# Wings of War

Theodore M. Knappen


**The NC 4, Liberty-Engine-Driven Conqueror of the Atlantic, in Flight at Pensacola, Florida**

Navy Photo

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An Account of the Important Contribution of the United States to Aircraft Invention, Engineering, Development and Production during the World War


By

Theodore Macfarlane Knappen


With an Introduction by

Rear-Admiral D. W. Taylor

Chief Constructor, U. S. N.

*With 43 Illustrations*


G. P. Putnam's Sons

New York and London

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## PREFACE

THE manuscript of this book was written in 1919. The numerous Congressional investigations of the management of the war which have taken place since the writing have revealed many shortcomings in both the army and navy that were concealed during the conflict period—and aircraft production is no longer singled out for a monopoly of hostile criticism and sweeping condemnation, as it was in the unhappy days when its managers were seeking to accomplish the impossible. Time is a great adjuster of judgments as well as a healer of wounds, and it is the writer's belief that the ultimate verdict of history will virtually coincide with the conclusion reached in the following pages that instead of being, as was once universally believed, the outstanding industrial fiasco of America's part in the World War, the aircraft achievements deserve to rank with any of those of our "second line of defense," which, taken as a whole, were highly creditable.

The war happily came to an end too soon for our huge industrial conversions and mobilizations to enjoy the spectacular triumph that would have been theirs in the spring of 1919. Nevertheless, the knowledge of the Central Empires that a country that was as innocent of knowledge of the art of making military aircraft in the spring of 1917 as it was before the Wright Brothers made their first flight in a heavier-than-air machine, was, in the fall of 1918, producing air service engines in greater volume than all the rest of the Allies together, with a similar preëminence in the production of 'planes rapidly approaching and a magical expansion of all related productivities, had its certain and conclusive though undramatic effect on the moral and mental processes that led to the collapse of Germany before the death-blow was delivered.

T. M. K.

WASHINGTON, D. C.
*May* 1, 1920.

# INTRODUCTION

THE story of the United States army aircraft production program is essentially a story of confident hopes, bitter disappointments, failures, and successes such as inevitably attend the creation from nothing of an immense industrial organization. The existing publications which give the history of this undertaking are largely the voluminous reports of congressional and other investigating committees which throw into strong relief all failures and unfortunate circumstances, and gloss over with very scant mention the successes and the fortunate circumstances. For this reason, it is especially desirable that a less one-sided account of the army air effort be published, and, hence, I am glad to see the appearance of this book.

The conception of a tremendous air program, and the courage to undertake it in spite of the obvious difficulties is, in my opinion, due to General Squier and Colonel Deeds, and, since these officers have received public criticism for any and all shortcomings in the program, it is no more than fair that they should also receive the credit for the wonderful success of other parts of the program.

The entire American aviation program centered in the conception, development, and production of the Liberty motor, and this I consider one of the outstanding achievements of the War. The army staked much on the Liberty engine, but the navy staked everything. The navy, in fact, for its service 'planes adopted a 100% Liberty motored program, calling for a series of large flying boats engined with one, two, or three Liberty motors. This program was adopted by the Navy Department before the Liberty motor was fully proved. It is of interest to record the fact that the first Liberty motor to fly was mounted in a naval seaplane, the first twin Liberty motors were flown in a naval seaplane, and, finally, the Atlantic was crossed by four Liberty motors in a naval seaplane.

Since the navy relied upon the army for its Liberty motors upon which its program was based, and since the army delivered the goods in this respect so that the navy program was not delayed a day by failure to have those wonderful motors ready when the navy 'planes were ready for their installation, it is natural that those of us in the navy who had to struggle with the production of 'planes should have in our hearts a warm spot for our brothers in the army who conceived and produced, with such astonishing success, the Liberty motor.

The history of the navy's aircraft production program has not been covered by the proceedings of investigating committees. The navy's problem was undertaken successfully with the existing naval industrial organization. The navy was, therefore, spared the tribulations incident to organizing a brand new industrial machine, tribulations which are little understood or appreciated by the layman. Also, the navy's problem was of less difficulty than the army's because not on such a gigantic scale. The navy entered the war with an existing shipbuilding organization, provided with aeronautical engineers, wind tunnel research facilities, training seaplanes and airships, and an adequate training station.

The naval program of service 'planes was adopted in the fall of 1917, and was never changed except to be increased twice as to numbers. Production was going ahead with full volume in the spring of 1918, and, by September, 1918, all fifteen naval air stations abroad, as well as our own coast-patrol stations, had been shipped full complements of service 'planes. Shipments were then stopped, and steps taken to slow production. The armistice came before shipments abroad had to be resumed. "Happy the people whose annals are uninteresting."

D. W. TAYLOR,
Rear Admiral (C.C.), U.S.N.,
Chief of Bureau of Construction and Repair.

WASHINGTON, May, 1920.

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## CHAPTER I

### THE TASK SET BEFORE THE BUILDERS

THE entire air force of the United States of America broke down and disappeared in the trifling contest with the Mexican bandit, Villa, in 1916. A year later the nation whose air forces and material were so pitifully small that they were unable to cope with the reconnaissance problems offered by the activities of a Mexican bandit was called upon to plunge into the greatest aircraft production program and into the training and organization of the largest flying personnel the world had seen.

It was almost as if some armorer of the feudal ages, after making his first arquebus, had been called upon to make modern rifles by the millions. Or, as if the artificers who cast the fifteenth-century "mystery" guns that conquered Constantinople and crushed the Byzantine Empire for the Turk had in a moment been ordered to produce the fifteen-inch guns of a modern battleship or fortress.

We knew nothing, one might say, of aircraft; and we were required to know all. We had done nothing; and it was demanded of us that we should do all. We had altogether of every kind and description, when the war with Germany came, some 60 planes all told. In the preceding year we had ordered 366 machines, had succeeded in getting 64 delivered, and so great was this task for our manufacturers that they had asked to be relieved of most of their contract obligations. They had tried to build 366 airplanes in a year and confessed to an 80 per cent. failure.

We lacked aeronautical engineers, we lacked large plants, we lacked skilled workmen, and, although the war in Europe had been raging for almost three years, we lacked absolutely knowledge of aeronautical military requirements. In fact we had not built a single land combat plane of any description either for ourselves or the Allies. We were as ignorant as a child unborn of the nature of the equipment of a military 'plane.

Suddenly we plunged all unprepared into the war and with a unanimous voice the Allies and our own people declared that perhaps our greatest contribution to the war would be such vast numbers of airplanes that the German army would be blinded and the whole German Empire overhung with a cloud of hostile airplanes. Almost gayly in our ignorance we undertook within three months after the declaration of war a program calling for the completion within one year of 22,500 'planes. We proposed to manufacture and maintain at the front 4500 machines. At this time France and England between them, after many years of preparation and three years of active combat, had been able to maintain at the front not more than 2000 combat machines. Had it not been for our blissful ignorance of the magnitude and complexities of the task, we would never have undertaken it. We were fools, rushing in where angels feared to tread. Yet if we had not undertaken so much we would not have done as much as we did. Had it not been for our optimism and our sublime confidence we would have undertaken little and accomplished less. The impossible was undertaken and its accomplishment was glowingly foretold; it was not achieved but the spirit that dared so much and predicted so much was the spirit that made it possible actually to do so much.

The task was of such unparalleled magnitude and so bewildering in its complexity that the men who undertook to carry it through were only able to stimulate themselves for the stupendous work by dwelling on its colossal proportions as something that they must and would overcome, without reflecting overmuch on the relations between its dimensions and the caliber of the instrumentalities with which it was to be accomplished. They refreshed themselves for the daily effort against the awesome job by the continual contemplation of it as a thing accomplished. They lived and worked in a sort of dream of mighty deeds that must be done. They were self-hypnotized and ofttimes spoke and acted as if the will to do was the thing done. Their enthusiasm and confidence were communicated to all who were associated with them. Everybody undertook the impossible and was sure it could be done. Manufacturers who had never built an airplane engine contracted to produce them more rapidly and in greater volume than the greatest builders of Europe would have dreamed of. Optimism reacted on optimism, confidence was expanded by answering confidence. Thus arose a sort of dreamland of herculean effort united with an illusory sanguineness, out of which came magnificent courage, wonderful audacity, and almost superhuman achievements, which were still short of what had been confidently predicted.

The aircrafters were judged not by what they did, but by what the public came to believe that they could do. They went at their task as a climber approaches a high mountain—by looking always upward to the eternal snows and proceeding steadily in the direction of the summit without discouraging himself by visualizing the intervening difficulties. Had our aircraft managers and manufacturers fully realized at the start how many gullies and valleys and canyons, how many rough slopes, how many precipices and crevasses were in their way, how much they would have to go down in order to go up, before they reached the summit, they would have given up in despair. Looking back now in the fatigue and reaction of achievement they would not dare to undertake what they finally did accomplish.

In the making of almost everything else that was essential to the material side of the war, America was more or less experienced. We had built ships before and we knew all the arts of cannon-making. We were expert armorers, we were the world's premier makers of rifles, and we had built vast quantities of machine guns. We were the chief manufacturers of military explosives. We even had the nucleus of a great army and we had a powerful navy. But in the building of aircraft we were as children; yet to us was assigned the greatest effort, comparatively, in that of which we knew least.

Ignorant of the aerial arts, the task set for us was nothing less than the conquest of the air. The war was to be won in the air. All the efforts of France, England, and Italy had not been sufficient to produce that vast aerial armada that was to encompass the German armies and the German Empire above as fleets and armies had encompassed them below. Ignorant as we were, our task was to convert our vast manufacturing resources and genius for mass production from known to unknown work, do it with surpassing speed, and gain for the Allies the dominion of the air.

## CHAPTER II

### BEFORE THE WAR

THE heavier-than-air flying machine was invented in America. It was used and applied elsewhere. The Wright brothers first flew in a self-propelled airplane, at Kittyhawk, North Carolina, on December 17, 1903. Sixteen years later, the birthland of the airplane, drawn into the vortex of the very world war the Wrights believed the airplane would make impossible, when sufficiently developed and multiplied, was woefully lacking in knowledge of the science and art of aeronautics and aircraft manufacture.

When the Germans struck their sudden and treacherous blow in August, 1914, they had 1200 military airplanes, France had 300, England 250. The United States had practically none. Three years later when the war engulfed us we still had practically none. There was not a man in the American army who had ever flown in a fighting 'plane of any sort, unless possibly as a guest;

scarcely anyone except the military observers had even seen such a thing as a modern military 'plane. Our little aviation section of the Signal Corps had some machines but by no stretch of the imagination could they be called fighting 'planes. The total personnel of the aviation section was 52 officers, 1100 enlisted men, and 210 civilians. Probably not more than a dozen of this force were expert flyers. There were not enough of them to make even a respectable start in training recruits. This meager body of men had at their disposal less than a hundred machines—of almost as many types as there were machines. The government whose inventive sons, the Wright brothers, had given the aeroplane to the world, had during eight years of mild and skeptical Congressional interest in aeronautics managed to collect 54 machines and had actually ordered 59. In 1916, after the war in Europe had been raging with frightful and ominous intensity for two years, we got around to ordering 366 airplanes; but only 64 were delivered. It took the nine leading manufacturers of the country a year to produce an average of five 'planes a month, and most of them asked to be relieved of a part of what they had undertaken to do. From the standpoint of quantitative production the business of aircraft manufacturing was almost non-existent in the United States. There was only one 'plane plant that was entitled to be called a large factory. The rest were hardly more than shops—some of them ludicrous shops. There were many manufacturing concerns on paper and quite a number had offices, but there were only six or seven that had really done anything even in the small prebellum way.

There were perhaps a dozen aeronautical engineers in the whole country who were men of marked ability and recognized achievements, but not one of them was then competent to design a complete up-to-date fighting aeroplane without further acquainting himself with the development of military aircraft in Europe. In brief, in a broad way of speaking, we had neither factories, manufacturers, nor engineers. We were as helpless technically and industrially as we were militarily—if not more so.

Some manufacturing had begun of engines of foreign design on orders from the Allies. Thus the Wright-Martin Company, of New Brunswick, N. J., had taken up the manufacture of the Hispano-Suiza engine; and the General Vehicle Company, of Long Island City, N. Y., had begun to make some Gnome motors. The Curtiss Company was making its own engines, the OX and the OXX, the former being of about 100 horsepower for use in training machines and the latter being of 200 horsepower for navy training 'planes. The Sturtevant Company was building an engine of 135 horsepower and the Thomas-Morse Company was producing an engine that was to be an improvement on the Sturtevant. The Hall-Scott Company was next to the Curtiss the largest producer, and was making four- and six-cylinder engines. The Packard Motor Car Company, the Pierce-Arrow Company, the Knox Motors, the Duesenberg Motors Corporation, the Union Iron Works, the Wisconsin Engine Company, and others were developing engines.

Among the engineers were Glen Curtiss of the Curtiss Company and several associates; Orville Wright; Willard of the L. W. F. and later of the Aeromarine Company; Charles Day of the Standard Aero Corporation; Starling Burgess of the Burgess Company; Grover C. Loening of the Sturtevant Company; B. D. Thomas of the Thomas-Morse Company; C. M. Vought of Lewis & Vought, New York City; Glenn L. Martin of Los Angeles; J. C. Hunsaker of the navy; and Capt. V. E. Clark of the Signal Corps.

J. G. Vincent, chief engineer of the Packard Motor Car Company, had been engaged in motor research and development work for two years and had produced several different models of 12-cylinder aviation engines of from 125 to 225 horsepower with the result that he had collected a vast amount of data regarding aviation engines and had gathered around him an efficient experimental and laboratory organization. This recent experience was added to a rich experience in the designing and quantity production of automobile engines—the sort of experience the aircraft manufacturers and engineers proper mostly lacked.

E. J. Hall of the Hall-Scott Motor Car Company had worked developmentally on aviation motors for eight years and had got into a very considerable production of a number of different types which his company had delivered to the governments of Russia, Norway, China, Japan, Australia, Canada, and Britain. He had also completed a 12-cylinder engine of 300 horsepower, but like the Vincent models it was too heavy in relation to its horsepower to be suitable for military purposes. Mr. Hall thus had a long and very practical experience in aviation motor engineering and was familiar with the problems of quantity production.

The largest order any manufacturer had ever had from the United States Government before 1917 was 22; and the Curtiss Company, which received that, had only made a limited number of training and some experimental seaplanes on foreign account. None of the manufacturers or engineers knew much about fighting 'planes. None of them had ever sent any except seaplanes to Europe. No land airplane made in America had ever except, possibly, experimentally carried a machine gun or any but the most ordinary and civilian equipment. Such things as oxygen apparatus, radio telegraph and telephone, landing flares, electric lighting apparatus, bomb-dropping devices, observation cameras, special compasses, machine guns adapted to airplanes, instruments for measuring heights and speed, and many others were an unopened book to American 'plane designers and manufacturers. Yet their importance and the difficulty of designing and procuring and adjusting them to the machines were so great that they afterwards came directly or indirectly to be the chief factor in the retardation of quantity production. Had it not been for them combat 'planes would have been produced in the United States on a large scale several months earlier than actually was the case.

This, then, was the situation of aviation and aeronautical science and art in the United States at the beginning of the war: only a handful of experienced flyers, of whom none had real military experience; only seven or eight manufacturing plants that could even by courtesy be called such; not more than a dozen aeronautical engineers, and none of them competent, by reason of inexperience, to design a fighting 'plane; some engineering and manufacturing experience in the development and production of aviation engines; no military organization worthy of mention; very few workmen used to the refinements of manufacture required in the production of such a delicate and yet powerful machine as an aviation motor.

This was the preparation with which in 1916 we looked forward into the dread year that was to see our entry into the tempest of the European War.

This was the domestic foundation on which resolute men were within a few months to be called to build the greatest aircraft industry in the world. No proper understanding of the magnitude and difficulties of their task, no measure of their degree of success or failure is possible without first of all a full comprehension of what they had to begin with.

## CHAPTER III

### THE BEGINNING

THE National Advisory Committee on Aeronautics had been created by Congress in 1915 and, though chiefly charged with scientific and technical phases of the general development of aeronautics, it began in the latter part of 1916 to collect some data regarding military aviation potentialities. Soon afterwards the Council of National Defense, authorized by Congress in the summer of 1916, began to function and established its Advisory Commission which early took up aerial defense. Some consideration was given to possible locations for flying fields, a sort of survey of existing aviation plants was made, some attempt was made to stimulate manufacturers' interest in the production of aeroplanes and engines, and a feeble effort was made by the Signal Corps (which despite all its efforts had received but the scantiest financial support from Congress) to bring into its slender organization some experience and ability drawn from civil life.

As the outcome of a visit of the National Advisory Committee to Detroit in November, 1916, Sidney D. Waldon, a Detroit manufacturer, who had been keenly interested in aviation since 1910 and had been active in the Aero Club of that city and in providing for aviation training in the Michigan National Guard, was induced to apply for admission to the Signal Corps. He did not receive his commission as Captain until some time in February, but in the meantime acted as a civilian assistant.

At that time the executive offices of the aviation section of the Signal Corps occupied a few rooms in the Anson Mills building in Washington. Capt., later Brig. Gen., William Mitchell, was then Aviation Executive Assistant to Lt. Col. Geo. O. Squier, later Major General, chief of the Signal Corps; Maj., later Brig. Gen., B. D. Foulois was in charge of the first aero squadron at San Antonio, Tex., Capt. De Witt Milling was in charge of engineering; Capt. Virginius E. Clarke, later Lieutenant Colonel, was assigned to engine design and W. H. H. Hutton, later Colonel, looked after the records of production. There were then only two flying fields controlled by the Signal Corps, there were only 28 officers and 1106 men in the enlisted and civil personnel. As stated above, there were less than a hundred serviceable machines of any kind and as late as January 1, 1917, the total number of machines that had been made for the army from the beginning of the air service was only 118.

In view of the imminence of the peril that then confronted the nation, it is almost pathetic to read of Howard Coffin—then a member of the Council of National Defense (Advisory Commission), who was devoting special attention to aeronautical matters and had made a preparedness industrial survey of the country for Secretary Daniels of the Navy—and S. D. Waldon making trips to inspect the few aircraft factories of the country, encouraging the aeronautical exposition in New York and scratching on the surface of the towering mountain of difficulties and tasks that were to be overcome. One of these early tasks was the working out of a plan whereby patent monopolies would not interfere with a general national effort in case of need. About the first order given at this time to stimulate production was one to the General Vehicle Company for one hundred Gnome engines, half for the army and half for the navy, at a price of $5000 apiece.

As showing how trivial were American official aviation efforts, Mr. Waldon relates that on investigation of the records he found that from 1908 to 1916 the army had ordered 59 'planes and received 54 and that during 1916 it ordered 366 and received 64—so that three months before the United States plunged into a war, every report of which for more than two years had told of the vital importance of airplanes to its successful waging, the army had received altogether only 118 machines, of which many had been destroyed or were obsolete. The original 54 'planes came from four makers—and the largest number awarded to a single manufacturer in the whole eight years since the Signal Corps had taken up aviation was 22. It took nine factories to turn out the 64 machines that were tardily delivered to the army during 1916. This was the kind of support the United States gave to the building-up of an industry which was really as vital to national defense as the army and navy. It was not until 1914 that Congress became liberal enough to appropriate $300,000 for the purchase of airplanes. It was in the same year that five officers were sent to the Massachusetts Institute of Technology for a special course in aeronautics. These five men were the regular army technically trained personnel with which to face one of the greatest engineering tasks ever imposed upon any body of men.

The situation improved little with the certain approach of war and was no better for a month after we declared war, except that there had been a rapidly developing dismay that was to be the father of enterprise and that there was a daily expanding understanding of how much must be done. As late as May 12, 1917, the outstanding orders for 'planes for both the army and navy were as small as 334, a number which was later to be exceeded by the weekly production schedule of a single company.

These orders were distributed between sixteen actual or so-called manufacturers, and the fact that most of them were never filled illustrates how large a proportion the latter constituted. The orders covered ten distinct types and thirty-two different designs, each manufacturer being permitted to produce about what his yearnings or his ingenuity suggested. The Curtiss Company—then the only aeroplane manufacturing concern in the country of important capacity—led with orders for 126 and their 53 R-4's were the largest number of any one design, and the largest number of any one type was 116 twin-engine hydroplanes. There were 72 training 'planes of eight different types; 85 were land reconnaissance machines of four designs; 26 were seaplanes of four designs; two were bombers of the pusher type and there were 31 pursuit 'planes of seven different designs.

The many different types, the few contractors, and the limited number of contracts reveal painfully that we had no program, no funds, and but a limited comprehension of what was necessary. Of the contractors only one—the Curtiss Company—was large, as an all around airplane manufacturing company—and the rest were either motor makers only, adjuncts, or feeble in resources or personnel and generally lacking in the organization and understanding of quantity production. Their value consisted more in their engineers than in their realized production ability. The list of these contractors is deserving of publication and record, for most of them subsequently played a great part in the engineering or production sides of the stupendous building program that was finally embarked upon. They were the Curtiss, the Standard, the Burgess, the L. W. F., Thomas-Morse, Wright-Martin, Sturtevant, Aero-Marine, Gallaudet, General Vehicle, Pacific, Christofferson, Heinrich, New York Aero, Pigeon Frazer, James V. Martin. Competent authority states that the first six in the list were the only ones that had ever built more than ten machines. That, perhaps, is a sufficient answer to the question so often asked: Why did automobile and other manufacturers who were not previously in the business of making aircraft have so much to do with the production program?

The domestic manufacturers or would-be manufacturers were profuse in their advice and suggestions, each believing in his particular aeroplane or engine or whatever else he had to offer and each eager to win distinction and to contribute to the success of the war. After and with them swarmed the representatives of foreign manufacturers who were anxious to dispose of their American rights and sometimes to establish American plants. Their offers ran into very high figures. The royalties asked by some of them, reduced to a basis of one thousand units for each, are as follows:

| | |
|---|---|
| Short seaplane | $ 675,000.00 |
| Sopwith 'plane | 500,000.00 |
| Clerget engine | 700,000.00 |
| Sunbeam (including cost of engine and royalty)—200 H. P. | 7,000,000.00 |
| 300 H. P. | 8,000,000.00 |
| Caproni rights | 2,000,000.00 |
| Gnome | 1,215,000.00 |
| Gnome, 100 H. P. | 500,000.00 |
| Le Rhone, 80 H. P. | 1,375,000.00 |
| Handley-Page 'plane | 200,000.00 |
| Le Rhone engine | 600,000.00 |

These offers and the support advanced for each of them added to the bewilderment of the aircraft officials and to the great body of criticism that began to engulf them. Each representative whose proposition was not promptly accepted or was eventually rejected could demonstrate how the aircraft organization was thereby failing to measure up to its opportunities and responsibilities. This was also true of some of the domestic manufacturers, though of the latter it must be said that in the end, whether they considered that they had been justly and understandingly dealt with or not, they loyally undertook the task that was assigned to them whether great or small. Nor can it be asserted confidently that they all received their deserts. Mistakes may have been made, doubtless were made. It could not be otherwise. Decisions, right or wrong, had to be made or the early confusion and indecision would have continued indefinitely. The odds were all in favor of following foreign practice, both in 'planes and engines—so far as combat airplanes were concerned.

## CHAPTER IV

### MAKING UP FOR LOST TIME

THE declaration of war precipitated an indescribable state of confusion in Washington. A government whose energies had been largely devoted to keeping out of war and defending the rights of neutrals and whose inclinations were all for peace found itself confronted by war—modern war, of which it was all but totally ignorant. In striving for peace it had failed to prepare for war. There is probably no parallel in history of a great nation remaining for three years on the edge of a war that involved its own future, reminded daily of the huge scale of operations and their infinite complexity, and yet doing almost nothing to arm itself. The small aviation organization of the Signal Corps was stunned. In the preceding months it had gradually grasped the idea that if war came a prodigious program would be inevitable, but the preparations for realizing and preparing for it were very meager. It called for help. In response the

Council of National Defense, which had for some months concerned itself with the impending problem, created the Aircraft Production Board, which thereafter became an independent body.

Like the body whence it sprang it had no real powers. It sought to counsel, suggest, and advise; and to coördinate and harmonize the aviation efforts of the army and the navy. Howard E. Coffin, an automobile manufacturer of great ability, industry, and self-sacrificing patriotism, who had long been interested in preparedness and in the development of aviation as an arm of the national military power, was made chairman. The other civilian members were Edward A. Deeds, who was subsequently to assume, as chief of the equipment section of the aviation division of the Signal Corps, the task of directing program and production; Sidney D. Waldon and Robert L. Montgomery. The other members were Gen. George O. Squier, Chief Signal Officer, and Adm. D. W. Taylor, Chief of the Bureau of Construction and Repair of the Navy.

Congress was blindly called upon for huge appropriations and blindly made them. The Allies, aware of the tremendous American capacity for quantity production and knowing from their own experience of the many obstacles in the way of such production, and being keenly convinced of the importance of supremacy in aerial warfare, advised that we undertake an aerial program that would dwarf all that had been done by themselves or the Germans. The popular imagination was captivated by the concept of illimitable American manufacturing potentiality turned to the conquest of the air. On May 12th, $10,800,000 was voted; on June 15th, $31, 846,000, and finally on July 24th, after the army air program had been decided upon, $640,000,000. Later appropriations in this and the following year made the grand total for the air service, $1,676,000,000, which was cut to $1,190,000,000 after hostilities ceased.

General Squier asked for the $640,000,000 more on general principles than as the result of careful calculation. He knew that the cost of the aviation enterprise, if conducted on an adequate scale, would be prodigious. But neither he nor anyone else knew at that time what an adequate scale was. Asked by one of his officers about this time concerning the program, the General replied that there was no program then and could not be one.

"Think of the largest program you can imagine as possible," he said in effect, "and then double it—and probably you will not have it large enough."

General Squier is a scientist and scholar rather than an executive, but he is entitled to credit for two policies that profoundly affected production of aviation equipment and the size of preparations as well as their manner of realization. He had been abroad and had a wide understanding of the necessity for extensive preparations. He, therefore, opposed all half-way measures. He was for plunging and plunging hard. He also gave his executive heads unlimited authority, thus enabling them to act with promptness and vigor. The Signal Corps administration of aviation, therefore, lacked neither vision nor initiative. Whatever criticism may be leveled at it, credit must be given to it for acting energetically and comprehensively.

The will to great things was in existence and the money was quickly provided, as it seems now, though to an impatient country the time seemed long then. But at first the aircraft authorities were like a man on a desert island with a barrel of gold. They did not know how to exchange their funds for aircraft.

In January and February officers of the Signal Corps had talked about the possibility of building 1000 'planes in 1917 or in twelve months, but in the view of past experience with aircraft manufacturers, nobody believed it could be done. On

March 23, Capt. V. E. Clarke prepared a report that looked to the production of 2500 'planes a year. By the middle of April a three-year program was beginning to take form requiring the production of 3700 'planes within the first twelve months but it was never approved by higher authority than General Squier. About the same time Mr. Waldon, who as a manufacturer was anxious to know what the program ought to be, got from Colonel Bennett, who was then head of the aviation section of the Signal Corps, an estimate based on an army of one million which called for thirty-six aero squadrons and 1296 military machines. Ten training schools, it was calculated, would require 334 machines at the start and 500 during the second six months to make good the wastage—or in all 834 training machines. On May 14th Mr. Waldon made an estimate of 5158 machines for the ensuing fiscal year. On May 23d the Joint Army and Navy Technical Board raised this estimate to 7775 machines of which 7050 would be service machines, and the rest for training. But on May 24th the French Government called on the United States to undertake a program that would put 4500 machines at the front in the spring of 1918. The Army and Navy Technical Board, acting on this advice, then calculated that such an objective

Enthusiasm Arousing Meeting of Airplane Workers in the Heat of War's Fever

would call for about 22,500 airplanes of which 10,000 would be for training purposes and 12,000 for service. This, then, was the program to be carried out in less than a year by an army that had only 334 'planes on order and did not have more than two dozen capable flyers on its rolls, and in a country that had produced only 320 aircraft of all kinds and on all orders, foreign and domestic, in the first six months of 1917.

How amateurish the earlier estimates had been is shown by the fact that whereas Colonel Bennett had figured on more service than training 'planes, the Technical Board at first calculated on ten times as many training as service 'planes and finally decided to make them about equal. The estimates for the navy and for training foreign flyers brought the total program up to 22,600 plus requirements for replacements and wastage. At the most this was a twelve-month program.

This program was, of course, physically impossible, but in those days impossibility was not admitted in connection with anything that the war demanded. The men at the head of aviation affairs believed it could be done, and the manufacturers believed likewise.

The civilian members of the Aircraft Production Board, being men of large affairs and wide manufacturing experience, were irked by their lack of power and irritated by the inability of the army to cope with such a great planning and production problem. On the other hand the army men, who were doing the best they could, retorted that it was easy to advise but hard to do. The upshot was that Mr. Deeds, yielding to the urging of General Squier, accepted the chiefship of the equipment division of the Signal Corps, which was created on on Aug. 2, 1918, and was soon thereafter made a Colonel in the regular army. The scope of the office included both engineering and production for all the requirements of the Signal Corps, aviation as well as other. A finance and supply division, already in existence, was reorganized and Mr. Montgomery, subsequently commissioned as a Colonel, was placed at its head. Mr. Waldon, also commissioned as a Colonel, was chosen by Colonel Deeds as his assistant chief. The two divisions were united a little later with Colonel Deeds at the head.

Congress later replaced the Aircraft Production Board, created by the Council of National Defense, with the Aircraft Board, and on October 22d General Squier and Colonels Deeds and Montgomery became the army members thereof (Colonel Waldon having gone to France); and Admiral

Taylor, Captain Irwin, and Lieutenant Commander Atkins the naval members. Richard Howe and L. R. Thayer were added as civilian members, and Howard E. Coffin continued as chairman.

Thus were established the bases of the organization of aircraft production, civilians in army uniform taking up the stupendous task. In January, 1918, Colonel Deeds was transferred to General Squier's office with the still larger duties of Industrial Executive.

Colonel Deeds as chief of the Equipment Division and later as industrial executive was the responsible head of army aircraft production. He had been called to Washington by Mr. Coffin a month before war was declared and appointed by Secretary of War Baker to the short-lived Munitions Standard Board. Two days before the declaration of war Mr. Coffin again called on Mr. Deeds for assistance in aviation matters and on May 10th invited him to become a member of the Aircraft Production Board. This selection was a judicious one as Mr. Deeds was a man of national reputation as a successful manufacturer and engineer, and had, as the friend and fellow-townsman at Dayton of the Wright brothers, been long interested in aviation and had been associated with Orville Wright in aeronautical experimentation.

He was widely known as an excellent executive and an acknowledged master of quantity production—and quantity production was what the United States was expected to realize in the manufacture of aircraft. Another special qualification that peculiarly fitted Colonel Deeds for this work was that he had had a very exceptional experience in the developing of new highly technical apparatus and thereafter putting it successfully into quantity production, and it was well understood that the work of producing aircraft in this country would especially demand such qualifications. Europe had not succeeded in realizing mass production by machine methods but it was hoped that America, the acknowledged home of such methods and of standardization and machine tools, would be able to do what the old world had failed to do. Indeed, it was well understood among American industrialists and mechanical engineers that if we succeeded at all in attaining volume in aircraft production it would have to be by our characteristic methods of manufacture.

Colonel Deeds, as chief of the Equipment Division of the Signal Corps, summoned to his assistance the following men of affairs, believing that as his job was in its simple outlines a big manufacturing job, men who had done big things in the business world were the ones to fill the positions.

Sidney D. Waldon, later Colonel, active in the Signal Corps aviation section since November, 1916, formerly vice-president and general manager of the Packard Motor Car Company, afterward associated with the Cadillac Motor Car Company, and later acting in an independent consulting capacity as an automobile engineer and executive, was made assistant chief.

R. L. Montgomery, later Colonel, a banker of experience in Philadelphia and New York, was made chief of finance.

Melville W. Thompson, later Lieutenant Colonel, an expert accountant and valuator, of New York City, was appointed assistant chief of finance.

George W. Mixter, later Lieutenant Colonel, vice-president and manager of manufacture of Deere & Company, a manufacturer of broad experience, who was placed in charge of all inspection.

J. G. Vincent, later Lieutenant Colonel, vice-president Packard Motor Car Company, chief of engine design.

Harry L. Shepler, later Major, production manager of the Willys-Overland Company, chief of 'plane production.

Leonard S. Horner, later Lieutenant Colonel, general manager of the Acme Wire Company, of New Haven, chief of production of instruments and ordnance. Later he became the efficient executive officer of the Bureau of Aircraft Production.

W. H. H. Hutton, Jr., later Colonel, formerly associated with the Timken Company.

Lieutenant Harold H. Emmons, U. S. N. R. F., in civil life an attorney and manufacturer of Detroit, as chief of engine production, "loaned" to the army by the navy.

Each of these heads of sections chose his own sub-executive from among the business men and manufacturers of his acquaintance and confidence, thus creating, as well as could be done in so short a time, the counterpart of the executive organization of a great manufacturing business in which the members are bound together in an efficient whole by mutual esteem, personal acquaintance, confidence, and even personal friendship.

## CHAPTER V

### SEEKING GUIDANCE

If the men who were groping in the dark to find some solid foundations on which to plan and build in the early days of the war were frank to confess their lack of knowledge of aeronautics and aircraft, the country at large was full of well-meaning men who knew precisely what should be done and how it should be done. Inventors, dreamers, aeronautical enthusiasts, business men without expert knowledge, promoters without capital, manufacturers without factories, and plain patriots who wanted to help, descended in droves on the impotent Aircraft Production Board and upon the Signal Corps. The height of manufacturing absurdity was reached by a thrifty patriot who offered to dispose of a perfectly good clam-shell dredging outfit as the nucleus of a plant to make Nieuport pursuit 'planes. These self-constituted advisors consumed hours and days of time of many officials and afterward elected themselves all around critics and censors of all aircraft matters. The whole air organization was like a town meeting dealing with an abstruse problem in municipal finances. Everybody was keen and eager and willing to work but nobody precisely knew what to do. There were many ideas, many suggestions, much advice and few plans. It could not be otherwise. Upon a small body of men inexperienced in this particular field was thrown the overwhelming responsibility of doing in an impossibly short time far more than had been done by the best technicians and the most experienced makers of aircraft in other countries in a number of years. Yet there must be action and so the men in charge began striking out in the dark to find something solid and definite. The first thing they did was to try to outline the task after the Army and Navy Technical Board had finally decided on a program calling for the production of 22,500 machines, and their quota of spare parts, training and service. This is what confronted them:

First: The manufacture of that many machines without any definite knowledge as to what the different types should be and without any real information as to what was needed.

Second: The establishment of a comprehensive system of training, training schools, technical instruction and training fields.

Third: The expansion of a peace-time organization of less than 1500 persons into a war-time organization of more than 150,000.

Fourth: The enlargement of the aircraft manufacturing capacity of the country about three hundred times.

Fifth: The creation of a large engineering and technical force with but a ridiculously inadequate nucleus with which to start.

Sixth: The ascertaining of the materials needed, arrangements for their production, and the creation of many new industries to supply the equipment of the 'planes—all the way from dope for the wing-coverings to machine guns.

The outlining of the problem only served to remind how helpless the country was with respect to the knowledge and experience needed to perform each part of it.

Naturally, the first thought was to appeal to the Allies for advice and counsel. So, immediately after the declaration of war, General Squier, through the embassies, cabled to Europe asking that aeronautical experts and aviation instructors be sent to America. Next American mechanics were sent abroad to learn foreign practice in manu-

facture. Canada, as the nearest Ally, was appealed to for advice and example and responded promptly. Then it was decided to send a commission abroad to learn from the Allies what we might and should do, for not only were we in military aviation as little children compared to them, but they held from the first the idea that the American aviation effort should not be a perfect whole but should be considered as a part of the Allied aeronautical unit.

It is important to an understanding of what the United States later did or did not, to grasp firmly the fact that we were looked upon and so considered ourselves from the start, as the complement of the Allies. This was the central idea and whether it was sound or erroneous is now immaterial. The point is that our aircraft managers must be judged by what they did in accordance with a general scheme that they could not conceivably have rejected even if it did not seem to them, as well as to our Allies, to be the perfectly evident course. In general the Allies were to tell us what to do in order to fill out the common program looking to control of the air. Thus it was that the French determined the scale of our effort, and the French and British together its general nature, and French, British, and Italians acted as our

instructors. It is true, that as our aircraft managers began to get their bearings, they departed somewhat from their instructions in their manner of realizing the purpose, but throughout they steadfastly sought to supply through the American aviation effort what our more experienced friends across the water judged we should. In detail this counsel from abroad was often conflicting and consequently confusing. While many and competent experts soon came across the ocean, it became evident that to get a clearer understanding of what was required of us and also a more complete knowledge of the state of aeronautical development in Europe, as well as a more authoritative understanding of the situation, it would be necessary for us to send representatives abroad to get in touch with foreign sources of policy and practice and also with our own military commanders.

The Bolling Commission, as it was known, was accordingly sent abroad about the middle of June, 1917. It was headed by Col. R. C. Bolling, who was later to lose his life heroically in a revolver battle with German officers after having unwittingly entered the German lines, during the great German offensive of March and April, 1918. The army members were Captain Clarke (later Colonel), and his assistant, Edgar S. Gorrell, after-

ward Colonel, both being aeronautical engineers of the then existing regular aviation organization; Commander Westervelt and Lieutenant Childs of the navy; and two civilian members, viz., Howard Marmon, engineer of the Nordyke-Marmon Company of Indianapolis and an acknowledged expert in the design and production of motors, and Herbert Hughes, an accomplished engineer of the Packard Company.

In the meantime the work of locating aviation fields, expanding the service personnel and creating the training organization were proceeding rapidly, for these were tasks that were quickly comprehended in their outlines, rendered difficult though they were by lack of trained aviators, instructors, mechanics, and officers. The development and expansion of these branches of the great work constitute a vast subject in themselves and will herein be considered in only a cursory manner, the proper purpose of this book being an account and interpretation of aircraft production in America during the war.

## CHAPTER VI

### TRAINING 'PLANES AND ENGINES

THE inevitable confusion and uncertainty that existed in the early stages of the aircraft effort were quite promptly dissipated in regard to training 'planes and engines. It was obvious that they must be had before the combat equipment, and in large numbers at an early date. As soon as the size of the active air service was determined, the approximate requirements for training became easily calculable. Moreover, suitable 'planes and engines for training purposes, at least in the earlier stages, were already being made in this country. The problem did involve some elements of choice but mostly it was a problem of securing quantity production of existing types.

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The Willys-Morrow plant at Elmira, N. Y., was called on for 5000 of the OX5 engines, the

Hall-Scott Company for 1250 of its A7A engines, and the Nordyke-Marmon Company for 1000 of the same, and orders for the corresponding number of 'planes and spares were placed with various manufacturers as follows: Curtiss Aeroplane and Motor Corporation, Buffalo, N. Y., Engle Aircraft Company, Niles; Fowler Aircraft Company, San Francisco; Springfield Aircraft Company, Springfield, Mass., and St. Louis Car Company, St. Louis, Curtiss JN 'planes; Rubay & Company, Cleveland; Sturtevant Company, Boston; Remington Aircraft Company, Los Angeles, JN spares; Standard Aerocraft Company, Plainfield, N. J. (afterwards the Standard Aircraft Corporation of Elizabeth, N. J.); Dayton-Wright Company, Dayton, Ohio; Fisher Body Corporation, Detroit; Glenn-Martin Company, Los Angeles, Standard SJI 'planes.

Had it not been for the difficulty presented by the lack of complete working drawings, other large manufacturing companies that had not hitherto made aircraft might have been asked to assist, but in the circumstances it was considered wise to give contracts to a limited number of companies that had some knowledge, experience, or understanding of the work in hand. The contracts for spare parts were given to companies which it was hoped would later develop plants capable of making entire machines. This indeed was the general policy of bringing American manufacturers of other experience into the aircraft work; that is, they were to be started on parts and later and gradually prepare themselves for complete production of training 'planes. Those who did well on training 'planes would be graduated to the manufacture of service 'planes. This policy proved very successful, as later developments showed.

The difficulty caused by lack of complete drawings in the case of the Curtiss and Standard 'planes serves to call attention to the fact that American manufacturers, being accustomed to absolutely standardized production, are unable speedily to adapt themselves and their methods to the manufacture of any new article unless they are provided with drawings that are complete in the minutest detail. The European manufacturer, not being so completely wedded to standardization and machine production, can begin his comparatively slower production sooner after taking up a new thing. This elemental difference between American and European practice was the occasion of a world of delay in the quantity reproduction of European designs of engines and 'planes in this country, and constituted one of the arguments for the adoption of the Liberty motor instead of some

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While there has been much criticism of the Standard training 'plane equipped with the Hall-Scott engine and it was at a later period abandoned by the Air Service when it had reached such a stage of sufficiency of equipment that it could be hypercritical of what was delivered to it by the production department, the record of casualties in American training fields does not indicate that its choice as an emergency measure was not wise. Neither the 'plane nor the engine was considered perfect, but it was known that they would meet the purpose—and they did.

The advanced training program called for the use of a rotary engine which would train the student for work in the small, swift pursuit 'planes and for a fixed-cylinder type of engine that would familiarize him with the use of machines of greater speed and power. The 100-H. P. Gnome rotary was being made in small quantities by the General Vehicle Company, but neither the Gnome 150-H. P. rotary nor the Le Rhone 80 H. P. was available, yet the recommendations from Europe were for the production of 5000 of the 150-H. P. Gnome and 2500 of the 80-H. P. Le Rhone. As so many Gnomes were entirely beyond the capacity of the General Vehicle Company an effort was made to get the General Motors Company to coöperate with the General Vehicle Company and take the burden of production with its many and large plants, having the advantage of the General Vehicle experience. Before this arrangement was consummated the word came from France to abandon the 150-H. P. Gnome.

Meanwhile, the Union Switch and Signal Company, of Swissvale, Pa., a Westinghouse subsidiary, was persuaded to take up the task of making 2500 of the 80-H. P. Le Rhone. "Persuaded" is the word, for this company, like most of the other great American manufacturing companies, recognized fully the numerous and baffling difficulties that were certain to be encountered in producing a machine of European design by American manufacturing methods. The company's reluctance was well justified by the event, for even though a complete engine was received from France in September, the drawings that accompanied it did not agree with it in all respects, either in design or dimensions, nor was it accompanied by complete or accurate drawings, and precise specifications and metallurgical instructions. These may seem trivial matters, but it took months to revise and check the drawings and then still more time to prepare the detail drawings necessary for standardized production. Owing to the inaccuracy of the metallurgical instructions every part of the engine had to be chemically analyzed, in order to ascertain its composition. Finally it was necessary to bring from France M. Georges Guillot, the engineer of the Gnome-Le Rhone factories. So it was not until May, 1918, that the Union Switch and Signal Company, one of the most competent manufacturing corporations in America, with all of its own great engineering ability and the assistance extended to it by M. Guillot and the engineers of the Signal Corps, was able to begin production. Associated with this Le Rhone achievement were Lieut. Frank M. Hawley, government engineer in charge, and Alex. K. Hamilton, Pittsburgh, district manager of engine production, and his assistant, Frank C. Moore. It should be remembered that this Le Rhone engine is a small affair of only 80 H. P. That so much difficulty was encountered in getting it into quantity production of a comparatively small total number is a hint of the vastly greater and more widespread involvements of time and manufacturing plants that would have followed the reproduction in America of a high-powered foreign engine by the tens of thousands.

This is an appropriate place again to direct attention to the fact that to take up an European design even of the most accepted and proved type and undertake its quantity production in America is by no means the simple thing it seems when suggested. It is far more than a parrot-like imitation. Because America does not produce by hand and has not the kind of mechanics that thus build machines, any European machine that is brought here for manufacture must go through a considerable period of adaptation to American methods, whether these be merely multitudinous and tedious drawings of the parts and the tools, jigs, and fixtures to make them, and the making of the tools, or of actual changes in the detail of design to fit American shop practice. The fact is that ordinarily a new American design, can be put into quantity production in American shops sooner than an imported design, even though it be accompanied by a completed machine. The machine and the human do not manufacture in the same way. Had we but begun to naturalize the standard European types of engines and 'planes in this country a year before the war, even if we had not essayed quantity production, there would have been all the difference in the world, not only in the prompt and voluminous production of primary and secondary training engines, but even in the foreign combat engines and 'planes. That this was not done is not the fault but rather the grave misfortune of the men who were called upon to do everything years too late.

The story is the same with the Hispano-Suiza engine which was chosen as the power plant of the advanced training machines, with the Curtiss JN 'plane. The Wright-Martin Aircraft Corporation had acquired the American rights for this motor in the latter part of 1915 and had begun work on its Americanization in January, 1916. Yet it was February, 1917, thirteen months later, after infinite efforts and the expenditure of millions of dollars, that the first machine-tool production machine came through. The Wright-Martin Company was originally working on a contract from the French Government, but at an early date a large American order was placed with it for 150-H. P. Hispano-Suizas for advanced training and even, as was thought at first, for combat purposes, but the 150 H. P. soon fell behind the procession of military aeronautical advance for that purpose.

Including 451 Lawrence engines, the manufacturers of engines for training purposes had delivered 16,134 up to the signing of the armistice (this number was considerably increased before production ceased), of which about 500 went to the navy directly, about 300 to the A. E. F., and the rest were incorporated into training 'planes at home, the distribution by types being OX, 8458; Hispano-Suiza, 3549; A7A, 2250; Gnome, 280; Le Rhone, 1298; Lawrence, 451.

These experiences with the Americanization of foreign engines showed that by the time European types could be brought to mass production here they were far behind European development. It requires in Europe at least one year to design and develop a new engine to the point of determining its value. Another year is required to attain mass production in this country. So the original design is two years old when production begins here. Thus the 100-H. P. Gnome and the 150-H. P. Hispano were both obsolete for service use by the time our manufacturers could make deliveries.

In getting a proper perspective on the aircraft production effort care must be taken to give due consideration to the production of training engines and 'planes. The public attention was naturally concentrated on combat 'planes and the engines that went with them, notably the Liberty motor. The public was paying for results and was disposed to overlook the laborious toil, the many manufacturing difficulties and the time required for preparation for air power. The fact that while combat engines and 'planes were being designed and produced, a great manufacturing feat was performed with respect to the training apparatus and equipment is and was entirely overlooked. The Liberty motor, the De Haviland 4, the great bombers, the big seaplanes—all these were spectacular and appealed to the public imagination, just as soldiers at the front in France interested the public more than soldiers tediously drilling in camps at home. The humble training 'planes and motors without which the fighting airplanes would never be utilizable were almost forgotten. While the public was "fed up" with accounts of delays and disappointments in the production of the fighting aircraft it was not informed that the manufacturers and the aviation division of the Signal Corps were making a marvelous record in the production of training apparatus. The production began with 9 'planes in June, 1917, and gradually increased until the maximum was reached in January, 1918, with an output of 729. Thereafter, training requirements being well in hand, the output slowly decreased until it fell to 162 a month just after the armistice was signed. Roughly, then, it may be said that within the first year of the war, notwithstanding the confusion that inevitably existed at first and that led to some loss of time, the aircraft managers found ways to provide the training 'planes and engines, not to mention the thousand and one other accessories of training, for an aviation organization of more than one hundred and ninety thousand men of whom about one-tenth were student aviators.

## CHAPTER VII

### THE BOLLING COMMISSION AND FOREIGN ASSISTANCE

THE Bolling Commission, whose composition has been given elsewhere, was sent abroad to secure information as to what the Allies expected of us, how we should proceed to carry out that advice, to confer with General Pershing and his staff in regard to their aviation requirements, and generally determine the objectives of the American aviation effort.

The members of this commission soon came to a clear understanding of the absolute impossibility of any extensive American contribution to the numbers of service machines at the front before the summer of 1918. When this situation was explained by them to General Pershing, it was decided to procure as many machines from foreign manufacturers as possible both for service and for advanced training of our aviators in France, it having been decided that advanced training under the circumstances could best be provided in France.

The French manufacturers were very confident that besides supplying all of the needs of their own army they could within a year provide the American air service with sixty-five hundred 'planes and about eighty-five hundred service engines, besides about a thousand training 'planes with their engines, provided that they could be supplied with materials from the United States. This was most encouraging information, for it seemed to promise fighting machines on a par with those used by the Allies much sooner than anything like such a number could be produced in the United States, where the service machine industry was non-existent. Such a course pointed to the quickest possible route to American aviation representation at the front, in large measure relieved American manufacturers from the necessity of making the pursuit machines, and left them free to concentrate on the high-powered engines and larger types of 'planes, for reconnoissance, night and day bombing, etc., which was what the Allies seemed to expect of us. Moreover, as the fashions in pursuit 'planes changed almost daily, it was felt that it was an ideal arrangement to have them made almost in sight of the battle line and in immediate communication with its changing requirements. The European system of manufacture was, too, especially adapted to meeting changes during the course of construction.

Nor did it appear at the time that this was imposing an unwelcome and onerous burden on the French. It appeared, on the contrary, that the capacity of their factories had advanced beyond their own requirements and that it was a piece of fine inter-Allied economy to use their facilities for the common end. Here, however, as at home there was to be a disappointment in performance. The more experienced French manufacturers were as overoptimistic as to their ability as our inexperienced manufacturers and managers were. According to the schedule all the machines were to be completed by June, 1918, and the rate of production was to go as high as eight hundred in January; eleven hundred in February; fourteen hundred in March, and thence decline. About 6000 airplanes were ordered from French manufacturers, as follows: Nieuport training, 725; Spad training, 150; Spad service, 2000; Breguet service, 1500; New Spad or Nieuport service, 1500. Instead of the 6000 only 1299 airplanes were actually delivered up to May 23, 1918, of which 1180 were the various Nieuport types; in addition 532 machines of various types were obtained from French sources, so that the A. E. F. at the end of a year had only 1832 service and training 'planes, instead of the 6000 promised. By the time the armistice was signed the total number of foreign made machines, including some English and Italian, had grown to 5071.

The failure of the French manufacturers was due partly to an impossible schedule, partly to our failure to deliver all of the material promptly, but especially to the increased demands of the French aviation service, which even led to the diversion of much of the American machinery and material in the manufacture of machines for the French army. On the whole, though, the contract to deliver materials was very well carried out and constitutes a performance that is greatly to the credit of the aviation executives, considering that it was undertaken simultaneously with the throes of the great production effort in America. Some ten million dollars' worth of an almost unlimited number of articles or commodities were collected and shipped through the agency of J. G. White & Company, of New York. The shipments included five million feet of lumber, one thousand tons of machine tools, fifteen thousand tons of

**French-Made American Spad at the Front**

**"The Flying Fish," a Decorated Nieuport at the Front**

U. S. Air Service Photo

materials and supplies such as steel, brass, copper, and aluminum tubing; steel, copper, lead, and aluminum sheets; bar steel, tool steel, structural steel, ball-bearings, crank shafts, turn-buckles, radiator tubes, wire cable, bolts, screws, nails, fiber, cloth, felt, and rubber. Moreover, 19,000 mechanics were sent to France and England and fabricated parts for 9000 engines and 1800 'planes, besides 150,000,000 feet of airplane lumber, and more than 30,000 tons of wood chemicals.[1]

[1] The following summary of aviation aid furnished by the United States to the Allies was laid before the House of Representatives Committee on Naval Affairs (aviation hearings, second session, Sixty-sixth Congress, p. 1525):

"*Aid Furnished Allies by America.*—Under an agreement with France, made in the fall of 1917, France was to furnish certain airplanes and engines to the American army. America was to furnish certain material and fabricated parts to France. However, it was distinctly agreed that France's delivery of planes and engines was not dependent upon American delivery of raw materials. This agreement meant the delivery of 23,000 tons of material, and of this amount 46 per cent. had been delivered by December 31, 1917, 84 per cent. by March 31, 1918, and 96 per cent. by June 30, 1918. Included in these deliveries were fabricated parts sufficient for 9000 engines and 1800 planes. In addition to this the American army delivered to the Allies 150,000,000 feet of airplane lumber and over 30,000 tons of wood chemicals. Prior to the armistice we furnished 1422 Liberty engines to our Allies. We furnished to the British 15,000 mechanics and over 4000 to France. In fact, the Allied air programs of the various countries depended absolutely upon the help of America. The aid of the American army enabled the Allies to produce the materials they furnished us and placed them in far better position to supply both their needs and ours than they would have been to supply their own needs alone without our help."

It was not until December, 1917, that the French indicated that they would have to default on their contract. Though America had not provided all the materials on schedule time, the chief reason was that when M. Loucheur became the French Minister of Munitions he decided to double the French aviation production program and notified the A. E. F. that it could not rely upon the French contractors carrying out their contracts. This change in the French program, rather than lack of materials, was the true reason of the non-realization of the general scheme of having the Allies fully supply our service and overseas training 'planes until the middle of 1918. In fact, the contracts provided that in the event of American materials not arriving as per schedule the French would draw on their own supplies and replace them later from the American stocks. The practical canceling of the French contracts was serious from the American point of view, but from the standpoint of Allied aircraft success considered as a unified whole, which was the governing principle of American coöperation, it was not such. The American individual aerial effort during the war was thereby circumscribed, but the French effort was correspondingly extended and intensified.

It will be well here to emphasize the fact that the underlying conception of the American participation in the aerial branch of the war was that it was to be a part of a unified whole. We were called upon to do what we could best do to contribute to the success of the common cause, and the Allies were to do likewise. Thus the American program was never a symmetrical whole and had to be altered from time to time to suit the changing conditions of the common effort, and was even more important as a common source of mechanics, materials, and parts than as a contributor of a separate military face.

One of the things required of the Bolling Commission was that besides investigating European types of engines and 'planes with a view to advising regarding their manufacture in this country it should procure and send samples of different engines and 'planes as soon as possible, so that our engineers would have models from which to make drawings and otherwise prepare for production. This seemed a thing as simple and as easily to be performed as it was necessary. But, whatever the cause, these samples, even when procurable, were very long in reaching America. This simple failure serves to illustrate the difficulties in the way of putting foreign machines into production in America. Six types of engines and six of 'planes, the number of samples of each varying from two to eight, were asked for from France; three types of 'planes and engines from Italy, and ten from England, ranging from two to sixteen in number of samples. Also four of the Lorraine-Dietrich engines were requested from France.

The first sample to arrive was a De Haviland 4, which reached Washington, July 27, 1917, without engine, ordnance, or any of the other accessories which go to make up a fighting airplane. The last of the samples did not arrive until the following winter. The fact that we had been at war four months before it was possible to get the first sample of a combat machine to America throws a great light on the feeble beginnings with which the designers and makers of aircraft had to start.

It seemed a simple thing to say, "Reproduce approved foreign designs in America," and an obvious thing to do. But it was maddening to find that the samples were incomplete and drawings insufficient. If at the start complete drawings of European engines and 'planes that it was desired to put into production in this country could have been secured, the output of service 'planes, at least, would have been realized on a large scale several months before it was. An American manufacturer will undertake almost any feat of production if he can have the necessary drawings and blue prints complete at the start. They are the soul of machine-method quantity production.

If someone had had the foresight to study European models of fighting aircraft and prepare from them merely one complete set of drawings in the year preceding our entry into the war, we could have produced chasse machines for service at the front sooner than the aviators could have been trained to use them. We would not have had to rely on the French for an insufficient number of them, and at the same time our development and production of high-powered engines and large air-planes could have gone on unimpeded. In the same way the production of the larger 'planes would have been greatly expedited. For while, in the end, we came to rely chiefly on the Liberty motor, which was not conceived until the latter part of May, 1918, the lack of accurate drawings and other data regarding the De Haviland as well as the big night-bombing 'planes greatly delayed their production.

A scrap of paper is a little thing. The war in Europe began with the tearing up of one. A few scraps with drawings on them filed in a few pigeon-holes in Washington might have ended the war six months sooner.

Without going into detail as to the recommendations of the Bolling Commission, it may be said that its recommendations and those of General Pershing tended toward the idea that the business of the United States was to produce aerial engine power in great volume and in large units, both for itself and for the Allies, and corresponding types of 'planes. It is important to grasp this fact fully. It explains why even on the last day of the war there was not a single-seater fighter of American make at the front. There were none there because they were not on the American program.

As early as December 14, 1917, General Pershing cabled: "United States should leave production single-place fighter to Europe." Prior to that elaborate preparations had been made to manufacture the Spad in this country, but on receipt of this cablegram the order was canceled. Even before this time the trend in Europe seemed to be away from the single-seater and toward the two-seater, and it was the opinion in both Paris and London in January, 1918, that no more of the former would be ordered after July by either France or England. Europe felt amply able to supply itself and us with whatever single-seaters might be needed, and, owing to proximity to the front, with a quicker appreciation of the lessons of experience, better than we could possibly do it. So, we repeat, we made no single-seater fighters because we purposely left them off our program, on the advice of foreign authorities and our own representatives abroad. Our general plan, then, was:

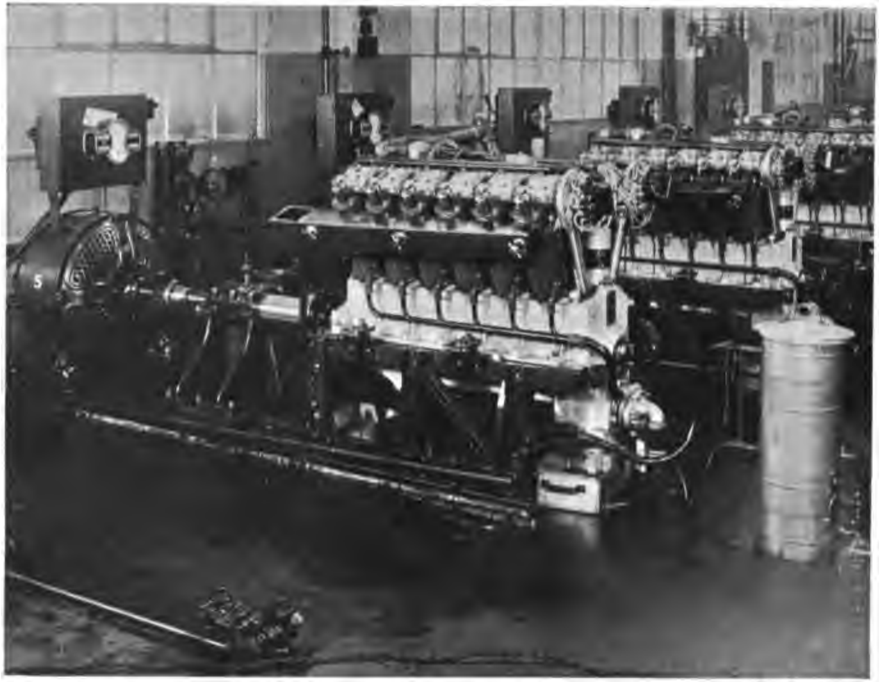
First: Early attainment of quantity production of two-place machines of the observation type, such as the De Haviland 4 and its modifications.

Second: Follow with quantity production of two-place machines of the fighting type, such as the Bristol.

Third: Come on as rapidly as possible with the great bombing machines such as the Handley-Page and the Caproni.

Owing to its great speed, when equipped with the Liberty motor and its powerful armament, the De Haviland 4 was really a three-purpose 'plane, viz., observation, bombing, and defensive fighting.

"The decision not to proceed with the single-seater type of fighting machine (*i. e.* the Spad)," says an official statement, recently issued, "was undoubtedly based on the conclusion reached in the fall of 1917 that the era of independent fighting was almost gone. Flying and fighting in formation offered marked advantages. There are no blind spots in a formation of fighters, each equipped to fight to the front, to the rear, and to the sides." If formation fighting were the coming tactics of the air it appeared that there was little use for the single-seater. Its chief value is its superior maneuverability but formations are essentially unwieldy. They were to be protected by their armament rather than by manipulation. As a matter of fact further development of squadron flying brought the single-seater into greater favor; in the meantime we had definitely eliminated it from our program. But in so fickle a matter, it might have turned out that we had made single-seaters only to find them useless. As it was we didn't make them only to find them desirable. But on this point it should be said that considering the facilities of Europe for providing single-seaters it was better that we should have neglected them than the various types of two-seaters. We followed the best advice we could get and the best judgment of General Pershing and the Bolling Commission, though it transpired that just as we abandoned the chasse machines the front began to appreciate them more than ever.




Liberty Motors under the Dynamometer Test

# CHAPTER VIII

## ORIGIN OF THE LIBERTY ENGINE

THE demand from all quarters of Allied air effort was for an engine of high power. When we entered the war Europe was rapidly growing away from the smaller engines. Practically every proved and accepted engine then in service was acknowledged to be behind the times. European inventors and manufacturers were working on engines of much greater horse power than had hitherto been used. So far as taking a proved European engine and putting it into production in this country was concerned, it was certain that by the time production had been attained, it would be more or less antiquated for those uses calling for motors of large power. There was nothing to do but to take the risk in part, for some kind of a motor in large numbers was better than none. That being the case, the obvious thing to do was to stimulate the production of those European types that had already been put into production in this country and to limit the new effort to such a machine as the Le Rhone which was likely to be of some utility either for advanced training or for pursuit service 'planes. So, our aircraft executives did promptly take up the Hispano-Suiza 150 H. P. which the Wright-Martin Aircraft Corporation—formerly the Simplex Motor Company—had finally put into successful production and the 100-H. P. Gnome which was in minor production by the General Vehicle Company, and proceed from the beginning with the Le Rhone. Even with this conservative decision, it was soon found that the little Gnome would have to be abandoned and that the Hispano-Suiza would have to be remodeled to give greater power.

As to the problem of the demand for a motor of far greater power than had yet been successfully developed, the first suggestion was that we take up one or more of the new foreign engines which were then being developed but were not in production, such as the Bugatti and the Lorraine-Dietrich. There was also the Rolls-Royce, which was then the most highly powered engine in use in Europe. It seemed that the proper course to take was to join in the development of the untried foreign engines and begin immediately the production of the Rolls-Royce in this country. These matters, however, had to be left in the early months very largely to the determination of the Bolling Commission. In other words it was impossible to arrive promptly at a judicious decision, and it was felt that we must not make the mistake the Allies had made of littering their training fields and the battle front with innumerable different designs and types of 'planes and engines. The French and English were experimenting with or producing eighty-three different types of engines and 'planes—none of them fully standardized—with chaos in factories, machine shops, repairs, and replacements. The Germans had concentrated on a few types of engines and 'planes and their general efficiency in the air was largely due to this fact. This was one of the lessons of the war up to that time. It would have been folly for us not to have acted in accordance with it.

Within six weeks after we entered the war we had decided on these three things with respect to engines:

First: We would make use of the accepted American engines, which were adapted to training purposes.

Second: We would put into production three types of foreign engines, which promised possibilities of early realization of quantity production

—engines that seemed likely to be of some service in the program, regardless of the daily growing demand for engines of greater power.

Third: We would proceed as promptly as possible with the selection of one or more types of the then developing high-power foreign engines. Because of the lack of information an early decision was here impossible, except in the case of the Rolls-Royce, and unexpected difficulties of another nature arose in connection with it, difficulties that will be explained in another chapter.

The impossibility of an early decision in this vital matter led to one of the grand decisions of the war—a decision whose boldness was of the kind that stakes all on a single resolve. Mr. E. A. Deeds, afterwards Colonel, was in May, 1917, simply a member of the impotent Aircraft Production Board, but as such he was involved in all the deliberations and determinations of the hour, as well as all its bewilderments and futilities. As a great manufacturer and a successful executive, used to prompt decisions and swift performance, as one thoroughly familiar with the great productive capacity and mechanical engineering ability of America, and especially of the automobile industry, it was maddening to him to think of the gulf between potentiality and realization.

Must this resourceful and industrially powerful America wait for months before it could choose the great motor or motors of the war? Must the great potential capacity of the nation for the production of aerial power remain inert while the coming engine was chosen from the European candidates for the honor? The tendency had been all toward such a paralyzing delay. Americans were infants in aircraft engineering and manufacturing, as such, and were properly humble and desirous of following foreign precepts and instruction. But as he chafed at the delay it was borne in on Colonel Deeds, who was coming more and more to be looked upon as the evolved leader of the inchoate aircraft organization, that after all an aircraft motor was nothing more than a highly refined and specialized internal combustion motor. We had not undertaken to make the highest types in this country because there had been in them no business appeal to the great manufacturers of motors. An aerial motor of extraordinary power was a new thing, then on the lap of the gods. Our motor engineers were familiar with all the principles of design and they knew the essential requirements of materials. Why, since a new thing was demanded by the progress of aerial warfare, should not America bring it forth? Months might thus be saved in choosing an engine and months more in achieving quantity production of it. While exploring Europe for the coming engine why not explore America as well, and take the great chance of beginning to do something great?

The momentous decision was reached about the 25th of May, 1917. At any rate it was on that day, less than three weeks from his entrance into the aircraft council, that Mr. Deeds communicated to Mr. Waldon, with whom he was most intimately associated, his decision to undertake to produce a new, high-powered, unit-system, standardized American motor, which according to the number of cylinders would give, in the different steps of power required for different purposes of aerial use, the maximum of power combined with the minimum of weight.

Mr. Waldon received the idea enthusiastically, for he had been thinking along much the same lines as Mr. Deeds. In his mind the idea was reinforced by his experience in connection with official aviation matters since the preceding November.

Each passing month had reminded him that while the adoption of European models in part or altogether was inevitable, the gap between the time of adoption and the time of attainment of quantity production would be intolerably long and tedious. He had been greatly impressed by the fact that it had taken the Wright-Martin Company with a capable engineering organization, with numerous models, the completest drawings and specifications, according to European ideas, and the assistance of a numerous staff of French engineers and mechanics thoroughly familiar with practical production in the home factories of the Hispano-Suiza, thirteen months and the loss of millions of dollars to get into production. He was also familiar with the somewhat similar experience of the General Vehicle Company in transplanting the Gnome.

American manufacturing methods are basically the methods of machine-tool production. European methods are basically the methods of the expert and intelligent mechanic and machinist. The European has not our perfection of machines; we have not his perfection of the mechanic—at least not in such numbers as to give quantity production. You can introduce a mechanic or a group of mechanics to a machine, provide the materials and hand-tools, and tell them to make others like it. In a few days, or a few weeks, they will be in production—on a small scale. You cannot introduce a model of a machine to a machine-tool or a group of them and tell them to begin forthwith to reproduce their fellow. In fact you must first make the machine-tool. And then it is only mechanical—not human. American manufacture is the mechanical making of parts by the thousands—each precisely like its predecessor—and then the assembling of those parts into the machine—each exactly, too, like its predecessor. Nothing can be left to chance or fitting or adaptation by the workmen. The workmen are manipulators of machines—not mechanics in the European sense. Before production in quantities in America, therefore, must go a tedious period of preparation—the making of thousands of drawings of the parts, the infinitely careful preparation of the dies, then the thousands of tools, jigs, fixtures, etc., and also the machines that are to apply these tools in the making of the parts. All this process has to be gone through with an American design as well as an adopted foreign design, but in the case of the American design the engineering and the drawings are from the start adapted to American manufacturing methods. In the case of the foreign machine the drawings are not only inadequate for machine reproduction but parts are not designed with a view to much adaptation. It is impossible quantitatively to reproduce a complex foreign machine in this country without changing the shape and design of its parts to some extent.

So, both Messrs. Deeds and Waldon perceived a distinct advantage in the creation of an American type. In the stage of design and experimentation, moreover, while much might be gained, nothing was to be lost except the trivial cost of the development work; the survey of European engines proceeding undeterred. The critical decision would come when the moment arrived to accept the proposed American motor and order it into expensive and extensive production.

The decision arrived at by Colonel Deeds clarified the American aviation problem to a very great extent. Its successful realization put us into the aerial side of the war with American-made equipment to the degree which the early termination of the war and the vicissitudes of the realization of the decision permitted.

But for this decision and the vigorous ways in which action followed in those rough-and-ready days before the strait-jacket of military red-tape had encompassed the resourceful and highly initiative civilians who were left to face the problem, there would not have been a single American-made airplane in France when the war ended.

The number of such airplanes in France and in service when the armistice was signed was much larger than commonly realized. Out of the 3227 De Haviland 4's actually delivered by November 11, 1918 (since increased to 4842), according to the official statistics, 1885 had been shipped abroad, 1185 had been received at the French ports, 1025 had been assembled at the American aviation bases in France, 984 had been put into service there, and of these 628 were in service at the front, 457 being daily in commission. American machines arrived in time to be of great assistance in the St. Mihiel salient offensive and still more so in the Argonne fighting. Looking backward now it is possible to assert positively that this would not have been the case had the decision not been made in May, 1917, to develop and manufacture an American designed engine.

Much has been written that tends to show that the American forces in France were not sufficiently supplied with airplanes. Some of this is based on the feeling of the infantrymen and artillerymen that a sufficient force would be one that would always prevent the enemy avions from crossing the lines. In this sense our armies were insufficiently supplied, and so were the French and British armies. Besides, as Gen. Peter A. Traub remarked in telling of the work of the Thirty-fifth Division in the Argonne fighting, "the air is a very large place." Right up to the end of the war, the German air service was, all things considered, about on a par with that of the Allies. There is competent authority, though, for the assertion that from a military organization point of view the supply of aerial forces kept pace with the expansion of the American fighting forces in France. Confessedly, this is a statement that the public will receive with skepticism, but it should be remembered that it does not apply to the subject of territorial bombing operations, but only to the combat equipment of armies. The public looked upon the possibilities of bombing operations against enemy territory as of greater importance than direct aerial military activities. Army men largely took the opposite point of view. If the latter is the correct one the general inference from statements made by our aviation officers is that notwithstanding all delays in production as compared with program, the delivery of the equipment kept pace with the development of our armies at the front. That most of the airplanes were supplied by the French up to the signing of the armistice does not detract from the importance of the fact, for as with artillery and other equipment, the general program counted on the French filling the gap until America could get into production with the machines that were novel to her manufacturers. Thus it appears that notwithstanding the failure of the French to make deliveries according to schedule, they did come as fast as our armies grew. Lieut.-Col. Lewis H. Brereton (Chief of Air Service Operations, U. S. A.), positively states that "the air service organization at the front was at all times abreast of the requirements of the armies at the front." He further says:

"At the cessation of hostilities, we had a total of forty-seven squadrons in active service on the front, eleven of which were equipped with the American 'plane and Liberty motor. The total number of 'planes in our forces on the front at this time was eight hundred and sixty. The total number of Allied 'planes on the Western front has been estimated as from fifty-five hundred to seventy-five hundred. I believe that seven thousand is more nearly correct. Various estimates have placed the German effective strength as between thirty-five hundred and four thousand on the Western front. These figures apparently give us an enormous preponderance of air service over the Western front. Actually, however, conditions were such that we were at all times in an area of active operations opposed by an air service which compared very favorably with ours in strength and efficiency."

## CHAPTER IX

### BIRTH OF THE LIBERTY ENGINE

ONCE the conception of an American standardized motor of power possibilities that would keep it in the field for two or three years or longer was crystallized it won almost immediate favor in the higher aircraft circles. The idea was in accordance with the views of all the foreign aviation missions then in America, at least so far as the phase of standardization and large power was concerned. Even though they strongly favored their own evolving engines of high power they could but see in the proposed new motor one more candidate for the final honors. There was no reason why America should not try to create the desired engine. The new idea promised action, and as the engine is the major factor in aircraft construction, it also promised a solid foundation for the whole future structure of the program. It was as a beacon in the darkness.

Having firmly grasped the idea of an engine which should develop greater power than any other proved engine in the field, the next thing for Mr. Deeds to do was to find the engineers who would sympathetically receive the suggestion and faithfully carry it out along the lines he laid down. These were: (1) that it must be light in proportion to power; (2) that it must embody no theory or device that had not already been proved in existing engines, and (3) was to keep away from all experimentation and be adaptable to quantity production. It was not to be an invention, but the simplest and most powerful composite of the best known practice.

The selection of engineers who were equal to the task was vital. In the first place it was thought that they must be engineers who were not only familiar with aeromotors but also men who were familiar with production processes and requirements. Various men were suggested and discussed and the choice finally fell on J. G. Vincent, chief engineer of the Packard Motor Car Company, and E. J. Hall, of the Hall-Scott Motor Car Company. The choice proved to be an inspiration. Mr. Vincent was already a believer in the idea of a standardized engine with a maximum of interchangeable parts and a power development according to the number of primary units—an engine which might conceivably in the end give us but one basic type for all the fixed-cylinder engines the program might require. He had developed experimentally at the Packard works, during two years of painstaking research and effort, an engine that he thought would about meet such requirements. He was ambitious to have his engine adopted as the American engine, and he was in Washington for that purpose. Mr. Vincent was a highly educated and trained engineer and was as familiar with German and other foreign aviation engine development as any other engineer in America. Taking the German Mercedes as his starting point he had developed powerful automobile racing engines and several aviation motors. He brought to the task the special equipment of the engineer learned in the theory of design and the technique of his profession. He was subjected to the severe test of having the motors he had fathered rejected as too heavy and otherwise unsuited for the purpose in view, and being at the same time required to sit down with another engineer to design a composite machine that would be better than his own and yet would not be exclusively his. He met the test in a whole-souled, patriotic manner.

Mr. Hall was a fitting foil for Mr. Vincent. If the latter was an engineer of thought and theory, the former was one of work and practice. The one was learned in a scientific way, and the other was learned empirically. Mr. Vincent had acquired his knowledge through the eye; Mr. Hall had acquired his through his hands. The former arrived at his objectives by calculation; the latter by feeling his way. If Mr. Vincent was the scholar-engineer, Mr. Hall was the mechanic-engineer. The latter had had more experience in the actual designing and production of aerial engines but the former had had a more extensive engineering association with the best American quantity production processes. Mr. Hall had to submit to the fate of being told that the 12-cylinder engine which he had developed was too heavy for the purpose in view, which was to get a motor of about 225 H. P. and eight cylinders with less than two pounds of weight per unit of H. P. Like Mr. Vincent he took the adverse decision and the new instructions in good part.

Mr. Vincent had arrived in Washington about the time Mr. Deeds had made his great decision and Mr. Hall had just left for San Francisco. A telegram caught him at Cleveland and turned him back. The two men who were to find the way out of the aviation wilderness were brought together in suite 201, Willard Hotel, Washington, on the afternoon of Saturday, May 29, 1917. The objective was explained to them carefully and they were facetiously told that they would be shut up together until they produced what was required of them—and that the first one who reached out for some pet original idea or any untried principle would "have his hand taken off." They were strangers, never having met until the great engineering task of the aerial side of the American effort in the war was laid before them. Mr. Deeds knew that between them they had the peculiar combination to achieve the purpose. Both were in a receptive mood that afternoon, and to lose no time Messrs. Deeds and Waldon went out and got drafting boards and carried them themselves to the room with the twin beds where the two engineers were to live until they had evolved the coming engine. J. M. Schoonmaker, Jr., an engineer known to Mr. Deeds, happened to be encountered on the street by the latter, and although he was on his honeymoon, was drafted from his bride and commandeered as a temporary draftsman. K. M. Zimmerschied, metallurgist of the General Motors Company, was in Washington and was immediately called to assist. The two engineers began at once to compare opinions, exchange views, discuss general principles, and begin making layouts. The first session lasted all the afternoon, all the night, and until 2 o'clock Sunday morning. And, so, tensely the creative work went on for five days. Whatever was required was furnished on the spot. It was regarded as a race against time. At midnight of the first day Dr. Stratton of the Bureau of Standards was brought to the hotel to be asked to provide room for the draftsmen who would elaborate the layouts, which he gladly consented to do. When the decision was communicated to the aviation representatives of the foreign governments then in Washington that the United States was seeking to produce an engine that would be freely given to the Allies they unhesitatingly brought out the confidential drawings and specifications they had of foreign engines, and Messrs. Vincent and Hall had the benefit of all they contained. During these momentous days other engineers came, conferred, offered their suggestions, and departed.

The main decisions on which the two engineers early agreed was that the new engines should be built around 5 x 7 individual steel cylinders, with aluminum piston, forked connecting rods, and a direct-drive propellor. This size of cylinder was adopted because both the Hall-Scott Company and the Curtiss Company had found it the most satisfactory after much experience and because Major Tulasne of the French mission was just then informed that the new Lorraine-Dietrich engine then coming out in France had cylinders of approximately that size.

The end of five days of concentrated effort found the engine designed in the main. After that it was a draftsman and mechanic's job, so far as the first engines were concerned, except that the design was passed in review by eminent motor engineers, who proposed some changes. Copies of the first drawings were sent to such men as H. M. Crane, chief engineer of the Wright-Martin Company, who had wrestled with the American adaptation and production of the Hispano-Suiza Motor; David Fergusson of the Pierce-Arrow Company; D. McCall White of the Cadillac Motor Company, who had been associated with the Napier Company in England, and Fekete of the Hudson Motor Car Company. These men were chosen because of their ability and experience and because they were neither "professorial" theorists nor "mentally dishonest." They thought straight and consistently. They were told to find every possible fault they could and make every possible suggestion that would be in harmony with the general design. As Colonel Deeds well says: "It was important at this time to protect the poor engine from the professor, the theorist, and the would-be engineer. It was an engine based on practice—on what had been done—and it must be kept so." This statement evinced no disrespect for the scientific engineer or the technical man, but an engine that was based on proved practice would have suffered had any new theory been applied to it.

This is really why there was no such doubt about the success of the motor in the minds of those who were early acquainted with its nature, as the public may have felt. It was not only an engineer's engine and an aviator's engine with all engineering ventures left out, but it was also—which was of vital importance—a *producer's engine;* for before the first engines were built, such masters of production as Henry Ford and his associates, Beall and Roberts of the Packard Company, Leland and Lang of the Cadillac, and Chrysler of the Buick were brought into consultation.

There was nothing magical or revolutionary about the Liberty motor. Its essential planning in such a short time was wonderful, but the two able engineers who put it together from the world's best in such a dramatic manner were not originating or making any revolutionary innovations. Secrecy regarding its design was necessary, and secrecy means mystery—and a mystery is apt to be conjectured to be a miracle. It was a marvel but not one of fortuitously successful engineering venture into the unknown. The "insiders" fully understood this. The public and even some of the outside experts did not. Thence arose much well-meant criticism, the burden of which was that our aviation authorities had staked all on a novel motor that it would take months to develop and that might then be a failure, while there were tried and approved engines that could be put into production at once. The fact was that they had not staked all on the Liberty motor, that they were seeking to utilize the high-power foreign engines that were available, that only one of them was in production abroad, and that the foreign engines of lower power that were put into production in this country had to be enlarged later. As will be shown farther on, the demand for increased power was so great that initial production of the Liberty itself had to be shifted from the 8- to the 12-cylinder, and the power of the latter in turn stepped up to keep up with or ahead of the demand—thus delaying production to be certain of meeting the purpose of production.

# CHAPTER X

## MAKING THE FIRST LIBERTY MOTORS

EVEN after the grand decision was made, the two engineers had done their basic work, and the drawings were being made—yes, even after the first sample motors were made and production had been ordered, it was no easy matter to hold to the purpose. Skepticism among the uninformed was almost universal and Colonel Deeds, Colonel Waldon, and their associates were implored to abandon their course before it was too late. Criticism soon became rampant, and the more so, as with each passing day the confidence of the responsible men in the Liberty motor increased, with a consequent tendency to centralize effort on it to the exclusion in some degree of the other possible motors. Time was the great desideratum, action was imperative. So, the first decision to create a new motor was followed by the audacious one—a really critical one—to proceed with production immediately. In fact the one blended rapidly into the other. It is not too much to say that this was one of the great decisions of the war. It was courageous beyond belief. It revealed the fact that aircraft production had found a leader. Its luster is in no wise dimmed by the subsequent delays in realizing production in large quantities as early as promised.

Similar and other delays would have attached to any motor that might have been taken up at that time. Colonel Deeds and his associates and the manufacturers may perhaps be justly blamed for their aspiring programs, but they were striving to meet the requirements of a volume of production that was determined by the size of the aviation arm, with the purpose of putting that arm into the field full-fledged in the spring and summer of 1918. It was put up to them to do the impossible, they firmly believed that they could do it, they said they could do it. It was a day when men, hot with the urge of patriotism, of self-sacrifice, had deleted the word "impossible" from their dictionaries. If the general staff wanted something in six months, it declared that it must be done in four, and the aircraft managers persuaded the manufacturers that it could be done in three, and the latter promised that it would be done in two. These underestimates of the time required to do the work led to disappointments but it can be said for them that they had the effect of arousing determination and stimulating effort all along the line. The mark set was unfortunately impossible of attainment but the actual achievement was made extraordinarily remarkable because of the superhuman requirements.

Even as the drawings were being snatched from the hands of the feverishly toiling draftsmen and despatched to the tool room of the Packard Motor Company, verbal orders were given to the manufacturers to get ready for production. In those days the business men who had come into the organization had not learned the devious and time-killing routines of government methods. They acted for the country as they were accustomed to act for themselves. They decided swiftly and telephoned, telegraphed, and talked orders. The first small motor had not arrived in Washington before there was the lively activity of great preparation in the plants that were to undertake the work, and one colossal plant—that of the Lincoln Motor Company—was started from the grass-roots. The making of the first engine was as composite as its designing.

The parts for the first engine were made in various plants as follows:

The General Aluminum & Brass Manufacturing Company of Detroit made the bronze-back, babbit-lined bearings.

The Cadillac Motor Car Company, of Detroit, made the connecting rods, connecting-rod upper-end bushings, connecting-rod bolts, and rocker-arm assemblies.

The L. O. Gordon Manufacturing Company, of Muskegon, made the cam shafts.

The Park Drop Forge Company, of Cleveland, made the crank-shaft forgings. These forgings, completely heat-treated, were produced in three days, because Mr. Hall gave them permission to use his dies.

The crank shafts were machined at the Packard factory.

The Hall-Scott Motor Car Company, of Berkeley, Cal., made all the bevel gears.

The Hess-Bright Manufacturing Company, of Philadelphia, made the ball bearings.

The Burd High Compression Ring Company, of Rockford, Ill., made the piston rings.

The Aluminum Castings Company, of Cleveland, made the die-cast alloy pistons, and machined them up to grinding.

The Rich Tool Company, of Chicago, made the valves.

**Woman Operator Machining Cylinders of Liberty Motors (at the Cadillac Plant, Detroit). The War Emergency Necessitated the Employment of Thousands of Women in the Aircraft Industry**

The Gibson Company, of Muskegon, made the springs.

The Packard Company made all the patterns, and the aluminum castings were made by the General Aluminum & Brass Manufacturing Company.

The Packard Company used many of its own dies in order to speedily obtain suitable drop forgings, and also made new dies.

The carburetors were supplied by the Zenith Carburetor Company of Detroit.

The ignition apparatus was made by the Delco Company of Dayton, Ohio.

The Packard Company produced all the other parts.

As fast as completed these parts were assembled in the laboratory of the Packard Motor Company in Detroit and the first complete engine arrived in Washington on July 3d—just thirty-five days after the decision that it should be born. Every part went into its proper place without difficulty. The engine—an eight-cylinder—was kept in the building room as a life-size model and was never tested. The second eight-cylinder was completed two weeks later and passed severest tests. The first twelve-cylinder was next rushed to completion and had successfully passed its 50-hour endurance test by August 25, 1917.

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This test removed the last shred of doubt that might have lingered in the minds of the managers and the experts who were acquainted with its results. From this time on production was the one consideration. The practical manufacturers who were to make the new machine in record-breaking quantities were given every opportunity to suggest changes that would facilitate production and detect any lingering "bugs" that might still be harbored in the new motor. All of them received the new creation with enthusiasm, and none of them ever doubted its success even in the most trying days of changes and fault-finding that were to follow. They were veterans in development and production and they knew that troubles were ahead of them, but they never for a moment doubted that they would be surmounted successfully.

At first it was planned to have a very large proportion of eight-cylinders in the first orders. In fact, an order for ten thousand of them was placed with the Ford Motor Company, and if that order had stood there is little doubt that volume production would have been reached within six months. But so rapidly were things evolving and moving forward at the front, that within a month it became evident that the 225 H. P. of the eight-cylinder was not enough to meet the major require-ment of the times. So, this order, on advice from the front, was canceled and all efforts were concentrated on the 12-cylinder. Subsequent events showed that so sweeping a change was a mistake. It turned out that the wisest observers at the front did not themselves know which way they were going. The requirements did call for more and more large motors, but the turn of favor toward the single-seater left ample room for large numbers of engines from 200 to 300 H. P. This, however, was not the business of the producers. Their business was to produce what the front demanded.

The original order for 22,500 motors was distributed as follows:

| | |
|---|---|
| Packard Motor Car Company | 6000 |
| Lincoln Motor Company | 6000 |
| Ford Motor Company | 5000 |
| Nordyke & Marmon | 3000 |
| General Motors Corporation (Buick and Cadillac) | 2000 |
| Trego Motors Corporation | 500 |

The criticism was immediately forthcoming that automobile makers instead of aircraft manufacturers were entrusted with the task. If we had had a group of powerful aeromotor manufacturers in this country the task would naturally have been theirs. We did not have such a group, and such domestic manufacturers of strength and organization as we had, as well as many of the smaller ones, were already staggering under the loads relating to other parts of the aviation production program that had been placed on them. All the firms named above were makers of motors and skilled in quantity production.

They had large and accomplished engineering staffs and they had the "know-how" and the basic facilities of production, and they were to have the advantage of the continuous counsels of Messrs. Vincent and Hall, two of the best aeronautical motor engineers in the country. It is easier to erect buildings and install machinery than it is to create the human organization of successful manufacturing. Doubtless the engine makers would have been less confident of early results and they would have avoided many difficulties if they had previously been making delicate and precise flight motors.

Most of them were not eager for the job, except as they were eager to do their part in the war. But all of them were inspired with the same enthusiasm that led "Uncle" Henry Leland in his seventy-fifth year to take a contract to erect a vast new factory—the Lincoln—and undertake to pro-

**Packard Motor Car Company Plant at Detroit. Original Plant and Emergency Extension, Devoted Largely to Liberty Engine Production During the War**

**Lincoln Motor Company Plant at Detroit, Rushed to Completion in Record Time for Manufacture of Liberty Engines. Building Erected, Organization of 6,000 Persons Created, and 2,000 Liberty Motors Produced, All in Twelve Months**

duce six thousand motors within a year. It is giving a small measure of credit to say, in passing, that Henry Leland, father of the Cadillac car and company, who is affectionately known as "Uncle" in the American automobile industry, of which he is the acknowledged dean by reason of seniority, was, on account of his patriotic devotion, his manufacturing ability and prestige, and his unfailing enthusiasm, a great factor in the Liberty motor's success.

All worked with energy and concentration, and moreover, with a magnificent spirit of fellowship and coöperation. House pride, trade secrets, and even patent rights were forgotten. It was all for one and one for all. Thus were united in a great manufacturing undertaking the resources, the experience, the engineering ability, and the peculiar specializations of at least five of the most solid, careful, reliable, and efficient manufacturing institutions in America.

These statements are not mere glittering generalities. The spirit of mutual assistance was the spontaneous product of the union of men in a common cause for an unselfish purpose, but it was applied practically and methodically. The manufacturers were given to understand that in undertaking the production of the Liberty motor they had made it their child and that they thereby became as much responsible for it as the engineers and the Signal Corps. It was their business to find its faults either from an engineering or production point of view—as well as to make it in great numbers in record time. They accepted this view, and that they acted on it is proved by the fact that ninety per cent. of all the changes made in the course of production were suggested by them. They pooled their criticisms as well as their resources. They exchanged ideas as well as tools and facilities and even made parts for each other, each plant doing more than its proportionate share of what it was best fitted to.

This voluntary and irregular but none the less admirable coöperation of the first days was soon reduced to regularity and routine. Lieut. Harold Emmons, who was charged by Colonel Deeds with the supervision of engine production, and performed his functions with signal ability and success, took advantage of this union to apply to production the same idea that had dominated the creation of the Liberty motor, viz., practicality. The engine had been designed without interference from the dreamers and Lieutenant Emmons intended to have it produced without obstruction from the perfectists. The current of changes or demands for changes by engineers set in early but Lieutenant Emmons soon checked it. His motto was that there is a place for the engineer and a place for the producer—and also a place for the engineer to stop and the producer to begin. He was determined that only absolutely necessary changes should be made and that they should be the result of joint agreement by engineers and producers. In consequence Colonel Deeds issued an order concentrating Liberty motor engineering and production control in the Detroit district, thus taking it away from Washington and from long-distance entangling. Engineering, production, and inspection were all brought together there responsibly and ultimately in the hands of a committee of engineers and manufacturers made up of Maj. James G. Heaslet, Henry M. Leland, the Cadillac veteran and the Lincoln motors recruit, C. Harold Wills of the Ford Motor Company, Messrs. Beall and Roberts of the Packard Motor Car Company, D. McCall White, of the Cadillac Motor Company, Walter Chrysler, general manager of the Buick Company, and Lt. Col. E. J. Hall, one of the designers of the engines. Major Heaslet, who was formerly a vice-president of the Studebaker Corporation, was in general charge as district manager, and his work in that office was one of the great executive feats of the war. Five of the six Liberty motor contractors were within a short distance of his office and consultations were easy and frequent. Engineering and production thus went together, and the Liberty motor was developed and produced from half a dozen plants by an admirable system which made them exactly like one great plant producing something new of its own. The head and the body were together. This idea of decentralization into strongly authorized districts came later to be taken up by the War Department in most of its activities, but not until the narrow idea of central domination and scrutiny of everything from tacks to transports had badly scrambled production in many lines.

In this union of all for the common good, the Packard Company became the sacrificial goat, generally speaking. It pushed on a little ahead of the others and they had the benefits of its pioneering. It was mostly the Packard that did and undid and wrought and unwrought, and mapped and scrapped in that considerable degree of development of the new engine that was overlapped with production. The laboratory the Packard Company had established in connection with Colonel Vincent's two years of research and experimentation peculiarly fitted it for this pioneering work. On the other hand, the superb organization of the Ford Motor Company especially adapted it to dealing with peculiar problems of production in regard to the new motor. So, altogether the Liberty motor went into production as auspiciously as it had come out of composition.

The event proved the wisdom of the conception and the soundness of the design. "In approximately one year from the time it was originally designed," says Maj. L. S. Simons, of the Air Service, "and in spite of the avalanche of criticism during the last six months of that year, it became the standard motor of the American government and, practically, of the Allied governments as well."

While Messrs. Vincent and Hall were still in the midst of their creative task, Mr. Deeds had asked the Aircraft Production Board for two hundred and fifty thousand dollars for the development of the first five, each, of the eight and twelve engines. The Board was skeptical but quickly granted the funds, and set July 24th as the time limit for the delivery of the first engine. This was on June 4th. The first engine arrived in Washington on July 3d.

The new motor was at first designated as the American or the United States motor, but Admiral Taylor was the first to call it the "Liberty Motor" and it was thus christened by general consent, because it was for the world-cause of Liberty and it was no single man or nation's motor. It was eclectic. The chief features of the Liberty motor are officially described as follows:

*Cylinders*—The design of the cylinders for the Liberty engine followed the practice used in the German Mercedes, English Rolls-Royce, French Lorraine-Dietrich, Italian Isotti-Fraschini, and others, both before the war and during the war. The cylinders were made of steel inner shells surrounded by pressed steel water jackets. The Packard Company by long experiment had developed a practical production method of welding together the several parts of a steel cylinder.

*Cam Shaft and Valve Mechanism above Cylinder Heads*—The design of the above was based on the general arrangement of the Mercedes and Rolls-Royce, but had been improved for automatic lubrication without wasting oil by the Packard Motor Car Company.

*Cam-shaft Drive*—The cam-shaft drive was the same general type as used on the Hall-Scott, Mercedes, Hispano-Suiza, Rolls-Royce, Renault, Fiat, and others.

*Angle between Cylinders*—In the Liberty the included angle between the cylinders is 45°. This angle was adopted to save head resistance, to give greater strength to the crank case, and to reduce periodic vibration. This decision was based on the experience of the Renault and Packard engines with approximately the same angle.

*Electric Generator and Ignition*—The Delco system of ignition, which had been successfully used on hundreds of thousands of internal combustion engines, was adopted, a special design being produced for the Liberty engine to provide a reliable double ignition.

*Pistons*—The die-cast aluminum alloy pistons of the Liberty engine were based upon extensive research and development work by the Hall-Scott Company under service conditions.

*Connecting Rods*—The well-known forked or straddle-type connecting rods as used on the De Dion and Cadillac cars, and also on the Hispano-Suiza and other aviation engines, were adopted.

*Crank Shaft*—The crank-shaft design followed the standard practice for large-bore engines, every crank pin operating between two main bearings as in the Mercedes, Rolls-Royce, Hall-Scott, Curtiss, and Renault.

*Crank Case*—The crank case followed the design of the Mercedes and Hispano-Suiza, in which the crank case is a box section carrying the shaft in bearings clamped between the top and bottom halves by means of long through bolts.

*Lubrication*—The original system of lubrication combined the features of a dry crank case, such as in the Rolls-Royce, with pressure feed to the main crank-shaft bearings, and scupper feed to crank-pin bearings, as in the Hall-Scott and in some foreign engines. This was subsequently changed to add pressure feed to crank-pin bearings, as in the Rolls-Royce, Hispano-Suiza, and other engines.

*Propeller Hub*—The propeller hub design followed such well-known engines as the Hispano-Suiza and Mercedes.

*Water Pump*—The conventional centrifugal type of water pump was adapted to the Liberty.

*Carburetor*—The Zenith type of carburetor was adapted for use on the Liberty engine.

While the engineers and manufacturers who contributed to the Liberty motor engineering and development are entitled to unstinted recognition—and there has been some controversy concerning the distribution of credit—it is but fair to say that to Colonel Deeds is to be assigned credit for the creative concept and decision that there should be a standardized American motor along certain well defined and tried lines. Without that far-reaching decision there would have been no Liberty motor, but only adaptations of European designs and, probably, a multitude of individual American designs, which would have resulted in the Babel of engines that cumbered the aviation programs of the Allies.

## CHAPTER XI

### LIBERTY MOTOR PRODUCTION

THE beginnings of Liberty motor production were, indeed, auspicious. In principle and intrinsically it continued so. Nevertheless, within four or five months the public was fearful that the motor was a failure and was convinced that chaos characterized production and engineering. This public attitude, which resulted in bringing aircraft production into such great disrepute, was based on a misconception and on a failure.

The misconception was in the inability of the public to grasp the fact that as a necessity of war development and production were coincidental in the case of the Liberty motor, and that even if development could have preceded production, the latter would have revealed the necessity of further alterations.

The failure was that of not realizing production in accordance with the schedule.

The public was overwhelmed with adverse criticisms of the motor itself and its parts and was deluged with accounts of innumerable alterations. At the same time it was disillusioned as to the celerity with which substantial production could be attained.

In the ordinary course of bringing out a new and complex mechanism a year or more is devoted to what is known as development. The first machines are tested, experimented with, severely tried, and altered in the light of this experience. The next step is production. But it is invariably found that development must in some degree overlap production. In other words the most careful preliminary tests and studies do not reveal all the weaknesses or defects. Production is often far advanced when it is found necessary to retrace the steps and make some change that may hold up production on the very verge of shipment or even after shipment has begun.

The plan imposed by inexorable war upon the aircraft managers and makers was to merge development and production. They all knew that they had a design that was essentially sound; they all knew that it must be developed by experimentation and they all knew that this development must be coincident with production. This was the only way in which two years could be crowded into one.

It was expensive and tedious, but there was no other way. It involved changes in design and in the strength of parts and the wastage in some degree of parts completed or in process of manufacture when the changes were found necessary. A third class of alterations was the consequence of an imposed change in the objective. Production began with a 12-cylinder engine of about 330 H. P. Responding to the best advice and judgment this objective was changed during production to 375 and finally to 400 H. P. Thus there were three classes of changes:

First: In design.

Second: Those necessitated by increase of power.

Third: Changes in "manufacturing limits."

It is remarkable that there was only one change of essential design—that in only one case was the judgment of Messrs. Vincent and Hall set aside. This was the abandonment of the scupper system of oil "feed" for the pressure system. Either system gave good results but experience showed that the pressure system was better, chiefly because it was "foolproof." This change was not productive of great delays and did not involve the abandonment of the motors completed at the time it was decided upon.

The changes necessitated by the successive decisions to increase power were entirely extraneous to design. They involved considerable delays. About three hundred 12-cylinder engines were in production when the horsepower was raised from 330 to 375. This necessitated strengthening various parts, chiefly the crank shaft. Several hundred engines of this power were delivered, when in response to the insistent demand from abroad for still more power the change was made to 400 H. P. This necessitated the strengthening of a large number of the moving parts of the engine, including the crank shaft, connecting rods, bearings, etc. The changes were not only in form but were also metallurgical. The greatest difficulty and the most delay of all these power changes related to the connecting rods. The alteration of so many important parts was a very serious matter, involving as it did changes in a large part of the special tools of which there were about twenty-five hundred different kinds and as many as ninety thousand altogether in a single factory. The changes in equipment involved changes in the engine plants, the forging shops, the parts plants, and so on "clear down the production line to the producers of raw materials."

Such sweeping changes were inevitably productive of disconcerting delays. In the last analysis they were imposed by the trend of aerial warfare as determined by those in authority at the front. It is a moot question whether the additional power was worth the retardation of production that followed. It might have been better to have had two thousand 330 H. P. engines in May, 1918, instead of eleven hundred 400 H. P. This presumptive advantage was, however, in fact offset by the greater delays in the production of the 'planes that were to receive the engines. Even with the delays imposed from without the motor manufacturers arrived ahead of the 'plane makers.

The most numerous changes, those relating to manufacturing limits, were but trivial in their effect on production. As a rule they were changes in dimensions that tended to facilitate production rather than to delay it, though they kept the draftsmen and the tool-makers busy. They were portentous in numbers but harmless or helpful to speed of production.

The outstanding fact in regard to change is that the actual delays in production resulting from driving development and production together were insignificant. Had the original power limits been maintained production would have come much closer to the impossible schedule. The outcome fully justified the decision to put the new engine into production regardless of development. In

**Assembling Liberty Motors at the Plant of the Lincoln Motor Co.**

**Section of Track System for Machining Upper Half of Liberty Motor Crank Case, Lincoln Motor Co.**

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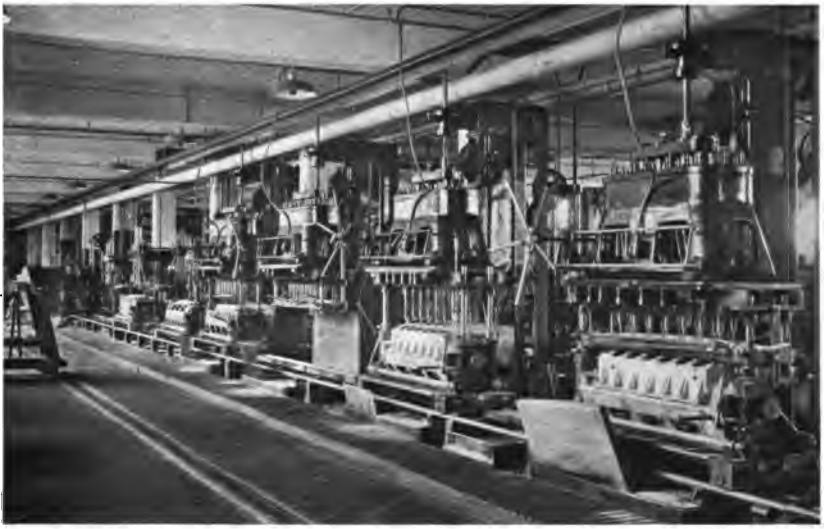

**Section of Track System for Machining Upper Half of Liberty Motor Crank Case, Lincoln Motor Co.**

truth the experience with the Liberty motor in this respect was marvelous. It is commonly lost sight of in the shadow of the grand total of delays, but it is essential to keep it in mind, as it completely refutes the criticism so thickly showered upon the aircraft managers—that they had made a vital mistake in taking up the production of a new engine on a large scale.

Altogether outside of the delays that resulted from the three classes of alterations, production fell behind schedule for many reasons, most of which flowed from the lack of comprehension of all concerned of the sweeping changes that war had wrought in all industrial conditions and because of the failure of the manufacturers to perceive how much more difficult and laborious was the making of a high-power aerial engine than that of an automobile engine. One of the Liberty motor makers is on record as saying that it was their optimism as to their ability to achieve that deceived themselves and the whole aircraft organization. This optimism was unfailing and continued to the last. The aim was high, but so also was the hit.

But when these facts are admitted, the other fact must also be conceded—that with all its delays piled on delays the delivery of eleven hundred completed engines within one year from the day that the first pencil was put to paper in the beginning of design was a truly remarkable performance. It was matched in no other country during the war.

Even with the simpler manufacturing processes of Europe, we have the authority of the British war cabinet for the statement that experience shows that as a rule, from the date of conception and design of an aero engine "to its delivery in series by the manufacturer more than a year elapses."

Let us consider the difficulties that strewed the path of the makers of the Liberty engine. In the first place, existing plants did not have machinery of adequate size to handle the parts of the Liberty. This necessitated the building and sometimes even the designing of new machines. These machines required, in turn, from twenty-five hundred to three thousand different tools, jigs, and fixtures, which, according to the size of the plant, had to be multiplied many times. The making of the immense number of tools took a longer time than was allotted. Tool-makers were scarce and there was a tremendous demand for their services and of the tool-making shops for many other war purposes. Then it developed that men who had done very well as automobile engine mechanics were not possessed of the skill required for work on the Liberty motor. They had to be re-trained or replaced by thousands of men and women specially trained for the work. Many skilled men were drafted into the military service. It was difficult to obtain the high grade of materials required for such a light and powerful machine as the Liberty engine, which has twenty-five per cent. less weight than a 12-cylinder automobile engine and generates four times as much power. Then there were exceptional fuel and power shortages and distressing failures of railway transportation in 1917 and 1918. It is easy to mention these difficulties but hard to appreciate them. They were so baffling that more than one overworked and over worried executive, who found all his well-conceived plans and arrangements thrown into an absolute chaos wherein order gave way to disorder and routine to a succession of the unexpected, broke down and quit his post in despair.

In the face of all difficulties production from machine tools began in December, 1917, with twenty-two engines and gradually grew to 620 in the following May; 1102 in June; 1589 in July; 2297 in August; 2302 in September, and 3878 in October. Up to November 29th, eighteen days after the armistice was signed, the total production of Liberty motors was 15,572, and it eventually reached 20,478, equivalent to more than eight million H. P. When the war ended the Liberty engine program had been extended to 56,100 of the 12-cylinder and 8000 of the eight, thus giving the power that insured air control to the Allies. This enlarged program was necessary to meet the growing requirements of our army and navy and of the Allies. The British required 5500; the French counted on taking twenty per cent. of the entire output and the Italians were planning to take a large quantity. To meet this increased demand new orders had been placed with the plants then engaged in Liberty engine production and with the Willys-Overland plants at Toledo and Elyria, O., and Elmira, N. Y., and with the Olds Motor Company, at Lansing, Mich. Of the completed engines (as of November 11th), 5323 were delivered to airplane manufacturers for installation in airplanes; 4511 were sent directly to the A. E. F. in France; 3742 were delivered to the navy; 1089 were sent to the Allies and 907 to the training fields. When John D. Ryan, as Assistant Secretary of War in charge of the air service, was abroad in September, 1918, he promised the French 1500 engines by December 31st and 750 a month during the first six months of 1919. The British were promised an additional thousand a month during the early months of the same year.

An idea of the volume of production already attained may be received from the fact that in October the output of Liberty motors was at the rate of 150 a day for every working day in the month, whereas the rate of production of its nearest rival in size that ever got into real production—the Rolls-Royce—was ten a day, though the Rolls-Royce was in production years before the Liberty was dreamed of. During 1919 the rate of production would undoubtedly have passed two hundred a day, sufficient to have supplied the Allied armies with an amount of aerial power that was beyond the remotest possibility of German production. *It is hardly necessary to add that the record made in the production of Liberty engines has never been even remotely touched in the production of any like complex mechanism. Indeed no other motor program than its own ever surpassed this actual achievement.*

It is one of the bitter ironies of history that the men who were responsible for the great decision that gave us the Liberty engine have so far had little honor and much obloquy. The public tried and condemned them and the manufacturers early in the war—and years may elapse before they will get their dues. One of them, Colonel Deeds,—the man who took the responsibility of decreeing the

Liberty motor,—was even in the shadow of court-martial for a time and had to submit to the humiliation of a temporary detachment from duty just at the moment when his decision and his labors were meeting their recognition in manufacturing and military results. It was much as if General Pershing had been relieved from duty while the victorious guns of St. Mihiel were still thundering the proof of his victory.

It is an illuminating commentary on the discouragements that were set in the way of the designers and producers of the Liberty engine that it is a common saying in aircraft circles that foreigners had to "sell" it to us, meaning that it was appreciated abroad at its true worth before it received general recognition at home. Brig. Gen. J. D. Cormack of the British War Mission in America, in a speech at the Army and Navy Club, Washington, December 20, 1918, said: "An aeroplane is much more complicated than it looks. It is built around an engine, and *the manner in which you buckled to and produced a really good engine is, in my opinion, the finest feat in design and production that has been accomplished during the war so far as aircraft matters are concerned.* You know the history of the Liberty engine and its fine performances in aeroplanes and flying boats and you will appreciate how greatly you and all the Allies have to thank Colonel Deeds for his efforts in connection with its design and production."

The British Air Ministry adopted the Liberty engine "in the first line of high-powered engines" in June, and in September, 1918, it reported that in the same 'planes the Liberty did at least as well as the Rolls-Royce. Berkight, designer of the French Hispano-Suiza engines, stated that the Liberty motor was superior to any high-powered engine developed on the continent.

The Liberty engine, it must be remembered, is not only a great aerial motor and the best high-power motor that has so far been produced, uniting a minimum of weight with a maximum of power, but it is a quantity production motor. It was believed in Europe that American automatic machine methods of manufacture along standardization lines could not be successfully applied to so delicate and precise a mechanism as an aerial motor. American manufacturing processes have therefore achieved a brilliant feat, for they succeeded in pouring out of their factories, in an unending procession, motors that are the equal of the carefully hand-made engines of Europe. It is these engines, each simply one of a quantity and without individual tuning and perfecting, that are now filling the aviation world with accounts of their triumph. It was simply a Liberty motor installed in a De Haviland 4, also a quantity production structure, in which Capt. E. F. White made the first non-stop flight, on April 19, 1919, from Chicago to New York in six hours and fifty minutes, a distance of 727 miles. It was simply another regular Liberty motor and another De Haviland 4 which Captain Theodore C. McCauley used in his record-breaking flight in the same month from Tuscon, Ariz., to Stillwater, Texas, 880 miles in a little over eight hours, making the then world's non-stop record flight. In both cases the motors performed perfectly throughout the long hours of tremendous strain. The supreme triumph of the Liberty motor came when Commander Read, U. S. N., in the navy flying boat NC-4, equipped with four Liberty motors (high compression), completed the first aerial crossing of the Atlantic, May 27, 1919. It was a DH-4 driven by a Liberty motor in which Lieutenant Maynard won the transcontinental airplane race from New York to San Francisco and return. All of these engines were regular "run-of-factory" standard, quantity-production machines.

These achievements and many others of note are the final and sufficient answer to the indict-

**At Work on Liberty Engine Parts at the Packard Plant**

ments made against the Liberty in its embryonic days. The American aircraft managers set out to design an air motor of great power that was susceptible of quantity production by the characteristic American methods of machine-tool utilization and standardization of parts. The attained rate of output of 150 a day justified the ambition to obtain quantity production; the brilliant and solid performances of individual motors on land and sea and under every condition of weather, climate, and altitude[1] demonstrate that reliability and efficiency were not sacrificed in obtaining quantity.

[1] It was in an American built Lepére biplane driven by a Liberty engine that Major R. W. Schroeder made the world's altitude record, 36,020 feet, at Dayton, Feb. 26, 1920.

# CHAPTER XII

## INCIDENTS OF LIBERTY ENGINE PRODUCTION

THE development of production of the Liberty motor was accompanied by many interesting and ingenious methods of speeding up manufacture. Each of the six companies to whom production was confined at the moment of the ending of the war, has its own collection of industrial adventures and achievements in connection with the work, which will become house traditions. Whatever anyone discovered immediately became the property of all. The Packard Company pioneered and sacrificed itself for all and discovered many masteries of efficient production, but perhaps the most spectacular innovation was the triumph of the Ford Motor Company in cylinder forgings.

The enormous number of steel cylinders that would be required for the first Liberty motor order of 22,500 machines, which, allowing for spares and wastage, would run to more than three hundred thousand, was dismaying to the aircraft managers and was the one feature that gave them pause in their early optimism. Hitherto, the light, thin steel aircraft motor cylinders had been bored out of and lathed down from solid steel forgings. A forging weighing 140 pounds was thus reduced to a finished cylinder weighing only seven pounds. The process was tedious and laborious. The need was for two thousand cylinders a day when production was in full blast. Anything less meant retarded output.

Colonels Deeds and Waldon decided to take the problem to the Ford Motor Company because of its extensive resources, experience, facilities, and special achievements in forgings. Taking with them three wooden blocks representing the size and shape of the forgings from which the cylinders were then being made, and one finished cylinder, they called on Henry Ford one Sunday afternoon at his home in Dearborn, near Detroit, and appealed to him for help. The manufacturing crisis interested Mr. Ford. He offered all the ingenuity of his organization to meet it. The next day the two officials met again with Mr. Ford at the offices of the Ford Motor Company. With them were Messrs. Mayo, Wills, Knudson, and Edsel Ford of the Ford staff and also Henry M. and W. C. Leland of the Lincoln Motor Company; C. F. Kettering, the Dayton automotive engineer, associated with the Dayton-Wright Aircraft Company; F. F. Beall and Edwin F. Roberts of the Packard Company and E. J. Hall, one of the designers of the Liberty motor. It was one of the strongest assemblages of engineering and productive ability that could have been brought together in America. Four suggestions came out of the conference—then the meeting adjourned and the whole matter was left to Henry Ford.

Three weeks later Mr. Mayo, of the Ford Company, walked into Colonel Deeds' office in Washington with a cylinder forging, made, he said, by a method that yielded unhoped-for speed. One glance at the forging and Mr. Mayo's assurance was enough. Instantly Henry Ford was called on the long distance and asked if he would start at once to make two hundred thousand cylinders.

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Letters, contract, and prices followed later. It was the big business way of the big business men who were running things in those days. After manufacture had been proceeding long enough to estimate costs, Mr. Ford fixed the price at seven dollars a cylinder. The cost by the other method was about twenty-five dollars.

Without waiting for further authority the Ford people moved from their plant in Windsor, on the Canadian side at Detroit, one of the enormous presses they had there—the largest machines of the kind ever built. Then they tore out all their regular installations in a whole vast section of their plant and turned their heaviest machinery on to the cylinder job. Money was spent without stint and men worked without saving themselves to rush this installation to conclusion.

The process was unique. It consisted of taking steel tubing of the requisite diameter and cutting it up obliquely. This oblique slice supplied the material for closing the valve-head end of the cylinder. The sections corresponding to the cylinders that were to be were then put through the requisite heat treatment and forging. The resulting forgings were not very much heavier than the cylinders that were eventually ground down from them. Almost from the start of this process the Ford Company turned out hundreds of cylinders a day, against a maximum of 151 by the old process and was soon making as high as two thousand a day. It is estimated that the three weeks the Ford engineers took to solve the problem of cylinder forgings represented a saving of nine months in attaining maximum output of Liberty motors.

From that time on the Fords made the cylinder forgings for all the Liberty motor makers—each of them, of course, finishing the forgings in his own plant.

It is easy to talk of profiteering and to say that all who fought in the war with the forge and the machine fought only for gain. There were many greedy profiteers, but one of the fine experiences of the war for those who were in the press of the industrial preparation was the fact that patriotism and the desire to serve at any cost were the dominating motives with thousands of our manufacturers. In no effort was this better exemplified than in the conception and production of the Liberty motor. The spirit of sacrifice was shown when the two engineers, Hall and Vincent, gave up their pride of name and firm that an all-American motor might be brought forth. Afterward it was shown in every step of production. Every manufacturer of the "Liberty" was of the mind of "Uncle" Henry Leland, who chose aerial engine-making as his form of service even before war was declared, and despite his seventy-five years made a record of accomplishing greatly in a short time that might stir the emulation of vigorous men of half his years. Like the Packard Company, with Alvan Macauley leading, all were willing at any time to suffer that the common cause might be well served. For the time and the cause they ceased to be rivals and brought together much of the best engineering genius and productive talent in America to do their part in giving to the Allied cause the greatest of aerial motors.

While they pooled their strength and their skill they did not shift responsibility from the individual group. Each company played its part of the game with more energy and more perseverance than it ever played its own private trade game. It was a thankless game, too. At one time, when the wind of public opinion sat strongly against the Liberty engine, to be associated with it was to be soiled with scandal. It was a service of dishonor rather than honor. The cloud of misunderstandings and fallacious judgments that resulted from inevitable delays and the hullabaloo raised by investigations, private and public, journalistic and official, which promoted delay rather than progress, is already well cleared away. Time will do full justice. Through it all the manufacturers, like Colonel Deeds and his staff, never wavered in their faith in their engine. In time to come they will point to their loyal work on the great motor as the noblest achievement of their careers.

## CHAPTER XIII

### DEVELOPMENT AND PRODUCTION OF ENGINES OTHER THAN THE LIBERTY

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Some account has already been given of how the Curtiss engine, the OX5, was adopted as the engine around which the training equipment was built up, and how the Hall-Scott engine was used in a supplementary way. Also there has been some mention of the three foreign engines that were put into production in this country primarily as the power for secondary or advanced training.

It was the first intention after the adoption of the Liberty motor idea to have the motor made in 4, 6, 8, and 12 cylinders, thus giving every degree of power that might be required for the different uses—all the way from training to the highest type of single- and two-seater pursuit machines, observation, bombing, etc.

This symmetrical program, realizing as it did the height of simplicity and standardization, was never fully worked out. As a matter of fact the eight-cylinder was the only variation from the standard 12 ordered in production. Both the four- and six-cylinder sizes were built, tested, and proved but had not been put in production on the signing of the armistice. The first plan was to put a large number of the 8's into production, even ahead of the 12's. Then on advice from abroad, the ever-repeated advice in favor of higher power, the eight-cylinder was given up—only to be returned to during the closing days of the war. When the necessity of having engines of intermediate power became apparent with changing counsels and changing circumstances, it was found an easier matter, with the organization concentrated on the Liberty 12's, to fill the gap with Hispano-Suizas. So preparations were made with the Wright-Martin Company which was then making the 150 H. P. Hispano-Suiza to take up the 220-H. P. model. Then reports came in from abroad that on account of troubles arising from the gearing it should be discontinued. Another shift in the aviation wind in 1918, making an engine of 300 H. P. desirable at an early date for the smaller service 'planes, to the manufacture of which we were then swinging back, resulted in an order for 10,000 of the 300-H. P. Hispano-Suiza engines which had just been developed abroad. As such an order was quite beyond the capacity of the Wright-Martin plant at New Brunswick, the government-owned plant at Long Island City, formerly belonging to the General Vehicle Company was leased to the Wright-Martin Company to enable it to handle half of the order. The other 5000 were placed with the Pierce-Arrow Motor Car Company of Buffalo. To assist both of these companies in their heavy task, the entire manufacturing plant and facilities of the H. H. Franklin Company of Syracuse, New York, were placed at their disposal. These large Hispano-Suizas would have gone into production in January, 1919, had not the end of the war intervened.

One of the most common criticisms of the management of aircraft production relates to the Rolls-Royce, the excellent British motor. It is not generally known that it was originally the fixed intention, and a very persistent effort was made, to put it into production in this country, notwithstanding the great difficulties that were found to interfere with the naturalization of any foreign machine in American factories. It is possible that had negotiations not been so delayed and so productive of problems the Rolls-Royce might have been the high-power engine of the American program. It was the one European engine of high power that had been well developed when the United States entered the war, though its power at that stage of development was not great as compared to the power later developed by the Liberty 12. To those who did not appreciate the difficulties and time required to put a foreign engine into successful manufacture in the United States it always seemed that one of the obvious things to do was to produce the Rolls-Royce in the United States. At one time there was a fixed intention to bring about that consummation. Through Lord Northcliffe, head of the British business mission in the United States, arrangements were made for Mr. Claude Johnson, managing director of the Rolls-Royce Company, to come to the United States with competent assistants, samples, drawings, specifications, etc., in order to prepare for the manufacture of his engine in this country. The first plan was for Mr. Johnson to make an arrangement with the Pierce-Arrow Motor Car Company for it to undertake the building of the engine. This sug-

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One of the most common criticisms of the management of aircraft production relates to the Rolls-Royce, the excellent British motor. It is not generally known that it was originally the fixed intention, and a very persistent effort was made, to put it into production in this country, notwithstanding the great difficulties that were found to interfere with the naturalization of any foreign machine in American factories. It is possible that had negotiations not been so delayed and so productive of problems the Rolls-Royce might have been the high-power engine of the American program. It was the one European engine of high power that had been well developed when the United States entered the war, though its power at that stage of development was not great as compared to the power later developed by the Liberty 12. To those who did not appreciate the difficulties and time required to put a foreign engine into successful manufacture in the United States it always seemed that one of the obvious things to do was to produce the Rolls-Royce in the United States. At one time there was a fixed intention to bring about that consummation. Through Lord Northcliffe, head of the British business mission in the United States, arrangements were made for Mr. Claude Johnson, managing director of the Rolls-Royce Company, to come to the United States with competent assistants, samples, drawings, specifications, etc., in order to prepare for the manufacture of his engine in this country. The first plan was for Mr. Johnson to make an arrangement with the Pierce-Arrow Motor Car Company for it to undertake the building of the engine. This suggestion was not well received by Mr. Johnson because it meant turning over to a rival manufacturer, as it were, the inside knowledge and experience of his own business. After the war the Pierce-Arrow Company might conceivably have turned to its own advantage what it learned in manufacturing the Rolls-Royce aero engine. Mr. Johnson's idea was for the United States to acquire and fully equip a factory and hand it over to him. He stipulated that the factory must be located in a good labor supply center and within a suitable distance, having in mind the transportation of raw materials, from Pittsburgh. Then began the pursuit of the ideal factory. If the Signal Corps approved of one, Mr. Johnson did not, and the plants that were satisfactory to Mr. Johnson were not liked by the Corps. Weeks of such negotiation dragged into months. Meanwhile the Liberty engine was designed, experimentally built, tested, and approved; and by that time, in view of estimated outputs, there seemed little reason for taking up the Rolls-Royce. Another element in the Rolls-Royce problem was the fact that Mr. Johnson wished to produce at first his 190, developing 250 to 270 H. P., seemingly because he could bring from England a complete set of jigs and fixtures. With the aid of these he thought he could make 500 engines by the end of the fiscal year; *i. e.*, June 30, 1918. But the demand of the times was for the Rolls-Royce 270 rather than the 190, and for it the jigs and fixtures would have to be made in this country, thus lengthening the schedule of deliveries. In the light of the record made in the manufacture of Liberty motors the final decision to drop the Rolls-Royce seems to have been wise, as 1000 Liberties were actually completed a month sooner than Mr. Johnson figured on completing 500 of the smaller Rolls-Royce. It is noteworthy, too, that the Liberty 12 weighed 100 pounds less and developed about 100 H. P. more than the larger Rolls-Royce. It is now plain that if the Rolls-Royce had finally been put into production in America the net result would simply have been the output of a machine whose place in the program would have been previously met by the Liberty Motor and that in doing so the manufacturing resources of the country would have been overtaxed to such an extent that neither the Liberty nor the Rolls-Royce would have attained quantity production at anywhere near the time the Liberty alone did.

The Bolling Commission was much impressed with the Bugatti engine, which it found in the developmental stage in France. It was a 16-cylinder engine, weighing approximately 1100 pounds, and was built around a small-caliber cannon. The Bolling Commission strongly recommended that it be put into production in the United States, and that it be pushed side by side with and just as energetically as the Liberty. The Duesenberg Motor Corporation, of Elizabeth, N. J., was accordingly diverted from the Liberty and turned to the Bugatti. The Fiat plant at Schenectady, N. Y., and the Herschell-Spillman Company of North Tonawanda, N. Y., were assigned to coöperate with the Duesenberg company. However, when the sample engine arrived, it was found that owing to an accident during a test in France it was not in running order. Also, the French mechanics and engineers who came with it frankly admitted that the design and development of the engine had not been completed and that much work remained to be done. Charles B. King, one of the Signal Corps engineers, was assigned to this work. It took months to re-design the engine and it was just getting into production when the war ended.

Early in the war Mr. Harbeck of the Duesenberg company suggested a plan of designing and building an engine of 800 H. P. The idea met with the approval of the authorities and the Duesenberg company was authorized to build four. One of

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Early in the war Mr. Harbeck of the Duesenberg company suggested a plan of designing and building an engine of 800 H. P. The idea met with the approval of the authorities and the Duesenberg company was authorized to build four. One of them was completed before the armistice was signed. The purpose of this experiment was to keep the organization thinking in terms of larger power all the time. The Liberty was years ahead of any other engine, it appeared, but it was considered wise to be ready for further advances. The boldness of this step is illustrated by the fact that technical experts had just figured it out that it was not practical to absorb 400 H. P. in one high-speed propeller, though the Liberty was doing it. Instead of accepting their conclusion they were asked to prepare calculations for one that would go with the 800-H. P. engine.

The contracts for and deliveries of other engines than the Liberty up to November 29, 1918, are as follows:

| Type | Contract Number | Delivered |
|---|---|---|
| OX5 | 9,450 | 8,458 |
| A7-A | 2,250 | 2,250 |
| Gnome | 342 | 240 |
| Le Rhone | 3,900 | 1,298 |
| Lawrence | 451 | 451 |
| Hispano-Suiza | | |
| 180 H. P. | 4,500 | — |
| 150 H. P. | 4,000 | 4,100 |
| 300 H. P. | 10,000 | — |
| Bugatti | 2,000 | 11 |
| Total | 36,893 | 16,848 |

Including the Liberty motors (64,100) the orders for engines at the time of signing the armistice amounted to 100,995—which were to have been completed by January 1, 1920, or thirteen months after the cessation of hostilities. There were delivered 32,420 with a total horsepower of more than 7,800,000. Deliveries were somewhat further increased in some items before production terminated, the final total for Hispano's, for example, being 6176.

The distribution of engines completed up to November 29, 1918, was as follows: Of the training engines 325 Le Rhone rotaries went to the A. E. F., the various airplane factories received 9069 of different kinds, 6376 of them were sent to the training fields, and 515 Hispano-Suizas went to the navy; of the combat engines, mostly Liberties but including some of the higher-power Hispano-Suizas, 3746 were delivered to the navy, 1090 were taken by the Allies, 941 were sent to training fields, and 5327 were sent to 'plane plants for installation in airplanes.

It is true that this engine-making achievement, great as it is, is not up to the promise of the rosy early days. In general the full realization of the early program, taking engines and 'planes together, would have come in about twenty months, instead of the hoped-for twelve months, from July 1, 1917. Yet, as John D. Ryan recently pointed out, we did well in comparison with our allies or our enemies. "We built more 'planes," he said, "month for month, from the time we began than any other nation in the war built from the time it began. We had more engines ready and we had more 'planes ready, month by month, from the time we commenced than any nation in the war had from the time it commenced." The same fact may be stated in another way by saying that in each corresponding period of time in our participation in the war we produced aircraft in greater volume than any other nation in it.

# CHAPTER XIV

## CENTRALIZATION OF MANUFACTURING RESPONSIBILITY

ONE of the fixed ideas of the early nebulous stage of the American aircraft program was that of brevity in respect to the list of machines that should be manufactured. There were to be but few types of engines and 'planes—and the engines were to be as far as possible modifications of a standard type.

This was exactly the reverse of the French and British method of procedure. With them each manufacturer was allowed to go ahead almost independently with his own conceptions. It has been asserted that while the American method had its advantages, it also had the disadvantage that it tended to check development and invention and practically relegated them to the official organizations. Doubtless this was true in a degree, but one of the offsets was that in some measure all of the available engineering talent of the country was united and concentrated on the lines the aircraft organizers sought to lay down. If there had been more aeronautical engineering ability in this country at the beginning of the war it might not have been necessary to concentrate it to so great a degree as it was along the lines laid down by the government.

Both the aeronautical engineers and the existing aircraft plants had to be carefully conserved. Far from being ignored, they were zealously cultivated, though not always in the ways they preferred. Doubtless some of the small plants, simply because they were called aircraft plants, thought that even the Liberty motor should have been entrusted to them, rather than to the highly organized and amply equipped automobile manufacturers—the great internal combustion engine designers and builders of America.

The automobile manufacturers besides being most proficient in the designing and making of internal combustion engines had the decisive advantage of organizations and plants that lead the world in the excellence and capacity of their quantity production methods. One of the most irrational criticisms of the aircraft managers that was made in the hectic early days of the war was that they had entrusted the building of aerial motors to the manufacturers of automobile motors. The authors of this criticism did not point out what American industry, in the absence of an extensive and highly specialized aerial motor industry, should build aeroplane motors if not the makers of automobile motors. In France, England, Italy, Germany—everywhere—the automobile manufacturers have inevitably evolved into producers of aircraft. The conversion of a number of the superb automobile-making plants of the country to the making of Liberty and other motors and of 'planes was one of the notably logical industrial mobilizations of the war.

The aeronautical engineers were utilized, as a rule, not by bringing them to Washington or to the engineering headquarters at Dayton, but in conjunction with their own existing plants or some that were later built up around them. The existing plants that amounted to anything were divided, in the first place, between the army and navy. In magnitude the army aviation effort was so much in excess of the navy's that it may have been overlooked that the Aircraft Board had always to make equitable provision for the latter.

To the navy were assigned exclusively the Burgess factory at Marblehead, the Aeromarine plants at Nutley and Keyport, N. J., and the

Boeing plant at Seattle. The enlarged Curtiss plants were used for both army and navy work and the Standard Aircraft Corporations' plant at Elizabeth, N. J.; the Thomas-Morse Aircraft Corporation, Ithaca, N. Y.; the Wright-Martin Aircraft Corporation, Los Angeles, and the Sturtevant Aeroplane Company of Boston were turned over to the army.

The engineering tasks were roughly assigned in the following manner: To Glenn Curtiss and the engineering staff of the Curtiss company the JN-4-D and the development of the drawings and the manufacture of the French Spad—the single-seat chasse machine which was early adopted as the type of single-seater fighter that would be put into production in this country. Later the Curtiss company got the unfortunate Bristol two-seater fighter and finally the U. S. D9-A, that was intended to take the place of the Bristol.

A new company, the Dayton-Wright Airplane Company, was encouraged to build up around the nucleus of Orville Wright and engineers and trained mechanics associated with him, and to it was assigned the development and pioneering of the De Haviland 4 with the Liberty motor as power.

Originally the Signal Corps Engineering Department was assigned to the Bristol but the latter part of that development was transferred to the Curtiss company.

The Thomas-Morse corporation, with B. D. Thomas at the head of its engineering, was assigned to the development of a rotary motor advance training 'plane, and later, a chasse machine.

Grover C. Loening was instructed to develop a two-place fighter.

Glenn L. Martin was told to develop a two-engine bomber.

Lewis & Vought were told to develop an advance training 'plane under the guidance of C. M. Vought.

Several orders for experimental machines were also placed.

This seemed like a rational and simple arrangement, but the admitted fact is that engineering confusion ensued in 'plane manufacture. "The engineering confusion which followed the program throughout the first year," says an official statement, "must be frankly admitted." It somehow seemed impossible to introduce into the engineering of the 'planes the orderly method that governed the development of the Liberty motor. That was partly due to the fact that it was an American design and did not wait upon foreign counsel; it was also due to the fact that an engine was a complete unit in itself and did not have to be considered with respect to numerous accessories. But above all there were highly organized industrial facilities for engine production which did not exist for 'planes. In the case of the 'planes there was also the difficulty of a lack of definite knowledge of just what was required and the further complication of determining upon and designing the accessories, as well as providing for their manufacture from the ground up in many instances, at the same time that the 'planes were being designed. A place for each of the accessories had to be found, but it was never certain just how many kinds of them there would be, because of our varying demands from the front. On the other hand the accessories had to be adapted to the limitations of space in the cockpit, in the engine compartment or the landing gear, or on the outside of the fuselage. Doubtless, at some point someone should have been able to step in and say that a certain number of machines should have such and such an equipment, leaving additions and improvements to a following series. But the early general air service organization seemed to make this impossible. The engineers felt constrained to look upon a request from the A. E. F. as an order—so, much time was wasted in trying to overtake an

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The general policy of simplicity also governed the choice of manufacturers. There were thousands of applicants for contracts—and from one point of view it seemed that the thing to do was to start everybody who offered on some sort of aircraft production. This policy was not followed because Colonel Deeds understood that American manufacture was of the quantity kind and could not adapt itself to a multiplicity of participants as the group manufacturing methods of Europe did. Hundreds of the applicants were, however, painstakingly investigated but the majority of them were found hopelessly unfit for the task. Many of them felt that they had a grievance—and it was therefore, easy for their sympathizers to complain that but a small percentage of the potential aircraft production of the country was being utilized, whereas the real difficulty was to make effective use of the facilities of the plants that were enlisted. One of the aspirants for 'plane manufacture was a stone quarry company and there were many others almost as impossible. As a rule, original contracts were put into a few responsible hands. The holders of these contracts then contracted secondarily for those parts they did not make in their own plants—as well as for materials. In the end over three hundred plants and more than two hundred thousand work-people were engaged in the making of 'planes and accessories.

As the delays in production were chiefly due to engineering confusion, it is now easy to see that the situation would have been indescribably chaotic if the plants affected had been much more numerous than they were. They had ample capacity but the engineering jam held them back. The same policy of concentration in the hands of the strong gave us engines in abundance before it gave us 'planes.

In considering this subject it is necessary to bear in mind that in the automobile industry we had in America a great body of trained builders of internal combustion engines of which, after all, an aero motor is only a specially refined and adapted type. The builders of the 'planes were generally without corresponding experience and their work-people were without training, and yet it was their task to fit the new engines to the 'planes and also properly place in them numerous sorts of equipment apparatus which never ceased to grow in number and complexity. Thus, in a way, it may be said that most of the elemental difficulties of producing finished combat aeroplanes piled up in the aeroplane factories where the 'planes proper, the motors, and the accessories were assembled into the functioning whole. In the same manner they had to bear the brunt of the delays and alterations of all kinds that affected motors and other equipment. That this point is well taken is supported by the comparative ease and rapidity with which the manufacturers of training 'planes attained volume production. The latter merely had to build or build and assemble simple 'planes and engines and had little or no engineering or pioneering developmental work to do. They merely traveled along a separate and well-beaten path. Their brethren of the combat 'planes, however, had all of the problems of the adaptation of foreign 'planes and then had to wait on the solutions by their predecessors in the line of production of all their problems of origination and adaptation.

Another step toward simplification that was early taken was the matter of patents and royalties. It was clear that if American manufacturers were to pool their efforts for the common good some equitable arrangement for common access to all existing rights must be obtained. Permission to use these rights could not be left to the disorder of individual bargaining, with its delays, disappointments, and general tendency to result in excessive cost. Howard E. Coffin and S. D. Waldon took the initiative in this matter several months before war was declared and succeeded in getting an Aircraft Manufacturers' Association formed around a so-called cross-licensing agreement that was at one time the cause of much criticism. It is important to note that the initiative came from the government, and that the motive was most laudable—the purpose being to serve the common cause in an equitable manner without doing injustice to the pioneers of the industry who held the basic patents as well as desirable designs and processes of manufacture. All members of the association—and membership was open to any legitimate manufacturer—had the privilege of using the basic patents on the payment of a certain sum for each commercial machine turned out and half as much for each government machine. The solution of the inter-relations of manufacturers thus arrived at eliminated all patent litigation which at one time was threatening untoward complications and gave just recognition of the pioneering work that was so necessary to the success of the aircraft program.

The rights to European designs of engines and 'planes were dealt with through the Allied governments. Enterprising Americans as well as foreigners saw a chance to make an honest penny or mayhap a million or two by acquiring the American rights of foreign 'planes and engines. Many of the machines thus covered did not interest the American producers but among them were the "Clerget" engine, recommended by the Joint Army and Navy Technical Board for use in training 'planes; the Sopwith, also favorably considered; the "Sunbeam," not favorably considered, and such desired rights as those of the Caproni, Gnome, Le Rhone, and Handley-Page. The valuation placed on these rights made the figures of the cross-licensing agreements with American manufacturers look absurdly small. As the election of foreign types was left to the Bolling Commission this matter of royalties was also left to it and it settled it on the sensible basis of free interchange of rights between governments, leaving each government to deal with the rights of its own designers. The two exceptions to this practice were the negotiations with the Rolls-Royce company and the three French engines and 'planes that were selected through Major Tulasne of the French military mission at Washington.

# CHAPTER XV

## THE WRESTLE WITH THE 'PLANES

THE uncertainty as to what to undertake in this country in the way of service 'planes resolved itself in August, 1917, on instructions from abroad, into a general determination to adopt the De Haviland 4 as the type for reconnaissance, with secondary functions as a day-bomber and a defensive bi-place fighter. The Bristol two-seater was adopted as the type for the two-seater fighter and the Spad as the single-seater chasse machine. By that time, too, the Bolling Commission was beginning to get a very clear view of the engine situation and had cut its immediate production recommendations down to only the Rolls-Royce, the Gnome, and the Le Rhone of foreign engines.

The De Haviland 4 was the first foreign service 'plane to reach this country. It was a seven days' wonder in Washington, where it arrived in the latter part of July, even though it came without engine, ordnance, and the operating equipment.

Incomplete as it was, it was the first service 'plane to reach America. It had to be redesigned to take the Liberty engine and altered to suit the Marlin and Lewis machine guns, four in all, and finally shaped and stretched to hold a host of accessories, the number of which, it seemed to the despairing engineers, never ceased to grow.

The aircraft managers then got their first glimpse of the troubles that were ahead of them. Accustomed to American practice, they had considered that with regard to the foreign machines, engineering would be the least of their difficulties. The naked De Haviland 4 and the incomplete drawings that followed it opened their eyes. This sample arrived at Dayton, Ohio, on August 18, 1917, and was turned over to the Dayton-Wright Airplane Company for study and reproduction. The first American-made DH-4, without equipment, took the air with a 12-cylinder Liberty motor October 29th. It gave perfect satisfaction from the first; and patched up from time to time, with the tireless Howard M. Rinehart as operator, this veteran "Canary," as it came to be known on account of its color, was the operating subject through all the long struggle that followed to get more things into the 'plane than there was room for. The fact that the first 'plane was ready so soon—even though it was not a machine-made one—and the other fact that quantity production from a well-organized and ably directed plant was not in full swing until the following April tells the tale of the accessories. But for them and their baffling problems of design, location, and manufacture the 'planes should have been coming out in quantities much faster than the engines, whereas in fact, it was the other way about. It is hopeless to convey any idea of the exasperating nature of the complications with respect to them. The task would have been simple, indeed, had it been merely the matter of duplicating a foreign machine with each accessory in its place, complete drawings, and the accessories available. The latter were the current by-product of aerial warfare. Mostly, they were entirely new to America—all the way from suitable photographic apparatus to machine gun synchronizers. Besides, each morning's cablegrams brought some more recommendations either for additional accessories or variations of those already adopted. And always there was a warning that 'planes without these up-to-the-minute devices would be antiquated before they reached Europe. During these intense and critical days the storm of criticism and investigation was at its height and reorganizations were adding to the

**General Arrangement of Throttle and Gas Control, and Other Instruments in Pilot's Cockpit of a DH-4. The Numerous Installations in a Limited Space were a Hard Problem for the Designers**

U. S. Air Service Photo

burdens of the aircraft managers; all of which took up the time and diverted the energies of those in charge to the point of discouragement and demoralization. By this time also army organization was beginning to get its grip on the civilian method of doing business and was crushing it into the rigid and angular process of government routine plus military stiffness. The De Haviland 4 had, too, all the familiar troubles of inaccurate, partial, and incomplete foreign drawings. Manufacturing drawings, in the American sense of completeness and detail, do not seem to exist in Europe. At least that was the conclusion our aircraft manufacturers arrived at. The fact is that the European system of individual work and a small measure of standardization do not require it. If this difference in practice had been understood sooner, there would not have been so much confidence as to early 'plane production. The actual manufacture of 'planes was not considered as difficult as that of engines. The motor is a complex power producing machine, with hundreds of moving parts, whereas the 'plane for all its forty thousand parts is a rigid structure; and it was believed that in view of the fact that the body was largely of wood and cloth and the metallic parts easily adapted to machine production it would not be difficult. Incomplete and unsatisfactory drawings, which necessitated the making of thousands of new drawings from the model, the problem of placing the ever-accumulating and ever-changing accessories and changes incidental to adaptation to the Liberty motor dispelled the dream of an easy job. So, in the end the naturalized foreign 'planes came through more slowly than the home-born Liberty motor. This fact suggests the possibility that a naturalized foreign motor might have been relatively much longer in reaching production.

The De Haviland 4 was officially released for production in April and the Dayton-Wright Company thereafter lived up to its manufacturing schedule. In June it was turning out fifteen complete machines a day—guns, accessories, and all—and in August completed its thousandth machine on time. When the armistice was signed it had realized the unprecedented rate of forty complete 'planes a day. More than two thousand 'planes of its make were in or on the way to France when hostilities ceased. The Fisher Body Company, Detroit, had attained an output of thirty-five De Havilands daily. When De Haviland 4 production ceased in December there had been turned out by all makers 4587 machines, practically all in eight months.

The first DH-4's had their faults and imperfections and the experience of actual military use resulted in alterations and improvements by the aviation shops in France and like changes in the manufacturing plants at home, but this did not interfere with production and was all part of the interminable game of keeping up with the daily lessons of experience at the front.

Maj. A. A. Cunningham, commandant of the Aviation Section of the U. S. Marine Corps, in telling of the excellences as well as the defects of the American DH-4's, as used by the marines in coöperation with the British service, says that they were so much faster than the British DH-4's equipped with the BHP motor that they found it very difficult to stay in formation with the latter. This difficulty was overcome by throttling down the Liberty motor and carrying only about one half the regular weight of bombs. Even in flying with the 'planes using Rolls-Royce Eagle-8 motors, it was found desirable for the latter to carry a smaller weight of bombs. "On account of the excellent performance of speed of the American Liberty motored 'planes," he says, "the British were well pleased with them. When the first few received were recalled, in order to start independent (American) operations, one squadron commander wrote an enthusiastic report regarding the performance of these 'planes while in use with his squadron."

"In my opinion," continues Major Cunningham, "the Liberty DH-4 and DH-9-A were the fastest and climbed better, at above fifteen thousand feet, than *any plane*, Allied or German, on the front, As an illustration, the Hun biplane and triplane Fokker scouts had been accustomed to meeting the British DH's and could outclimb and outspeed them. On our first independent raid, the formation was attacked by about twice their number of Fokkers. We promptly shot down two of them and then climbed away from the remainder as if they had been tied down. The actions of the Huns plainly showed their amazement. This was their first experience with the Liberty motor."

As a step in advance the U. S. DH-9-A was designed soon after the De Haviland 4 got into production and four thousand of them were ordered from the Curtiss company after the Bristol two-seater was abandoned. While most of the De Haviland 4's were made by the Dayton-Wright Company, the Standard Aircraft Corporation and the Fisher Body Company (Detroit) had got into production before the war ended.

The characteristics of the De Haviland are as follows:

**Making Airplane Wings**

**Bird's-Eye View of the Dayton-Wright Airplane Company's Plant at Moraine, near Dayton, Ohio**

| | |
|---|---|
| Endurance at 6500 feet, full throttle | 2 hrs., 13 min. |
| Endurance at 6500 feet, half throttle | 3 hrs., 3 min. |
| Ceiling | 19,500 feet |
| Climb to 10,000 feet (loaded) | 14 min. |
| Speed at ground level | 124.7 mi. per hr. |
| Speed at 10,000 feet | 120 mi. per hr. |
| Speed at 15,000 feet | 113 mi. per hr. |
| Weight, bare 'plane | 2391 pounds |
| Weight, loaded | 3582 pounds |

The production of De Haviland 4 machines is as follows:

| | |
|---|---|
| November, 1917 | — |
| December | — |
| January, 1918 | — |
| February | — |
| March | 4 |
| April | 15 |
| May | 153 |
| June | 336 |
| July | 484 |
| August | 234 |
| September | 757 |
| October | 1,097 |
| November | 1,072 |
| December | 456 |
| Total | 4,587 |

The De Haviland 4's were the only American-made service machines delivered to the A. E. F. The decision made on recommendation from

General Pershing and the Bolling Commission in 1917 to leave the pursuit machines to European makers was reversed too late for us to be represented by them, and the failure of the attempt to adapt the Bristol two-seater resulted in lack of representation in two-seater fighters. However, there was a great need for the reconnaissance machines when they did arrive—and after all the main military value of airplanes was reconnaissance. The fighters' *raison d'être* was chiefly to protect and assist them—and though the De Haviland 4's were technically classed as observation and bombing 'planes, they were able on account of their speed, the rapidity of their ascent, the height of their ceiling, and the nature of their armament, to give a very good account of themselves in a fight. By the time they began to arrive in France in numbers, the foreign deliveries of fighters had much improved, and when the armistice was signed our forces abroad had received more than five thousand 'planes, service and training, from foreign makers—mostly French—and 3302 were in use.

To be sure, one feels a sort of diffidence about saying much about the French contribution to our aerial fighting equipment—for no matter how sufficient the explanations it is not pleasant to have to admit that so great an industrial country as ours had to lean so heavily on French industry. It was so and inevitably so in order that American man power might make itself felt decisively in the battle front of 1918.

The Allies understood the situation, and when Bolling left for Europe in June, 1917, he carried with him the firm conviction, upon which all his later conclusions were based, that America with no engine or 'plane industries and without engine and 'plane designs suitable for war service, could not be ready to begin making shipments to France under twelve to fifteen months whether we copied or originated. Bolling knew even then that the Allies must not only hold the battle line, but must *help* us in training and in equipment until we could overcome the tremendous lead in the new science and art of aerial combat, which had been gained by the great European powers while American aviation slumbered. Bolling fully presented the deplorable status to General Pershing and recommended that all aviation equipment needed in France, before July, 1918, be bought from the English, French, and Italians. Accordingly, orders were placed in France and Italy, as described elsewhere, for the machines that were to stop the gap until the American "ships" should arrive, just as French artillery, tanks, etc., had to be provided for about all the American combat units of 1917 and 1918.

Very likely aircraft and artillery matters might have been handled better but the real mishandling was before the war. The responsibility rests with leaders and people who permitted the now inconceivable folly of letting the horrific war in Europe drag through well-nigh three years with no preparation worthy of the name on this side. To deal harshly with the self-sacrificing men who did so well to correct the fundamental blunder when it was too late is merely to divert attention from the cause to the effect.

Looking backwards, it is now plain that the United States should not have withdrawn its efforts to produce a single-seater fighting 'plane, as it did when the Spad order was canceled in December, 1917. In consequence of that decision we should have been very short of a much needed type in 1919, as we were in 1918. It was taken, however, on the practically unanimous opinion of General Pershing, our aviation representatives abroad, and the Allied government authorities. This subject has been touched upon heretofore, but it is worthy of further elucidation, because none of the critical investigations of aircraft production have given it proper weight. They have been content to state the bare fact without the circumstances, and leave the inference that it was another fault of the equipment division of the Signal Corps. The Spad sample reached the Curtiss works in Buffalo on September 27th and it was ordered into production on a large scale, only to be revoked in accordance with instructions from abroad, because it was the best judgment there that the day of the single-seater was about over.

The attempt to Americanize the Bristol two-seater fighter was the big, flat failure of American aeronautical engineering. There is no doubt that the selection of the Bristol was a wise one. The failure was in adaptation. It is the common impression that the failure was primarily due to the fact that the Liberty motor and the Bristol were incompatible, because of the much greater power of the former than the Rolls-Royce engine that had been used in it in the British service. Engineers now state there was no such essential incompatibility, and point to the successful designing of other two-seaters around the Liberty 12. The redesigning of the Bristol was first taken up by the Signal Corps aeronautical engineering staff, working from a sample that reached Washington, September 5, 1917, and from the original drawings. When the Spad contract with the Curtiss Company was canceled the work was turned over to that company with the government engineers coöperating; next the engineering responsibility was entirely shifted to the company; finally it was sought to complete the work under the direction of government engineers. The basic trouble, which so much engineering shifting did not help, was the fact that in attempting to put onto the Bristol all the equipment of the De Haviland 4, some eight hundred pounds of weight were added without a corresponding extension of wing surface. The machine was overloaded. Notwithstanding this elemental error, so much time was taken up with the baffling problems of redesigning to accommodate equipment, that even sample machines were not ready until well along in the spring of 1918. Their performance was unsatisfactory and productive of casualties, and when John D. Ryan, then at the head of the air division of the army, witnessed the death of two aviators in an experimental flight at Buffalo, he ordered the Bristol experiment stopped.

This failure, while it was a costly one in respect to waste of time and material, was not a disastrous one, for the reason that the De Haviland 4, though designated as an observation machine, and the Bristol two-place fighter were in fact essentially the same type. Had the Bristol experiment succeeded it would have gotten a very considerably larger number of machines in France before the end of the war, but it would not have given any pronounced variety to our aerial equipment there. The great restriction of American aeroplane force in France was due to the abandonment of the single-seater, the Spad, in 1917. This was not a production fault, being rather an error of military judgment, made, as it now develops, against the conviction of Colonel Deeds and his associates. Their prompting was to go ahead with the single-seaters, but the decision did not rest with them.

While the Bristol experiment was approaching its dismal end, Captain Lepère, a French aeronautical engineer originally brought to this country for the purpose of designing a two-seater fighter around the Bugatti engine, was achieving a brilliant success with such a 'plane built around the Liberty motor. His work was done at the Packard plant, a contract having been made with the Packard Company to provide him with the shop facilities to build 25 experimental 'planes. The Lepère 'plane attained a speed of 136 miles an hour at low levels and of 102 at 20,000 feet, to which height it climbed in 41 minutes. Even at 10,000 feet its speed was 127 miles an hour, as compared with the Liberty De Haviland's 117. Four thousand of these machines were ordered, but there was no production before the armistice was signed. It was confidently believed, however, that in the Lepère the American air forces at the front would have had the supreme two-seater fighter in the spring of 1919. The Lepère represented the union of the training and technique of the best engineers of France with the Liberty motor, admittedly the best of all aviation engines. Captain Lepère also designed two other two-place fighters, as mentioned below.

Just as 1917 saw the Liberty motor developed and 1918 saw it in vast production, so 1918 saw the development of 'planes in America and 1919 would have seen both American engines and fighting 'planes produced in unequaled quantities and in action at the front by the thousands. The other experimental orders, all but three of which have been delivered, and most of which are very promising, are as follows:

SINGLE-SEATER PURSUIT

Thomas-Morse MB-3—300-H. P. Hispano engines
Vought VE-8 one-place fighter—300-H. P. Hispano engines
Ordnance Engineering Model D—300-H. P. Hispano engines

**A Loening Monoplane on the Ground**

U. S. Air Service Photo

**Loening Monoplane in Flight in the Clouds**

Pomilio—Liberty 8 engine
Pomilio—Liberty 12 engine
Verville—300 H. P. Hispano engines

TWO-SEATER FIGHTER

Lusac—11 Liberty—12 engines
Lepère (armored) C-21—Bugatti engine
Lepère Triplane (day bomber)—two Liberty—12 engines
Curtiss Triplane—Kirkham engine
Curtiss Ground Harassment Biplane—Bugatti engine
Loening 2-place Monoplane—Liberty 12 engine
Loening—300-H. P. Hispano engine
USD9A and B—Liberty 12
USXB-1—300-H. P. Hispano
USXB-2—Liberty 8
Thomas-Morse MB 1 and 2—Liberty—12 engine, geared Martin Bomber (day bomber)—two Liberty engines

The Thomas-Morse Company, it should be remarked here, also produced a scout machine that was primarily intended for advanced training. In the beginning it was the intention to complete advanced training of aviators in Europe, and great preparations were made at Issoudun, in France, and elsewhere, for that purpose. Later it was decided to complete the training of at least part of the flyers in this country. The Bristol Scout was recommended as the suitable machine for this purpose. When the sample was received in this country it was turned over to the Thomas-Morse people for adjustment and adaptation. It was the general plan then to have this company develop into the manufacture of single-place fighters using the rotary engines. A sample Nieuport was also provided for them as an object of study and source of suggestions. Ultimately the army aviation authorities reported adversely on the Bristol Scout design and it was abandoned. The Thomas-Morse Company then continued the development of a one-place machine, of its own design, using the Gnome engine at first and the 80-H. P. Le Rhone later, and this machine has since become one of the regular training machines.

The Morse MB-3, mentioned above, designed to take the 300-H. P. Hispano-Suiza engine, is a very promising machine.

Chas. M. Vought, besides designing the VE-8 single-seater pursuit machine, to use also the 300-H. P. Hispano engine, was first instructed to build a two-place advance training machine around the 150-H. P. Hispano. This machine had been approved and put into production at the plant of the Springfield Aircraft Corporation. Production was just beginning when the armistice was signed. It gave promise of great excellence, and was pronounced by veteran fliers as the best of all two-place training machines, foreign or American.

The Pomilio machines were the fruit of the effort to have Italian designers build models around the Liberty engine. Two of the Pomilio brothers were brought to this country, and the Alison shops at Indianapolis were turned over to them. Their single-seater promised speeds around 150 miles an hour or better.

The Loening machines are also very promising.

# CHAPTER XVI

## THE PROBLEM OF THE NIGHT-BOMBING MACHINES

THE problem of choosing types of night-bombers, and developing and putting them into production in this country, was even more baffling than the problem of the smaller 'planes. It led to even more public disapproval, because it was chiefly the night-bomber that would realize the popular desire to see the German hinterland punished and terrorized by the night-flying engines of destruction, even as France and England had been. Liberal provision for the big bombers was made in the 1917 program, but the difficulties were so great that the end of the war found a total production of only about 120 of them. These slow, enormously large, great-weight carrying machines required two or three engines to propel them and presented most difficult manufacturing problems. The selection of types was practically limited to the Caproni and the Handley-Page, each using Liberty motors. On the whole, the Caproni bi-

**General Peyton C. March, Chief-of-Staff, President and Mrs. Wilson, Inspecting Handley-Page Bomber at Washington. Small Single Seater at Right**

U. S. Air Service Photo

plane, using two Liberty engines, was probably regarded as the superior machine but it soon became involved in a maze of negotiatory complications regarding the rights, which caused the drawings to be withheld indefinitely and blocked utilization of the models that the first Italian air mission brought to America in the fall of 1917. As the Handley-Page drawings were obtainable, it was decided to put it into production, anyway, though it was well understood that its ceiling was low and that the advance in anti-aircraft guns might soon retire it.

The same old trouble as to drawings soon appeared in regard to the Handley-Page. The first set was received in August, 1917, but two complete sets followed later from England and each involved a change of practically all the parts. When it is recalled that there are more than a hundred thousand parts in each machine, the complications of adaptation to manufacture appear as appalling. The headquarters of the Handley-Page effort were placed with the Standard Aircraft Corporation, Elizabeth, N. J., but the manufacturing division of the work was distributed.

On account of the enormous size of these machines with their wing spread of more than one hundred feet it was evident that it would not be practicable to ship completely assembled machines abroad. It was therefore decided to make the parts in this country and ship them to an English plant for assembling. Even the packing of the parts so that they would withstand the vicissitudes of shipping was a delicate matter. Incidentally it may be said here that not only was this packing wonderfully well done with the Handley-Page parts but also with the De Haviland 4's that were shipped to France, and the manufacturers were cordially complimented on their fine work in this respect. A contract was entered into with the British Air Ministry for the erection of an assembling plant at Oldham in Lancashire. It was arranged that the parts were to be collected prior to shipment at a special warehouse of the Standard Company, which was also to complete the erection of ten per cent. of the machines for training use in this country.

Liberty engines of the standard 12-cylinder type furnished the power.

The fittings, often very intricate fabrications of pressed steel, were almost all made by the Mullins Company of Salem, Ohio.

The wood parts were supplied by the Grand Rapids Airplane Company, which was a combination of the Grand Rapids furniture manufacturers,

**The De Haviland 9, Successor to the DH-4**

**The First American-Built Liberty-Caproni**

whose great industry was thus brought into the airplane effort.

Delays comparable to those of the smaller 'planes of foreign design beset the work from start to finish. Aside from the engine installations, there was the always present problem of inadequate and altered drawings. Finally the English assembling plant was slow in building. When operations were discontinued one hundred full sets of parts had been shipped to England and seven complete machines had been erected in this country, the first one having been flown in June, 1918. Of course, there was a great accumulation of parts and production was in full swing. The following facts regarding the American Handley-Page are taken from official sources:

| | |
|---|---|
| Power | 2 Liberty 12's, 400 H. P. each |
| Climb to 7,000 feet | 18 minutes, 10 seconds |
| Climb to 10,000 feet | 29 minutes |
| Climb to 14,000 feet | 60 minutes |
| Total weight | 11,270 pounds |

On the trials from which these figures were derived the machine did not carry guns, ammunition, or bombs but did carry seven men, 390 gallons of gasoline, and twenty gallons of oil.

Engineers from the Handley-Page Company were brought from England to assist in the Handley-Page development in this country, but between vacillating advices from the front and the complications incident to redesign for American production, progress was very slow toward the stage of quantity production. Like many other war machines it can only be said of the Handley-Page that it was just getting into its stride when the signing of a piece of paper in Compiègne brought to an end hostilities and all that unimaginably great volume of production that America had planned and wrought for a war that might have lasted years longer.

It was not until January 1, 1918, that tentative agreements were made with the Caproni interests for the production of their night-bomber in the United States.

Soon thereafter Captain d'Annunzio with fourteen expert Italian workmen arrived in this country and undertook to redesign the Caproni biplane to take three Liberty motors. Unconscionably long delays ensued. These were partly due to the changes that were made in the organization of the Signal Corps, which left the executive impaired for a time, and partly to the difficulties in securing the hearty coöperation of the Italian military mission with the American plants which were working on the Caproni. The Fisher Body Company, of Detroit, was entrusted with the major part of the Caproni job and early made all its arrangements with characteristic rapidity and thoroughness, but it was not until the war was over that the production stage was approached, though a few samples had been completed. The Fisher brothers would not have believed in June that the end of the year would find them still shy of production, but they had to go through the same old story that has been told and retold of the tasks of naturalizing foreign machines for American production. In tests at Mineola, L. I., September 21, 22, 1918, the American-made Caproni made the following records:

| | Test No. 1 | Test No. 2 |
|---|---|---|
| Speed at ground level...... | 100 mi. per hr. | 103.2 mi. per hr. |
| Climb to 6,500 feet........ | 16 min. 18 sec. | 14 min., 12 sec. |
| Climb to 10,000 feet....... | 33 min., 18 sec | 28 min., 42 sec. |
| Climb to 11,200 feet....... | 49 min. | |
| Climb to 13,000 feet....... | | 46 min., 30 sec. |
| Total weight............. | 12,904 pounds | 12,350 pounds |

Glenn L. Martin early offered his services to the Aircraft Board and the Signal Corps and to him was assigned the designing of a powerful bombing machine which in size would be somewhat between the two-place day bombers and the great night-bombers. In fact, it was the intention of the authorities to have Martin produce a large and powerful machine for day bombing, with a very high ceiling and exceptional speed, but on account of its size it is here classed with the night-bombers. Mr. Martin received very promptly an order for four experimental machines, each using two Liberty motors. This order was placed early in 1917. Mr. Martin is one of the leaders of American aeronautical engineering. He had every assistance from the Government and he was able to surround himself with a competent organization in the Glenn L. Martin Company of Cleveland and yet it took him about a year to bring out his first machine. This fact is referred to only to indicate that American dependence for aircraft could be based only partly on American engineering and established manufactories of aircraft.

The first official test of one of these machines was made in October and aroused the greatest enthusiasm. Although its wing spread was only seventy-five feet, which was much less than that of the Handley-Page, its bomb-carrying capacity was not much less. Its ground level speed of 118 miles an hour was markedly greater than that of the Caproni or the Handley-Page and it was evident that its ceiling of probably more than eighteen thousand feet would be greater than that of the Caproni. Had the war continued the Martin would probably have been the basis of the future American heavy bombing squadrons.

Although the Martin bomber did not reach the production stage in time to be a factor in the war, the time and effort spent on it have not been wasted. It can be used for mail and express carrying and the transportation of freight and passengers. It can carry eleven passengers or in lieu of them a ton of mail. The air service is using the Martin machine for training purposes and is equipping it for forest border and coast service work.

Thus in the night-bombers, as in practically every other feature of the aircraft construction policy, these two things were done: (1) the most suitable designs were taken up; and (2) American designs were encouraged. All available American engineering ability was utilized in some way in designing and developing and at the same time British, French, and Italian engineers were brought to this country, either to adapt their existing designs to the Liberty engine and American production processes, or to work out new designs in the American environment.

The results of the preliminary tests of the Martin bomber, which follow, are interesting to compare with the corresponding figures for the Handley-Page and the Caproni, given above:

| | Test No. 1 | Test No. 2 |
|---|---|---|
| Speed at ground level | 113.3 mi. per hr. | 118.8 mi. per hr. |
| Climb to 6,500 feet | 10 min., 45 sec. | 7 min. |
| Climb to 10,000 feet | 21 min., 20 sec. | 14 min. |
| Climb to 15,000 feet | | 30 min., 30 sec. |
| Total weight | 9663 lbs. | 8137 lbs. |

**Glenn Martin Bomber with Two Liberty Engines**

U. S. Air Service Photo

# CHAPTER XVII

## AIRPLANE PRODUCTION RESULTS

WHEN one is disappointed in his own performance as compared with hopes and ambitions, there is a sort of consolation in finding that at least he did better than some of his fellows. We didn't produce 22,000 airplanes and all the extra parts that are the equivalent of many thousands more in the twelve months between July 1, 1917 and July 1, 1918. In those first twelve months, however, we did make 6146 airplanes of all kinds. There are no figures at present available for French and Italian or for German production. But according to the Lockhart report of November 1st, quoted in "Aircraft Production Notes" issued by the Bureau of Aircraft Production, it appears that in the calendar year 1915, which could correspond in aircraft production evolution to our fiscal year 1917–1918, the British Army and Navy production was only 2040 machines and that not until 1916 did it equal the American first war year production for the army alone. In 1917

British production attained to 14,400 'planes. In 1918 the British turned out after four years 30,000 machines and we 11,815 after one year, but had it not been for the armistice we would have produced 12,808. We were headed for a production of 4000 'planes a month by April, two years after our entry into the war. Our engine production was much further advanced and was probably going at the rate of twice as much as French and British output combined when the war ended. Our October rate of production of 'planes was actually at the rate of 20,000 a year. Two years before, outside of one plant, we were not making 50 airplanes a year.

As to 'planes actually in service at the front, it is nard to get figures that may be relied on. The Chief of Air Service, American Expeditionary Forces, estimated on July 30, 1918, that the Germans had 2592 machines in service at the front, and the Austrians 717. The relative standing of the Allies as of November, 1918, as given by Lockhart and as estimated by the American Air Service follows:

| | Lockhart's Report as of Oct. 1, 1918 | Air Service Est. Nov. 11 |
|---|---|---|
| France | 3609 | 3600 |
| Britain | 3641 | 2100 |
| United States | 1032 | 860 |
| Italy | 1017 | 600 |

These figures or, at least, those of the American Air Service are of fully equipped machines ready for service and do not include replacement machines at the front or in reserve or training machines. The smallness of the numbers in actual service in all countries as compared with total production is worthy of note. To maintain one 'plane in action eight had to be made yearly.

On account of the rapidly rising volume of production and the ten thousand or twelve thousand first-class flyers that the United States would have had in the spring of 1919, the outlook was that it would have taken the lead by a large margin. England and France had probably about reached the limit imposed by lack of human material.

## CHAPTER XVIII

### THE STRIVING FOR SPRUCE

THE effort to obtain the equipment for mastery of the air was more than 'planes and engines. It was also a thousand and one things that went with them to outfit a 'plane for service. And for 'planes and engines and for all the other things it was not only a struggle to make, but a struggle to find, procure, or devise the raw materials.

The Equipment Division (Aircraft Production Bureau) early grasped the significance of materials and accessories for aeroplanes. From the very start Colonel Deeds and his associates made prompt and bold decisions and put forth extraordinary efforts to stimulate and organize the production of the indispensable raw materials both for the United States and for the Allies. This work was foundation building and, therefore, its importance and magnitude were not appreciated, being obscured from public view in matter-of-course ordinary commercial preparation of raw materials plus the extraordinary production for war. The decisions as to what was needed were made quickly and as quickly carried into effect. From the cotton fields of the Sea Islands and the Imperial Valley of California to the somber and gigantic forests of the Pacific Northwest and the towering-stack industrial centers of the east, the country was searched and combed to devise and produce, and with hot haste, all the varied and numerous material needed.

The struggle royal was for spruce. To get spruce was no mere matter of telephoning the lumbermen to ship it. The spruce for airplanes must be of the best nature grows and it must be treated with the greatest care. As splicing was little resorted to at first it had to be obtained in single pieces of the length of the wings.

Spruce was an international problem. All the Allies required it. It was the wood *par excellence* for the framework of 'planes. On its successful production in abundant quantities depended not only the fate of our own embryonic program but likewise the programs of France, Britain, and Italy. The Pacific Northwest was the principal source of supply for the world. It had been logged commercially in connection with fir and sometimes other woods. Now came such a demand for it in quantity and also in quality that it must be logged on its own account. Trees of the proper quality had to be searched out in the dense and tangled forests of the Pacific slope of Washington and Oregon. The principal stand of spruce was in the remote fastnesses of Clarke County, in the southwestern corner of Washington. To reach it roads had to be slashed through the dank and dripping wilderness and whole forests scarred and even ruined to obtain the coveted white wood.

At first it was thought that the lumbermen of the Northwest would be able to meet the situation by their own efforts. Unfortunately the lumber industry of this section was prostrated in the spring and summer of 1917 by a great strike. It was partly a strike of organized labor and partly of the I. W. W., but the latter succeeded in dominating the movement for sinister and even hostile purposes. All lumber production in the Northwestern region was held up and there were many acts of savage sabotage. Moreover, the mills were not equipped to cut the straight-grained lumber required and they did not have men skilled in the selection and analysis of logs to secure the maximum amounts of suitable lumber from each stick. Again it was difficult to get the sawmill men to take the pains to meet the exacting requirements of the government. Months dragged by and the output amounted to only two and a half million feet a month, as against requirements of ten million feet. Finally the crisis arrived and extreme measures were taken immediately. On recommendation of the Aircraft Board the Chief of Staff of the army issued an order on October 17, 1917, creating the spruce production division of the Signal Corps, with Colonel Brice P. Disque in command, with headquarters at Portland, Ore. Colonel—later General—Disque, put soldiers in uniform into the forests and the mills—more than twenty-five thousand picked men—and organized the Loyal Legion of Loggers and Lumbermen, seventy-five thousand strong, as the patriotic answer to the I. W. W., including in it employers as well as employees. Its principles were no strikes, fair wages, and the meeting at any cost of the country's war needs in spruce. On March 1, 1918, the operators and the men entered into an agreement which gave General Disque absolute power to settle all differences.

Specifications were standardized and modified to meet milling conditions as far as possible; financial assistance was extended to operators who needed it, "methods of instruction were agreed upon and a price was fixed by the government for aircraft spruce, thereby stabilizing the industry and definitely providing against delays from labor disputes." Thus the I. W. W. were routed, and peace and productivity attained and maintained. The spruce forests were studied and mapped and hundreds of miles of railroads and wagon-roads were built to get out the logs. Farmers were encouraged to split or rive spruce that was available on their lands, and a cut-up mill with a capacity of 300,000 feet a day was erected in record time at Vancouver, Wash. Experienced men entered the Spruce Division as a means of satisfying patriotic aspirations to render service, and it became more and more efficient. Order was brought out of chaos and the spruce victory was won. The airplane factories at home were amply supplied, 60,000,000 feet going to them and 120,000,000 feet being moved across a continent and an ocean to back the gallant flyers of France, England, and Italy. It is very hard to give an adequate idea of all the difficulties that stood in the way of this admirable consummation. Besides the local and inherent difficulties there were great obstacles in the way of railway transportation to be overcome and even in procuring the logging and lumbering equipment that was necessary to the purpose.

There was also the technical problem of the proper drying of the lumber by artificial means in such a manner as to preserve its strength, the ordinary commercial practice being to dry it so as to assure retention of shape rather than of strength. This problem was chiefly solved by the efforts of the Forest Products Laboratory of the United States Forest Service at Madison, Wis., which in this and other wood-utilizing matters supplied the underlying scientific principles of treatment. It is asserted that in consequence American practice in this respect was better than that of France and England although the subject was a novel one in this country when the spruce effort began. The knowledge thus disseminated among the country's woodworkers will have a lasting benefit for commercial purposes.

As time went on, economical methods of utilizing the spruce were found, so that there was no such wastage from the log as at first. Splicing became general for the longer pieces and the required thickness was often attained by lamination, that is by glueing together two or more pieces. Where it had at first taken 5000 feet of spruce in the rough to yield the 500 feet placed in the 'plane eventually 1000 feet sufficed. It was also found that fir and other woods could be substituted for spruce, with care in preparation.

Somewhat similar problems were met with in the matter of mahogany and other hard woods suitable for propeller making, and the experience gained in treating and handling these woods for aviation uses will be of general benefit to the hardwood industries.

The success of the aircraft producers in dealing with the spruce problem, resulting as it did, in keeping the European airplane industry abundantly supplied with an essential material, is a conspicuous example of the important contributions that were made through their tireless efforts to the Allied air effort in other form than that of American 'planes and engines. Our work was not only, it should be remembered, to build up a military aviation body of our own, but also to keep the aviation corps of the Allies going.

# CHAPTER XIX

## DEVELOPMENT AND PRODUCTION OF DOPE AND COTTON FABRIC

ONE of the numerous difficulties that faced the aircraft managers in the development on an extensive scale of a great technical and complicated industry from the ground up was that of the fabric which covers the wings. Previous to the entry of the United States into the war the fabric used for this purpose had been made almost entirely from linen. Linen is made from a peculiar variety of flax grown under certain favorable conditions in Belgium, Russia, and Ireland. The Belgian supply was of course cut off when Germany invaded Belgium in 1914 and the Russian supply which had always been precarious was also cut off after the Russian revolution. Ireland then remained as the only source from which flax could be obtained for airplane linen for the Allies. A further complication arose from the fact that Great Britain used large quantities of flax in the manufacture of duck sheets and like materials. However, until August, 1917, the British Government representatives felt confident that a sufficient supply of Irish linen would be available for the American aviation program. Soon after that, however, it became evident that the Irish supplies were inadequate and could not be depended upon. In truth it was not until after Mr. Peter Fletcher, a large importer of linen, who was sent to England as a direct representative of the Signal Corps to procure aeroplane linen, reported the actual situation in Great Britain and Ireland, that it was realized that the United States must produce its own wing covering. As early as July, 1917, Mr. Fletcher reported that far from being able to meet American requirements the Irish mills would not long continue to produce enough fabric for the rapidly extending British aircraft manufacturing. So correct was Mr. Fletcher's forecast that it turned out that the cotton fabric originated in America was eventually drawn on by the Allies themselves, so short was the supply of linen. This is but another of the numerous instances of the way in which we supported the air fleets of the Allies while struggling to create our own.

On the receipt of Mr. Fletcher's report, the building program and the whole aviation enterprise seemed in danger from the lack of a single material. As each one of the ordinary training machines, or a fighting machine like the DH-4, needed about two hundred and fifty yards of linen and as the prospectus was for the construction of more than twenty thousand machines in the first year, it can be seen how essential was an abundant supply of a suitable fabric.

The Bureau of Standards came to the rescue. For several months before war was declared on Germany that Bureau of the Department of Commerce had been doing experimental work on airplane cloths; a large variety of fabrics had been examined and several experimentally promising cloths had been produced. As soon as it became evident that America must find some other fabric than linen for covering the sustaining surfaces of airplanes the problem was put directly up to the Bureau of Standards. There had been a decided prejudice against cotton but that material seemed to offer the only hope of sufficient quantities.

"It is long staple cotton or nothing!" the experts of the Bureau of Standards told the Equipment Division of the Signal Corps.

Without waiting for experiments to show which it would be, Colonel Deeds immediately placed orders for $4,500,000 worth of long staple cotton.

"It may be all off the market to-morrow," he said. "It is this or nothing—consequently, we will buy it all."

It did not take thirty minutes to decide on this venture.

General Cormack, of the British Military Mission, is quoted as saying that the creation and production of the type of cotton growth that is "at least the equal of the best aeroplane linen" was the greatest contribution in the way of raw material that America made to the joint aeroplane effort. All credit should be accorded for this prompt decision but the scientific men of the wonder-working Bureau of Standards (which filled many a deadly industrial breach in the course of the war) who conducted the experiments and the scientist of the Department of Agriculture who investigated long staple cotton nine years ago, must not be overlooked.

The experiments resulted in two grades of cotton airplane cloth: Grade A with a maximum weight of 4½ ounces per square yard and minimum tensile strength of 80 pounds per inch and Grade B with a maximum weight of 4 ounces per square yard and a minimum tensile strength of 75 pounds. A gratifying development as production was attained was that Grade A turned out to have a strength of 85 to 90 pounds. After February, 1918, this grade was used altogether, for the additional strength more than offset the slightly increased weight. As soon as it was certain that the new cotton fabric would be acceptable for that purpose the equipment division of the Signal Corps insured itself against any eventuality by purchasing 15,000 bales of Sea Island cotton, the long staple of which best adapted it to the purpose. Orders for 20,000 yards of cotton airplane cloths were issued in September, 1917. By March of the following year the production had reached 400,000 yards a month; in May, about 900,000 yards and at the termination of hostilities the rate of production was approximately 1,200,000 yards a month. Special manufacturing facilities had to be provided by the textile manufacturers who were engaged on this work and it kept about 2600 looms busy. Altogether 10,248,355 yards of this fabric were woven and after August, 1918, the use of linen, which had been declining in proportion as the production of cotton increased, was entirely discontinued.

The substitution of cotton for linen was one of the American achievements of the war, and is now considered not as a makeshift substitution but as providing a material at least equally good as linen.

It is doubtful whether linen will ever again be used in large quantities for the manufacture of airplane wings in this country.

Dope was another manufacturing problem. It is the preparation which is applied on all the fabric surfaces of the airplane in order to stretch the cloth tight and to fill the fabric and thereby create a smooth, waterproof surface. Over this dope ordinary spar varnish is applied to protect the surface. The dope problem was not so much one of difficulty of making material in this country as it was of interfering with the British munitions requirements, as acetone, which is the basis of cordite, an explosive extensively used by the British, is required in manufacturing one kind of dope. There are two kinds, namely, nitrate dope, which is made from the nitrate cellulose and wood chemical solvents, and acetate dope which is made from acetate and wood chemical solvents, including acetone. The latter kind had an advantage in that it is slow burning, whereas nitrate dope burns very rapidly. The latter not being exposed to incendiary bullets when used on training 'planes would do for them but acetate dope was indispensable to fighting 'planes, and nitrate was the chief form of dope at the time of our entry into the war. The Allied governments, especially the

British, had been consuming the major part of the output of acetone and like products, and it was a matter of grave concern to the British Government when it found what extensive quantities of acetone would be required in the manufacture of American aircraft. It was estimated that the American demand would be twenty-five thousand tons for the 1918 program alone, whereas the requirements of the Allies and those of domestic commerce would be alone greater than the total supply ordinarily available. Faced with this situation it was therefore determined that the government should take control of efforts looking toward increased production. A new kind of dope had to be devised and this necessity led to many and diverse chemical researches, for there was not only a shortage of acetate of lime, but also of the refined ingredients needed in the dope such as cellulose, acetate, acetic anhydride, and glacial acetic acid. It was necessary to commandeer the entire existing supply of acetate of lime, it being the base from which acetone is made, and also to commandeer other supplies needed for this work. By means of the government's active interest and cash advances ten large chemical plants, representing an investment of about twenty million dollars, were established at Collinwood, Tenn.; Tyrone, Pa.;

Mechanicsville, New York; Lyle, Tenn.; Fremont, Mo.; Sutton, W. Va.; Shelby, Ala., and Terre Haute, Indiana.

As a result of these efforts, 1,324,356 gallons of dope were manufactured during the war, which was enough to meet all requirements. Had the war gone on the new plants which the government had started would have been able of themselves to meet all requirements without further commandeering of privately owned plants. Pending the completion of the new plants, the entire available supply of chemicals required in the manufacture of dope was moved and allocated to the different countries by the wood chemical section of the War Industries Board, the British undertaking to act for themselves as well as the other Allies. An arrangement was also made between the Signal Corps and the British War Mission by which the American and British governments were to share equally losses resulting from the erection of the new government plants, or otherwise.

# CHAPTER XX

## MACHINE GUNS FOR AIRCRAFT

In view of the many fighting uses made of airplanes during the war it is not easy to realize that the war in Europe had lasted about a year before they were seriously taken as a new means of combat. Their uses for observation and scouting were so important and so much relied on that little attention was given to their possible combat uses. Indeed, stories are told of hostile aviators confining their inimical operations to shaking their fists at each other. The early use of offensive weapons was confined to revolvers; then service and automatic rifles and shotguns were taken up and grenades and darts were used. The first step in the use of machine guns was to take up an ordinary ground gun, the observer operating it from his shoulder. As early as 1912 a machine gun had been successfully operated from an airplane in this country but it was an isolated experiment. At the outbreak of the war the French had a few heavy airplanes that were designed to carry machine guns, but the fact is that as a bearer of weapons not much attention was paid to the airplane until the war had been going on a year. One reason why little attention was given to fixed armament was that the pilot could make little use of a gun firing forward because of the interference of the propeller; and, indeed, on account of his attention being required in the operation of the 'plane he could make little use of a weapon that was discharged laterally. It was not until the idea of a synchronizer was developed, whereby a fixed machine gun was so timed in the discharge of its projectiles that they passed between the rapidly revolving blades of the propeller, that the airplane machine gun era was entered. Before that fixed machine guns were mounted above the 'plane at a sufficient height to clear the arc of the propeller with their fire. It was difficult to reload a gun thus placed and so, to bring it down to the pilot's level, the synchronizer was developed. At first the bullets were actually discharged blindly through the revolving propeller, those that struck the blades being deflected by properly placed steel plates, or else the chance of destruction was taken, as it was found that several bullets might pass through a blade before it would break. The

Curtiss JN 4 Training Plane, Showing Marlin Machine Gun and Part of Synchronizing Device

Germans appear to have been the first to put the synchronizing device into general use, with their Fokker monoplanes in 1915. Even as late as 1917 machine guns were used without synchronizers. It is not possible to say who hit on the idea of so regulating machine gun fire that the bullets would pass between the propeller blades, but credit is quite generally given to the famous French aviator, Roland Garros.

Aircraft armament was even stranger to Americans at the beginning of the war than aircraft themselves. Neither the ordnance department nor the Signal Corps had any experience with machine guns worth mentioning. They were not used on the few 'planes that were sent to the Mexican front during the Villa disturbances. Nothing was then known in this country about the installation of aircraft armament, although the Savage Arms Company was manufacturing Lewis flexible aircraft guns for the British Government. To show how difficult a task the matter of armament was to producers who knew nothing about it, some attention should be given to the special requirements of aircraft machine guns. As little can be done in the way of overhauling guns while in the air, the jamming of a gun may be fatal, as in that case the aviator is left at the mercy of the enemy. The gun must be so constructed that it will work in any position. To prevent jamming the ammunition must be exceptionally excellent. Also a machine gun to be adapted for use in the air must have a very high rate of fire, as the gun is usually on the target for only a second or two, and every possible shot counts. With ground guns a rate of fire of 500 shots a minute is considered enough, but aircraft guns deliver from 950 to 1000 bullets a minute. The aircraft guns are simpler than ground guns in one respect, and that is that water-cooling is not required for them as the conditions for aerial combat do not necessitate continuous firing for a long period.

Single-seater machines use only fixed guns which are so placed that the barrel is parallel to the axis of the airplane and the gun is therefore aimed by aiming the 'plane, and the guns of such machines must, as previously explained, shoot through the propeller. The flexible guns that are used in the rear seat of two-place machines are, of course, not fired through the propeller and do not require synchronizing devices but they do have special mounts which permit them to be fired in any direction. It is interesting to note that all the flexible aircraft guns in use among the Allies have adopted the principle of the Lewis machine gun, which was

Installing Liberty Engines in DH-4's at the Dayton-Wright Plant invented by Colonel Isaac N. Lewis, U. S. A., retired. Experts say that the Lewis gun principle of a drum magazine is better adapted to flexible guns than any type of belt feed. In this respect the Allies had an advantage over the Germans whose flexible gun used the belt feed.

The only fixed gun used by the French and British at the time of our entry into the war was the Vickers, the entire production of which in the United States had been already contracted for by the Allies for use in the ground form.

Through efforts of officers of the equipment division of the Signal Corps the Marlin-Rockwell Corporation in New Haven, Conn., developed a fixed type of aircraft gun. The Marlin was chosen because it was the only gun then available. Notwithstanding marked opposition an order for Marlin guns was placed in the fall of 1917 and resulted in giving the American air service a sufficient supply of fixed guns.

Had it not been for this order other departments of the service would have been seriously handicapped. For example, on June 24, 1918, the chief of ordnance presented cable No. 1168, from the A. E. F., demanding 7220 machine guns for tank use. Within twenty-four hours 500 guns were shipped by express to France from the air service depot at Fairfield, Ohio, and the remaining 6720 guns were forwarded in the next two weeks. The Lewis aircraft guns were first ordered on December 19, 1917. Deliveries began in February, 1918, with about 1500 guns a month and by October 6000 guns had been delivered. However, the Marlin gun was used at all times as the American fixed aircraft machine gun. The first order was placed by the Signal Corps on September 25, 1917, and over 37,500 were turned out before December, 1918, as many as 7000 guns being produced in one month. Satisfactory as the Marlin gun was the Browning aircraft machine gun was considered superior, chiefly because it had the high rate of fire of about 950 shots a minute and was extremely reliable and very accessible. In time it would probably have replaced the Marlin and all other fixed machine guns.

The Marlin gun shoots a 30-caliber bullet at the rate of 600 to 650 shots a minute. American aircraft guns were equipped with the hydraulic type of gun control known as the Constantinesco, with some special American adaptations. In this type of gun the impulse of the cam of the aircraft engine is transmitted to the gun through a system of tubes containing glycerine under high pressure. This device is so effective that at maximum fire

1300 shots per minute can be fired between the blades of a propeller turning at the rate of 1600 revolutions per minute, without striking the propeller blades. Even four guns have been fitted to one 'plane and so controlled that none of the bullets hit the blades. At the time of the signing of the armistice 6827 of the Constantinesco gears had been manufactured in this country and shipped, although nothing whatever was known of their nature or process of manufacture at the time we entered the war.

Early in the war (with the Bolling Commission) 130 selected American mechanics were sent abroad to familiarize themselves with the many and various problems of aircraft mechanisms. One of these was named Nelson and to him was assigned the study of the synchronizers. He undertook the development of a mechanical synchronizer, carrying on this work in the experimental laboratory of the Signal Corps and the Aircraft Production Bureau at McCook Field, Dayton. He succeeded in getting a machine that will permit of more rapid firing and the concentration of the bullets in a smaller arc than is possible with any other type of synchronizer. Using the Nelson control device it is possible to fire a Browning machine gun through a four-blade propeller without hitting any of the blades. More than one hundred of these synchronizers were completed, and had the war gone on they would have superseded the hydraulic synchronizer in both American and foreign practice.

Enormous quantities of ammunition were required for these guns and it was being made at the rate of ten million rounds a month. Besides the ordinary projectile ammunition there had to be developed tracer cartridges which leave a trail of smoke behind them, armor-piercing cartridges, and incendiary cartridges containing a charge of yellow phosphorus and intended to set fire to whatever they strike. Many of the armament sundries such as the metallic disintegrating cartridge belts of the machine guns, the details of fitting the guns to the 'planes, the providing of proper sights, electric heaters for keeping the guns warm at high altitudes, etc., constituted very considerable problems of development of manufacture in themselves.

# CHAPTER XXI

## RADIO TELEPHONE AND AERIAL PHOTOGRAPHY IN CONNECTION WITH AERIAL OBSERVATION, THE CHIEF FUNCTION OF MILITARY AVIATION

THE thrilling duels and other combats of the air which have marked this war as being conducted in a third element which was not the medium of attack or defense in preceding wars have centered public attention on aerial combat as the end of military aircraft. Attacks on troops by airplanes flying low and raking them with machine-gun fire have led to their being called the cavalry of the air. Audacious bombing expeditions against enemy bases and far behind the lines have led them to be considered as a sort of substitute for artillery. No doubt the popular idea of the program of building an aircraft fleet whose vessels would be numbered by the thousands was that they would by means of bombing attacks on the enemy become one of the chief agencies of winning the war. While military men admit the great value of airplane offensives on account of their effect on the morale of enemy troops and civilian population, the prevailing view among them seems to be that the chief military use of the airplanes is as a means of securing information—as the modern scout. Time might have proved this to be an erroneous view, as it has in the course of history overthrown many a technical view. However, this was so strongly the conviction of the French army that it is authoritatively stated that the reason the French did so little in the way of bombing German towns and cities, even when their own communities were being attacked nightly, was their judgment that the results were not worth the losses of men and machines that they would entail. Their conception of the airplane was that it was for observation and direct combat work at the front. Our own officials were largely of the French view. Whether this be the right or the wrong position is immaterial at the moment, except that it supplies a justification of the fact that the only American made service 'planes that reached the front were of the observation type, though also adapted to combat. In other words, the type of machines that we sent to France was the type that was considered most important, though it was not the type whose exploits got on the front pages of newspapers.

"The basis of all war-time aviation is the observation air service," says Lieutenant Colonel Lewis H. Brereton, U. S. A., in some notes on the activities of the American air service on the Western front, "and the proportions of other branches of the air service to this arm are always related to the necessities of the special situation, that is, the strength of the opposing air service, the kind of operations which is in progress, etc. Our experience is that the proportion of one pursuit squadron to one squadron of any other type, that is observation or bombardment, was sufficient, but not ample. . . . The three general classes of military aviation can be headed under the titles observation, pursuit, and bombardment. . . . Our best observation 'planes were the Salmson and the DH-4, Liberty motor. The Salmson was furnished by the French and was equipped with a nine-cylinder radial stationary motor of about 275 H. P. It was a very staunch, reliable ship and exceedingly popular both with the French and with us. The DH-4, of course, developed nearly 400 H. P. and was a very capable ship.

"The DH-4 was also used for bombardment. These 'planes carry two men, pilot and observer, and without long instruction and the overcoming of the effects of airplane vibration on the apparatus. As to the first problem, only, it may be remarked that a way was found literally to strain the sound waves of the voice from those of the motor, so that the observer could transmit his voice, though when talking into the transmitter he could not hear himself.

As far back as 1910 Col. C. C. Culver of the Signal Service, looking upwards at a flock of eleven airplanes demonstrating at an aviation meet, at Belmont Park, remarked that if they could only talk to each other another wonder would have been accomplished. Eight years later, Colonel Culver, who had kept his eye on this objective all the time, was to have the proud distinction of demonstrating in France the complete superiority of the American method of adapting radio telephony to aerial uses. Largely due to Colonel Culver's insistent interest in the subject of radio communication as applied to airplanes, the successful demonstration of long distance radio telephony for naval uses by the engineers of the Bell system, and particularly of the Western Electric Company in 1915, was followed by successful studies of the utilization of the radio telephone for various military purposes, such as communication with and

**View of Observer's Cockpit of DH-4, Showing General Arrangement of Apparatus, Including Wireless Sending and Receiving Outfit, and Scarff Mounts for Lewis Guns**

and three or four machine guns. Two of these guns are mounted on the tourelle or revolving mount and can be fired in almost any direction by the observer in the rear of the pilot; the remaining guns are fired by the pilot in one direction only, straight ahead. Right here you can see the enormous advantage of the two-place ship over the one-place ship in combat. The monoplane can only fire one way, that is heading straight, as the guns are fixed. The observer of the bi-place machine can fire all the time his opponent is in range except when the opponent gets into one of his so-called dead spaces; that is, in front, under or over his wings, or under his tail. I would myself be perfectly willing to engage in combat against two enemy pursuit ships, if I have a good observer, in either a DH or a Salmson bi-plane."

The air service observation is the most important intelligence agent of an army, according to Lieutenant Colonel Brereton. The high command looks to it for the greater part of its information concerning the movements and dispositions of the enemy and also for information regarding his intentions. The latter class of information, which is exceedingly important, is derived largely from aerial photography, and Colonel Brereton illustrates this function by giving the outlines of the

**Observer's Seat in DH-4, Showing Lewis Machine Guns on Universal Mount**

U. S. Air Service Photo

manner in which the French High Command ascertained the German intentions in the offensive beginning July 15, 1918. For two weeks before that day French aviator-observers had systematically photographed the whole of the Marne salient—Rheims, Château-Thierry, Soissons—and by studying the data thus obtained the French General Staff was able to forecast the German drive within forty-eight hours and ascertain almost exactly the sector of the effort. The enemy's intentions were disclosed by the appearance of new second-line defenses, by new supply depots and ammunition dumps and the enormous increase of traffic on the highways, the pushing of ammunition dumps nearer to the front, new telephone lines and roads; and finally as an indication of the imminence of the attack "a sudden great increase in the activities on the roads immediately behind the German front lines; the construction of ramps and new roadways leading from battery positions and trenches to facilitate the egress of troops; and one particularly damning indication of attack, the fortunate location by a French aerial observer of a German pontoon train, located not far from the Marne and just north of Dormans." With this and other information the French High Command was able to make such dispositions that the German offensive was not only stopped in its tracks but was immediately followed by an Allied offensive that reversed the whole course of the war and continued until the Germans acknowledged defeat.

Observation is just as important during a battle as before it. The work of the observation 'planes while the battle is progressing consists among other things of keeping headquarters informed of the progress of its own front lines, as well as the locations of the infantry. This involves flying very low for visual observation and identification of units and is very perilous as the observer is taking chances with the barrage fire of his own troops, to say nothing of the flock of pursuit 'planes that is seeking to destroy him, with the result that the two-place observation 'plane has to fight an unequal battle before it can get away with its information.

The use of bombing 'planes in battle is well illustrated by Colonel Brereton's account of the greatest aerial concentration that took place during the war, viz., at Damvilliers, during the American offensive of the Argonne-Meuse, which began on September 26th. The reports of the observers indicated a tremendous concentration of German artillery and infantry at Damvilliers in the center of a forest eight kilometers behind the German front lines, apparently preliminary to a German counterattack. Of what follows Colonel Brereton says:

"After a consultation with the High Command, the Chief of Air Service (Brigadier General William Mitchell) gave directions to our bombardment pursuit aviation and to the French aviation under our command for a concentrated bombing attack on the woods in which Damvilliers was located. Shortly after the order was issued, one of the largest formations of airplanes ever assembled passed from army headquarters on its mission. It consisted of 352 ships, French and American, composed of French and American bombardment squadrons with pursuit squadrons for protection. More than thirty-two tons of bombs were dropped in the space of less than thirty minutes. The attempt of the German aviation to block this maneuver resulted in a spirited air fight in which the enemy 'planes were cleared from the air, having had twelve of their 'planes destroyed and several others shot down out of control. Our losses were—one 'plane shot down on our front lines and eight aviators wounded, none missing. The counter-attack was completely dispersed and, although the German casualties are not known, photographs taken of the area bombed the following day showed very extensive demolishment of the greater part of the area and it was subsequently known that parts of two German divisions had been concentrated in this area."

Viewed in this light the chief purpose of a military airplane is to act as a conveyance for the observer or scout and for the instruments he requires in doing his work. Chief among these are the radio telephone and the photographic camera, the one being voice and ear and the other the eyes of the airplane. Both underwent tremendous development during the war, and the American contribution to such development was very important, especially in respect to the radio telephone, it being generally conceded that the American apparatus was best. The radio telephone is of great use, not only as a means of communication between the units of a flying squadron but chiefly in connection with directing artillery fire. Radio telegraphy was further developed than radio-telephony at the beginning of the war and when the United States entered it the former had been very successfully adapted to aerial use. The Signal Corps was especially at home in this work and thousands of radio telegraph sets were promptly provided. In fact aerial radio work had been closely studied and carefully developed since as far back as 1911.

Previous to the application of aerial electrical communication, indirect artillery fire, which is practically the only kind of artillery fire in modern warfare, was controlled—in so far as it was controlled at all—from airplanes or balloons by various forms of visible signals, which were obviously inadequate.

Before the United States entered the war little had been done to adapt the radio telephone to aerial uses. About that time both the French and English began to make considerable headway, and our specialists worked unremittingly on the idea. It is superior to radio-telegraphy as used in the air because it is communication by word of voice instead of by signals. It provides the means of conveying full instead of skeletonized information both to the ground and to other airplanes. The subject is so technical that no attempt will be made to describe the apparatus here. Some of the problems that had to be solved to utilize radio telephony were the overcoming of the drowning effects of the thunderous noise of the motor, the rush of the air, and the rattle of machine guns; the reduction of the weight of the apparatus to smallest possible minimum; the avoidance of all fire hazard from the electric current; the obtaining of such a simplicity that flyers could operate it easily and without long instruction and the overcoming of the effects of airplane vibration on the apparatus. As to the first problem, only, it may be remarked that a way was found literally to strain the sound waves of the voice from those of the motor, so that the observer could transmit his voice, though when talking into the transmitter he could not hear himself.

As far back as 1910 Col. C. C. Culver of the Signal Service, looking upwards at a flock of eleven airplanes demonstrating at an aviation meet, at Belmont Park, remarked that if they could only talk to each other another wonder would have been accomplished. Eight years later, Colonel Culver, who had kept his eye on this objective all the time, was to have the proud distinction of demonstrating in France the complete superiority of the American method of adapting radio telephony to aerial uses. Largely due to Colonel Culver's insistent interest in the subject of radio communication as applied to airplanes, the successful demonstration of long distance radio telephony for naval uses by the engineers of the Bell system, and particularly of the Western Electric Company in 1915, was followed by successful studies of the utilization of the radio telephone for various military purposes, such as communication with and

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between ships at sea. Dr. Frank B. Jewett, chief engineer of the Western Electric Company, and his assistant engineers, including Edward B. Craft and E. H. Colpitts, were finally interested in concentrating their attention on the radio telephone as adapted to airplane service. Then there came a day when the Aircraft Board and the Joint Army and Navy Technical Board were wonderingly introduced to the achieved apparatus at Dayton, to the work of developing which they had given every possible encouragement. After that demonstration, however, it was necessary to convince the active army of the merits of the new means of communication. Then after the army had approved it, came the work of manufacturing the radio-telephone sets and installing them on the planes.

"It would take volumes to describe the innumerable experiments and heartbreaking failures before the first real successes," says Mr. Craft in an article on the subject. "At length a head set inside an aviator's helmet was devised, which would exclude the noise of the airplane engine and the rushing air. A brilliant line of experiments, largely at the hands of J. P. Minton, resulted as well in a transmitter or microphone, which possessed the remarkable quality of being insensitive to wind and engine noises, and at the same time very responsive to the tones of the voice. Then three solid months of the hardest kind of work was necessary to iron out all the kinks and get the thing in shape so that it might be considered a practicable device for the everyday use of other than experts.

"Finally in October, 1917, we reached the point where we thought it was time to spring it on the A. E. F. and accordingly Colonel Culver was sent abroad with several trunkloads of the apparatus to show our people overseas that we had not been asleep on the job and had a new tool for their use. In early December the next historical event took place at South Field, Dayton, Ohio. To those of us who were mixed up in this little affair those were three days which we will never forget. Colonel Carty and Colonel Jewett were in the party which was made up of admirals, generals, foreign representatives and experts galore, all willing to be shown but decidedly skeptical.

"It must be remembered that the idea had not yet been told to any but the wild enthusiasts who had been living with the job for the past six months. Pilots are, to say the least, fussy about what is loaded into the 'planes they are to fly, to say nothing of the trailing wires which serve as antennæ. Designers and constructors hold much the same view, so it took a lot of maneuvering and diplomatic jockeying to get our stuff aboard and into the air. Finally, just about dark on the evening before the fatal day we did get one machine into the air, and found that the apparatus worked.

"The plan was to have two 'planes in the air at once and for the official party to listen in at a ground station located on the top of a hill on Moraine Farm near the field. That night we all congregated in one of the rooms of the hotel, worked out our scenario, and held a rehearsal. I must confess that I didn't sleep very well that night. Next day we were out at the field bright and early, fussing around trying to keep busy until it was time for the big show. Upon arrival of the exalted ones we showed them the apparatus in the 'planes and explained what it was expected to do.

"They went to our little station on the hill, where we had rigged up a loud-speaking receiver connected to the wireless apparatus so that all could hear without the use of head sets. The 'planes left the ground and after what seemed an interminable length of time we got the first sounds in the receiver which indicated that they were ready to perform. The spectators were only mildly interested and some seemed a bit bored.

"Suddenly out of the horn of the loud speaker came the words, 'Hello, ground station. This is 'Plane No. 1 speaking. Do you get me all right?' The bored expression immediately faded and looks of amazement came over all their faces.

"Soon we got the same signal from No. 2 and the show was on. Under command from the ground the 'planes were maneuvered all over that part of the country. They were sent on scouting expeditions and reported what they saw as they traveled through the air. Continuous conversation was carried on, even when the 'planes were out of sight, and finally upon command they came flying back out of space and landed as directed.

"From that moment the radio telephone was sold."

Another form of radio adaptation enables the observer to locate his position with reference to certain fixed points by means of radio signals sent from the land. In this radio compass development as well in radio telephony the United States was well in the lead both in engineering and in production.

Photography is essentially the means of aerial observation. The sensitive plate can detect at

10,000 feet what the eye does not perceive; moreover, it records as it observes. Aerial photography made the recent war unlike all others, because it supplied such accurate information of enemy dispositions and lines of entrenchments, roads, supply bases, etc., that each side was about as well informed of such enemy affairs as of its own. Combined with direct visual observation it also made it very difficult to move large bodies of troops to new positions without detection. Thus surprises became very difficult, and were only possible by night marches and the utilization of weather unfavorable for observation. The chief value of aerial photography lies in its map-making possibilities, and cameras were developed that automatically mapped the underlying country as the airplane moved over it, even at great heights.

Aerial photography militarily applied was entirely new at the beginning of the war in Europe but it developed with great rapidity, so that when the United States came in it was utterly unprepared in this regard, the nations at war having, of course, kept developments and inventions to themselves. Apparatus had become very refined, and highly specialized and complicated. Some work in aerial photography had been done in this country by Arthur Brock, Jr., of Philadelphia; the

G. E. M. Engineering Company of Philadelphia, and the Eastman Kodak Company of Rochester, N. Y. Also the Signal Corps and the Bureau of Standards had given some study to mapping cameras. The Allies soon communicated their knowledge and experience, but it was necessary for our manufacturers to make the equipment, and improve on it if possible. Both these things were done, and before the war was over, 1164 automatic aeronautical cameras had been made complete with their spring suspensions to offset vibration, motors, and other accessories.

This figure refers only to the mapping cameras. Large quantities of hand cameras and photographic accessories of every kind were supplied. The amount of supplies procured and forwarded was prodigious. During the Argonne advance in four days alone the American observers took 100,000 pictures of the enemy line. The number of prints of these pictures is not given but in the British service as high as 280,000 prints were issued in a single month. It was the excellence of the photographic equipment as well as the provision of a sufficient number of airplanes to hold and use them, that enabled General Pershing to state that "no army ever went out with the information as to what was in front of it as the American army did in St. Mihiel and the Argonne." This authoritative statement is sufficient answer to the captious critics who were wont to assert bitterly that our army fought "blind" in France.

The development and making of the peculiar sort of lens required to take detail photographs at great heights, the devising of ray filters to overcome haze, were scientific, technical, and mechanical problems of the utmost difficulty. And yet, it has been well said that the cameras themselves were only the beginning of successful aerial photography. Among the articles and supplies that had to be provided in great quantity were lenses, paper, plates, chemicals, tanks, trays, printing machines, sterescopes, and traveling dark rooms. In the month of October alone more than 1,500,000 half sheets of photographic paper were shipped and 300,000 dry plates, more than 20,000 rolls of film and forty tons of chemicals.

The placing of photographic and radio apparatus in the airplane was one of the problems that gave the 'plane designers trouble. And these were only a part of the equipment for which the right place and sufficient space had to be obtained. It was nothing less than a complex, time-killing puzzle. And if placing and the necessary designing and redesigning were a limitation on production it is an equally important fact that the limit of effective production of the 'planes themselves depends on the accessories. An airplane without the military accessories is as useless as an untrained civilian is as a soldier.

So, making airplanes for the war was not only a matter of engines, wings, and fuselages, but it was that of photographic equipment, oxygen apparatus, aerial navigating instruments, radio, guns, bombs and bombing apparatus, rockets, flares, special clothing and personal equipment for the aviator, and much besides. The development or adaptation of all this apparatus as well as its manufacture had to go forward parallel to that of the airplanes themselves. In fact, the problems of all sorts were so complex and interrelated that the aircraft managers stoically abandoned as a thing impossible an explanation that would adequately answer the criticisms that were showered upon them. One had to be on the inside to understand, and being there he was condemned to suffer in bitter silence uninformed fault-finding that was at times little short of scurrilous.

# CHAPTER XXII

## AIRPLANE BOMBS, AERIAL PYROTECHNICS, AND AVIATORS' PERSONAL EQUIPMENT, ETC.

It is not possible in a brief work to discuss in detail the important subject of airplane equipment. Machine guns and photographic equipment have been described briefly and a short account of airplane bombs, aerial pyrotechnics, and aviators' personal equipment such as clothing and the oxygen apparatus will be given in this chapter.

Bombs had been dropped from airplanes during the Italian Tripolitan campaign and American aviators serving with Mexican civil war forces had used them. The German Zeppelins were the first aircraft to attempt to use bombs systematically. At first, however, they were not very effective because not properly designed and incapable of accurate aiming. Owing to the fact that an airplane is moving rapidly when the bomb is discharged it describes a curve as it falls, and must therefore be released before the airplane is directly over the object it is desired to hit. The proper shape is somewhat like that of a torpedo with a fin-tail to hold the bomb in the proper position. Traps or release mechanisms must be provided that will detach the bombs from their storage places beneath the fuselage, or the wings, or in the case of the large bombers from inside the fuselage. To promote accuracy of projection, bomb sights must be provided. These devices are ingeniously arranged so that when adjusted to height, speed, and wind, the bringing of two sighting points into line gives the aim. During the war there were produced in the United States 8371 of these sights, following the English Wimperis model. Releasing traps were provided for all the machines that were designed to carry bombs.

Three general kinds of bombs were made, viz., demolition, fragmentation, and incendiary. The demolition bombs, used against buildings and earthworks, were made in weights of 50, 100, 250, 500, and 1000 pounds. Such bombs are made with a light steel casing filled with T. N. T. or some other high explosive and have a detonating mechanism that is made ready for action on contact at the moment it is released from its position. Most of these bombs were of the 100- and 250-pound sizes. The fragmentation bombs usually weigh about

A Completely Equipped De Haviland 4, Showing Bomb Racks under Lower Wing, and Fore and Aft Machine Guns

U. S. Air Service Photo

20 pounds, have a thicker case than the demolition bombs and are arranged to explode a few inches above the ground. These bombs are used against personnel and depend for effect upon the scattering of the fragments. Incendiary bombs weigh about 50 pounds and are loaded with oil emulsion, thermit, and metallic sodium which upon the explosion of the bomb burn with intense heat for a few minutes. These bombs are used particularly against ammunition dumps and for the purpose of starting fires.

Had the war continued another six months, the American aircraft producers would have treated the Germans to a surprise, comparable only to the introduction of poisonous gas and tanks as weapons of war. A small and inexpensive automatic airplane, fitted with a specially adapted Sperry gyroscope as a stabilizer had been secretly devised and developed and conclusively tested. Loaded with several hundred pounds of T. N. T., it would follow a set course to a distance of forty or fifty miles or more and then, at the predetermined place, would shed its wings, the fuselage plunging to the ground as a huge bomb. All preparations had been made to manufacture and send 100,000 of these engines of destruction to the front. It was confidently believed that they would have turned the German

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Pyrotechnics were used during the war by the aerial forces to signal to and from the ground or back and forth in the air. For this purpose service airplanes carry a signal pistol known as the "Very" pistol. Its ammunition consists of cartridges not unlike those of a shotgun shell but larger, and are in effect the ordinary Roman candle. The cartridges come in three colors, red, green, and white, and by using these colors in different combinations a large number of different signals is possible. The stars are visible in the daytime as well as at night. Special use of the pistol at night time is to enable the pilot to signal his approach to the home landing-ground. The pistols have also been used to enable the aviator to carry out his orders to destroy his machine in case of landing in enemy territory by firing into inflammable parts of the airplane. This is one of the few items of airplane equipment that was purchased abroad and was not made at home. To facilitate night-landing, wing-tip flares are also used. These consist of a small cylinder of magnesium material in a metallic holder, one being fitted under each lower wing of the 'plane, and can be ignited by means of an electric current. In making a night-landing these flares when lighted brilliantly illuminate the ground beneath.

The airplane flare proper is used for illuminating enemy territory during night-bombing raids. Each weighs about thirty-two pounds and is contained in a cylindrical sheet-iron case, the illuminating charge being capable of giving a light of thirty-two thousand candle power for about ten minutes. The flare is attached to a silk parachute, so attached to the airplane that it can be easily released. Immediately after discharge from the case the parachute opens and so lowers the flare slowly to the ground, the light from it brightly illuminating a large area underneath. An incidental effect of the flares is to dazzle the eyes of anti-aircraft gunners so that their aim is very inaccurate. They are also of value in obtaining aerial photographs at night. American production of these flares was just starting when the war terminated.

Even such apparently insignificant matter as obtaining suitable clothing for aviators was in effect one of no little difficulty. At first like almost everything else connected with the aviation effort it was not known just what was the proper apparel equipment for an aviator, or a balloonist. It was necessary that the clothing should be as warm as possible without being cumbersome, also that it should be strong and durable and that each part should be adapted to the others. The head-gear consisted of a woolen hood of double thickness, having between its layers an electrically heated unit connected with an air-driven generator on the 'plane, by copper wires that also extended through the suit proper. A soft leather helmet lined with fur was worn over this and the face was entirely covered with a leather mask lined with wool with an opening for the eyes over which was fitted a pair of goggles. When using the radio a special radio helmet was worn in place of the fur-lined helmet, so fashioned as to hold the receivers of the wireless telephone over the ears.

The body clothing consisted of a one-piece flying suit extended from the feet to the throat, belted and tightly buttoned at ankles and wrists and lined throughout with fur. One of the little big problems of the war was the securing of enough of the right kind of fur for this purpose. Chinese Nuchwang dogskin was chosen for this purpose and it demanded practically all of the skins that could be obtained in both this country and China, and nearly five hundred thousand of such skins were obtained. Through these suits between the fur and outer covering were placed wire cables ending in snap-fasteners at the wrists, ankles and neck to which could be attached a silk covered wire leading to the electrical-heating units in the gloves, moccasins, and helmets, all of which were electrically warmed. For the hands, besides the electrically heated gloves was provided a pair of muskrat fur gauntlets extending well up the arms and so designed as to allow the trigger fingers to remain in a fur-lined pocket or be withdrawn from it when necessary without removing the glove. On the feet were worn both electrically heated socks and electrically-warmed moccasins extended well over the calf of the leg and lined with heavy sheep wool. Of course, there were many other items of aviators' clothing, such as sweaters, leather coats, fur-lined coats, and two styles of hard helmets used mostly by students and observers, and many different kinds of goggles. As a result of the great care taken in these matters it was generally acknowledged that our flyers were by far the best and most efficiently equipped at the front. More than 50,000 fur-lined flying suits, over 100,000 leather helmets, more than 100,000 leather coats, and over 80,000 goggles were included in a personal equipment

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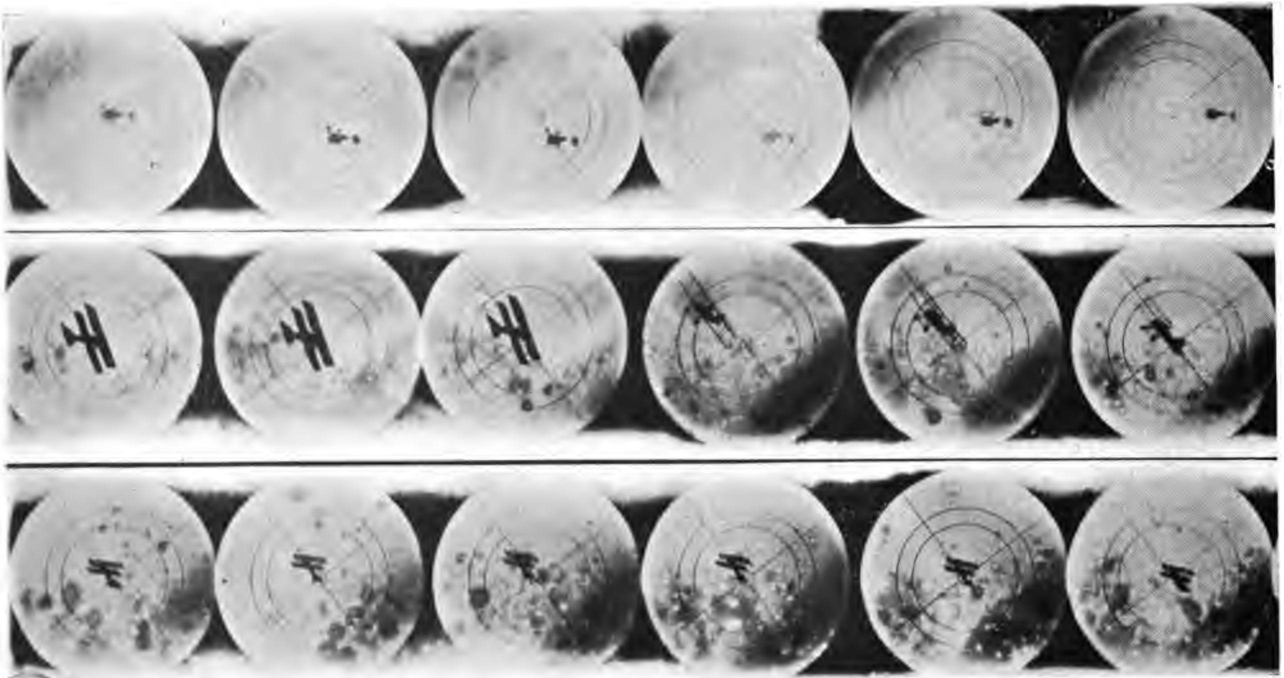
In high-flight work it was also necessary for the aviators to wear oxygen masks made of rubber containing a transmitter allowing the aviator to speak as well as hear by wireless. This mask was attached to a tube leading to a tank of oxygen carried in a convenient place in the 'plane and so adjusted as automatically to feed to the aviator different amounts of oxygen as different altitudes were attained.

This oxygen apparatus is so important that it is not possible to give a sufficient account of it in a brief space. Its purpose was to supply aviators with the right proportions of oxygen when flying in the rarified air of great altitudes, which the increasing range of anti-aircraft guns made necessary, it having been found that the efficiency and health of the airmen were greatly impaired on account of lack of enough oxygen at high altitudes. The American aircraft producers had to take a hand-made apparatus of French design and adapt it to American manufacturing methods, while also improving it. It was the same story as with almost everything brought from Europe for American adaptation, and presented the usual problems and difficulties, all of which were successfully overcome.



Film from Machine-Gun Camera Showing "Shots"

The work began in January, 1918, quantity production was attained in May and by October one thousand sets were being turned out monthly, the shipments to France totaling near four thousand.

The realization that the varying degrees of oxygen at different heights was the major influence on the efficiency of aviators led to searching studies of the adaptability of aviators to different heights and resulted in a remarkably efficient method of determining the aviator's limitations, so that aviators came to be put in different classes according to the heights at which they could successfully fly.

One of the aviation accessories successfully developed by the Signal Corps equipment division was the machine-gun camera which was used to teach aviators how to shoot accurately with machine guns. Obviously, in practice aviators cannot have airplanes for targets with actual machine-gun bullets. This raised the question as to how students could be prepared in advance for the actual experiences of battles in the air. The machine-gun camera was the answer. It is simply a regulation Lewis machine gun with a roll of films sustituted for the cartridge belt. The aviator works the gun precisely as if he were firing bullets, but instead of doing so he takes pictures of his target and the film record shows the accuracy of his aim. This was a bit of war preparation unknown to the Germans and they therefore marveled at the accurate marksmanship of our cub aviators in their first battles in the air.

# CHAPTER XXIII

## MILITARY BALLOONS

It is an interesting fact that the development of the airplane to its present degree of effectiveness has not held back the utilization of the stationary balloon in warfare. Concentration of attention on the airplane undoubtedly resulted in the Allies giving less attention to mobile balloons or dirigibles than they would otherwise, and previous to the use of helium gas because of its non-inflammability, as well as for other reasons, the general policy of the Allies in this respect was most wise. On the whole, the German Zeppelins were not a military success, though more because of their inflammability than for any other cause. They were of great aid to the German fleet in the North Sea, as scouts; and with the use of helium and other improvements will loom large in the future of aeronautics.

Early in the war it was found that for observation purposes anchored or kite balloons had certain advantages over the rapidly moving airplanes, and toward the end they were more relied on than airplanes for control of artillery fire.

France and England had devoted some attention to the modern type of observation balloon—the stream-line or so-called "sausage" type, and Germany a good deal, but as in all other things pertaining to aerial warfare America was much behind. The German Drachen type, though crude compared with later developments, was much superior to anything the Allies had, and the numbers of them possessed by the Germans gave them a distinct advantage in control of artillery fire in the first part of the war. Captain Caquot of the French army met the situation with a kite balloon that had superior stability in high winds and that could operate at higher altitude than the Drachen, and it came into general use by the armies and navies of France, England, and America and was imitated by the Germans. The somewhat grotesque appearance of these balloons is due to the air lobes attached to the rear third of the gas envelope, which are filled with air by the action of the wind and give the balloon stability. The Caquot also has an ingenious device for offsetting the leakage of gas, with a view to keeping the surface of the envelope firm and symmetrical. It

**A Navy "Blimp"—Non-Rigid Dirigible—in the Air**

consists of an air chamber within the gas-containing envelope which fills and expands as the gas pressure decreases on account of leakage.

The United States army had used one captive balloon on the Mexican border, and though European developments in balloons had been closely watched there was little manufacturing capacity for them in this country and many quantity manufacturing problems had to be dealt with. So, the heavily burdened Equipment Division of the Signal Corps, later to become the Bureau of Aircraft Production, had to wrestle with another great task. Only two or three balloons a month were then being made, and plans and specifications for the approved types were lacking. Balloon making was the opportunity of the rubber companies for patriotic service and they responded energetically and cordially, the Goodyear and Goodrich companies at Akron, Ohio, taking the lead and being followed later by the United States Rubber Company, the Firestone Tire & Rubber Company, the Connecticut Aircraft Company, and the Knabenshue Manufacturing Company.

A Caquot "R" type of kite balloon is 93 feet long and 28 feet at its greatest diameter, thus requiring a great yardage of rubberized cloth for the envelope; in fact an output of 10 balloons a day required 600,000 yards of special balloon cloth, the toil of many hundreds of weavers, and the use of 3200 looms. Balloon cloth, proper, is made of cotton and must be made with the greatest care with 140 threads to the inch both ways. Very little such cloth had been made in the United States and because of the difficulties of training weavers, the wastage from imperfections, and the small possible output per loom, manufacturers were reluctant to undertake contracts. At first the wastage was as high as 60 per cent., but with increasing skill was reduced to 10 per cent. To see that perfect cloth was produced the government and the manufacturers had to employ and train hundreds of inspectors. Thousands of men had to be instructed in making the cloth.

It was a tedious process to develop and expand this cloth-making industry, but by November, 1918, the American capacity had increased from enough for two balloons a day in April, 1917, to sufficient for ten a day. Moreover, the output was always abreast or ahead of the balloon-making program. In ordinary times such an industrial achievement would have been a seven-days' wonder, but it was lost sight of in the whole mountain range of unusual manufacturing deeds during the war, and entirely overlooked in judging the aircraft managers.

After the cotton cloth is made it has to be rubberized in order to make an air-tight fabric. This meant the development of another specialized industry. The fabric consists of a film of specially made rubber between sheets of the cloth, and the outside cloth ply is covered with a rubber compound which serves as protection against moisture and the actinic rays of the sun and for a camouflage. In blending the cotton cloth and the rubber film, the fabric is sometimes put through the presses thirty-five or forty times. While American manufacturing of this fabric followed European practice in the main, there were some departures and the American article was regarded as superior, chiefly because it was slower burning. This was an important consideration for it was the common fate of observation balloons to be set afire sooner or later and a slow-burning fabric gave the observers more time to take to their parachutes and escape.

A necessary accompaniment of the balloons was the machinery and apparatus to operate them successfully. Windlasses had to be built for the purpose of letting up and pulling down the balloons, and these had to be of great strength and high speed. As the French had developed a satisfactory windlass, it was put into production in this country to be on the safe side while the American types were being developed. This task was successfully undertaken by the James Cunningham, Sons & Company, of Rochester, N. Y. The first American windlasses were operated by steam, but later electricity and gasoline motors were used. The best-known gasoline type had one motor to operate the windlass and the other to move it from place to place. This kind could pull down a balloon at a rate of sixteen hundred feet a minute, and travel unimpeded at the rate of twenty miles an hour, or at five miles with the balloon in tow. The United States Army Balloon School developed one type of windlass, which was manufactured by the McKeen Motor Car Company of Omaha, and another was developed and made by the N. C. L. Engineering Company of Providence, R. I.

Another manufacturing achievement worthy of mention was the designing and making of a special anchor cable, which also enclosed the telephone wire cable by means of which the observer communicated with the ground, thus doing away with separate telephone cables, which had been a great nuisance. The Chas. A. Roebling & Sons Company and the American Steel and Wire Company coöperated in the important work.

**6-Cylinder, 100-H. P. Rear Windlass Engine Caterpillar, Tractor Adapter, for Towing and Controlling Observation Balloons**

Caquot "Sausage" Balloon, Beginning Its Ascent

U. S. Air Service Photo

Hydrogen gas is the buoyant element with which balloon envelopes were inflated. Before the war it was manufactured in this country in only a small by-product way, but the requirements for millions of cubic feet for the balloons were promptly met by new government plants and the expansion of private plants. Portable hydrogen generators for field use were also manufactured, but most of the hydrogen was made in the United States and shipped to the front in steel containers, of which 172,000 were ordered and 90,000 made, under a pressure of 2000 pounds to the square inch. Before the armistice was signed the private manufacturers alone had made and delivered near 18,000,000 cubic feet of hydrogen. The special problems of the field generators were in themselves manifold, as were those of many other balloon materials and accessories, such as the parachutes, rigging cordage, and "nurse" balloons, which carried reserve gas for the service balloons.

As the war approached its end, the balloon section achieved its most original success, in the practical utilization of non-inflammable helium gas, a fact that was a military secret until after hostilities ceased, the gas being disguised verbally as "argon." Using it instead of hydrogen, balloons and dirigibles eliminated fire-risk from enemy action, lightning, and whatever cause, thus overcoming the chief obstacle to safe employment of airships. Helium was known before the war, but its production was so small and it was so costly, being worth $1700 a cubic foot, that it was not to be immediately considered as a substitute for hydrogen. It was known, however, that it was to be found in small proportions in some of the natural gases of the United States, and with financial assistance from the Signal Corps, Navy, and Bureau of Mines, the last two supervising the experiments, satisfactory production was attained by the gas liquefaction processes known as the Norton and those of the Linde Air Products Company and of the Air Reduction Company. So far had this work progressed that on the day the armistice was signed 147,000 cubic feet of helium were ready to be loaded on ships for France, and a permanent plant was building with a capacity for treating 5,000,000 cubic feet of natural gas daily, at an estimated cost of ten cents a cubic foot for the realized helium. At 100 per cent. efficiency the product would be 50,000 feet daily.

The Norton process was an entirely new system of liquefaction of natural gas and was taken up by the Bureau of Mines. The so-called Norton plant was established at Petrolia, Texas. The need for the cheap and abundant production of such a gas as helium was so great that soon after work on the Norton process was started the British sent two high naval officers to the United States to urge that the American Government use all possible means to rush the production of helium. With a view to doing so, therefore, contracts were made with the Linde Air Products Company and the Air Reduction Company for the erection of experimental plants at Ft. Worth, Texas. The Linde Company began operations on March 6, 1918, and these were so successful that a large production plant using the same process was undertaken by the army, and this plant is of permanent construction and will begin producing helium gas at the actual rate of 30,000 feet a day and at a cost of about five cents a foot, sometime in the middle of 1920. The Air Reduction Company plant went into operation on May 1st, and while it produced helium it was not so successful as the Linde process. The Norton method is still in the experimental stage, but if it should succeed the cost will be lower than by either of the other methods. To facilitate the production of helium, the construction of a pipe-line was authorized from Petrolia to the plants at Ft. Worth, Texas, and steps were taken to conserve the gas production of the Petrolia pool, thus saving an enormous amount of helium and extending the life of the pool over a period of approximately ten years. Helium has been found also in natural gases of Kansas, Ohio, and Montana, and because of its incombustibility 500,000 cubic feet are wasted daily in the United States.

An interesting fact about helium is that the United States contains practically all of the known utilizable sources. Col. A. L. Fuller of the Army Air Service in an article in *Air Service* comments that it is remarkable that an element once unknown on the earth's surface, and originally discovered in the sun, and one so rare before the war that the largest quantity ever collected in one place was approximately sixty cubic feet, should now be used in the enormous quantities necessary for balloon work. It is quite possible that the new gas besides bringing buoyant airships into new favor and great possibilities may have many scientific and commercial uses. Already it has been used to obtain lower temperatures than were possible by any other means. It is intended to locate all possible sources of helium in the United States and conserve them. "Helium" is described by Colonel Fuller as "one of the most remarkable gases. It is a light, monatomic gas and the light-

A Unit Assembly Room in the B. F. Goodrich Company's Balloon Plant at Akron, Ohio

U. S. Air Service Photo

est of rare gases. It is the last of the so-called perfect gases to be liquefied, and it liquefies at a lower temperature than any other gas. It is one of the constituents into which radium breaks down when undergoing a transformation which accompanies radioactivity, particles of helium being given off as the different types of the radium series are changed."

An amusing incident of the helium research work was that some members of Congress having learned that Colonel Deeds and Commander Atkins, having on behalf of the Aircraft Board purchased the output of certain natural gas wells in Texas of such a poor quality that it could not be used to fry eggs, suspected some sort of corrupt intention, and started an informal investigation which, had it not been promptly nipped, might have resulted in another formal Congressional investigation of aircraft production. It was with considerable difficulty that it was made plain to the legislators, without betraying a supremely important military secret, that the one reason why this gas was desirable was its lack of heat production.

It is confidently held that the success attained in perfecting methods of separating helium gas cheaply will greatly widen the possibilities of buoyant aircraft in peace as well as in war.

The official statistics of the production of balloons and accessories in the United States during the war for the army alone are as follows:

April 6, 1917—November 11, 1918

| | |
|---|---|
| Balloons: | |
| Type R, observation | 642 |
| Type M, observation | 22 |
| Type C, observation | 7 |
| Type J, observation | 1 |
| Experimental observation | 4 |
| Supply balloons | 129 |
| Spherical balloons | 10 |
| Propaganda balloons | 215 |
| Total | 1,030 |
| Parachutes | 285 |
| Windlasses | 50 |
| Cable, feet | 1,221,582 |
| Gas equipment: | |
| Hydrogen cylinders | 89,225 |
| Hydrogen, cubic feet produced by private manufacturers | 17,634,353 |
| Helium, cubic feet | 147,000 |

The above production for the army provided, not only for the requirements of A. E. F. and the balloon schools in the United States, but permitted furnishing a substantial quantity of this class of equipment to the Allies.

The supply balloons mentioned in the above table are simply "nurse" balloons under another name. The propaganda balloons are small balloons, carrying propaganda literature with an automatic device for freeing printed leaflets and pamphlets, and so arranged as to be self-destructive when the balloon ultimately comes to earth. These balloons were sent over the enemy lines when the weather was favorable.

Although as yet little recognized, the balloon providing achievements of the aircraft production department constitute one of the industrial feats of fame during the war. Beginning, like the airplanes, from nothing, like their development too, it attained a supreme place in this field of military endeavor.

## CHAPTER XXIV

### TRAINING FIELDS, CAMPS, AND SUPPLY

THE construction side of the mammoth aircraft enterprise had not only to produce the flying machines and other equipment for the use of the fighting and training personnel but it had to provide sites and facilities for their use. When the war began, there were only two government flying fields in America. The training of 15,000 flyers and the assembling and organizing of the 190,000 men of the flying service required an enormous physical establishment, and the business of providing, acquiring, and preparing the fields, all sorts of supplies for the men, their housing, and the shops was in itself a task that would have sorely tried a highly trained and developed industrial organization. It involved at home and abroad an expenditure of about $80,000,000 and everything had to be done with feverish haste, which even when realized seemed in the nervous tension of a war in which every minute was supremely important, all too slow.

Col. C. C. Edgar, on recommendation of Col. Waldon, was put in charge of the Supply Division to which this work was entrusted and he later had as assistant Lieut.-Col. E. Lester Jones, who was granted leave of absence from his position as director of the U. S. Coast and Geodetic Survey for this duty. The Supply Division was established May 21, 1917, and in the next 11 months it had undertaken 47 main projects and completed 35 of them, not counting its work in connection with the flying school and aviation bases in France.

The home establishments included, in part, 15 single-unit flying fields, 4 double-unit fields, 3 concentration camps, 3 balloon schools, 5 supply depots, 3 repair depots, 1 experimental station, 1 radio laboratory, 3 mechanics' schools, 1 artillery field, 4 acceptance parks, 1 quarantine camp, and the permanent stations at Langley Field and San Diego. These camps, depots, and schools were located all over the country, from Mineola on Long Island to San Diego, California, and from Arcadia, Florida, to Minneapolis and St. Paul, though most of the flying fields were in the southern part of the country, for climatic reasons.

The following is a list of construction work completed or in progress about April 5, 1918:

| Location | Description | Est. Cost |
|---|---|---|
| Americus, Ga. | | |
| Souther Field | 1 four-squad. camp | $ 812,100 |
| Souther Field | Warehouse | 400,000 |
| Arcadia, Fla. | | |
| Carlstrom Field | 1 four-squad. camp | 812,100 |
| Dorr Field | 1 four-squad. camp | 812,000 |
| Belleville, Ill., Scott Field, | 1 four-squad. camp | 1,680,529 |
| Dallas, Tex., Love Field | 1 four-squad. camp | 929,100 |
| Dallas, Tex. | Repair depot | 551,500 |
| Dallas, Tex., Concentration Camp | Miniature range, building, & sundry equipment for existing buildings | 16,766 |
| Dayton, O. | Supply Depot | 800,000 |
| McCook Field | Experimental sta. | 1,000,000 |
| | 1 eight-squad. camp, including gunnery school | 3,097,777 |
| Fort Omaha, Nebr. | Balloon school | 493,266 |
| Florence Field | Add'l balloon outfit unit | 77,000 |
| Fort Sill, Okla., Post Field | Aerial observers' camp | 1,485,480 |
| Fort Sill, Okla. | Balloon school | 385,000 |
| Fort Weed, N. Y. | Supply depot, addition to building | 47,000 |
| Fort Worth, Tex. | | |
| Taliaferro, No. 1 | 1 four-squad. camp | 1,121,600 |
| Taliaferro, No. 2 | 1 four-squad. camp | 1,007,100 |
| Taliaferro, No. 3 | 1 four-squad. camp | 857,100 |
| Houston, Tex., Ellington Field | 1 eight-squad. camp | 2,130,900 |
| Indianapolis, Ind. | Repair depot | 582,000 |
| Lake Charles, La. Gerstner Field | 1 eight-squad. camp | 2,266,600 |
| Little Silver, N. J. | | |
| Camp Alfred Vail | Radio laboratory | 368,350 |
| Lonoke, Arkansas, Eberts Field | 1 four-squad. camp | 812,100 |
| Memphis, Tenn., Park Field | 1 four-squad. camp | 1,769,600 |
| Middletown, Pa. | Supply depot | 613,000 |

**Captive Caquot "Sausage" Balloon**

| Location | Description | Est. Cost |
|---|---|---|
| Mineola, L. I., Hazlehurst Field | 1 five-squad. camp; 1 concentration camp, and general aviation supply depot | $ 4,218,149 |
| Minneapolis, Minn. | Mechanics' school | 150,000 |
| Montgomery, Ala., Taylor Field | 1 four-squad. camp | 812,100 |
| Montgomery, Ala. | Repair depot | 600,000 |
| Morrison, Va. | Concentration camp | 1,603,100 |
| Mt. Clemens, Mich., Selfridge Field | 1 four-squad. camp | 2,903,203 |
| Rantoul, Ill., Chanute Field | 1 four-squad. camp | 1,130,482 |
| Richmond, Va. | Supply depot | 1,000,000 |
| Riverside, Cal. | 1 four-squad. camp | 800,000 |
| Sacramento, Cal. | 1 four-squad. camp | 850,000 |
| San Antonio, Tex., Kelly Field | 1 eight-squad. camp; 1 concentration camp; 2 storage warehouses | 3,498,555 |
| Brooks Field | 1 four-squad. camp | 837,100 |
| Balloon School | | 144,480 |
| San Diego, Cal., Rockwell Field | Temporary buildings, construction of bridge and part of temporary bldgs. | 1,164,200 |
| Waco, Tex. | | |
| Rich Field | 1 four-squad. camp | 1,016,600 |
| Camp MacArthur | Barracks and quarantine camp | 192,000 |
| West Point, Miss., Payne Field | 1 four-squad. camp | 812,100 |
| Wichita Falls, Tex., Call Field | 1 four-squad. camp | 1,016,600 |
| Various fields | Additions to barracks | 340,000 |
| Various fields | Architectural services | 150,000 |
| Sundry projects | | 296,391 |
| Total | | $47,863,228 |

The advanced training school and field at Issoudun in France and the great repair and assembly shops at Romorantin and the whole physical plant for the maintenance of the air service in France required the assembling and forwarding of a vast amount of material and machinery, and the erection of many extensive buildings, hangars, warehouses, shops, etc. In addition to the work that was done by contract at home and abroad, it ultimately required 49 construction squadrons, 23 construction companies, and 12 labor companies, with a total of almost 13,600 officers and men to do the work that was performed directly by the supply division. Of these men about 6500 were sent abroad. The assembly shops at Romorantin were on such a scale that they could receive and erect daily 100 'planes and forward them to the front. The repair shops were of sufficient capacity to handle all the repairs of injured and "crashed" machines from the front and from the school. The field shops at home eventually reached such a magnitude that it is calculated that they were capable of building 200 'planes a week. The actual construction work in France, except for the aviation school and the hangars that were originally provided or diverted from American fields was attended to by the A. E. F.

Three weeks after the building of the aviation school at Issoudun was approved by the Air Prod. Board all the materials for its erection were on the docks in New York harbor accompanied by two hundred mechanics and the necessary complement of officers, and on September 15, 1917, the school was ready for use, this work including the building of seven miles of standard gauge railway to connect the field with the railway trunk line.

To give some idea of the great amount of construction work done at home it may be stated that a typical single-unit flying field and school called for 50 buildings of all kinds, occupying a space ⅝ of a mile long by about 600 feet wide with graded and macadamized roadways, railway tracks, water and sewerage systems, lighting plants, etc., to say nothing of the grading and draining of the field proper. The standard plan was developed by Albert Kahn, the Detroit architect, from the basic scheme worked out by Cols. Waldon and Edgar.

An idea of the size and complexity of the tasks assigned to the Supply Division may be gained from a recital of its divisions which were: executive, buildings and grounds Langley Field branch, finance, traffic and storage, engine and 'plane maintenance, aviation repair depots, oil and lubricating branch, material branch, salvage, motor transport, real estate.

All of these branches had an endless amount of work to do and it always had to be done in a hurry. The oil and lubricating branch, for instance, had to conduct the development of suitable lubricants for aviation engines, arrange for the planting of one hundred thousand acres of castor beans by 18,000 farmers provide supplies of oils for the home forces and the A. E. F., look after gasoline and many other things.

One of its triumphs was the production of "Liberty aero oil" without which the Liberty motor would not have been properly lubricated.

The traffic and storage branch handled about seventy-five thousand carloads of materials.

The Supply Division was the man behind the gun for the aviator from the day he began his training until he began to fight in France. On it he depended for everything he used and consumed to be always ready and exactly right. Its unknown officers and obscure men worked with all the ardor, zeal, and self-sacrifice of the more fortunate fighters whose names were inscribed on the roll of fame. There are records of mechanics and engineers working four days and nights at a stretch in the shops at the fields in order to keep the maximum number of machines and student aviators in the air all the time.

**Partial View From the Air of the Vast American Air Service Assembly Repair and Salvage Shops at Romorantin, France**

U. S. Air Service Photo

## CHAPTER XXV

### NAVAL AIRCRAFT PRODUCTION

WHILE army and navy aircraft production were coördinated in a measure by the Aircraft Board and by direct arrangements, and the development and production of engines and some other apparatus and the procurement of materials were left to the army in whole or in part, the navy maintained throughout the war its own independent aviation sections and directed development and production to meet its own ideas and its peculiar needs. Before 1916 the navy paid as much attention to aircraft as was possible with the limited appropriations available. The first appropriation for Naval Aviation was made in 1916 and during this year the Navy Department developed training planes and training facilities in addition to adequate research and experimental facilities, including the largest wind tunnel then in the world. However, in 1917 it was clear that Naval Aviation should concentrate itself upon anti-submarine operations and for this duty large patrol seaplanes carrying depth charges were necessary. Steps were taken promptly to obtain models for such planes by development from existing types, but it was not possible to fly these types until the Liberty engine became available in the early autumn of 1917. The planes were ready as soon as the engines were developed. The trials were successful and the Navy Department entered upon a program of production of two types of flying boats, which program was adhered to. The uncertainty as to program in the case of the navy did not arise so much from a vast and varied foreign experience as from the fact that naval aeronautics had not advanced so rapidly during the European war as military aeronautics, and the field was more of an unknown or untried one. From 1912, when aeronautical experimentation began in the navy, to 1915, inclusive, only $55,000 had been set aside for this work. In 1916, Congress appropriated $1,000,000 for naval aviation, and its development in any important way dates from then. At the end of 1916, the total aircraft deliveries to the navy consisted of about 95 seaplanes of experimental and training types, "mainly prototypes of the Curtiss N9 and R6, 3 kite balloons, and 1 nonrigid dirigible." Thirty Curtiss N9's were delivered in the fall of 1916, and early in the spring of 1917 64 more N9's and 76 R6's were ordered.

Thanks to the wise forethought of Admiral Taylor, chief constructor, the entry of the United States into the war was preceded, in 1916, by the ordering of a small number of machines of different types for the purpose of securing data from which to choose the most suitable ones for future training. These orders were placed with the Curtiss Aeroplane and Motor Corporation, the Burgess Company, the Sturtevant Airplane Company, the Aeromarine 'Plane and Motor Corporation, the Thomas-Morse Aircraft Company, the Standard Aircraft Corporation, the Boeing Airplane Company, and the Gallaudet Aircraft Corporation. Following these experimental orders, contracts were given to the Burgess Company for 30 of the Curtiss N9's (later increased to 360), to the Curtiss Company for 122 R6's, later changed to R9's, and to their respective companies for 50 Boeings, 200 Aeromarines, and about 15 Curtiss F-boats, sportsman's type.

The problem of service 'planes, owing to lack of knowledge of requirements and developments, was not so easily disposed of. A board of officers was sent abroad in September, 1917, to investigate, and on its return, reported that because of foreign concentration on land 'planes there was no satisfactory type of seaplane for coast patrol and that it was desirable to develop American types, equipped with the Liberty motor. Acting upon this information and knowing that it had been decided to establish fifteen coastal air stations abroad, the Joint Army and Navy Technical Board laid down a program that was accepted in October, 1917. That it took six months before it was possible to determine the service program is both a commentary on our unpreparedness and an explanation that disposes of accusations of tardiness of action when the emergency arose. Neither the navy nor the army could achieve the impossible; neither could act intelligently nor with important results before it could establish an objective.

The program, having in view both initial requirements and replacements for the stations abroad and for home training was:

First: Eleven hundred and eighty-five HS-1 flying boats with Liberty engines.

Second: Two hundred and thirty-five H-16 flying boats with Liberty engines.

Both of the service "boats" decided upon were Curtiss models.

The controlling considerations in this program were the fact that the Liberty engine was by that time fully proved and a desire to avoid the dangers of highly varied types. The two types chosen had been demonstrated, and it was necessary to have two, because there was need for both large and small machines, especially as the smaller type could be built more rapidly than the larger, and shipping difficulties for the latter were anticipated. The fighting objective of both types was the German submarine, and for that purpose the larger kind was favored, but the smaller was better than none. The H-16 was the larger and was an improvement on the H-12 which was a Curtiss design adopted by the British navy, the Curtiss company having early taken the lead in the development of flying boats. In 1918 the H-16 was succeeded by the F5L which is slightly larger; and the HS-1 was followed by the HS2L.

The H-16 is described as a tractor biplane, carrying two Liberty engines. It has an over-all length of 46 feet and an upper-wing spread of 95 feet. Stripped, it weighs 7400 pounds and with ordinary equipment 10,900, while it has carried a gross weight of 11,500 pounds. Its usual crew is four men, its armament five Lewis machine guns and two 230-pound bombs. Its cruising limit is nine hours light or six hours fully loaded. The

F5L has a wing spread of 103.75 feet, a bare weight of 8250 pounds, a permissible load of 13,000, and has actually flown with 13,600 pounds. Its armament is the same as that of the H-16, with the exception that it carries four 230-pound bombs and it has a cruising limit at economical speed of eleven hours, and with geared Liberty engines has attained a speed of 100 miles an hour. The equipment of both these boats includes radio apparatus, range lights, signal lamps, intercommunicating telephone sets, food, water, and a medicine chest.

The HS1L is about a third smaller in dimensions than the F5L and is a single-engine coast-patrol machine, the engine being a Liberty. Its gross weight is 5900 pounds and its armament is one machine gun and two 180-pound bombs.

Contracts for these machines were awarded entirely to existing plants except that in order to augment the volume of production the navy erected a large plant of its own at Philadelphia.

This program seemed large when adopted, but two months later, on the advice of Admiral Sims, the number of the twin-engine boats was increased to 864, all to be delivered by the spring of 1919. When this decision was made it was found that 480 of the total would have to come from some new source, as about 400 was the outside capacity of

**Hulls of F-5-L Type Seaplanes. Curtiss Elmwood Plant, Buffalo**

U. S. Air Service Photo

**Final Assembly of Flying Boats at Curtiss Plant, Elmwood, Buffalo**

U. S. Air Service Photo

the plants with which orders had already been placed. It was not deemed wise to place complete orders with new companies and on the other hand the prospect of building and organizing a government factory of adequate size was dismaying and of doubtful wisdom. The problem was handled by building an immense assembly plant as an extension of the naval aircraft factory, already erected, and having the various parts built in many different established yacht-building, metal, and woodworking plants that were quite capable of making the parts though not qualified for executing the whole job. It was the fabricated ship idea of Hog Island applied to flying boats.

Quantity production of the service boats began in April, 1918, thus running parallel with army 'plane production, with six HSL's and three H-16's a week. From that time on production rapidly increased.

In June, 1918, the program was again expanded, so that it called for additions of 700 F5's, 300 HS2's, 300 F-boats, and 200 N9's—a total of 1800. Another hundred F-boats were added in September. In that month production reached its height, twin Liberty engine boats coming out at the rate of 13 a week, and single-engine (mostly Liberty) at the rate of 38 a week. The former were made by the Naval Aircraft Factory, Curtiss Aeroplane and Motor Co., Buffalo, Curtiss Engineering Corporation, Garden City, L. I., N. Y., and the Canadian Aeroplanes, Ltd., Toronto, Canada. The latter were made by the Gallaudet Aircraft Corporation, East Greenwich, R. I., the LWF Engineering Co., College Point, N. Y., Curtiss Aeroplane and Motor Co., Buffalo, Standard Aircraft Corporation, Elizabeth, N. J., and the Boeing Airplane Company, Seattle, Wash. In the same month, training machines were being delivered at the rate of 22 a week by the Burgess Company, the Aeromarine Company, and the Curtiss Engineering Corporation.

Before the armistice was signed, it was realized that naval aircraft were being manufactured far more rapidly than they could be utilized either at home or abroad, and early in November the program was curtailed by canceling 550 F5's, 248 HS2's, and 300 training machines. After the signing of the armistice, there was a further cancellation of 145 HS2's, 512 F5's, and 100 school machines.

Several new types of 'planes were developed by or for the navy during 1918, with a view to meeting the progress of naval aeronautics. The Aeromarine company developed the Model 40 Flying

**Captain K. G. Pulliam, Jr., and His 15-Meter, Decorated Nieuport Plane, "The Jazbo"**

**American-Made Handley-Page Bomber with Single-Seater at Left**

Boat and the Curtiss Engineering Corporation the Model MF Flying Boat for training purposes, and both were adopted by the navy. Several different service machines were designed, built, and tried, the most conspicuous being the NC-1, the Curtiss model 18-T or Kirkham fighter, the N-1 or Davis gun carrier, and the HA or Liberty fighter.

The NC-1 was built by the Curtiss Engineering Corporation, under the direction of officers of the Bureau of Construction and Repair. It is a biplane with an upper-wing spread of 126 feet, and an over-all length of a trifle more than 68 feet. Its weight with full load was 22,000 pounds; stripped, it weighed 13,200 pounds. It was driven by three Liberty motors and had a hull of unique design, which rather resembled a large pontoon. This machine made a flight at Rockaway Beach, L. I., on November 27, 1918, with 51 persons on board, thereby establishing the world's record for airplane passenger carrying. Later four engines were installed in the NC-1, three tractor and one pusher. Due to this change the light weight became 16,000 lbs., and the total weight 28,000 lbs. The NC-1 was followed by three other NC's of like type, and it was the NC-4 that won the high distinction of being the first aircraft to leap the Atlantic.

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The Curtiss 18-T is a two-place tri-plane land machine, designed as a guard for the heavy naval bombing machines along the French coast. It is driven by a Curtiss K-12 engine and has a speed of 162 miles an hour, which makes it the fastest 'plane ever built up to this time.

The N-1 was designed to carry a Davis 9-pounder non-recoil gun, and is of the pusher type—that is, has the propeller behind instead of in front, as is the arrangement with the ordinary or tractor type, in order to put the gun at the nose. As it was afterwards found possible to mount the Davis gun on the HS-2 flying boat, less attention has been paid to the N-1 than it would have had otherwise.

The Liberty fighter is a single pontoon seaplane, designed to meet enemy aircraft. It is a two-seater and carries four machine guns and has attained the remarkable speed, for a seaplane, of 127 miles an hour.

One dirigible balloon was built for the navy in 1916 by the Connecticut Aircraft Company, and that was about the extent of the navy's equipment with the buoyant aircraft when we entered the war. In the January before the war was declared a single-engine, tractor, training dirigible of 80,000 feet capacity was designed by the Bureau of Construction and Repair, and in March orders were placed for 16, the contracts for the envelopes being taken by the Goodyear Tire & Rubber Company, the B. F. Goodrich Company of Akron, the United States Rubber Company of Akron, Ohio, and the Connecticut Aircraft Company. The obstacles in the way of rapid progress at first have been set forth elsewhere, but in general they were those of a new industry which must be developed in an industrial hothouse. The first vessel of this type was tested in July, 1917, and the rest were delivered by the spring of 1918. Their success in coast patrol work was such that it was decided in the spring of 1918 to build 10 twin-engine dirigibles of 175,000 cubic feet capacity, this number being later increased to 30. These airships were known as the "C" class and designed by the Bureau of Construction and Repair. The first of these larger vessels was ready in October but the armistice came before the others were done, and it was decided to reduce the number to be completed to 15.

The kite balloon program provided for 600 balloons, and 50 of the Caquot M type were delivered in the first part of 1918. Later the Caquot R type was taken up and finally an improved M type. With the coming of peace the balloon program was reduced one half.

In connection with the use of balloons the navy had much the same problems as the army with special variations to meet nautical conditions. Some of these problems were solved with the army and some separately. The development of winches and cables for handling the balloons from vessels were serious and difficult matters. The N. C. L. Engineering Corporation of Providence, R. I., developed the gasoline engine winch or windlass along the "surge" type, following foreign practice, which avoids a compression of the cable by winding it in a single layer in grooves on one or more drums, which take all the pull, the stored part of the cable being wound around other drums under slight tension. The Lidgerwood Company of New York modified its cargo vessel steam winch for balloon handling and towing in an ingenious manner, but it was finally found that this class of winches was not adapted to handling balloons at great heights, especially when the telephone cables were inside the holding cables, owing to the crushing compression. Seventy-five of the NCL gasoline winches were ordered and quantity production was attained in the spring of 1918. Another variation of the winches was the use of steam power with the "surge" drum; and still another, the "surge" drum with electrical power; the latter being specially adapted to capital ships. The manufacture of the balloon cable and its problems have been mentioned elsewhere, they being problems common to the army and navy.

The navy shared the dope and fabric tasks and problems with the army, but in a large measure faced and solved its own spruce problem. At first it had intended to rely on the army for all its spruce, as the latter had found it necessary to make arrangements on a mammoth scale for the procurement of the fine Sitka spruce of the northwestern Pacific States. The troubles the army encountered, owing to labor and other obstacles that presented themselves, prompted the navy to consider other sources, the chief of which turned out to be the New England spruce forests, and it was agreed that the cultivation of this field of supply should be left to the navy. By May, 1918, about seventy mills were turning out New England white spruce at the rate of a million feet a month, by which time the northwestern supply was so abundant that the navy had more lumber than it needed. Some of the surplus stock was sold to the British Government. In July, however, the army began to run short of spruce for struts and the navy surplus proved to be very opportune for some plants. There was much disfavor for New

England spruce because of its small pin-knots and short lengths, but necessity enforced its use and specifications were altered to meet its requirements. Later when waterproof glue and laminated construction were developed, it came into considerable favor and there was a steady preferential demand for a considerable quantity of it. The navy supplemented its New England supply with small quantities of Sitka spruce from sources overlooked by the army, which were shipped east by the Canadian Pacific railway and sold to the New England lumber mills having navy spruce contracts.

The rapid erection and prompt operation of the government naval aircraft factory is worthy of special notice. The reasons which prompted the decision to erect such a plant have already been noted. On August 6, 1917, a contract was let for a plant that would have a capacity of 1000 training seaplanes a year. The factory proper was 400 feet by 400 of permanent construction and there were some auxiliary buildings. Work on the first boat in this plant began on October 12th and the building was entirely completed on November 28th. When it was decided to meet the requirements of the greatly enlarged program adopted in December, 1917, by having the parts of the seaplanes made elsewhere and assembled at the naval factory, two other great buildings, 350′ x 400′ and 680′ x 200′, besides large auxiliary buildings had to be erected. This great assembly plant was fed with seaplane parts by the Victor Talking Machine Company, which had almost abandoned its ordinary work to turn its workers and equipment to the government's work, seven yacht yards, two small aircraft factories, by a number of furniture factories and automobile body and sheet metal products factories. Over 7000 persons were employed on the naval work in these private plants, in addition to 3643 in the naval aircraft factory, itself. The groups of coöperating factories were managed as parts of the naval factory that happened to be long distances away, instead of right alongside the executive offices; thus welding the whole enterprise into a single unit. The assembling and training of the workers was a great problem in itself, not more than 25 of the 3700 in the central plant ever having had previous experience in aircraft-making. The objective of the factory and assembling plant was the making of 830 twin-engine "boats," and the necessary spares, which would cost $23,000,000. On December 31, 1918, the production amounted to 183 of these vessels, 50 sets of spare parts, and 4 experimental machines; not to mention experimental work, individual fittings, and parts for service machines.

It is noteworthy that in these naval records and accounts of army production of aircraft and accessories it is found that quantity production is rarely mentioned before the early spring of 1918. From this, as well as from the like experiences of other production for war purposes, it is fair to generalize that it took the United States one year to mobilize industrially—and, all things considered, that was a wonderful achievement. That is to say, in a general way, that a year elapsed from the declaration of war until the manufacturing resources of the United States began to be felt in the special machinery of war, except in the cases of those industries and plants that had already been mobilized to meet the demands of the European nations, previous to our entry into the war. It also took about a year to get ready to send troops to Europe in large numbers. These facts may well cause serious reflection as to what would have happened to us had the war been solely between the United States and Germany. We had a year to get ready this time, *after war was declared.* Even then, it would have been a year more before we were ready to exert the full strength that our industrial development represented.

## CHAPTER XXVI

### "LYNCHING THE AIRCRAFTERS"

No branch of the American war production effort has been subjected to so much persistent, widespread and relentless criticism as that of aircraft production, although the fact is that the production of aircraft and all of its accessories is really one of the most wonderful achievements of the war and it abounds with records of great tasks greatly done. Why then, it may be asked, was it singled out for such a flood of persistent and, often, virulent criticism? The answer is fourfold.

First, aircraft design and production were so comparatively new in this country that there was room for wide divergence of opinion and judgment as to the best course to follow in regard to many features of the undertaking and ample opportunity for anyone to set himself up as authority.

Second, publicity that was flamboyant and exaggerated on the one hand and insufficient on the other hand.

Third, underestimates by the aircraft managers and the manufacturers of the time it would take to get American aircraft plants of all sorts into large production.

Fourth, lack of a thoroughly coördinated and efficiently functioning organization of the air service as a whole.

The first answer requires no elaboration here as it is really dealt with throughout this work.

The mistakes of publicity arose partly from overconfidence and partly from the fact that so little of a definite nature could be given out, under the regulations of military secrecy, that generalities had to be resorted to, and the rest left to the imagination of the eager writers who were fascinated by the magnitude of the American air effort and the results that would follow if it were realized. On the other hand, looking back now it would appear that much of the data regarding the procurement of materials and the production of 'planes, engines, and the numerous accessories might well have been given to the public and thus familiarized it with the enormous difficulties the aircraft managers faced. The result of the ill-advised publicity was to raise false hopes of early achievement on a scale of great magnitude while not informing the people of the extent and variety of what was actually being done, with a correspondingly great disappointment when it was learned that those hopes were not to be realized, though the actual achievement was of surpassing brilliance and solidity.

While the faulty publicity was only partly the error of the aircraft organization, it must be charged with responsibility for underestimates of the periods of production. For reasons which have been made plain elsewhere the aircraft managers erred in this respect, partly because of an abiding optimism, which was essential to the successful prosecution of their work, and partly because they allowed themselves to be deceived by the sanguine time-estimates of manufacturers.

Now that the situation is better understood, that the public is beginning to understand that the aircraft producers did a great work greatly, and time has confirmed their judgment and their confidence in the ability of American manufacturers successfully to apply quantity production methods to aircraft-making, there is little need to dwell at length on the bitter criticisms of the aircraft managers and producers. Neither is more than a passing reference required to the various investigations which followed each other throughout the war and culminated in the Senate Military Affairs Committee investigation and the executive investigation conducted by Chas. E. Hughes in association with the Department of Justice. The passage of time, the record of the facts, the full and accurate publicity that the termination of the war has made possible, and the realization that these investigations could not have the impartiality resulting from the personal detachment which only a lapse of time makes possible, have made them largely unimportant. At the time they loomed large and threatened to discredit permanently a vast field of American war effort and all who were associated with it, and most certainly had the effect, along with some good, of cruelly harassing and seriously retarding progress.

The defective organization was inherent in the American military system and was largely the inevitable result of leaving in a minor place a department of military preparation that was soon to surpass in magnitude and complexity the most extravagant of pre-war forecasts, and trying to supplement it with a largely impotent but complication-adding Aircraft Board. Time pressed so urgently that there was no leisure to conceive or perfect an adequate organization at first. The aircraft production managers had all they could do in the stress of preparation for production on an enormous scale without diverting thought and energy to a campaign for the attainment of a proper place and system for the air service as a whole in the government's organization for war, much as they realized the need of a different scheme.

One good result of criticism and investigations was a shifting of the place of the air service in the general military scheme and of a simplification of the internal organization. Changes in the latter became necessary to restore public confidence, and also to restore the morale of the organization which had suffered so much from criticism. Thus it came about that eventually, some months before the termination of the war, the whole air service was withdrawn from the Signal Corps, and placed under John D. Ryan as Assistant Secretary of War, and under him was the Bureau of Aircraft Production on the one hand and the Division of Military Aeronautics on the other hand. Major General W. L. Kenly was placed in charge of military aeronautics which had to do with the fighting air service and W. C. Potter, who was Colonel Deed's chief of the equipment division of the Signal Corps, was made chief of production. At the same time all matters relating to aircraft were divorced from the Signal Corps. In this manner the air service attained an independence and degree of authority that it had not hitherto enjoyed. Mr. Ryan inspired great respect and confidence, and supplied a centralized headship that had not been possible under the old system. He found, however, that the production or equipment work was well organized and efficient, and so far as it was concerned it continued about as it was under a different name and authority. Mr. Ryan has frequently stated that he came into the organization too late to be credited with the results achieved in creation and production. He modestly claims for himself merely the filling of a harmonizing function, which the progress of events had made necessary.

In a public address in New York City not long since, Mr. Ryan said:

"Mr. Toastmaster, ladies and gentlemen, public speaking is not in my line, but I would be a poor sort of a fellow if I couldn't say a word to you men assembled here to-night, I would be a poor fellow if I couldn't say—in appreciation of what you have done for the country, and done for the Cause, that we have won so gloriously, done for me in the short time that I had to do with aircraft production—that probably no one has come out of the war with as much credit for what somebody else did as I have.

"I was called into aircraft production at a time, as Mr. Marshall says, when there was a great deal of discussion, a great deal of criticism, and a great deal of blame, and I say to you to-night in all earnestness, most of it was totally and entirely undeserved.

"Aircraft production had to start at the beginning. It had to find a way from nothing, to meet the demands of the American people, and be brought to a point that was beyond all reason. People talked of clouds of airplanes, of tens of thousands of sparrows, and it was just as impossible to realize that dream as it was to realize any kind of a dream. Aircraft had to be built slowly, carefully, they had to be built to conserve, first, the lives of these gallant boys who took these ships in the air. They had to be made sure, every wrinkle, every crinkle, every thing that could be a menace to the life of these boys had to be taken out of them, if it was possible, before they were sent to fight across the line, and they had to fight across the line.

"The work that was done before me made it comparatively easy for me to win a good deal of praise, as I say, that I was not entitled to. The work of my predecessors, the work of the aircraft manufacturers of the United States was a thing that, when I got into it and studied it, was amazing to me in its competency, and all it lacked was just time enough and just some organization to center it, to drive it in the direction, and to finish it.

"The manufacturers of this country, with singular devotion to the country, with great patriotism, and with the greatest earnestness that I have ever seen in any body of men, had built an organization for the manufacture of aircraft that certainly has never been equalled in the world, in the time in which it has been done.

"The brains that were in the aircraft organization at the time that I took charge of it had been well-directed. There were some things that might have been better done. There are things always that might have been better done, but in the main, in the mass, the work was well laid down, it was under way, and the manufacturers of this country who were making aircraft were doing a wonderful job, as far back as last May.

"The greatest effort necessary to build aircraft, as you gentlemen know, to start the building of aircraft, was in the building of the engines, and is there anybody here to-night who doubts that the accomplishment of the American manufacturers of engines was one of the greatest accomplishments in the war, one of the greatest things done in the war? When the war ended there wasn't a nation on our side of the war—and I am sure there wasn't one on the other—who would not take every engine we could build for them of the types we were building, there was not a single nation in the war that did not want more of what we were making than we could build for them.

"And we did not do so badly. From the time we began, we built more engines, and we built more 'planes, month for month, from the time we began, than any nation in the war built from the time it began. We had more engines ready, and we had more 'planes ready, month by month, from the time we commenced, than any nation in the war had month by month from the time it commenced.

"But the American manufacturers of aircraft, the American engineers, with their ingenuity, their brains, their patriotic devotion, the tremendous work they put into it, were building so well and even so fast that the day the armistice was declared there were 686 American 'planes at the port of embarkation that could not be loaded. That was not the fault of the shipbuilders. Mr. Marshall gave us more credit than we were entitled to. But the reason for it was that while we were building a good many 'planes, a great many other people were building other things that General Pershing and the people on the other side wanted very badly, and they were taking trucks and ordnance and other things that they needed very badly, and leaving aeroplanes for the last few days, but the fact remains and we have it to our credit that we had more 'planes ready for them than they were ready to take. It was a great adventure, and we are all proud of it."

Since the signing of the armistice the Aircraft Board has been abolished and the air service has been reorganized again with Maj. Gen. Chas. T. Menoher, who commanded the 42d Division in France, as Director of the Air Service, which is divided into four groups, namely, Supply, Information, Training and Operations, and Administrative. The group of Training and Operations really succeeds the division of Military Aeronautics of the Ryan régime; Brig. Gen. Wm. Mitchell therein succeeds Gen. Kenly. Col. W. E. Gillmore is at the head of Supply group, which takes the place of the Bureau of Aircraft Production; Maj. H. M. Hickam at the head of Information and Col. W. F. Pierson at the head of the Administrative staff. Gen. Menoher's executive officer relating him to the rest of the organization is Col. M. F. Davis and there is also an advisory board made up of Col. W. S. Kilner, Col. A. L. Fuller, Col. H. C. Pratt, Lt. Col. G. B. Hunter, Lt. Col. B. Q. Jones, and Major C. R. Cameron.

In the end, the men of the equipment division of the Signal Corps who were so aspersed and even humiliated were fully vindicated officially. They needed no vindication in American business and manufacturing circles. As the public gets the right perspective and a proper understanding of the multitude of almost insuperable difficulties under which they tirelessly, patriotically, and thanklessly struggled, it too will accord honor where it was wont to give censure.

# CHAPTER XXVII

## REVIEW AND PROSPECT

Now that it is possible to survey the whole field of America's industrial production for war purposes it is plain that the country did much better than it seemed to be doing during the war when the emergency was so pressing, celerity so vital, and each mistake, or delay, or error of judgment loomed so large. In consequence of the basic national fault of not preparing for what was coming, it was necessary to try to do everything in an incredibly short period of time. There was little time for deliberation. Plans and their realization had to be almost simultaneous. Often realization was far advanced before the plan was revealed to be faulty. Marshal Foch's admonition, "Do not delay half a minute!" rang in everyone's ears. Almost everyone who was in touch with the vast effort for production was aware of confusion, personal incompetence, ill-advised courses, and the dilatoriness of official routine. The accumulation of this discouraging personal experience resulted in a widespread pessimism which tended to obscure the fact that whether by muddling or by clear-headedness, thanks to a prodigious output of energy, the great enterprise was moving ahead all the time with increasing momentum.

Assistant Secretary of War Benedict Crowell has recently published a voluminous report on the production of munitions during the war, which though it does not have the value of an impartial review does enable one to get an adequate impression of the colossal extent of the munitions work and compare relative degrees of success and progress of the different departments of the effort. It shows clearly that aircraft production was at least as well and as swiftly done as the other parts of the mountainous job. Reviewing what was accomplished, some of the outstanding features might be mentioned as follows:

Prompt provision of training fields, quarters, general equipment, schools, and supplies for 190,000 men.

Rapid procurement of training 'planes and engines on the requisite scale, 1406 'planes and 1905 engines being produced in 1917, production beginning as early as June on the 'planes and in July on the engines; that is to say within two or three months after the declaration of war; and being adequate for the training requirements of a force of 190,000 men within a year. The total of training 'planes for the first year of the war—with only nine months of real production—was 3428. This compares favorably with the total British production of 2040 for the calendar year 1915, after giving the British producers a starting period from August 1 to December 31, 1914. Our engine production for the same period was probably 25 per cent. greater than the corresponding British production.

The designing and production of the Liberty engine is now conceded on all sides to have been a brilliant and praiseworthy effort. It is now perceived that taking all things into consideration, to design and manufacture such a nice, complex, and powerful mechanism, far in advance of continental development with respect to amount of power, within one year was an extraordinary achievement. The best promise for a transplanted foreign engine was 500 machines in that period, whereas there were actually produced 1100 Liberties. The decision to produce the Liberty engine, widely criticized at the time, as a fundamental mistake, turned out to be one of the most judicious decisions of the war. It put us aerially on the battle line with American equipment.

The production of battle 'planes, pivoted on engineering and military advice and judgment, and was slower in getting under way than that of training 'planes and engines and the Liberty motor, but when the gates of production were opened progress was exceedingly rapid, and the rate of output of them was near 20,000 a year when hostilities ceased, which again compares very favorably with a total British production of 14,400 in the third year of the British effort. Our actual home production of 'planes of all kinds during ten months of 1918 was 11,815, and had the armistice not been signed in that year, would have been 15,000.

The progress made in balloon production was more than satisfactory.

The record of the designing and manufacturing of all the accessories for airplanes and balloons is one of the brightest chapters in American industrial history.

The discovery of economical methods of producing helium gas was a brilliant and momentous feat, which will have a profound effect on the future of lighter-than-air craft.

The adaptation of cotton fabric to airplane wing-covers was a lifeline for the Allies as well as for ourselves.

The production of spruce in sufficient quantity to keep going all the French, British, and Italian aircraft factories, as well as our own, was a marvelous feat.

The production of dope was similarly important and meritorious.

The ample provision of machine guns of both the fixed and flexible type for aerial use reflected prompt and wise decision and swift production.

The immense material equipment forwarded to France and England for the aviation supplies and training camps there as well as for the manufacture of airplanes for the American army by French manufacturers is extremely noteworthy. Hardly less important to the Allies were the 18,000 American mechanics who were sent to their assistance.

The actual shipment of a considerable surplus of Liberty engines to the Allies within eighteen months of our entry into the war was an exceptional achievement.

While we were toiling and moiling at aircraft production at home we kept the shops and factories of the Allies going with our endless supplies—in itself an achievement of the first rank.

The building up in about fifteen months from almost nothing of a great executive and administrative organization and an aircraft industry of more than 300 plants and more than 200,000


**148th American Aero Squadron at the Front, at Petite-Sythe, France, Equipped with Sopwith-Camel Planes**

U. S. Air Service Photo

workers that had already achieved an engine production greater than that of all the Allies and that was soon to have realized a corresponding rank in 'plane production, is now seen to have been a supernormal deed. Viewed in the perspective it seems hard to understand why the ability and success with which the work was being prosecuted were not understood when we were in the midst of it.

It reflects no aspersions on other fields of war production to say that the most lauded and appreciated of them did not do better than the aircraft producers. A few not invidious comparisons may be made.

The war had lasted a year before the first ordered ship was delivered to the Shipping Board. The first steel ship on order from an Atlantic Coast yard was not delivered until September, 1918.

Only 80 tanks were completed when the armistice was signed and only 16 had been floated overseas.

Up to May 1, 1918, only 85 heavy Browning machine guns had been turned out.

Practically no hand or rifle grenades that were satisfactory were delivered from American factories until about the end of hostilities. Before

November 11, 1918, we had shipped to France only 181 75-millimeter guns and only 114 155-mms.

Our total shipments of artillery of all kinds were 815 units and the total production 2034.

This may be compared with a total production of 16,000 Liberty motors and more than 30,000 air engines of all kinds. Exclusive of the 1800 Liberty engines shipped over-seas in 'planes, 6210 were floated uninstalled.

The total shipments of combat 'planes to France were about 2000 as against 815 guns.

Of trench mortars we had completed only about 1500 at the signing of the armistice. We produced only 101 anti-aircraft guns, counting only complete units.

These facts are cited merely to show that even with unlimited financial resources, great manufacturing capacity, splendid executive ability and with speed of production as the supreme objective, miracles cannot be accomplished. Except in respect to service rifles and machine guns, it required a year and a half to get into the full volume of production that the magnitude of the war required. In fact, we found that we could not adequately equip an army of millions from our own factories before the spring of 1919, that is, two years after the war began. Had not

France and England, but especially France, been able to furnish the artillery and much of the other equipment of our first two million men, we would have contributed almost nothing to the effective land forces of the Allies before the spring of 1919. The offset of this deplorable fact is that we were able to supply the Allies with vast quantities of war materials for their factories and food for their armies and civilian populations. While we were taking the punishment in the form of two years of delay for our incredible folly of not preparing for war we were able to contribute decisively to keeping our friends in the field until we could come up. The time it took us to get ready shows clearly how helpless we would have been even in a defensive war against Germany or any other first-class military power if the navy could not hold the seas.

In profiting by the expensive lesson of the recent war, our authorities must give great attention to aircraft of all sorts. In a future war we shall be largely dependent upon the degree of progress that the civil utilization of aircraft shall make in the meantime. To promote civilian interest in aeronautics and to keep alive some of the aircraft organizations that were created during the war, liberal government appropriations are necessary.

Moreover an adequate engineering organization must be maintained and to maintain it there must be ample funds available for experimentation with and the purchase of new types. By being in the market for the purchase of a considerable number of machines yearly the government will not only keep aircraft manufacturing alive and vigorous but it will make opportunities for private aeronautical engineers and engineering companies to continue their researches. There is thus a certain need for a large government engineering establishment. As this establishment and private concerns bring out new types that are approved and adopted, drawings and blueprints can be made, dies can be prepared, and all the preliminaries of manufacture made ready against the day of need. When these are ready, quantity manufacture, through the conversion of plants, is but a matter of a comparatively short time. But beyond this, it will be necessary to maintain constantly on hand an amount of up-to-date equipment far in excess of the numbers of the aviation military personnel. This means constant renewal and scrapping to keep abreast of the progress of the art. So, an adequate program of aerial defense will provide a considerable volume of business for a few manufacturers even in peace times.

The greater the civilian interest in and use of aircraft the smaller the government establishment may be; so, it would seem to be wise economy for the air service to use its aviators and all its facilities and resources to stimulate the demand for aircraft. With thousands of civilian flyers and machines there will be a sufficient demand to maintain many factories; and the flyers, the machines, and the plants will be ready in an emergency. The air service must therefore proceed on a much larger scale with its plans for landing fields all over the country, with the mapping of air routes, with the encouragement of the use of airplanes in the postal service, where a good beginning has already been made, in forest patrol, in coast patrol, in meteorology, with the encouragement of aeronautical clubs and associations. All this work could probably best be done by creating an independent air service that would be both military and civil, though there are not lacking arguments against centralization of control.

The end of the war found us potentially the world's leader in the quantity production of aircraft. Most of the machines used by all the nations will soon be obsolete, so that we have only to adopt and maintain an aeronautical policy corresponding to the size and resources of the country from now on to take and maintain the first place in the air. The "jump" in the next war will be enjoyed by the combatant with the superior air service. It is conceivable that other branches of the military service may never even get an opportunity for action. The war may be over and decided in the air before land and naval forces can be utilized. Have we learned anything from this war or shall we again lapse into indifference and again expect our leaders and builders to accomplish the impossible and then blame them instead of ourselves as we did in the great war that is just now receding into history?

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