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THE AERONAUTICAL INDUSTRY

by

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Gentlemen, I suppose I should start this time by telling about California. The last time I was over here I was asked why I moved to California and after I had carefully explained it somebody made the remark that the real reason I went to California was that my wife did not like it in Baltimore. She did not.

One thing about the airplane business that is a little different from most manufacturing is that the units are very large and require a great deal of space. Further, the turnover is not fast because of the fact that the tooling is not as good as it is in the automobile industry. The number of units are less. A large airplane will be anywhere from three to six months going through the plant and it will probably spend a month on the assembly floor - that is a ship as big as a bomber. That means that if you are building a lot of bombers you have at least fifteen or twenty such airplanes on the floor. If those airplanes are as large as the modern bomber it means that you are going to have to have an assembly floor probably 150 feet wide, 600 or 700 feet long, with a head room of 35 feet to clear the trestles, or going up into the trussing, say 45 feet. Such a big barn as that is very difficult to heat. Furthermore, with a large expanse snow loads and high wind loads result in a very heavy structure and that sort of structure is a vicious circle because you make it heavy to hold the dismal snow and wind loads and then you have to make it still heavier to hold itself.

This story about the freight rates is just a little bit wrong. It was a comparison of the saving in heating versus the saving in freight rates, or the slight loss in freight rates. I had to make quite a study of this problem of moving to California in order to convince an Eastern. Board of Directors who thought that California was all climate that it was the proper thing to do to abandon a plant already in operation in Baltimore and move all our personnel and equipment to California and build a new plant out there. They would not do it because my wife did not want to stay in Baltimore, you see, so I really had to get a good story. We worked on it very diligently, and as a matter of fact the results show that by comparing the heating costs per cubic foot of several eastern factories

with the heating cost of the Douglas plant, and comparing that with the amount of freight on an average capacity of 80% of the plant operation the saving in heating would pay the freight six times over. That is just one of the things.

Another thing is the cheapness with which we could build the building because of no snow load, light structure requirements, and because we could design for a very low wind velocity. The highest wind velocity recorded out there where we built the plant is 40 miles an hour. We were able to build an extremely light structure and we built a very modern plant, a very nice plant to work in, for an average cost, including the structure, the heating (we do use a little heating, you know), the plumbing, and the complete sprinkler and electrical system for $1.76 per square foot first unit. Then by taking further advantage we built another unit of a little over 200,000 square feet this spring for $1.61 per dquare foot. The Martin Company's buildings built for the eastern climate and eastern conditions are costing around $3.00 to $3.25 per square foot. The Vought plant in Hartford, built when costs were a little higher, ran almost $4.00 per square foot.

The original investment in the plant is very much smaller, less than half per square foot, but there is another very important point in this being in California which is all climate. In the east from December until March you can be assured of very little flying weather, particularly for test work. Frequently an airplane is being built for a competition date; it must be done on that day or you have lost all the investment in it. The planes are just about getting done on that date; there is some testing necessary, of course, before we can deliver, and if we were back in the east here, as I was for one year, we could be held up indefinitely and just miss the competition completely. For instance, when I went over into Baltimore to the B. J. plant they were building a small experimental fighter for the Navy. That ship was ready to fly early in December. We managed to get four hours test flying by March. There were several good days but on those days we were not quite ready and when we were ready the ship would just sit there waiting because there was either fog or snow or rain, or something would prevent testing that type of ship and getting accurate results. The longest that I have ever been held up in California in a little more than twelve years is two to three days

because of bad weather. It is very seldom indeed that there is a day that we cannot fly on test work during some part of the day. That is quite important.

Another point is that we do get a little higher efficiency from our personnel. I made a check on that as part of the original study that I made on California. Commander Bogusch, who was in the Navy in charge of maintenance, was very kind and let me check his figures which showed that on the repair and overhaul of our course there, which has been reduced to quite a standardized operation, the average cost over a period of years in labor hours was from twelve to sixteen per cent less on the West Coast than on the East Coast and that was quite an accurate sort of comparison, as accurate as any comparison of that type can be because it was an identical operation done by the same personnel even because the personnel changed, you see, from West Coast to East and back again. He attributed it entirely to the climatic conditions. I found the same thing in Baltimore. In the summer I remember one particular period where for eighteen days the temperature rose over a hundred with a humidity over eighty-five all of the time and the men absolutely could not work. They would just stand there and drip. They could not sleep nights; they were tired. From May until the latter part of August and the early part of September those conditions occur. In the winter again there was a loss of efficiency because men will not work as well when the days are gloomy and cold and dreary as they will when they are bright and sunny. Furthermore, it got so cold over there at times that with a fairly good heating plant going we could not get all the plant warm enough and we found the men leaving their machines and going over and holding their hands in the jets of hot air to get them nice and limber so they could make careful adjustments on the machinery. I am sure that we get 15% greater efficiency from our personnel just due to the climatic conditions.

As far as this boat situation is concerned, we have not been able to take great advantage of boat transportation of material. The bulk of our material comes from Alcoa, Tennessee, the big sheet rolling mills of the Aluminum Company of America, and we have a rate from there that by rail is very little more than by shipping from there to the seaboard and then by water. Furthermore, due to the fact that all the material suppliers are so far

behind in their orders we have almost always been forced to ship by rail and sometimes by express to avoid being held up with the delivery of materials. If we were a little better stabilized, could plan a little further ahead, and could be sure of our deliveries, then of course we could take quite an advantage of water shipment, as we do on steels frequently and tubing, etc., that are shipped from a point more near to the coast.

The aviation industry is just about twenty years old. It was really born during the war. Those of you who were interested in it during the war may remember what a situation it was. I doubt if any of the people who were in the Air Corps were so interested in just what the industry was at that time as I. I put in my resignation from the Air Corps on Armistice day - I got in fairly early. It was just a mad house because they had built up in a year a tremendous industry without knowledge; no one knew anything about it. They were trying to copy European models; they were trying to build something about which they knew nothing, and while they spent money recklessly they got no results. Of course immediately that war was ended there was no work at all and all the plants just stopped and all these people were dissipated in all directions. I can remember very distinctly having an order for a thousand bombers cut to ten at the Glenn Martin Company and then getting nothing more for a year and a half. We had a beautiful, big assembly floor where we played volley ball for two years. It was not until 1924 that the Army and Navy, who have always financed and run the industry along, began to see that if they did not feed it a little it would starve to death. The Army and Navy then stopped the experimental work they were doing themselves, which had been rather unsuccessful, and put out competitions as a spur to the industry. This meant that there was quite a pickup in the engineering and development fields in the industry in a competitive manner, which resulted in building up very efficient organizations.

I went out to Douglas in 1925 because of the fact that there had been no incentive to engineering and development. They had six men in the engineering department; when I left in 1934 because of all this spur to development there were more than four hundred in the engineering department.

The years right after the Army began by design competition to encourage development were very productive of results because they got the industry in such shape that when the boom days of 1928 and 1929 came along everybody started buying aviation stocks. They were something for them to buy, something for them to start on, and there were over six hundred million dollars invested in aviation in just about three years' time, of which two-thirds were wasted. But it did at last start giving the aviation industry a chance to go ahead. The fact that two-thirds were wasted was not the industry's fault entirely - it was the investors' fault because they would buy any kind of a piece of paper that had a picture of an airplane on it. The development during that period was sound and excellent. The blow up of business in 1929 and 1930 and the fact that during that time or shortly after that time there were practically no appropriations from the Army and Navy left again a fairly well stranded industry but one which, because of the fact that money had been invested by the public, had enough food to go on. While it was very sad at the time it was really very good in a way, too, because the various companies did not want to give up these expensively developed engineering and research departments and they were able to put them to work on various and sundry experimental and development jobs, with the result that in the period from 1930 to 1933 or 1934 there was a greater advance made in technical development in the aviation industry than in any other period. Inasmuch as the aviation business had been stagnant for so long and there was so much slack to take up I would venture to say that at no other period in the future will so much progress ever be made because during that time new types of structure were developed, new thoughts aerodynamically were developed and airplanes increased probably three hundred percent in efficiency in three years as types.

In about 1930 Lockheed and Lothrop and Boeing brought out their first really efficient airplanes. They had washed out the struts and landing gears and the strings and the wires and had really gotten the thing down to its simple element, weighing the fuselage, the tail surface, etc., without any external friction. Starting at that time the modern airplane was really born.

The Douglas transport came along in 1933 and revolutionized the air transport industry because for the first time there was an airplane which had been really designed with some background of experience in transportation that was attractive to the traveling public. It was fast and carried a good load. A great deal of attention had been paid to passenger comfort in the way of seating accommodations, room to move about, room to stand up and walk around, heating, ventilating, sound equipping. They really had a vehicle to ride in that was comparable, in fact with a lower sound element than a Pullman car, comfortably heated and comfortable to sit in. The net result was that during the next two or three years there was about a two hundred percent increase in air travel which resulted in greater and greater orders for airplanes, not only Douglas's but Lockheed's and others, and by the time the Army and Navy again started a large procurement program through this depression period a new type of structure as well as a new type airplane generally had been developed.

At the present time there are approximately twelve major companies manufacturing airplanes. There are about twenty companies of the second class manufacturing small commercial planes and things of like nature. We have only two real engine companies that are capable of manufacturing fine, high-powered, efficient engines such as we use on our large transports and all of our military stuff. There are approximately ten companies making training engines and engines for the small private commercial planes. There is another company that is really starting now in the manufacture of a high-powered engine - the Allison Company. With that small group we have come down from over three hundred units in 1930 to a much better organized and a much better developed group. Practically all of these companies are on such a firm basis now that they are able to continue and to survive the little troubles that knocked this and that company out in a month before.

Many people have asked me why it is that it takes so long to produce an airplane, particularly a military airplane. They seem to think that a year from the time the idea that an airplane should be bought is conceived the airplane should be flying in squadrons, because to the average person it looks like a very simple thing. I made

a check on that time element by averages and it works out like this: On a bomber, after it has been decided to purchase a bomber in the Army or a boat in the Navy or anything equivalent it takes three months minimum to get out the specifications; they have to allow fifteen months after the specifications are out in order that the manufacturers who decide to bid on it may have time to build the experimental article; the testing, checking, and the delivery of the airplane up to the point where a contract can be written is an additional six months; it takes at least a year from the time the contract has been received until the first production article is out until they are building those airplanes in sufficient quantities to equip squadrons. I checked that from four or five angles and it is roughly correct. In other words, it is between three and one-half and four years until a production airplane is in service in full quantities of fifty to sixty from the time the original idea that that airplane should be bought was decided upon. For a trainer we figure a third of the time; and for an observation or attack plane from one-half to two-thirds of the time, because they are much less intricate.

Another angle on the development of the experimental airplane is the very high cost of such development. The cost of developing an airplane today is very very much greater than it was ten years ago simply because the airplanes have been carried to a point where they are much more intricate, they are much more precise; and where we are fighting harder for a little gain than we had to before because we are approaching that limit where the margin between where we have arrived and what is still before us to gain in efficiency within the scope of our present knowledge is small, and it takes much more work to get it. On an average a primary training plane for the Army or the Navy will cost anywhere from thirty to sixty thousand dollars to design, test, and deliver as a first article; a basic trainer from sixty to eighty thousand dollars; a pursuit plane from one hundred to one hundred and fifty thousand dollars; single engine attack and observation, one hundred and fifty to two hundred thousand dollars; twin engine attack, two hundred and fifty to three hundred and fifty thousand dollars; twin engine bomber from five hundred to six hundred thousand dollars; long range four-engine bomber from six hundred thousand dollars to a million dollars; and airplanes as large as the secret projects at least a million and a half dollars. That

money represents engineering, material, testing, and the delivery of the first airplane but does not mean that the airplane is ready for production in any sense of the word. It does not mean that you can start tomorrow and build them by the hundreds because no one is ever so sure that a project as expensive as that will be so perfect and successful that he will spend the time and the money in addition to the tremendous cost of in a minute manner tooling and designing for production. Furthermore, every airplane that I have ever seen has been reasonably lousy when it was first built. All the testing and all the checking and all the wind tunnel work in the world is great; it helps, it is fine, but it is not final. The proof of the pudding is in the eating, and it takes from three to eight to ten months of flying a large airplane to refine it, to get the gadgets and the power plant and the cooling system working, and all of the many things that enter into it. Then if that airplane at that time is successful and ready to be ordered in quantity the designs of the parts will have to be done over again if there is a large quantity to be bought because to design that airplane in the beginning the simplest type of fitting was made with the idea of making it by hand. Up to ten or fifteen airplanes everything is made by hand with a hacksaw and a file and a hammer, but if you get a larger quantity then every fitting is re-designed to be made more easily by machinery - stamping or forging or casting. The average airplane going from experimental through service test for a small quantity order and then into production will be designed in a large part three times. The engineering cost, for instance, of designing the Douglas DC-2 for production, the experimental work having been done, was 120,000 hours or $18,000.00. That amount was spent re-engineering that airplane for refinements and for correction of troubles and for the production tooling.

What we call "production" in the aircraft industry is a hundred airplanes. That is good production, and it means that when we do tool and make dies and fixtures we usually do it a little differently than would be done in the automobile industry because a lot of ingenious people have developed methods of making inexpensive dies for small quantities and we have developed several particular tools that work beautifully for just this sort of work that would be perfectly useless in the automobile

industry. We have to check, of course, each time a tool is made as to what the cost of that piece is going to be made from the tool versus made in some other manner, and if we are paying two or three thousand dollars for a die for a hundred pieces the tool cost still is frequently more than it would cost to machine it out and file it out and cut it out by hand. When you think in terms of the automobile industry it is quite different. For instance, Chevrolet will spend ten to twelve million dollars on dies and tools and equipment in a year but they will build a million two hundred thousand cars so that there is only a ten dollar tool charge on each car; whereas, if we build a hundred airplanes and spend one hundred and fifty thousand dollars on tools, which is about what we would spend, we have a fifteen hundred dollar tool charge per airplane, and that is with much simpler and different tooling than we would use in the automobile industry.

The thing that has helped most, I believe, in allowing us to build a lot more airplane per dollar now than we ever did before, and we certainly are doing that, is the drop hammer. This tool is a very ancient one. It has been used for fifty, sixty years probably and it is simply a frame like a guillotine which, by means of a rope or an air cylinder, the head is raised and allowed to fall into the material and form it. A skilled man on that can make the most intricate shapes with the simplest of equipment. I asked for a price on an orthodox die for making a piece of cowling, which is made to cover a machine gun, from a machine tool outfit, and they said $4,000.00. We made the die ourselves. I had no intention actually of getting it from them; I asked for the price only for comparison. We made the die in two days in the plant at a cost of $85.00 and it served perfectly. The method of making the dies for this is to make a hand formed piece, just as a tailor cuts a piece of cloth to fit a place; a man bumps it out with a hammer in several days to fit; then we make a plaster cast from that and using the plaster cast we make a zinc casting, which is the female part of the die, and then we pour lead into the zink. The difference in the melting point is sufficient that the lead makes an accurate punch. Of course, there is no clearance in the die but the lead is soft enough that by putting a piece of scrap material in and hitting it a few times it will automatically form itself to make a punch. A piece that

was made in forty hours by hand can be made in about twenty minutes on the drop hammer. This equipment has only been in general use about three years but they are practically building airplanes on that now for all the highly formed and curved sheets.

Since practically all the modern structure is made from sheet and since the ribs and the bulkheads and the structural parts of the airplane are basically a flat sheet ribbed with various grooves and things for stiffness, we needed another method for efficient handling of that type of material and the hydraulic press and a technique for using it in a manner that is rather remarkable has been developed. For years it has been common practice to form small pieces by the use of a die which was just a small form over which a piece of sheet was put and then squeezed under a press with a block of rubber over the sheet. Under terrific pressures that rubber becomes almost a liquid and will form around and press and will even shear. If you have a sharpened disk in there you can even shear holes as you do it, so that instead of a die for two thousand dollars say for a rib you can make a die for fifty dollars and it operates almost as fast as the actual pressure pad two part dies that would be used if they were making a dashboard for an automobile instead of a rib for an airplane. As a matter of fact, I was up to the General Motors Truck Company this summer and found that they have now put in a hydraulic press and drop hammer, copying from the aviation business because they run a lot of small unit stuff through, one hundred to two thousand trucks and busses, and it is working very well for them.

Our most expensive operation is riveting. We have no satisfactory method for eliminating riveting but we have evolved a great deal of tools and machinery for reducing the cost of riveting. We are also developing spot welding, which is working very well for non-structural parts. Speaking of the use of aluminum alloys - spot welding of stainless steels or steels is very simple - but spot welding of aluminum alloys is very difficult because of the fact that the aluminum alloy itself is a very good conductor; it has a very low melting point. That point between which you can get it to weld and in which it just melts and flows away is only fifty to sixty degrees probably, so it is

necessary to get control. It is much finer than has ever been achieved before for current, density, pressure, and swell or weld. We are now able to weld aluminum alloys in a manner that indicates that in a very short time we will be using a lot of structural parts that have been spot welded. We have a new spot welding outfit which we are using experimentally now where we can weld stainless steel beautifully with a 32-30 KVA set. We have a 750 KVA set for welding equivalent aluminum because it takes a tremendous current pressure for a very short weld or there is a hole in the sheet instead of a weld or there is no weld at all. Of course we also have to have a recording mechanism in effect that shows whether the current was proper for the condition. The operator has a series of bells which ring once if it is cold and twice if it is hot. A little resistance, a little dirt on the sheet, can make a lot of difference.

Those things are the principal developments, I think, in the process of production and the things that are making it possible to produce the intricate machine that the airplane is for a reasonable cost.

The industry from my angle and from your angle is a part of our national defense. I have been mostly interested, in the twenty years I have put in, in the military phase of it, and inasmuch as I have many friends in the Air Corps particularly who are interested in war plans I have had many fights with them on what we are going to do if we get into a scrap. I have been very much interested in following the results of Germany and England and France and Italy in their attempts to put their aviation industry on a war time basis immediately, and it has worked just about the way I thought it would and just about the way it will work here. They have been working for two years now. On the surface Germany has been working two years and actually she has been working four; in England they have been working for two years to get airplanes in production. The Germans are much more successful than the English so far because they have had that two-year under cover work but the English are just now, after two years, actually getting their airplanes out, and I feel that we will be much in the same condition. It is going to take machinery and equipment and plant capacity and personnel and, beyond all things, materials.

If we were to figure on five thousand airplanes per year, to build up to that point we would have to have fifty thousand men working directly on the airplane itself - I mean direct labor - and of course with fifty thousand men working that way there is another twenty-five to thirty percent indirect help that would go along with them. That would require about five million square feet of factory space. This represents four times the present number of men that are working at the peak in the industry (I am speaking of the airplane manufacturing industry alone, not the engine accessories and propellers) and more than twice the available space. All of this has to be provided. The material situation is the thing that is going to be the most difficult. We have had a rather accurate example in the last year of what we can expect in war time. A year ago there was a great boom in all forms of business. All the companies that were manufacturing things began to buy great inventories of raw material to really get started and they tried to get machine tools. They wanted to buy this, they wanted to buy that, and on a small scale it was much the same as that which we would have to do if war were declared -- we would have to get on a war time basis. The net result was that the time it took us to get steel tubing had gone from three weeks to four months; the time it took us to get dural sheets had gone from six to eight weeks to six months. We could not possibly get dies for forgings because everyone was trying to get dies made and we have not trained people in the last ten years in the tool making business, and the available talent that can make dies for forgings is very thin. A representative of the forging industry told me that there were not over twenty-five hundred expert die sinkers left in the country and most of them are old men. That is one of the reasons that you find the automobiles this year coming out looking almost as they did last year - they cannot get the tool makers and die makers. A die maker in average times gets about 85¢ to $1.00 an hour. This summer in Detroit they were paying $2.00 an hour, double time for overtime, and working them twelve hours a day seven days a week to get the work done. Of course we were just sitting waiting because our little bit of work was nothing but it did hold us up very badly.

To get into production the first thing we have to have is dies and tools and they are going to be hard to get. We can start without them, of course less efficiently, if we have material but where are we going to get the

material? We started a contract on February; our orders for material were placed within six weeks, and some of that material we still have not received. Some material that was ordered last fall with delivery promises in March and April began to be delivered in July and will be delivered completely, they now say, by next February. That is peace time. In my opinion there is only one way that it will be possible for the aviation industry to start making airplanes in a hurry and that is if there is a war reserve of the basic materials; not only the basic materials but a lot of fuel system fittings and electrical gadgets, etc., kept ready for that day when they will be needed. It will not be an expensive thing to do compared to what it will cost not to have it certainly, and as far as its loss is concerned and its upkeep it should not be too great because those materials do not deteriorate rapidly. There is no great change, or has not been in fifteen years certainly, in the types of material used, and if we are faced with such a change we can readily issue that material against current contracts.

The personnel angle I think can be solved more easily than any of the others. We are again in a similar condition as to a war time because whereas Army appropriations only a few years ago were a couple of million dollars a year for airplanes and there was no commercial business, the Army and Navy together are spending a hundred millions with eighteen or twenty million dollars worth of foreign business and twenty-five million dollars worth of commercial business being done in a year and there are no men to draw from because during this slack period they had gone into other work; therefore, it has become necessary to train people quickly. We have been working on that now for a couple of years and have finally worked out a scheme that is quite successful. We have a great number of young men right out of high school that are very anxious to get into the airplane business. We have a psychological and manual dexterity test that we give to about two hundred boys a week. Out of that two hundred boys we pick twenty and start them to work riveting through a regular routine that we have developed. At the end of a week we put them to work right on the job on the simpler parts and on the stuff we have trained them for in a small section. They do that over and over again. Within two weeks those boys are doing more work on that particular thing they

were trained to do than our old time craftsmen would do by far and it is just as good work. As an example, our cable splicers were getting a little out of hand. They were highly skilled people that ought to be paid in gold coin, rather thick gold coin, and all sorts of things, so we took a couple of boys who seemed to have peculiar dexterity in their fingers from their tests, trained them for one week, and moved them into the cable department without saying anything about it. Each had been taught to do a particular splice in a particular type of cable and that is all. The first day they went to work they were doing two for one to the old-timers - we have had no trouble with the old-timers since.

We can train personnel, we can probably requisition machinery and equipment and machine shops, but we cannot get material.

The airplane is now in a pretty stabilized position as far as development is concerned. I do not look forward to any great advances; I do not see a thing in experimental places, in the colleges and in A.C.A., etc., that indicates any great advance in speed or performance, nothing like we have had recently when we took up a lot of slack. I think if we are going to have a successful Air Corps we are going to fight with what we have when we go into the war and therefore at a time like this when we can safely do so we should build up a war reserve of airplanes, but by all means a war reserve of materials. Thank you.

Colonel Jordan: Gentlemen, Mr. Kindelberger has offered to answer questions. Are there any questions?

Q. Has anything been done to that molding process of wings and fuselages?

A. You mean the phenol resin stuff?

Q. Yes.

A. On small stuff it has been worked out fairly well. They are doing quite a lot of it in Russia and in England, but they are not molding a whole wing. In England they are using the phenol resin as a cement for special woods in making what is in effect a phenol phywood, which under heat can be formed to the shape of the wing and are using a wood frame inside of the construction. I don't know of any real use of it here. There have been several attempts to make a wicker work type of structure out of wood and then spray on it phenol resins and bake them. There has been no complete airplane developed or any really successful stuff. There are some encouraging experiments, I think more for a smaller airplane.

Q. To what extent are stainless steel and Dow metal used in the industry?

A. Dow metal is used quite a lot. Magnesia is used for engines, crank cases and parts, to a large extent in forgings and castings, and is used some in airplane structure for control parts and miscellaneous things. In some cases a lot of it is used as cowling in the form of sheet. The great trouble with Dow metal is that it is almost explosive. It corrodes so rapidly. The processes that have been developed for its protection are very

good. They help a lot, but if the material is badly scratched and salt water gets to it, you can just watch it explode. We have bought a lot of Dow metal castings for the DC-1. They were all treated against corrosion and they were machined and laid aside in the machine shop. The wind blowing right off the ocean brought a little salt in and deposited it on them, and they there were a few rainy, damp days which got the salt damp and started to take hold on the castings. We threw $15,000 worth of them away. They went back to aluminum alloy because of the very high corrosion. In the engines, however, the best protection in the world is oil and grease and its use on the crank cases and parts on an engine is fairly safe because they are almost always covered with oil or grease. The Germans use quite a lot of it for cowling but we don't here, simply because of corrosion trouble. You couldn't possibly use it successfully on Naval stuff, carrier work, or boat work, because nobody could keep it well enough protected that it wouldn't be dangerous from corrosion. Stainless steel is a very nice material, but it has one drawback. In order to get it thin enough to take advantage of its strength it becomes so thin that it is almost paper-like. Duralumin that thick would have some local strength. The stainless steel has plenty of strength but no rigidity, so it is necessary to either corrugate it and make it double like a corrugated box structure or to add many stiffenings to it. While it will spot-weld perfectly you have to put so many spot-welds in it that the spotwelding costs about as much. You can depend on the salt water not to dissolve it. The technique has not been developed anything to the point that it has with duralumin, and a lot of the structures that have been built have not panned out too well. There is one wing now out at Wright Field which looks very good and is

approaching duralumin efficiency from a strength weight condition. Most of the structures that have been built to date under any load look like a starved horse. The ribs show and if there are any loads on them they will wrinkle and crack. Also, the stainless steel hardens rapidly under fatigue and it tends to crack in thin gauges. It is a coming material without a doubt.

Q. You told us how the contracts between aviation construction companies and the Government are handled, those three and a half year lags. How is that same thing done between civilian firms?

A. It is very much less because you have one customer, one person to satisfy, instead of dozens. Furthermore, they are paying for it out of their own pocket and there's a difference there too. They are not so anxious to make changes and you can work very much faster. The best example I can give you of that is the Douglas transport development. In August it was decided to have a conference with T.W.A. to decide what the airplane was going to be. In October we were well at work and they sent out three pilots and their operation manager and they spent a week there and said, "That's it." They went home. We had to send nothing to them for approval. They had a funny idea that we could figure strength and get it right so we didn't have to send the stuff in and wait three months until some boy out of college had checked it for us and we didn't have to wait for somebody to answer a letter. We just went ahead and built an airplane. When we got it done the same group that had looked at it in the beginning, decided on it, came back and looked at it again. They thought it was pretty good. If it were for the Army, one group would have written the specifications, another group would have looked at the machine, and a third group would have tested the airplane. The first

group who looked at the machining up never did believe that the gang who wrote the specifications knew what they were doing. The gang who looked at the airplane were sure the machining up group was a little bit off, and so we do it over. This other was a straight down the alley job. It was a commercial concern trying to do something and they left us alone.

Q. We read the other day of a pilot in an Army airplane down in the Panama Canal flying along, I think he had seven passengers with him, and all of a sudden he found his plane had dissolved. He jumped out and took to his parachute with all his party. They were all saved.

A. I was in Panama right after it happened and Colonel Hall was telling me all about it. They are just as much at a loss as to how that could have happened and what did happen down there, including the people that were in it, as you are here and I am here because the fuselage landed without a shred of fabric on it. The wings had fallen off and twisted, and yet the people in the plane were not conscious of an explosion. All they know was it fell apart.

Q. Does the North American Aviation have a manufacturing and also have a transport branch?

A. They operate Eastern Airlines and the manufacturing branch.

Q. Are the Eastern Airlines mail carriers, sir?

A. Yes.

Q. Are the two companies under the same management?

A. Yes.

Q. I would like to get a little idea about the life of a plane, a Douglas transport? How long would the operating life of a Douglas transport be?

A. The Douglas transports have been in active since now, starting in August, 1934. There are none of them that have shown any serious depreciation yet. T.W.A., which I think has the finest maintenance engineering group in the country, has been conducting studies along that line. They took a sample of just one airplane, an experimental one, to check, and they checked it at 1,000 hours and 2,000 hours, 3,000, and so on. I think they have on that airplane something like 6,000 hours now and they have gone even to the point of cutting out sections of the material for fatigue tests, for decrystalization, and so on, and they see nothing to indicate that the airplane won't go 15,000 hours. The time element doesn't mean a great deal. They don't depreciate much with time if they are kept protected, and no corrosion is allowed to occur. I think that a modern airplane is good for at least 10,000 hours flying, and, furthermore, these modern airplanes are not going to be killed off by obsolescenee in the near future. I think that these DC-2 planes are good for a full five years in active service and still be good airplanes. The DC-3 will do five to seven years. We are flying DC-2 and DC-3 planes on Eastern Airlines right now and averaging ten hours a day per airplane. That is 3600 hours flying time per year. We have had minor troubles but nothing to indicate that we are approaching the end and we have 6,000 and 7,000 hours on our earliest airplanes.

Q. What can you say about high altitude flying from a commercial standpoint?

A. Well, I can get into a lot of arguments with it. You see, the whole idea of this stratospher flying is that with a given constant power you gain a little better, just slightly better than 1% in speed per thousand feet you

go up. If you go to 30,000 feet the same airplane would be 32% or 33% faster, with the same power that it had at sea level, but, of course, to get up there and fly you have many things to consider. If you go that high oxygen alone is not enough because there is not enough pressure in the air to force the oxygen in good contact with the lung tissues for a long period of time, so you must have a pressure cabin. Now to supercharge a cabin down from 30,000 feet to 10,000 feet just say arbitrarily is 8 pounds per square inch and 8 pounds per square inch is something like 1200 pounds, a little better, per square foot. You take the area of a cabin with that pressure on it and it results in having to put in quite a lot of structure. The bursting strains on your seams become quite large. You have got to double the riveting to take care of it. The fuselage section is circular, of course. It doesn't involve any great additional stress over the regular flying. But when you come to windows, a window so big has to be about 2 inches thick to hold properly, in consideration of the temperature changes as well. Then you have the problem of leading out to the average modern cockpit on a given engine airplane 60 some controls and gadgets, all of which have to go through stuffing boxes or something or you are going to lose your pressure. Then there is the problem of measuring pressure instruments and things of that nature, supercharged cabins against the outside pressure. In order to take advantage of that additional speed you have to fly long distances. It doesn't pay to go that high for your trip for less than 1500 miles. If you are going to go 1500 miles non-stop you have to carry so much fuel that with the additional weight of your supercharge airplane and all the gadgeting you cut your pay load to where you can't afford to do it economically. The

airplane that flies at 30,000 feet has to fly just as well at sea level because of the high wind velocity. There are well-known cases of 200 miles an hour winds at 30,000 feet and if you start off with a 200 mile an hour ship and gain 30%, which is 60 miles an hour, and you go up there to buck a 200 mile an hour wind you won't gain much. You have to be able to take advantage of the wind condition at all altitudes. Another idea was that it was always fair weather topside. Tommy Thomasson, who is the Technical Director of T.W.A., who has been working for us also as a test pilot made a flight here last winter. He took off from Kansas City, went up to 35,000 feet and started for Newark. He flew from Kansas City to Newark without once seeing clear sky at 35,000 feet. It was solid as far as he could get above and it looked thick way up. He made numerous flights and on most of them it was clear but frequently he went to 35,000 and 38,000 feet without finding this beautiful clear weather that is supposed to exist up there. The only thing I can see for this really stratosphere work would be trans-oceanic flying because there is no real need for it in this country and if there is no need in this country there is no need anywhere for much greater speeds from the standpoint of economy of business time. The people who travel in airplanes primarily are business people who want to leave Los Angeles at the end of a business day and get to New York, with the time difference against them, in time to get to work there in the morning. They are the only people who really pay for that trip and will take it. Of course there are a lot of other people who fly, but that is the backbone of the transportation industry. Right now you can leave Newark at 5 and be in Los Angeles at 7:15 and have a nice comfortable sleeper all the way. There is no tremendous demand for a lot

greater speed, but there is a demand for an advance in the other direction. As we gain technically we are able to get a higher efficiency. If these air transports are going to continue to live, and they can't live losing $500,000 in six months, they are going to have to carry more pay load and they are not going to carry more pay load by taking long 1500 mile hops, you see. So I am not an enthusiast about stratosphere flying. I have checked it with people like Eddy Allen, who is probably the best transportation technical engineer on that sort of work in the world, and he is of the same opinion. Thomasson, who is working every day for the T.W.A. along the same line, is anything but enthusiastic about it. It is probably going to come some day but I don't think it is right.

Q. How long would it take a manufacturer who was not familiar with building airplanes to produce airplanes if he were furnished production drawings? How long would it be before he could turn out the airplane, from the time he was furnished the drawing?

A. In the first place, from a set of somebody else's production drawings he probably wouldn't get started very well because drawings are never precise. The inter-changeability of parts is not determined nearly so much by the drawing as by the tools you build. By the time you had taken a set of production drawings cold and found out what they are all about and then ordered your material and built your tools you would be -- well, say it is an observation plane, 700,000 pound gross ship -- if you had your first airplane out in 15 months then production would be probably another year, getting built up and going. I had one experience like that. We got a set of drawings from the Curtis Company about 1923 or 1924 to build the S.O.C. which was a

fairly simple steel tube fuselage, wood wing, fabric cover, torpedo plane designed by Curtis for the Navy, thrown to the open bid and Martin got the order. We couldn't work from the drawings at all, just couldn'ts, so they finally sent us an airplane. By comparison of the airplane and the drawings we were able to get going but it took well over a year for even that simple ship to get started on production.

Q. The Maritime Commission has sent a report to Congress in which they advocate taking over trans-oceanic flying and putting into service ships that weigh about 150,000 pounds. Would you mind commenting on that, whether that's the best procedure?

A. I think that is perfectly practicable because these big ships don't lose in efficiency as they get bigger, if everything is kept equal. There is a square cube law that your volume goes up as a cube while your surface goes up as a square, and you fight that all the time in making your air-planes bigger. As an example of that, I have a little cast bronze model, 1 foot span solid bronze of an airplane. It has exactly the same wing loading in pounds per square feet as the full scale airplane. On the DC-4, which Douglas is now building, there are 6,000 pounds overweight due to the fact that they just thought they could step up from the DC-3 to the DC-4 type. Wing weights, take on a DC-3 just a little over 3 pounds per square foot, on a ship of 150,000 pounds they would probably be close to 6 pounds per square foot for your structural weight, but you can use a little less wing because the limitation on a land plane is a landing field. The limita-tion on a flying boat is how long a stretch of water you can get to take off and you can design hulls that will land perfectly well at 100 miles an hour and take off at 100 miles an hour, and with 5 and 6 mile runways in effect

most anywhere. Also, as your ship gets bigger it is a much better sea boat. If you do have to come down, the bigger your boat the safer you are. What applies to a sea plane will not apply to a land plane. In the land plane I don't believe in making them too big for many reasons. They are inefficient. You can build less of the big ones and therefore the cost per pound is greater than the others. You have a less flexible operating unit. If you have fluctuating traffic and have a number of medium size ships you can put on two and three sections. If you work the other way and have a very large, very expensive ship and fly it with half load you are losing money because it is the last two or three passengers that are profit. You carry all the rest for nothing.

Q. The Garbison Company in Texas is manufacturing radio Diesel engines. Are there any other companies interested in that and does the industry look toward that development as promising?

A. There is not too much excitement about it in the industry. I think Major Powers can probably tell you a lot more about it than I. He has been right in the middle of this engine stuff.

Major Powers: As far as I know there is nobody in the United States doing anything in production except Garbison. He is building three or four for the Navy, not too successfully. Other people are doing a lot of thinking about it and a lot of experimenting. There have been one or two contracts on single cylinders but no full scale engines except one a couple of years ago. It was very inefficient, much too heavy.

A. General Motors has spent a lot of money on aircraft Diesel, and so on, because they had this wing development program for the two single wing tone Diesel engine which is used on all the streamline trains, Diesel cars, and so on, and they have, I think, in this country carried the scientific development rather than any place else. Boss Kettering is very interested in it and his assistant is excited about the possibility of the aircraft Diesel. The trouble with it is that taking the most efficient Diesel developed, and even being a little more efficient than that, you have got to fly over 1500 miles again before you break even on fuel because your Diesel has a lower specific consumption in pounds per hour but it was more for the engine. For about 1500 miles you break even. Over that the Diesel gains. On the other hand, a thing that has held back Diesel development is the fact that engine development from the gasoline engine type has advanced so much. A few years ago a specific fuel consumption of .46 or .47 was just something to marvel at. The Diesel was down around .36. Now they have octane engines that are below .4 and experimental ones have been run as low as .37, so that from the fuel economy angle the gasoline engine is just right down with the Diesel. An excellent Diesel engine, the lightest you can possibly consider, is more than 2 pounds per horsepower. We are building these modern gas octane engines for about 1.2 pounds per horsepower. When you are getting into pounds per horsepower unit that difference is enough to take bombs or whatever you are trying to carry. The reason that Germany has gone so deeply into the Diesel is not so much because they were after the efficiency but simply because they can make

Diesel fuel from their low-grade deposits and they can't get gasoline if they are shut off in time of war.

Colonel Jordan: Gentlemen, I am going to close the discussion now because the speaker has an engagement at 12 o'clock. I want to thank you for your coming here and tell you how much we appreciate it. Thank you a great deal.