military airplanes exposed to the action of incendiary bullets and without means for dropping the tanks. Even in this case, special precautions must be taken to prevent the evacuated fuel from passing too near the fuselage and its accessories, even if the airplane dives suddenly.

Modern tank-dropping devices are not subject to such serious objections. They have been successfully used on many military airplanes and quite recently on a pursuit airplane under test at Cazaux. This airplane had performed several stunts in the course of which the overflow pipe of the tank had leaked slightly. The flame of an insufficiently protected machine-gun fire ignited the fuel in the cowling. By dropping the tank, the pilot was able to prevent the conflagration from spreading and to land safely. The use of tank-dropping devices necessitates installations which are often quite heavy. In the first place, there must be provided, in the pipes connecting the tank and engine, weak points designed to break as soon as the tank is dropped. These weak points, more than any others, are subject to injuries and leaks. On the other hand, the tank must be carefully guided during its fall until it has completely left the fuselage. The guiding process presents no mechanical difficulty, so long as the airplane flies horizontally or at a slight angle, but it may cease to work satisfactorily when the airplane dives vertically. It is often in such cases that the dropping of the tank does the most good, since it diminishes the danger of explosion always presented by a landing on the nose.

Lastly, the tanks and their guides are generally deformed easily, because the elements of which they are constructed are given the minimum dimensions so as to reduce the weight. Hence, jamming or friction often occur in operation, thus impeding the correct dropping of the tank after it has been released. One can easily realize the critical situation of an airplane, flying with a half-dropped tank, the pilot being uncertain whether he will be able to get rid of it in time to avoid a catastrophe. In any case, it is necessary to verify carefully, by periodical inspections, the good functioning of the tank-dropping devices on airplanes in service.

Except for the above reservations, the use of tank-dropping devices should be made compulsory on military airplanes exposed to the fire of incendiary bullets. They are recommended for transport airplanes whenever their installation is compatible with the general arrangement and with the correct balancing of the airplane. However, we should not consider the dropping of the tanks as a panacea taking precedence over all other means for preventing fires. It is better, on commercial airplanes, to place the tanks well away from the engines and to renounce the possibility of dropping them in flight, rather than to locate them near the engines in order to facilitate the installation of a dumping device. Besides, the position of the fuel tanks is determined by the weight distribution corresponding to the different load conditions and not by considerations affecting tank-dropping devices, however important they may be.

Chapter V

Various Precautions

Fire extinguishers.- If fire breaks out in spite of the measures taken against it, the crew should have means of combating it and, if possible, of extinguishing before its progress renders a catastrophe inevitable. The sooner the crew can intervene, the more efficacious will its action be. Its safety will often depend on seconds. These new requirements are met by fire extinguishers and alarms. Stationary extinguishers are the most powerful and effective. Recent statistics show that in at least two out of every three cases, their use makes it possible to stop the fire or delay its progress sufficiently to enable the rescue of the crew and part of the endangered airplanes.

Stationary extinguishers generally use carbon tetrachloride, which is projected on the fire by means of compressed gases. Tetrachloride vapor is poisonous owing to its phosgene content and in several cases pilots have been inconvenienced by it in flight. Its use therefore requires certain precautions, and extinguishers containing it should not be put into inexperienced hands. Thus, while these extinguishers can be safely used on military and commercial airplanes, it is doubtful whether they should be used, for example, on touring airplanes. The chief precaution to be taken in this connection consists in verifying periodically the tightness of the tetrachloride pipes and the complete absence of leaks. Besides, one must also make sure that the compressed-gas container, used for the projections, retains its pressure well and has a sufficient reserve of liquid for all emergencies in flight.

The extinguishing action of tetrachloride increases when it is exerted in a confined space where the ventilation is greatly reduced. The most favorable conditions in this respect are encountered in an engine compartment, completely enclosed by a cowling and separated from the airplane body by a gas-tight bulkhead. Aside from the fact that the tetrachloride then has its maximum effect, any poisonous vapors emitted are stopped by the bulkhead, which protects the crew against them. In order to confine as closely as possible the space within which the tetrachloride is used, it is also recommended to close the radiator shutters (if there are any) as soon as the extinguisher enters into action. When the engine compartment is only partly cowled (as in the case of air-cooled engines), the efficacy of the extinguishers is greatly reduced. This applies particularly to engines without any cowling at all, as is sometimes the case with radial engines and the side engines of some commercial airplanes. The advantages of this arrangement, as regards inspection in flight, easy access and cooling, are thus counterbalanced by the difficulty of combating a fire, if one breaks out.

The nozzles of stationary extinguishers are usually located in the engine compartments close to the carburetors and float chambers. This is generally the most satisfactory arrangement, since the fire hazard is greatest there. Besides, one should make sure, in each case, that the points through which flames are liable to break forth, are actually those covered by the extinguishing jet. On the other hand, the pipes and their accessories should be arranged so as not to be torn off or destroyed by any slight injury to the crank case or carburetor caused, for example, by the breaking of a connecting rod. Such injuries are, in most cases, inevitably followed by violent fires, which must be immediately localized to avoid more serious results. The use of extinguishers is then of the highest importance and it would be most unfortunate, if they failed to work at the moment when they are most needed.

Stationary extinguishers should be operated by a quick-acting and readily accessible control. In this respect, cocks of the quarter-turn type are satisfactory. Slow-motion cocks may be added if there is any doubt of the tightness of the quarter-turn cocks. These former would remain closed on the ground, to be opened as soon as the engine is started for the take-off. There should be a stationary extinguisher for each engine compartment, with as many nozzles as there are dangerous points to protect. Besides, large airplanes should also be provided with hand extinguishers at the rate of at least one for each main compartment. They should be of some current type, as put on the market for automobiles.

Lastly, it should be noted that, although extinguishers can stop incipient fires, they combat the effects rather than the original causes. So long as the cause is not suppressed, a fire may again break out after having been extinguished. This may happen when a fire is started by a jammed intake valve. If the engine continues to run, without the trouble being remedied, the uninterrupted back fires will rekindle the conflagration every time it is extinguished. A sufficient amount of compressed gas and extinguishing liquid should therefore be available, not only to extinguish a first fire but also to stop possible revivals and give the imperiled pilot enough time to stop the engine and even to land. This would require a reserve corresponding to three or four consecutive extinctions.

Fire alarms are not as indispensable as fire extinguishers, but they form a useful auxiliary. They depend on the use of compounds which burn or melt at relatively low temperatures, thereby operating a visible or audible signal, designed to call the attention of the crew to abnormal rises in temperature at any point of the airplane. They reveal the trouble as soon as it occurs and enable combating it with the least possible delay.

Fire alarms are usually simple and inexpensive. They should be used in preference to automatic devices which do not merely act as alarms, but simultaneously start the extinguishers. Such devices are rather complicated and heavy and are always expensive. They may function inopportunely, thus using up a reserve of tetrachloride which may be needed later. They may cause needless panics and lastly, they may unnecessarily emit disagreeable vapors.

Extinguishers, with and without alarms, have already rendered valuable service in aviation. Thus, their use is therefore compulsory on all commercial airplanes and in general, on all aircraft, the crew of which is qualified to take proper care of them. Besides, it is highly desirable that a modification in the refining or in the nature of the extinguishing liquid be effected, so as to eliminate its poisonous action. These properties are the only reason which can prevent its general adoption.

Cleanliness and Upkeep

Aeronautical activity is not confined to the building of suitably equipped airplanes provided with efficient fire-protection devices. It also extends to their maintenance in a state of absolute cleanliness. In analyzing the reports of investigations, one is struck by the high number of conflagrations, the causes of which could have been eliminated by proper care. Thus, several serious accidents which happened in France in 1926-28, were attributed to imperfect tightness or stoppage of carburetor elements, to pipe connections insufficiently tightened in reassembling, to unmounted accessories on the inlet pipes which had been badly reassembled, or to inadequate precautions in the handling of inflammable appliances (flares, etc.).

Those who frequent airports know that when negligent mechanics refuel, gasoline flows from the refueling hose or the filling hole. In the first place these overflows cause an expensive waste of fuel. Besides, they may damage the portions of the airplane which they touch. The chief danger, however, results from the fact that fuel gets inside the cowling where it creates a permanent fire hazard. This is evidenced by the burning of an airplane in 1927 during the Michelin Cup race, as a result of careless refueling.

Likewise, the crank case and accessories of certain engines lose their tightness for want of proper maintenance and let the lubricant ooze or sprinkle on the neighboring portions of the wing or fuselage. Such leakages form long trains which may propagate the fire far from its origin. The spongy state of the fuel or oil of these trains increases their inflammability.

We should not omit to recall, in this connection, the two or three fires per month which occurred in military aviation in 1925-26, on the ground, while starting the engines. In most cases, these fires had no serious consequences and were extinguished either by the crew or by the safety service of the airport. They have, however, a great indicative value. They cannot be attributed to any fault of the materiel, since the fires broke out at the take-off, i.e., immediately after the nateriel should have been inspected and carefully overhauled. It must therefore be assumed that fuel or oil trains left in the engine cowling, rendered the air about the airplane highly inflammable. Under such conditions, the slightest back fire, quite natural on a cold engine, would start a conflagration. It is most fortunate that these fires occurred on the ground where powerful means of combating them were available. These facts show the importance of keeping airplanes in a state of perfect cleanliness. It is certainly possible to avoid any considerable oil leakage on engines, even after long flights. Thus, Lindbergh's airplane, at the end of its transatlantic flight, impressed all who saw it by the cleanliness of its engine and by the almost perfect oil tightness it revealed.

In this connection, attention is called to the methodical cleaning required by certain American air traffic companies for maintaining cleanliness on their airplanes. Every week a cleaning is made with a jet of air, compressed at about 4 kg/cm² (56.9 lb./sq.in.). This jet drives either kerosene or a mixture of 50% paraffin and 50% gasoline. After each flight, or at least every week, the wings are cleaned with soapy water (about 20 grams of soap per liter of water), followed by rinsing with water. Lastly, the fuselage is cleaned by a jet of air, compressed at 4 kg/cm². The general adoption of such thorough methods of cleaning would doubtless greatly increase the comfort and the safety against fire. In any case there is room for much improvement, but a veritable campaign would have to be undertaken in order to convince every one of its necessity.

Conclusions

General considerations and examples.- Two examples will show how fire spreads on airplanes and how the means to combat it are used. These examples date back several years, to a time when precautions were not so complete and strict as now. They are all the more interesting to examine on that account.

On February 16, 1925, the pilot of a single-seater, flying at an altitude of 1500 m (4900 ft.), saw flames bursting forth from the left side of the engine compartment. The fire was due to the rupture of a connecting rod which staved in the crank case. The oil spread inside the cowling and caught fire. The pilot immediately operated the stationary fire extinguisher. Unfortunately, the cock was not readily accessible and required several turns to get it wide open. Time elapsed and the fire spread. As there is no fire wall, the flames first reached the tank and even the pilot, who was slightly burned. He immediately dropped the tank, which was already marked by the fire. The flames now attacked the fuselage. The action of the fire extinguisher, however, became manifest. Besides, the pilot, in dropping the tank, deprived the fire of its most dangerous ally. The flames gradually subsided and disappeared. When the airplane reached the ground, the fire was completely extinguished. Unfortunately, the landing was very rough and the pilot was found dead in his cockpit by those who ran to his aid. His burns, though only slight, the poisonous vapors which he may have breathed (since no bulkhead prevented them from reaching the fuselage), and finally the quick succession of events probably left him no time to make the straightening maneuver which might have saved him. This accident demonstrated the efficacy of fire extinguishers and of dropping the tank, the importance of the easy accessibility and quick operation of the fire extinguishers and the need of fireproof bulkheads.

The second example is that of a fire which occurred March 24, 1926. The flight started under normal conditions, but clapping sounds coming from the inlet side were soon heard, and almost immediately flames burst forth from the engine compartment. The clapping sounds revealed carburetor troubles due to irregular fuel supply (There was a leak in the joint of the fuel pipe leading to the carburetor) and perhaps to an abnormal air intake (The air shutter of the carburetor was missing, and the holes for the shutter spindles remained open). Bad carburetion caused back-firing. But, since the air inlet pipe of the carburetor opened outside the fuselage, these back fires should have been harmless. Unfortunately, the flames found passage through the holes left open by the missing shutter. They penetrated into the engine compartment. On the other hand, the leakage from the fuel pipe carburetor connection, close by, supplied the fuel for the flames. Fire broke out. The pilot immediately operated the extinguisher. At the same time he closed the radiator shutters, which increased the efficacy of the tetrachloride. He thus succeeded in mastering the fire, and the flames were extinguished. But, although the extinguisher suppressed the immediate effect of the conflagration, it was unable to eliminate the original causes (fuel leakage and penetration of air) which still persisted. The fire revived and the flames again burst forth from the engine cowling. In the meantime, the menaced pilot brought his airplane to the ground and succeeded in landing without accident. Scarcely had he left the cockpit with his observer, when the whole airplane was a mass of flames. This accident illustrated the serious consequences of bad maintenance of the carburetor accessories and fuel pipes, the necessity for absolute tightness of the air inlet pipes and the efficacy of fire extinguishers, requiring, however, a sufficient amount of tetrachloride to stop several consecutive fires in the course of the same flight.

The analysis of these accidents confirms, in a concrete way, the general conclusions of the present report, which may be summarized as follows: There is and can be no absolutely reliable means of preventing airplane fires. Even the substitution of so-called safety fuels or heavy oil for gasoline, in spite of the undeniable advantages which they would offer from the viewpoint of safety, would still leave certain risks, which could be overcome only by special precautions. There is a great variety of possible causes of fires and of the conditions under which they spread, as also of the corresponding precautions. None of them should be neglected. Also, no precaution should be exalted to the prejudice of others, since it will be possible to achieve actual safety only by combining their effects.

During the last three years considerable effort has been made in France to reduce fire hazards. The consequences are now becoming manifest. Out of a total number of 183 accidents, recorded by the Bureau Veritas in 1926, there were 14 fires (7.6%), while this proportion decreased in 1927 to 6 out of 206 (3%). Of course, this decrease in the percentage will have to be maintained for several years before it can be considered permanent. We may look forward with optimism, however, since precautions do not usually become fully effective for some time after they have been adopted.

Program of Investigation and Research

In any case, the efforts should be continued and intensified. The program to be followed has been directly derived from the considerations of the preceding chapters and takes the following form:

1. Tests and regulations which may take immediate effect:

Improvement of the tightness of the air-inlet pipes up to the point where they open outside the fuselage.

Improvement of the fuel and flame tightness of the fire walls; rapid elimination of airplanes not provided with complete fire walls.

General adoption of stationary fire extinguishers on all airplanes, the crews of which have adequate means for their maintenance.

Gradual elimination of rubber connections for fuel and oil pipes; substitution of metal joints wherever special elasticity is not required; methodical reduction of the number of joints, wherever their presence is not indispensable.

General adoption of fire-prevention devices and of protective casings for ignition wires.

Revision and improvement, from the viewpoint of fire prevention, of the existing installations for heating the intake air and the carburetors.

Revision and improvement of the conditions under which fuel tanks have to withstand horizontal and vertical stresses in flight.

Campaign by regulations and posters, showing the paramount necessity of careful maintenance and absolute cleanliness on airplanes.

2. Investigations, to be undertaken or continued, likely to give results shortly:

Improvement of exhaust pipes, mufflers and fire screens now in use; methodical study of the cooling conditions of these devices and investigations for the purpose of eliminating dangerous hot spots; drafting of test regulations in order to determine whether the devices presented meet the safety requirements in this respect.

Improvement of the present conditions of construction and acceptance of fuel and oil tanks, especially as regards the test pressure, the resistance of attachment fittings to normal stresses stresses, the bulkheads, the resistance of tanks and their fittings to horizontal impacts.

Design and construction of joints for fuel and oil pipes to satisfy the regulations of the new S.T.I.Aé. competition.

Design and testing of stuffing boxes and joints for the tight passage of controls and pipes through the fire wall.

Design and testing, from the viewpoint of fire prevention, of standard devices for heating the intake air and carburetors.

3. Extensive investigations to be undertaken or continued:

Experimentation and research concerning the possibilities and conditions of using safety fuels on aviation engines.

Experimentation and research concerning heavy-oil aviation engines.

Methodical investigation of the ignition conditions of gasoline, safety fuels and heavy oils as regards hot spots, sparks, incandescent coke, etc.; variations of these conditions as a function of pressure and temperature.

Investigations regarding the production and use of nonpoisonous extinguisher liquids.

Systematic tests dealing with the resistance and tightness of fuel and oil pipes to repeated vibrations, surging and impacts due to landing on the nose; experimental determination of the accelerations set up in this case; study of the influence exerted by the number, distribution and resistance of bulkheads on the general resistance of the tank to impacts; design of tanks capable of withstanding the impacts (special devices for the tank and its attachment fittings; relative weight and space requirements).

Investigations regarding the best location of tanks on airplanes. Possible design of a truss or cage, capable of partially protecting the engine, the fire wall and the tanks against direct impacts following landings on the nose; design of a fire wall capable of withstanding the above impacts.

This program is very extensive, but is justified by the value of the human lives and of the property to be protected. The investigations and researches mentioned in each paragraph have been, when possible, arranged in the order of their importance. The measures outlined in the first paragraph will enable an almost immediate improvement in safety conditions. Their adoption will depend chiefly on the attitude of the designers and users of airplanes. On the completion of an airplane, both should see that the necessary precautions are applied. Besides, they should periodically make sure that these precautions have not been impaired in service and still retain all their original efficacy.

One of the objects of the present treatise will be accomplished if it succeeds in convincing some designers and pilots of the fundamental importance of these points. The studies and investigations contemplated by the rest of the program are chiefly in the province of technical services and laboratories. They will require time, and their results will be manifest only after a long time. This fact, however, will only improve their efficacy. Several of these investigations are now being made (chiefly at the S.T.I.Aé.) and are nearing successful completion. It is hoped that the present treatise, in specifying the numerous elements of the fire-prevention problem, will help to render its solution more rapid and complete.

Translation by
National Advisory Committee
for Aeronautics.