JET ENGINE PRODUCTION

11 February 1952

1173

CONTENTS

Page

INTRODUCTION--Colonel D. B. Diehl, USAF, Member of the Faculty, ICAF.....1

SPEAKER--Mr. Horace Mansfield Horner, President, United Aircraft Corporation.....1

GENERAL DISCUSSION.....18

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Mr. Horace Mansfield Horner, President of United Aircraft Corporation, was born in New Haven, Connecticut, in 1904. He is a veteran of Pratt & Whitney Aircraft, having joined that organization in 1926, a year after the founding of the company. Mr. Horner served first in the purchasing department and later held jobs in the assembly, test, and inspection departments in the factory. Mr. Horner was general manager of Pratt & Whitney Aircraft during its largest expansion period from 1940 to 1943. He supervised the establishment of the licensee agreements with the automotive industry, the building of the Kansas City plant and the four satellite plants in New England. These projects resulted in production of half the horsepower used by all United States military aircraft in World War II. Throughout most of this period he also served United Aircraft as its vice-president in charge of manufacturing for all of its divisions. A native of New Haven, Connecticut, Mr. Horner attended Phillips Academy, Andover, and is a graduate of the Sheffield Scientific School of Yale University. He is a former chairman of the Aircraft Manufacturers Council, east coast; of the Aircraft Industries Association and a former member of the AIA's executive committee. Since 1943 he has held his present post of President of United Aircraft Corporation.

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COLONEL DIEHL: General Holman and gentlemen: Our speaker today has the unique distinction of having directed the production of more aviation horsepower than any other man in the world. In fact his company produced approximately half the military horsepower utilized during World War II. Today the backbone of our strategic Air Force, the B-36's and the B-50's, are powered by the mightiest reciprocating engines ever successfully developed, the 3800-horsepower Pratt & Whitney Wasp Major.

Technological progress has changed the aviation picture considerably in the last few years, particularly in the jet engine field. Pratt & Whitney, and our speaker, are now engaged in a race for supremacy in this field. It is on this very important subject, one that is in the spotlight today--jet engine production--that Mr. H. Mansfield Horner, President of the United Aircraft Corporation, will address us.

Mr. Horner, it is a great privilege for us to extend to you a welcome to the platform of the Industrial College of the Armed Forces.

Gentlemen, Mr. Horner.

MR. HORNER: General Holman, members of the Industrial College of the Armed Forces, and distinguished guests: General Vanaman is a chivalrous gentlemen, so I suppose that neither you nor I will ever be permitted to resolve a disturbing little coincidence that surrounds my visit here. A day or so before he and his colleagues sat down to invite me to speak to you on the subject of "Jet Engine Production," an event had taken place in Philadelphia that I somehow keep linking up with the privilege of appearing before you. There--and this was properly reported in the newspapers which General Vanaman so carefully studies--before 8,000 scientists who compose the American Association for the Advancement of Science, a paper was read which said in short: "It's not wise to destroy people's illusions on how good they are. People, because they have a false estimate of their own ability, succeed in doing things that by all the rules of reason they could not possibly do."

Please notice the emphasis on people. By and large jet engines are produced by people. They are people, I must confess, with illusions too. I suppose the oldest and most tedious saying in aviation is the one that says, "You don't have to be crazy to be in aviation; but, boy, it does help!"

1176

Nevertheless, if a share of our progress comes by way of a shield of illusions, I think an even greater share results from an honesty that sometimes sees in true dimension the size of the little tin cup which that old Yankee, Oliver Wendell Holmes, said all of us carry down to the ocean of knowledge. It's not an individual honesty alone; it's a team honesty and candor as well.

More and more in recent years I have tended to watch the development of aircraft power plants in the same mood that seized Wright Parkins, our engineering manager at Pratt & Whitney Aircraft, one day when he was conducting a visitor through our test houses.

"Actually, Mr. Parkins," this visitor said brightly, after watching the blue flame of an engine's exhaust, "you people simply are trying to contain and control fire, aren't you?" "Yes," said Parkins, who had been up to his ears in trouble all week, "but that's simply all the devil has to do in h---, too, as I understand it."

The world now is barely into its second decade of the aircraft gas-turbine engine. Its event was the great leveler in world air power leadership. The piston engine, particularly the radial air-cooled type that gave us supremacy in World War II, had a fundamental character that was peculiarly its own. It was an engine where background, experience, lore, a "feel in the fingertips," were vital to its successful design and production. It did not yield readily to theory and analysis. It was, to a major degree, designed on experience, and you often learned from it by deliberately breaking it, or its components, to smithereens. In a nonjet world, the nation with a solid leadership in the radial air-cooled engine possessed a priceless asset.

We were a third-rate air power in the judgment of our own military leaders from the end of the First World War until the final years of the 1920's. Then, with a national policy as set up by the Morrow Board, with the appearance of the R-1340 Wasp engine and its immediate successor, the R-1690, and a little later the advanced development of Wright's Cyclone series, this country's air forces, both Army and Navy, achieved first rank. Moreover, we swept the boards in the world's commercial air transport field.

All this was done at an incredibly cheap national price. If you want to sigh for the good old days of the 35-cent blue-plate special and the gentle tax-bite, you may be interested in this statistic: The design and three original Wasp 1340 prototypes, plus the original 1690 design and the first prototype, were accomplished in nine months

in 1925 and 1926 by six engineers and a score or so of shop craftsmen at a cost of 202,713.29 dollars. How far do you think you could get today with that sum in coming up, say, with two advanced turbojets that in comparative time would be roughly analogous--say a 7,500-pound thrust engine, of which you built three prototypes, and a 10,000-pound thrust jet, whose first prototype was about ready for the test block?

I have spoken at this length of the piston engine for a substantial reason. In our case, and in this discussion, the production of the gas-turbine engine inevitably must stand against the background of our long piston experience. In the early years of the jet, all our own efforts remained with pistons; the war precluded a quick jump into the new field. So when 1945 came, and we jumped, we were as little as Parkins's visitor had suggested. The jet, like the piston, is made of metal, and we are a metal-cutting shop. The jet contains and controls fire and we had been at the business of containing and controlling fire in a metal package for many years. We had produced or directed the production of about 700 million horsepower in our time, and a pound of thrust is no more awesome to an old engine man than a horsepower. In short, we had a widespread case of those Philadelphia illusions to which I referred earlier.

This was almost seven years ago. The Philadelphia illusions melted a few months thereafter. A sort of honesty, so powerful that it throbbed, reached into every corner of the shop. We learned--and we are in the process of learning--some things we doubt anyone ever thought of before. For instance, we have coined some wonderfully appropriate phrases comparing the piston and the gas-turbine engines, phrases that probably will be enshirned in Bartlett's future editions, such as: "It's a horse of a different color," "It's a different breed of cats," "Throw what you think you know out the window and begin with what you are finding out," and so forth. When these remarks became a plant-wide litany, running from design and various other engineering groups through production, assembly, test, and service, we knew we were on our way. A Philadelphia illusion may have the blessing of science; but in jet engine design and production we found nothing will bless you more than a candid look at the problem, a pair of good and dirty hands, and a plunge into the job.

The requirement for a new and fresh viewpoint began with the initial gas-turbine design. Even in piston engines, we always had followed the practice, depending upon how new the problem was, of weighing the initial design against its productibility. But since piston power plants were marked greatly by what you had done in the past, the analytical designers were less likely with the piston engine to underscore and recommend methods of handling production problems than they do with the gas-turbine

1178

engine. A gas-turbine engine takes far more man-hours of actual initial designing than a piston engine. For example, we spent about 730,000 design man-hours on the R-4360 piston engine in its first four years of intensive wartime development, compared with 1,338,000 man-hours on the J-57 jet in its first four years. Yet the gas-turbine engine design, costly as it is in man-hours and dollars, has removed many of the development problems by assuming the task of determining the answer to those problems in advance of manufacture.

Broadly, the gas-turbine engine design costs enormously more in money, requires far more time, and yields far better to theory and analysis than the piston engine. The gas-turbine is an easier engine to make and assemble, with certain qualifications which I shall speak of later and which may yield to experience in another decade.

Primarily, these two factors are true because in the gas-turbine engine we are dealing with rotational parts rather than reciprocating parts. While the forces at work in the jet engine are tremendous, they are in most cases a steady state of force as opposed to the up-and-down, fatiguing forces of reciprocating parts in the piston engine. It is unlikely that any part in a gas-turbine engine ever will be as complicated to machine and finish as a piston engine's master rod or crankshaft. Besides the intricate shapes of its parts, the piston engine has hundreds of parts subjected to all the fretting, rubbing, and galling that results from reciprocating action, all possible focal points for the start of fatigue failure. The gas turbine, on the other hand, runs relatively smooth, with relatively few bearings, and in the case of the straight jet, there are almost no gearing problems such as the piston engine has, although the gas turbine, too, has its own peculiar and bedeviling vibration problems.

In materials--and it is here that jet engine production poses one of its major problems--the two power plants differ radically. The piston engine for the most part was cut from forgings and castings, while the jet engine not only is fabricated from forgings and castings, but has a large amount of difficult sheet metal work. More than a generation ago, the basic idea of the gas-turbine engine was known, but nothing could be done until modern "superalloys" were developed, capable of maintaining their strength and resisting oxidization at the high temperatures encountered in the jet. Yet it is interesting to note that although we are shocked by the large amounts of critical alloying elements that are required in the metals selected for quantity production of gas-turbine engines, the critical alloying elements used are about in proportion, in equivalent power, to those required in the high-power piston engine.

The broad range of engineering's present assignment in the gas-turbine field--in which it somewhat invades production by its suggestions on methods--probably will endure for a number of years. The art is new and until a deep core of experience is established, design and development engineering must seek to solve many of the problems that require new methods hand in hand with production engineering.

Not only are we working with new combinations of metals and critical alloying elements, but there are fresh perplexities involving intricate thermodynamics, aerodynamics, and a host of other techniques, each of which requires its army of engineering and technical specialists to solve. In Pratt & Whitney's big J-57 jet, for instance, there are 40 separate airfoil designs, consisting of 16 stages of rotary blades, 17 stages of stationary vanes, 3 sets of turbines, and 3 sets of nozzle vanes. Believe me, to determine the flow of gases through that labyrinth of finely shaped passages is not done with a mirror and a slide rule in the hours between breakfast and lunch.

You all know something about the problems of getting the air to flow properly over the wing of an airplane under all conditions of flight. Imagine then what the problems are in a jet engine compressor involving the equivalent of 34 wings with every other one of them rotating at high speed within the confines of a housing which permits nothing to be seen or heard. Andy Willgoos, or beloved former chief engineer, who died three years ago and who worked on piston engines from the start of his career, knew them inside and out. He always threw his hands up in desperation when he got around a jet engine because there was nothing he could get those very sensitive hands on. He could look at the gages and play with the controls of a piston engine test stand, and as a result he could come to a quick conclusion as to how the engine was running. But when he got into the control room of a jet engine stand, all he could do was look at a myriad of pressure and temperature gages and hope that hours or days later, when the calculations were finished and the data analyzed, he could arrive at the happy conclusion that the engine had been running properly. Needless to say, he was disappointed 9 times out of 10.

Consider also the problem of lubricating the J-57. Compared with the piston engine, there are so few rubbing surfaces in a jet that the actual problems associated with wear are not great. On the other hand, the problems of keeping the lubricant from disintegrating, and from escaping either to the outside or into the gas stream as a reult of the action of heat, are considerably greater than in a piston engine.

A moment ago I said--with qualifications--that the jet engine is easier to make and assemble than the piston power plant. The big qualification there is grammatical tense. It ultimately will be easier

1180

to make and assemble. Right now, like engineering, the production force is encountering all those curious paradoxes that parallel, in a shop way, the odd and complex problems engineering also faces. I do not think Pratt & Whitney's shops is unique in its problems either; I would bet every gas-turbine manufacturer is wresting with the same difficulties. In our case, cast against our piston background, one of the horses of an astonishingly different color is the raw material for jets--new and tougher, with a wide range of components of large diameter and thin-walled section as well as a great variety of aerodynamic shapes of such awkward dimensions that our designers often complain that they have neither a beginning nor an ending. To work this material called for an extremely different breed of cat in machine tools, jugs, fixtures, and producing techniques. These odd horses and peculiar cats are in strange contrast to the piston engine's comfortable old forgings and castings, which were heavy and sturdy, and which supplied their own rigidity for machining.

The relatively flimsy structure of the jet part and the comparatively great size of its diameter have meant a monstrous outlay--I use "monstrous" advisedly--both in new tools and in ingenuity to design those tools and work them. At the same time, we had to master the sheet metal's allied art of precision welding and devise welding machines capable of intricate metal-fusing processes to extremely close tolerances. With the multiplicity of joints in the sheet metal parts of a jet, the distribution of stresses is one of the most important considerations. A weld becomes an actual design factor rather than a mere fastening device.

Under such circumstances, we could operate only under the creed that "The weld is as important as the parent metal." Our engineers, working with established welding companies, conceived machines for specific welding requirements and brought to our production lines a battery of welding machines that until just recently, after our designs were made available, could not be found in any other plant in the country. While we are still using resistance welding, and will continue its use, our trend now is toward precision fusion welding of metals that were never thought usable in weldments before. We believe today that we can handle almost any combination of metals in welding that we can envisage in the future. Furthermore, we have had to learn brazing techniques heretofore unknown.

Here (showing manifold assembly) is a part, the J-57 fuel manifold assembly, that illustrates well the factors of relative flimsiness, unwieldy diameters, multiplicity of operations, and the high cost in raw materials and man-hours that go into many gas-turbine parts. This fuel manifold has 276 parts; its total weight as a finished assembly is 46 pounds. It requires 465 man-hours to fabricate and its cost of fabrication is 2,225 dollars. The total brazing cycle requires

21.5 hours. There are 374 brazed joints and they are submitted to temperatures during brazing that reach as high as 2,150 degrees F. The raw material in this 46-pound fuel manifold costs 1,750 dollars.

The raw materials, as you can judge from the manifold assemblies, comes high, the labor is increasingly higher, and the tooling costs are really fantastic. Over the past 10 years there has been a very definite trend toward more complete and more highly perfected tooling to produce new types and models of engines; the trend swiftly quickened with the advent of the jet. This has been brought about by the refinements in engine design and new constructions, which make for complex processing together with ever-tightening tolerances and finishes. The skill required has been more and more embodied in the design of the tools and machinery rather than in the individual skill of the operator. And this trend must continue in the advanced jets, especially if we build them in quantity with labor that is trained largely for single-purpose operation.

We recently checked our production cost figures over a ten-year period. We found that whereas the base labor rate has increased from $.65 to $1.65 from 1941 to 1951, the labor cost per horsepower has changed only from $1.34 to $1.70 in the same period. Thus, one figure, wages, jumps more than 250 percent while the other increases less than 30 percent.

This increase of productivity is primarily the result of improved tools. Tooling cost per horsepower, comparing 1941 and 1951, has increased 122 percent. Even more striking is the increased cost of jigs and fixtures. For example, since Korea the average has risen from 500 to 1,300 dollars, some 250 percent. Nothing, I suggest, could better illustrate the increase in complexity of tool design, particularly for gas-turbine engines, than these figures.

Equally illuminating are the increased numbers of tools required to produce a new model or new type of engine. To produce the 19XB axial-flow engines in 1947 required 5,250 tools. We used 13,600 tools to build the J-42 centrifugal-flow jets in 1948, 1949, and 1950. We have 16,800 tools, with more to come, for the production of our J-48 centrifugal-flow jet.

The same growth applies to our shop standards of manufacturing. The introduction of new types and models and the continued demand for noncurrent spare parts have meant a growth from 30,000 shop standards in 1946 to 117,440 today. To put it another way, in four years, active operations in the shop have increased almost fourfold, and there is no leveling in sight.

I have spent all my life around tools and machines, but I never cease to be astonished and made humble by our native ingenuity in devising, improvising, or conceiving new tools and new machines to

solve what often seem to be insoluble problems. One of the particular benefits of a long history in engine making has been a traditional suppleness in the use of tools. True, in the jets our people often speak of throwing their old know-how out the window, but I notice they have a daily habit of reaching out, plucking up an old idea or machine, turning it around to fit the occasion, and coming up with a new answer for a really thorny jet production problem.

A general feeling of dissatisfaction surrounds the use of the conventional big swing lathe, used in machining thin-walled, stainless steel rings of large diameter for turbojet nozzle vane rings, stator shrouds, and tail pipes. The diameters to be handled, running up to 48 inches, required a large lathe, capable of a 60-inch swing, a size which is normally built only for heavy-duty work. But the jet engine rings are shallow and of thin-walled section and the cuts to be made are relatively light and precise. So the large horsepower of the conventional heavy-duty lathe is not actually needed; what was really needed was the range of a large car-wheel lathe with the sensitivity of a tool room lathe.

Although the principle of the large swing facing lathe have been known 100 years, Pratt & Whitney took these requirements, together with a revolutionary new lathe layout, to Lodge & Shipley. Their designers carried on the idea. The result was an entirely new lathe design--a right-angle chucking lathe with a T-shaped bed. The new lathe can handle facing, straight or taper turning or boring, and can be purchased with a contouring attachment. A battery of these lathes has been installed and Lodge & Shipley is now supplying them to others in the industry. As a second-operation machine to receive roughed-out work from a vertical boring mill, it is an ideal answer. The new design saves nearly half the floor space that would have been required by a standard 60-inch swing lathe--a real advantage in increasing our productive capacity, since the large jet parts and their big tools and fixtures blanket production space at an alarming rate.

I could go on with such examples for hours. This talent for seizing upon new methods, for improving, for boldly applying new conceptions to current problems, is a bonanza that comes only from experience and a clear mind. Certainly it is not a quality that exists in East Hartford alone or Connecticut alone or the United States alone. Joseph Henry, the American physicist, set forth the heart of this truth nearly a century ago when he said, "The seeds of great discoveries are constantly floating around us, but they only take root in minds well prepared to receive them."

This happy good fortune of the prepared mind and the accidental observation comes best when men are not under the eternal gun of meeting almost impossible assignments. We are constantly gratified that a multitude of fresh ideas on better jets, better production, and elimination of costly practices could flower when thousands of men are hemmed in by critical day-to-day problems. Speed is expensive in many ways.

The fantastic schedules that have been set, altered, reworked, and reset, take their toll in every fashion. The limitations of producing concurrently with primary development are unbelieveably severe. We are trying to leapfrog time in a field--aircraft power plants--wherein history time after time, and without a single major exception, holds a rigid yardstick of years for design, development, and service against the product. I cannot think of a single aircraft engine that ever surmounted the limitations of that yardstick.

All of us know that an obvious weakness of our present procurement is the tendency to accept quotations for engine performance and delivery dates and thereafter to predicate airplane delivery schedules on such quotations, even though the promises are fantastically overoptimistic. They are not met; a whole program is thrown out of gear. I wonder, as a suggestion, if procurement people should not invariably evaluate proposals which they receive by considering the previous history of aircraft power plant development with regard to the time it takes to go from initial design to the production engine, then, obtain a realistic evaluation of the actual stage of development by observing the number of development hours attained on the engine and the total expenditure on the engine to date. Although it is possible for an engine company to do a large amount of development running and spend a lot of money on an engine design without obtaining a useful aircraft power plant, it is virtually an impossibility, in my opinion, to obtain a useful aircraft power plant without undergoing a large number of development hours and spending a lot of money. Had procurement accepted this historical and immutable fact and set up criteria based upon it, I firmly believe that certain of our recent disappointments in engine development programs would not have been encountered.

Obsolescence is always with us in aviation. Production men view the engineer with a somewhat jaundiced eye, for no sooner does the engineer perfect one device than he embarks on another to make his first obsolescent. But the speed of the jet art has moved with such rapidity that even "obsolescent" is the improper word today; we move at once not to make the new "obsolescent" but to make it "obsolete."

1184

In the building of our semiproduction J-57 turbojets, there were 2,100 engineering changes between the first and the nineteenth engines, as we sought to carry on preliminary stages of development concurrently with production. These changes cost us 410,000 dollars in tooling, which does not include the loss in tools that already had been made for the J-57, and which now must be scrapped because of the engine's swift development. And while basically in time jet engine production will be simpler than piston engine production, the demand for flexibility in manufacture, we believe, will be much greater because of the growing necessity of tailoring a new engine design for every specific aircraft type. The rapid rate of obsolescence also will dictate increasing flexibility. When we reach that point, production is going to face some truly tough problems. And the day is almost upon us. It has never been so important as it is today that the power plant and the aircraft both be designed, built, and completely integrated to give optimum performance.

The J-42 and the J-48 can develop full take-off thrust if one main fuel pump fails. Both engines can be flown at constant R.P.M. from sea level to 40,000 feet without jockeying the throttle and, finally, both have emergency fuel-control systems. The development of these three features probably constitutes the most expensive factor in the development of the J-42 engine and delayed delivery of production engines. The latter two features also have been a prime production and service problem in the J-48. The three items, and similar gadgets, represent our best effort to fulfill American specification requirements as laid down by specialists seeking perfection.

Piston engines do not carry all of these duplicate features and as we become more familiar with the gas-turbine engine, I believe some of these gadgets will be dropped. As a matter of fact, the emergency fuel-control system is being dropped right now in the multiengine aircraft.

This tendency for complicated gadgets in the search for oversimplification in the operation of an engine is due, I think, to the way in which all of us tend to specialize. A specialist concerned with the fuel-control system thinks in terms of fuel-control systems--not in terms of a whole engine. The result is that the main goal--to develop dependable, readily producible, propulsive power--is sometimes lost from sight because of a specialist's enthusiasm in pushing his pet ideas.

The need for swiftly building up our Air Force and Navy air arms after the outbreak of hostilities in Korea led every major producer to look again at his network of subcontractors. For more than a quarter of a century our business has been based upon the skill and ability of

a network of subcontractors and suppliers. Traditionally we have subcontracted 50 percent of our total finished parts, and last year Pratt & Whitney Aircraft purchases in all categories ran over 200 million dollars. Ninety percent of the vendors and suppliers were small business firms, employing less than 500 persons. As a matter of fact, one of the first tasks I undertook when I joined Pratt & Whitney Aircraft as a kid just out of school was to help and evaluate 200 subcontractors for a little company which had little real business but high hopes. In Pratt & Whitney's case, the network now has grown to emcompass more than 5,000 individual companies scattered all over the United States. It is impossible to break the group of subcontractors down between jet and piston type parts; in fact, so far as we can determine, only one company is not working to supply us material for both types of power plants. The backbone of our subcontracting program rests with those companies that have moved along with us as we in turn have grown. In times of expansion, they increased their capacity for our work in times of normal production, they adjust to our needs. We have thus far been able to avoid the disorganized scramble for subcontractors that many in the aviation industry have had to make.

We are still seeking able subcontractors. We had an odd experience recently with a national company of wide reputation. Its men submitted a smoothly done brochure which showed the types of machines they had available and an impressive list of work they had done. Our people finally determined that they did own the machines, but in many instances the machines were separated by hundreds of miles and were in warehouses.

About the same time three massive gentlemen, liberally anointed with toilet water, with flowers in their buttonholes, with firm handshakes, and armed with an ash tray, a pen and pencil set, and a five-pound box of candy, strolled into our purchasing department and assured us that they did some of the finest quality machining in the world in their dandy little shop in the Midwest. Indeed, this was the first trip they had taken for months in which they had not flown their own personal helicopter--from their girth, our people were inclined to think they must have a secret new troop carrier. We gave them typical specifications and examples of our work and they left, after carefully handing around the box of chocolates among the most attractive of our girls. That was 14 months ago.

We have not heard from them since.

But it is not all that bleak. Some years ago we had a clerk in our production engineering department who never left the plant if he could avoid it. He wandered about, studying methods and operations in the machine shop. Presently, with two machinists, he started a

1186 tiny company in Newington, Connecticut, with 500 dollars that the three men had saved up. They rolled up their sleeves and reconditioned an old building for a shop; their intensity and vigor led us to give them a few simple parts such as tools, dies, pipes, and fixtures to make. For three years each of the three men paid himself 20 dollars a week in wages and they plowed all the rest of their earnings back into their little company. They spent Sundays, holidays, and nights making new additions to their plant and when the postwar period came, they took the long view and brought all the heavy equipment such as boring mills, turret lathes, and so on, that they could afford. Today they are the Atlantic Machine Tool Works in Newington. They today employ 315 men and women, are capitalized at 700,000 dollars and they are one of our most valued subcontractors.

I know other men far better qualified than myself are on your agenda to discuss such problems as critical materials, manpower, and various other phases of our broad mutual problem. But I would like to touch on one phase of the much-kicked-about critical materials question. We have attempted in the case of critical alloying elements to design all our new gas-turbine engines so that all parts could be produced from elements available here on the North American continent. The art of metal-working and the emergence of new metals are moving with extreme rapidity, but I submit that the best way that we can save critical metals, as well as critical manpower and critical time, is to build gas-turbine engines so dependable that the services buy far fewer of them. We must give them a durability that eliminates the necessity of having a spare-part volume as much as 250 percent of the actual engines that are in the field, as is true in the case of one engine now being used.

Since the cost in money, materials, and manpower is overwhelming, it is becoming increasingly important to try to select the type and size of an engine early enough so that when it reaches the production stage its tenure of usefulness will be long enough to justify its development.

The engine industry, both here and abroad, is in a great race at the moment to come up with a reliable, efficient turbojet in thrust category. Right over the horizon is the necessity of developing another for fighter use that will offer power with water injection and afterburner. I think we shall reach those goals, but they will be attainted only after we have followed the historic lines of research, development, test, and application. Meantime, we must utilize every skill and all our ingenuity to teach ourselves how to design and manufacture our products so that they are better and not much more expensive. Just as we are going to have to pour enormous

sums into laborsaving tools and machinery, so we must keep abreast of progress with all of our facilities. Great risks must be run, involving such investments, and the private companies must operate with the highest efficiency in order to attract the capital and to pay a return to shareholders who take the risks, for it is only by competition, as history has proved time and again, that we can attain and hold world leadership in aviation.

I would now like to show these charts, if I may.

This one (two diagrams of engines) carries back to the J-57 engine.

Chart 1, Time and Expense Comparison, page 14.--I mentioned during my talk with the matter of the development cycle. I think this chart shows it quite well. This is from the time that the design started, through as far as we have gone. This is the number of years. These spots are the first prototype engines shipped. You can see that you can't push it very much. With the relatively simple 2800 it was three years to this point. With the 4360 it was nearly five years. In the case of the JT-3, it was three years.

I can give you an indication of the tremendous amount of money that it requires today to develop any new, large, high-powered engine. These figures are purely expense items and do not include the capital investment which is necessary to develop a new engine.

In the case of the R-2800 piston engine, over its entire history of 15 years, it comes out to 22 million dollars. In the case of the R-4360 piston engine over its history of 11 years, we got up to 40 million dollars. In the case of the jet JT-3 Turbo-Wasp, which is now only four and a half years old, we are already up to 36 million dollars. That shows the rate of expenditure.

The development of an engine is a tremendously expensive project, in the facilities involved which are necessary. The engineers and the tooling with which to do the developing are also tremendously expensive and, of course, a tremendous risk.

Chart 2, Weight of Alloying Elements in Finished Parts/Engine - Lbs., page 15.--I mentioned the fact in my address that the critical materials which are so much talked about today actually are not used in much greater proportion to the horsepower in jets than they were in piston engines. The broad line shows the gross amounts used in

CHART 1

1188

TIME AND EXPENSE COMPARISON

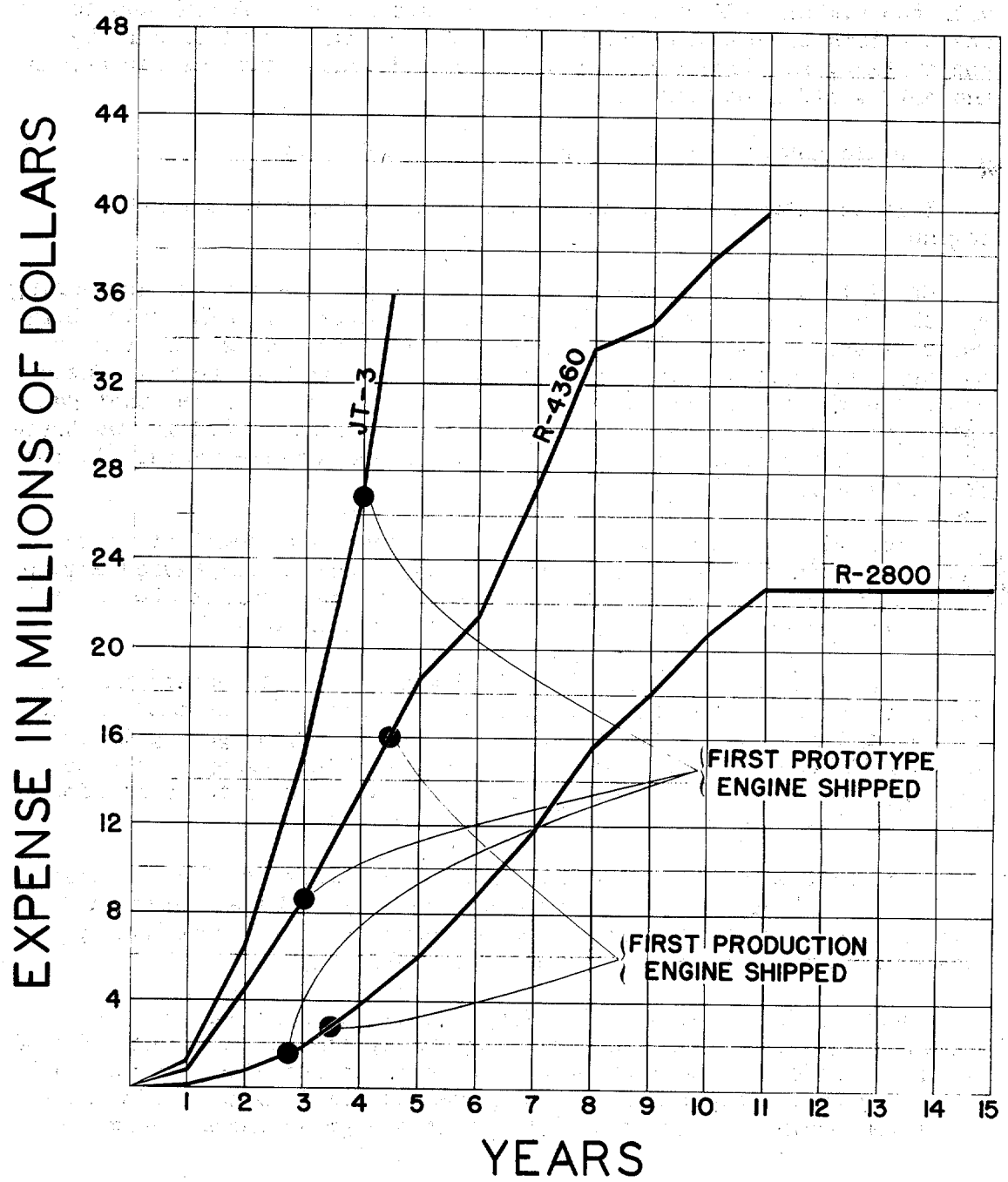
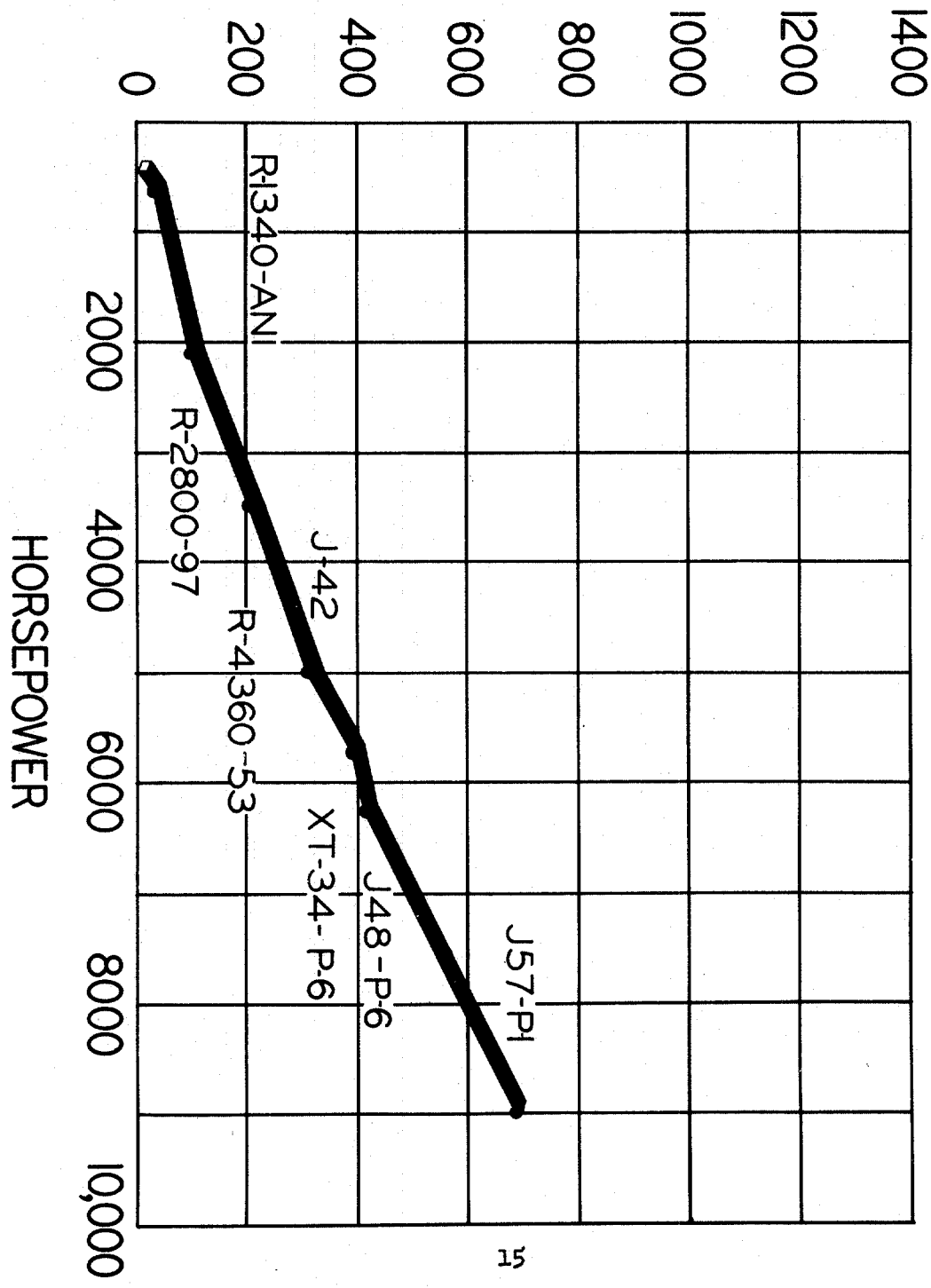


CHART 2

WEIGHT OF ALLOYING ELEMENTS IN FINISHED PARTS / ENGINE - LBS.

1189



finished parts and critical materials. However, putting it on the horsepower basis, this is the line you get. You have the J-57 here, the 4360 here, and the 2800 here. You have the old 4360 "war horse" here.

I think that is very significant. One reason why the critical metals get to such volume is because of the great power developed, as you can see. Here we have gone from 450 horsepower up to 10,000 horsepower.

Chart 3, Kilowatt - Hour Sales, page 17.--Another interesting thing, I think, is the consumption of electricity; this chart shows that. Up to 1938 we were at a low level. When the war came, our consumption shot way up. Look at where our kilowatt hours have gone, more than 150 million kilowatt hours.

Here (indicating engine parts on a table) are a couple of examples that I think you will be interested in. One of the expert pressing shops of the country undertook to manufacture for us this fuel nozzle support, which is part of the J-57 engine. After looking at this, they said, "The best way to knock out each one of these little bucket arrangements is to stamp these shapes separately and then weld it up." But, due to the vibration of the plane, which is way up, they couldn't keep these welds together. We were in a jam. Finally we took it to our own shop and said, "let us try to make it out of one piece." So we did do it and came up with this (indicating), which is just one standard. It took about three pass-throughs to do it.

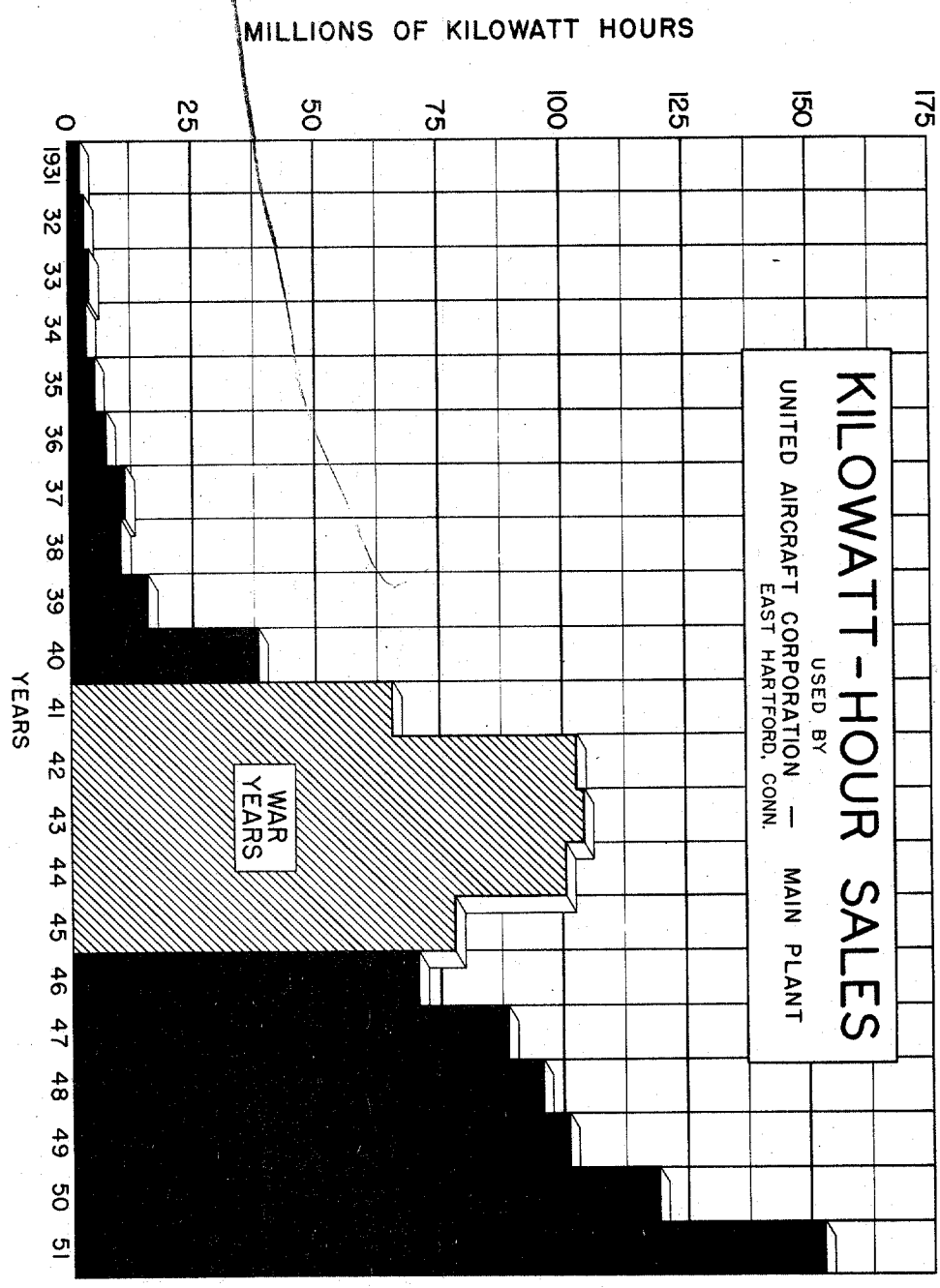
Everybody said it couldn't be done. We took it to this outfit. They said, "That is just nice. We are supposed to be the experts, but you have done it, but it shouldn't have been done."

Just another example here. This is a swirl vane assembly. It is a welded-up piece of equipment. We could make it the other way, but by a different process of brazing we came out with no laps. It is very much cheaper and very much more reliable and doesn't give us any trouble any more.

This is another example. This is a stator blade and shroud assembly. The old type of resistance welding has been pretty much superseded in our shop by this type welding, which we do on automatic machines. It takes all the question of individual ability from the operator. You just feed a sheet of metal into this and it is automatic. He just pushes a button and it comes down and makes this weld.

CHART 3

1191


KILOWATT-HOUR SALES
USED BY
UNITED AIRCRAFT CORPORATION — MAIN PLANT
EAST HARTFORD, CONN.
MILLIONS OF KILOWATT HOURS
175
150
125
100
75
50
25
0
1931
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
YEARS
WAR YEARS

1152

Well, gentlemen, I am most appreciative of the opportunity to have been with you today. It was very nice of you to invite me. Thank you.

QUESTION: Can you tell us about any production bottlenecks, important ones, that you have encountered up to this time that might be impeding you in meeting your production schedules?

MR. HORNER: If I may talk as of about a month ago: The schedules have been changed so much and are in such a state of flux right now that I am not sure what is the number one bottleneck this month. But with the schedules that we had a month ago, machine tools were still the major bottleneck. We have been forced to postpone our schedules and, instead of pushing the vote of increased deliveries up, we have had to push it down. On the 4360 this has had to be done five separate times from August 1950 through to December 1951, which was all primarily due to lack of machine tools.

When we originally went into this Korean emergency program with our promised schedules, we had no way of knowing what delivery we might be able to get on machine tools. We were very loath to give any delivery schedule. But after discussing it with both the Air Force and the Navy, they said, "Assume you can get the tools as fast as you need them, but give us some kind of a schedule." On the 4360 it was months before we could get the tools. So, of course, our schedule quickly became an impossibility. We had a number of unpleasant discussions with the military on setting these schedules back.

Actually, I don't think that our delivery of engines on the 4360 affected the military as much as it anticipated. The jet plane engine production was also pretty good. I think some of the other equipment, one example, such as electronic are more of a bottleneck now than the engines.

There have been some airplanes waiting for engines. But by and large I don't think that the engines were the number one bottleneck.

Right behind machine tools, and at times cutting tools, was the question of materials. That is, of course, entirely in the hands of the Government. It has an allotment system for materials. The lead time required from the start of a purchase order to the actual delivery has become so long that, unless the military has the ability to place orders for things like engines far enough in advance, you will always have delays. I understand that under the new appropriation laws passed by Congress you can buy products 18 months in advance. Well, for engines

you must have longer than 18 months if the airplane must have the engine 6 months in advance of the delivery schedule.

We have not run into shortages of manpower as such. We have, of course, a shortage of engineers and a critical shortage in the skilled mechanics of the old-time toolmaker type. But by and large during the war, we were lucky enough to put in mostly single-purpose tools. A girl just pushes a button and the work is done automatically. The tool has the whole range of operations and the required quality built into it. She has only to push the button at the right time and for it we pay her $1.55 an hour.

QUESTION: I notice that on chart 1 on the time and expense comparison on the JT-3 you don't have a dot for the first production engine shipped.

MR. HORNER: The first production engine schedule will be finished in April 1953--on about the five-year line.

QUESTION: In regard to this shortage of engineers, I understand that the requirement for engineers in the jet field is much greater than in the piston type. As we get more experience with the jets, as we get older, will your requirements for engineers reduce?

MR. HORNER: Not in my humble opinion, sir. The complexity of the project is going up at about the same rate as the JT-3 (which is the Air Force J-57) expense is going up. The simple centrifugal jet, if we could keep to that type, would have, in my opinion, in time required less engineering man-hours. But that type engine was limited because of the big diameter required for the higher powers and because of its higher fuel consumption. So we go to the axial flow, which is at least twice, maybe five times, as complicated as the centrifugal.

With this axial we can cut the fuel consumption down 20 percent over the centrifugal flow. In the meantime the engine has just gotten so much more complicated that, as I see it, if we continue to make progress--and I don't know what is going to stop us--we are going to need more and more engineering hours for original developing. So without reference to the special problems of the JT-3, engineering hours inevitably will increase with the size of the engine under development.

So in my opinion the complexity of aircraft production for engines in the air program is going to increase so rapidly that there is little hope of getting to the point of standardization where the engineering requirements will start to taper off.

QUESTION: Where are these engineers going to come from? I notice in the papers there are always ads for engineers for the aircraft industry. How do you propose to get these engineers?

MR. HORNER: I think that in the long range the opportunity in engineering is so apparent to a youngster and will be so attractive that he will choose engineering as an educational career.

Now, unfortunately, in the 1946 and 1947 era, the Government offically recommended to youth that they not take engineering, saying that there was a glut on the market already and that their chances of getting jobs if they took engineering were nil. Therefore our engineers now coming into graduation are, as I recall, something like one-third of the number that they were back in 1948 and 1949. That is one of the troubles.

On the other hand--and I am sympathetic with the Government--in the aircraft industry alone we changed in the 1946 era. Our requirements then were such that we were releasing engineers and not hiring them, because we didn't have enough money to keep them. We lost a lot of good engineers during that period.

The youth in these days are smart. If they see some kind of work fluctuating sharply up and down, they say, "To h--- with it. We are not going to go into that and maybe be out of work in a couple of years." That is another reason why, in my opinion, we must have a long-range air policy in this country. I don't care how big it is but it must be a long-range policy, so that the aircraft industry doesn't have these peculiar ups and downs which make these things so expensive from the taxpayer's point of view. If we could have an orderly production of airplanes instead of these big fluctations, the average cost of an airplane would be very much less.

A lot of the engineers that we have in industry as a whole are not as well trained as they should be because they have only recently come in.

QUESTION: You seem to have plenty of production problems. I would like to ask for a little side light on this question of the requirement of the Government for reports on production capacity, inventory, and things of that sort. How much trouble, expense, and interference with your production is that feature of the program?

MR. HORNER: I am sorry. I can't answer that. I don't know what reports are required today.

QUESTION: Were you able to estimate the thrust of that Mig engine? Could you compare the man-hours in your company to produce that engine compared to one of ours? Were you able to analyze that?

MR. HORNER: Well, I think there were two models of Mig engines. One that came out from the front was a pretty complete job. It was about 5,000-pound thrust. All of our studies indicated that it was about 5,000-pound thrust.

The bigger Mig engines are approximately the same size and concept as our J-48, that is, some 6,080-pound thrust. It is a remarkable job that the Russians did. We think we did a pretty good job in picking the proper size that was feasible in developing the original J-42 type, 5,000-pound thrust. But for the limit of diameter that we could go and still get it into the fuselage, and the development they showed in coming to their engine as quickly as they have--and it must be in production--was really remarkable. The workmanship was excellent.

They have a higher proportion of the critical alloying stuff, like columbium, than we have in ours, although about the same as the British have in their engine.

So far as trying to estimate the number of man-hours of production required, I wouldn't know. I would have to know what kind of machines they have; I have no idea what they have. But theirs is a very, very impressive effort and is surprisingly good.

QUESTION: I am wondering, with all the engineering changes, what problems we would have in standardization to obtain a higher degree of production, assuming that we have a freeze on changes in design.

MR. HORNER: In my humble opinion, any aircraft business in the country would be excessively stupid to put a complete freeze on design. I think the Germans made a pretty bad error there. There is a compromise that is the usual answer to most problems. I think that, going back to World War II, where we did have pretty much of a freeze in philosophy, I can show what I mean by the example of the F-51, North American and the F-47, Thunderbolt of Republic. By and large those two airplanes were in theory frozen for quantity production.

I think the primary thing is that the military didn't freeze changes of manufacturing origin. Further, they themselves required no changes except for those which came up in combat and required mandatory changes.

However, the competition between those two airplanes throughout the war led to the manufacturer in his own sweet way working in design changes. The power kept going up due to the competition, because Pratt & Whitney were very conscious of the Rolls liquid-cooled engine, and Rolls and Packard were very conscious of the Pratt & Whitney air-cooled engine. That competition gave those two companies design improvement that was remarkable. In was that spur of competition. It wasn't so much the dollars.

I think we have got, if possible, to utilize that great spur to improve quality. I think we should always do that, because we do want to keep our products improving and not get them static to the point where we could be beaten in the air because of quality. But the manufacturers in those cases were putting in changes themselves at the time it could be done without disrupting production.

QUESTION: Certainly, Mr. Horner, this product will be of greater vitalness in the event of a real hot war. With the assumption that if there should be a shooting war, started by the other fellow, have you given consideration to defense activities and restoration of production in the event you were hit?

MR. HORNER: That is a big subject and I would like to answer it in two parts.

First, Pratt & Whitney and United--and I don't mean here to seem to be patting myself on the back--really and honestly think of themselves as a responsible element of our national defense. As a result of that, in addition to subcontracting, even in peacetime, to the maximum, as soon as there is a threat of mobilization, and even before that, we are working with the automotive industry to have licensees ready to go to build any one of our products.

When Korea broke out in June 1950, I personally talked with General Johnson and said, "Look. The 4360 sure as h--- is going to be one of our number one bottlenecks. Let us get some licensees." So we had Ford in August, and Korea had started in June. We had the whole thing set and ready to start. We got the J-48 into Chrysler and we got the J-57 into Ford. They will be producing Pratt & Whitney products as licensees.

Now, from our own standpoint we have taken the responsibility for our possible plant damage due to air enemy action very, very seriously. Our primary responsibility is to try to protect the population. We have a team of engineers who are analyzing the buildings and locating areas underground in places like cafeterias where with the minimum of construction, braces, and so forth, we can make those places relatively safe unless there is a pretty much on the spot bomb. Any hit outside of a mile from us should leave our personnel reasonably safe.

We are training our people to get into those shelters. We are buying large amounts of disaster equipment to take care of the people who are hurt. We are training our force to do that job. We have a corps of engineers who are assigned entirely to civil defense within our own plant. They are working at it all the time.

We are building separate outlets from these underground places to get them away from the building in case the building collapses and they cannot get out of the normal exits.

We are doing what we can to study ways and means of rehabilitating facilities in case of damage. That is a much more difficult problem because of the unknown quantity and scope of the damage. But we are working on it. We are working on it in conjunction with our friends, Rolls-Royce and others, who had a similar problem during the war. We are taking it seriously. We are doing what we can about it.

COLONEL DIEHL: Mr. Horner, on behalf of the student body and the faculty, I thank you for an outstanding lecture.

(29 July 1952--750)S/mmg