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Copy for Sen. Kilgore

April 18, 1943

The Honorable Mon C. Wallgren, Chairman
Senate Subcommittee on Aviation
United States Senate

My dear Senator Wallgren:

In accordance with the procedure agreed upon in the conference with you, Senator Kilgore and Senator Ferguson on April 5, regarding the conditions at Wright Aeronautical Corporation plant, Cincinnati, I appointed a Board of Investigation at once and it met first on April 8 in Cincinnati and has been continuously at work since that date on various phases of the investigation.

Its work is far from complete since it became apparent, as facts were developed and testimony taken, that the problem led into Paterson, New Jersey, and elsewhere. It has been necessary to trace out former inspectors and employees and get their stories and the Board has had to get records and reports from operating units, depots, etc. I am advised that it will be some time before all the material for the final report will be complete. I have, however, requested and received a preliminary report which I enclose so that you may be kept as fully informed as possible. I invite your attention to the Chairman's comment in the first paragraph pointing out that this is merely an interim report and that the investigation is still in progress.

There is attached to the interim report an appendix, marked "A", which gives certain general engineering comments on which detailed studies are being prepared for submission with the final report. They are really "notes" in explanation and amplification of technical matters in the testimony requiring special engineering follow-up and investigation and are not conclusions. They are sent along in keeping with my agreement with your Committee.

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Corporation and were good enough to give me clearance to send a trained crew of engineers into the plant to check up on it, I undertook two personal obligations to you. First, to make sure that the Air Force Committee was absolutely first class in ability and completely independent. As to their ability, the names and records of the members I believe speak for themselves; as to independence and impartiality, the interim report and the corrective action recommended by them to date is an indication which my own observation of them confirms. Secondly, I agreed as soon as possible to tell you in complete frankness my non-technical conclusions from a personal inspection and from questioning and listening to a number of government and company employees in the plant.

For what they may be worth I give you these views based on evidence to date. Naturally they may be subject to some modification or change in emphasis in the light of the final report:

1. Comments.

(a) The general situation at the Lockland plant with respect to management control and inspection procedure was decidedly unsatisfactory.

(b) The conclusions of the Senate Subcommittee relating to unsatisfactory inspection procedure are supported by our own investigation in the majority of cases.

(c) The Company has stressed production at the cost of proper inspection.

(d) The Army Air Forces must share some portion of the responsibility for not discovering the situation and for permitting the company to get into present shape, over the last three months.

(e) The resident representative as to plant housekeeping and control, and the Chief of Inspection Service as to supervisory work in maintaining high standards in government inspection and shop practice, have not done their jobs in a satisfactory manner.

(f) The morale of government inspectors has recently been brought to a low level by lack of proper support from their superiors and by the over-riding of their decisions by others. (The activity of Mr. Bond from

Paterson, New Jersey, is being investigated further. At present it looks as though much of the trouble comes from his cutting behind the Chief Army Inspector in the Lockland plant.)

(g) Instances of sub-standard material passed by company inspection were found. The Board has not yet been able to uncover evidence as to whether this was deliberate. They are still working on it.

(h) It seems significant that much of the testimony indicates that present unsatisfactory conditions began about ten weeks ago.

(i) Wright Aeronautical Corporation has tried to run engineering procedure in the Lockland plant from Paterson, New Jersey.

(j) The contractor's quality control manager at Lockland is not up to the job and spends over half his time on the road checking subcontractors.

(k) The unsatisfactory performance reports and records of service difficulties of both Army and Navy so far examined do not as yet show the consequences one would normally expect from poor inspection. This may be because the unsatisfactory conditions did not become serious until the recent past, or because engines have not yet got into planes. Or, it is possible that airframe contractors in their inspection, engine run-in and the slow time flying required may have corrected any unsatisfactory condition, replaced parts, etc. This portion of the report has not been completed and I, therefore, do not express any conclusion but merely point out the development to date.

(l) The plant, or at least some departments, in its present expanded size is not entitled to a Class A inspection rating.

(m) Management has been slack.

2. Corrective Steps So Far Taken.

In the light of the facts disclosed by the Senate Subcommittee and the Army Air Forces Board of Investigation the following corrective measures have so far been put into effect:

(1) The Air Force officer serving as Resident Representative was relieved from duty. He is being replaced by an experienced officer.

(2) The Chief of the Inspection Section at Wright Field is being replaced by a more experienced and energetic officer.

(3) Army inspectors are immediately being increased to 125, exclusive of administrative and clerical employees, by the addition of experienced personnel.

(4) Reject stamps were supplied Army Air Force personnel on April 8.

(5) Emery wheels have already been placed in two salvage cribs for instant mutilation of rejected parts by Army Air Force inspectors.

(6) On April 10, the so-called "kitty" of parts from green run were put under lock and key and available only to inspectors.

(7) Salvage cribs are closed to all but inspectors and contractor has been directed to put a supervisor in each crib and supply necessary tools and guages to permit inspectors to check parts under Army Air Force supervision.

(8) Redliner is available to Army Air Force inspectors when needed.

(9) Air Force District Supervisor has instructed contractor to restore original run-in time, thus doubling the present total of green and final run. This step is considered one of the surest ways to maintain quality performance. The step will probably have to be taken in two stages of 50 percent each in view of the limiting factor of water supply for cooling and extreme shortage of 100 octane gas. (Reduction in run-in time was previously made in accordance with governmental policy to conserve 100 octane gasoline.)

(10) Steps have been initiated to reduce company to Class B inspection rating.

(11) Corrective measures in management are still the subject of study and await the result of check up being made of some personnel at Paterson, New Jersey, plant. So far

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it is obvious that the quality control manager at the Lockland plant is not competent for that job but we are also concerned about other officials. Decision is deferred until the final report is complete.

(12) We are now starting out on the big job of tracing, inspecting and checking all the engines produced at Lockland in the past three months. The majority are in airframe manufacturer's hands, modification centers, warehouses, and depots. These can be readily checked. Spares will be checked at depots. A quantity of engines have already been ordered to be disassembled, inspected and test run.

Copies of the final report and of statements relating to this subject taken by Colonel O'Dwyer will be forwarded to your Committee as soon as received.

Word from our men in the plant received Saturday indicates that government inspectors and company inspectors as well as workmen have come to them to tell them that "things are a hundred percent better this week." The beneficial effects in inspection are, of course, very obvious.

This whole situation has been a most tonic one for the Air Forces. It is their first experience of this kind since the war. I feel that we owe your Committee a great deal, not only for your helpful and generous attitude in making the facts available to us in the early stages of their collection, but also in letting us get started promptly on corrective measures that have saved much valuable time. It is probable that in no other way than through a Committee such as yours could we get some types of information, since the fear of retaliation or loss of job so frequently makes men reluctant to go through channels with complaints against their employers or superiors.

Very sincerely yours,

(Signed) ROBERT A. LOVETT

ROBERT A. LOVETT
Assistant Secretary of War for Air

Copy to:
Senator Kilgore
Senator Ferguson

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April 17, 1943

MEMORANDUM FOR: Mr. Robert A. Lovett,
Assistant Secretary of War for Air.

An investigation of conditions at the Wright Aeronautical Corporation plant in Lockland, Ohio, was begun on April 8, 1943, by a board of which the undersigned is chariman. The investigation is still in progress. The following is an interim report.

1. Management

a. It is the established policy of the Wright Aeronautical Corporation to run the Lockland plant from the Paterson, New Jersey, headquarters, particularly in matters such as engineering and finance. However, there is a great deal of latitude given to the resident manager in carrying out the company's policy. It is believed that the manager in an undertaking of this size should be furnished with competent personnel so that more of his work could be delegated. The charge that there does not appear to be competent management in the lower echelon is apparently true, especially in the department of inspection. Under the present arrangement the quality control manager spends 60% or more of his time on the road which may in part explain the apparent laxity of control in this department.

b. The problem of engine production, together with the related problem of quality control, has been doubly difficult in this factory, since the manufacturing operation is in the process of expansion from the original planned production rate of 1,000 engines per month to a maximum peak production in 1944 of 4,000 engines per month. There appears to have been no company executive in direct charge of the expansion phases of this production facility. It is considered of the utmost importance that the manager of so large a plant be furnished with high-grade assistants for the supervision of, first, the preparation of the facility for production; second, the supervision of production; and, third, the supervision of quality control.

c. Unsafe material has been discovered in completed engines ready for shipment. Whether this is deliberate or caused by a lack of knowledge has not yet been determined by this investigation. There is no testimony to the effect that the management has encouraged production of unsafe material. There is ample testimony that the company stresses quantity production.

d. The morale of Government employees stationed at this plant is extremely low although their loyalty is not only unquestionable but has been demonstrated to be of a high order. The morale of the company employees appeared to be satisfactory. There are several instances of company employees calling for more rigid inspection by company inspectors.

2. Defective Material and Faulty Inspection. - The following unsatisfactory conditions were found to exist at the plant:

a. The contractor, on a Class A inspection rating, has been losing control of recognized inspection procedures during the past ten weeks.

b. The need for production has been emphasized to the point of weakening company inspection.

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c. The control and segregation of salvaged material has been lax, making it possible for this material to be placed back in production.

d. Routing of parts has not been handled according to good shop practice.

e. Plant housekeeping was far from satisfactory.

f. The Air Force Resident Representative is unqualified for this position both by lack of proper technical experience and by lack of administrative ability.

3. Engineering comments on statements made by personnel of the plant relative to defective engine components, as well as manufacturing and inspection methods, are contained in Appendix "A" attached. Exhibits to this report are being prepared for submission with the final report.

4. Under the direction of experienced Air Force inspection personnel, a thorough survey is being made of salvage and inspection procedures. The procedures are being analyzed, and where necessary, corrective action is being taken. The complete report of the findings and corrective action taken by this group will be incorporated in the final report of this board.

The following remedial action has already been taken:

a. On April 8, 1943, the AAF personnel was furnished with reject stamps.

b. On April 10, 1943, the Army Air Force Resident Representative was replaced.

c. On April 10, 1943, the so-called "kitty" from which parts, having undergone a green run, are removed by the assembly personnel to be installed in engines for final run was put under lock and key to be available only to inspection personnel.

d. On April 15, 1943, arrangements were made to bring the personnel of Army inspectors at this plant up to 125, exclusive of administrative and clerical employees.

e. Emery wheels have been placed in two salvage cribs for instant mutilation of rejected parts by AAF inspectors.

f. Directions have been issued that no one will be allowed to enter salvage cribs except Wright Aeronautical Corporation and AAF inspectors.

g. The contractor has been directed to assign a supervisor to each inspection crib and furnish each crib with the necessary tools and gauges to

enable inspectors to properly inspect parts under the supervision of an AAF inspector

h. AAF personnel have been instructed to have Red Liner inspection tests made when necessary.

i. Reductions were made in engine run-in time in an endeavor to limit to the minimum the 100 octane gasoline required. Instructions have been issued by the Air Forces' District Supervisor to this factory to return to the original run-in schedule. In this connection the run-in schedule will be so established as to make the increases in those horse-power brackets where 91 octane gasoline may be utilized.

WILLIAM S. KNUDSEN,
Lieut. General, U.S.A.

APPENDIX "A"

The following engineering comments are made relative to statements by personnel of the Wright Aeronautical Corporation plant at Lockland, Ohio, concerning defective engine components, as well as manufacturing and inspection methods. Note: Exhibits referred to herein are being prepared for submission with the final report.

1. LEAKY ENGINES.

a. Intake Manifold -

Statement of witnesses. - Various witnesses, including Army and plant inspectors, stated that after green and final run a considerable number of engines were found having cylinders which leaked gasoline at the intake port sleeve. These witnesses stated that the leaks were detected by the presence of the blue dye which apparently had seeped out around the threads between the sleeve and cylinder head proper. This seepage or leakage was confined to the rear cylinders of the engine. The witnesses further stated that they believed this leakage is of sufficient magnitude to be dangerous on test stands, but their main point of issue indicated that this leakage would develop in the service engine to such a point as to result in a serious fire hazard in the airplane. Further, there seemed to be considerable confusion and disagreement between government and plant inspectors relative to the degree of leakage which could be tolerated. In other words, there was no clear conception as to the inspection standard on this particular item.

Comments. - The Materiel Command personnel and the engineering staff of Wright Aeronautical Corporation have been aware of the difficulty being experienced with occasional gasoline leakage between the cylinder head casting and the intake port sleeve on the rear cylinders. This problem has been given considerable and intensive engineering study by both the Materiel Command and the Wright Aeronautical Corporation and it is expected that an engineering solution to this problem will be arrived at in the very near future. For complete discussion of this problem by the Wright Aeronautical Corporation, see Exhibit A.

It is pointed out that only occasional cylinders are found to be leaking. However, the inspectors are correct in stating that even the occasional leakage should be remedied. It is also pointed out that it is the rear row of cylinders which are the offenders in this matter. From a strictly engineering point of view the amount of leakage experienced by these engines at this specific point (at the rear intake sleeve location) is extremely slight in comparison with the quantity of air that passes this point. Service experience has indicated that this type of leakage, although undesirable, is not a fire hazard and there has been no known case of fire which could be attributed to a leakage of this nature.

All fuels that contain lead are colored with a dye for identification purposes. The presence of a dye stain generally indicates a point of

fuel leakage. However, it is pointed out that the presence of the dye, although resulting from a slow leak, might mean to the layman that a severe leakage exists.

In view of this situation and until the final engineering fix is incorporated all intake sleeves which have been shrunk into the cylinder head should be rolled with the expanding roller to further seal and eliminate fuel leakage at this point. This corrective measure will simplify the inspector's problem. Fewer cylinders should be found after green or final run that would indicate leakage.

The point was made by various inspectors, that in view of the fact that they found leaky intake port sleeves on engines during green and final run and that often a cylinder which did not leak on green run would develop a leak during the final run, that this trouble would possibly develop in service. From an engineering point of view, there is a possibility that this trouble may develop in service with the type of intake port sleeve now being used on production. Immediate action should be taken by the manufacturer to issue a service bulletin containing the necessary instructions for repair of any of these cylinders which may develop a leak in service.

b. Rear Housing Studs and Gasket Leakage. -

Statement of witnesses. - Witnesses stated that a considerable number of engines were found after both green and final run with fuel leakage between the blower section and the rear section flange, and at the stud locations. The witnesses further stated that the cures now being applied, such as Permatex No. 3 on the gasket and further tightening of the stud nut after the washer had been replaced, were not satisfactory remedies. The witnesses further stated that considerable judgment was being exercised and that no clear-cut standard of inspection was set down on which to base acceptance of the engine with respect to this leakage. Further the witnesses were of the opinion that this leakage would develop further in service, resulting in a serious fire hazard.

Comments. - The seriousness of the fuel leakage problem has been discussed at considerable length in the previous paragraph and consequently no further discussion on this point will be included under this heading. Leakage around the studs in the rear housing is fully discussed by the engineering staff of the Wright Aeronautical Corporation in Exhibit B. It has been further suggested that a simple method of eliminating the possibility of leakage would be to drill a hole through the entire length of the stud, thus relieving air pressure or hydraulic pressure of any fluid which may be caught in the tapped hole in the housing. At the present time the method employed to relieve this pressure is the use of a small hole drilled through the housing into the supercharger diffuser. Experience has shown that unless a hole is provided failure often results at the time a stud is inserted in the housing, the nature of the failure being the breaking loose of a small particle of metal into the diffuser proper. While the use of a hole through the stud would effectively cure this difficulty, it is a difficult procedure for production use. Another method which is suggested is a relief of the stud threads by an axial cut. This method is currently used in other types of machines. There

is a possibility that the relief made in the threads may have some injurious effect on the housing. However, this matter can be investigated by the Wright Aeronautical Corporation.

Leakage of fuel past the rear housing gasket occurred and attempts to eliminate this leakage by the use of Permatex No. 3 were unsuccessful. Two types of gaskets were furnished the Wright Company by its vendors, one gasket being slightly harder than that previously furnished; however, both gaskets are within specification requirements on the gasket drawing. The use of Permatex on gaskets to prevent leakage of gasoline is not a recommended practice and therefore should not be permitted by government inspectors.

The inspectors are correct in stating that there is a possibility, in view of the trouble being experienced during production testing, that this trouble could develop in service. It should be pointed out that reports from service indicate that leakage at this point is not a serious problem and that normal corrective measures already issued in the form of service instructions can be applied to overcome this difficulty.

2. GEAR INSPECTION.

a. Hardness Test. -

Statement of witnesses. - Witnesses stated that considerable laxity exists in various gear inspection departments relative to the method of checking and the limits imposed during the hardness testing of gears. Statements were made that a considerable number of gears were being passed which were known to be outside of the drawing limits. This incorrect recording was directed by the witnesses' superiors.

Comments. - Prior to the sale of an engine to the government agency the gears to be used in this engine have undergone extensive development tests which have established certain specifications for each and every gear in the engine. The detail blueprint of the gear always specifies these specifications and the limits which are known to be within the safe operating range. During the inspection of these gears by the manufacturer it is mandatory that sufficient inspection equipment and qualified personnel are available to definitely establish that the production gear is within the blueprint specifications and limits. Whenever gears are found by the inspection methods to be out of the blueprint specifications and limits this gear should be submitted to salvage and the salvage committee should pass judgment as to the serviceability of the gear in question. In no case should the chief inspector in the gear department assume responsibility or direct his subordinates to exercise the function of the salvage committee. The hardness of gears is very critical and great care should be exercised in ascertaining that the hardness of gears falls within blueprint specifications.

b. Profile Inspection. -

Statement of witnesses. - One of the witnesses, a government inspector, stated that he was prohibited from inspecting gears by means of profile tests.

Comments. - Gears in general are received from a vendor in the form of forging blanks. These forging blanks are then normalized by the manufacturer and are given a hardness check to establish control of the normalizing heat treatment. The forging blank is then rough machined to such a point that it can be machined further on the gear cutting machine. After the gear teeth have been cut on the gear cutting machine an inspection should be made of this gear to determine whether or not the correct profile has been generated by the machine. This profile is checked on what is known as an involute measuring machine. This consists essentially of an indicating head which follows the tooth profile. The motion of the indicator is transferred to a recording oscillograph by means of an integrating electrical circuit. This circuit converts the involute profile to that of a straight line which is recorded by the oscillograph. The magnification on the oscillograph is such that deviations from the correct profile form can be quickly and accurately measured to within a few tenths of a thousandth of an inch. For a complete description of the involute measuring machine see Exhibit C. This measuring instrument is not now used as inspection equipment in this plant but is used only in maintaining manufacturing control and should not be available for use by the inspectors who are concerned with the inspection of the final product. It is pointed out here that by operating this involute measuring machine by hand at various speeds factors enter into the recording mechanism which will result in erroneous profile readings. However, in no case can this involute measuring machine be operated in such fashion that the record of the tooth profile will be any better than the actual profile of the tooth being inspected. This involute measuring machine is used to check a sufficient number of teeth around the circumference of the gear to assure that the gear in question is being properly manufactured on the gear cutting machine. After the gear teeth have been cut the gears are hardened by any one of the hardening processes. After hardening, the final operation on the gear is performed and the gear is submitted to an inspector for final inspection. This final inspection is performed on a machine known as the Red Liner constructed by the Fellows Gear Shaper Company. The machine checks the entire gear. This machine automatically records such errors as eccentricity, tooth spacing and tooth shape in combination, but in such a way that these errors can be identified and the amount of each definitely determined. The details of the operation and function of this machine are described in Exhibit D.

c. Other Inspection Methods. -

Statement of witnesses. - There was considerable confusion among certain inspectors in regard to the type of inspection equipment which should be used in inspecting gears. Mr. Christiansen asked for a profilometer or a brush machine for gear inspection, which was refused by the company.

Another point raised by the inspectors which should be carefully checked on gears was the question of concentricity of certain pump gears. The witness stated that a number of these parts were found to be out of concentricity. He was ordered to pass them as this point was not checked in final inspection and consequently if he passed them there was no further inspection.

In addition to the question of concentricity, another inspector testified that a large number of gears had been passed over his objection with the axial hole out of round.

Comments. - Other inspection equipment which was suggested by Mr. Christiansen were the use of either the profilometer or Brush Surface Analyzer for gear inspection. These instruments are sensitive laboratory devices for measuring surface finish to within a few millionths of an inch and are not manufactured with the intent of being used as production inspection equipment.

Relative to the question of the eccentricity of the pump gears, either fuel pump or oil pump, it is reasonable to presume that the manufacturer has not set up the Red Liner as an inspection procedure for these gears in view of the fact that these gears are not highly loaded and that defects in these gears will be readily shown up after the green run and can be rejected upon visual inspection at that time. However, should these gears be consistently found to be defective after green run, the Inspection Department should take the necessary action to establish suitable inspection methods; for example, the Red Liner in this department until the defect is eliminated.

Equipment recommended by the engineering department of Wright Aeronautical Corporation for inspection of gears both during manufacturing and final parts inspection is attached as Exhibit E. A brief description of the procedure which has been developed for the control of gear production at the Wright Aeronautical Corporation - Cincinnati plant since engine production started is included in Exhibit F.

3. MASTER ROD BEARING INSPECTION.

Statement of witnesses. - Various government inspectors objected to the methods used in the inspection of master rod bearings. One government inspector stated that he was prohibited from using pocket knife blades or a pencil eraser to remove indium plating from the surface of master rod bearings for the purpose of inspecting the master rod bearing. Further, when these practices were prohibited, the Army failed to furnish the inspectors with alternative methods of inspection.

Comments. - The master rod bearing problem in R-2600 engines has been a source of considerable trouble since the inception of the engine. This is not only true of this engine but considerable engineering effort has been expended on the master rod and main bearing problems in all high powered aircraft engines. There is considerable past history on the development of materials that can be used and recently the most promising development seems to be the soft silver bearing material. This bearing material is presently being used in other manufacturers' engines and as soon as sources of supply can be developed it will be used in the R-2600 engine to assist in overcoming the inherent bearing difficulty. Every known precaution is being applied to assure the use of satisfactory bearings in production engines. For a complete discussion of the bearing problem, as experienced by the engineering staff of the Wright Aeronautical Corporation, your attention is invited to Exhibit G.

It is further pointed out that along with the bearing material development basic bearing design has also had a history of development and it is known that the Wright Aeronautical Corporation has complete knowledge of

the latest design methods as brought out in Appendix E.

The main point of issue among the inspectors seems to be in the application of the inspection methods. From all of the testimony submitted on this problem, it is quite evident that there is no dissatisfaction with the methods used prior to the installation of the bearing in the engine for green run. After green run some bearings are found to have been completely destroyed and others are found which are of questionable character. The inspection technique of the questionable bearings is not too well established. Inspectors are prone to use methods for the inspection of this bearing which have proved satisfactory in the inspection of older type bearings. The question of scraping or removing the indium plate with a rubber eraser for inspection serves no useful purpose and is likely to destroy an otherwise satisfactory bearing. The indium plating would be marred further and evidence of possible bearing failure would be destroyed by use of the scraping or erasing technique. Slight superficial mars or scratches on the bearing surface may be removed by careful burnishing.

In view of the fact that considerable difficulty is being experienced with master rod bearings on green and final runs and that this difficulty can easily be carried over into the service, it is mandatory that bearings which are suspected or which show indications of irregularities in the basic copper-lead plate and lead plate be subjected to black light inspection. In no case should this bearing be touched with a loose abrasive in the form of pumice, crocus cloth or any other abrasive or wire brush of any kind.

Records of service engines manufactured at the Cincinnati plant indicate that there have been only six master rod bearing failures on the R-2600-B series engines. One failure was the result of defective material, one due to lack of oil and the cause for the four remaining failures are unknown at the present time.

4. NITRIDED CYLINDER BARRELS.

Statement of witnesses. - Mr. R. W. Clark stated that one of the difficulties with the Wright engine was the fact that they are using nitrided cylinder barrels and that the Wright Company is the only company using this barrel material. The use of the nitrided cylinder barrel was alleged to cause engine failures through excessive ring wear. In the opinion of Mr. Clark excessive ring wear will not be overcome until this type of barrel is eliminated. No other inspectors complained of this material. Several inspectors, however, reported red and smoky cylinders which showed up in the green run.

Mr. Hoff, one of the government inspectors, stated in his original testimony that cylinder walls are inspected after the green run merely by inserting a small light through the spark plug hole and that it is impossible to see more than a small portion of the cylinder in this type of inspection.

Comments. - The nitrided cylinder barrel as used in this engine is not responsible in itself for the high ring wear as charged in the complaint. The present piston ring combination as used in this engine is unstable, particularly at high power outputs and under conditions of dusty operation. The

long periods of satisfactory operation heretofore obtained with an exactly similar piston ring setup as used in a similar type engine in airline operation consist of relatively short periods of high power operation and long periods of operation power at 60 per cent. Also the conditions of dust and dirt usually experienced in military operations are not encountered in normal airline operation. However, this engine with the same ring setup has been proven by military service experience to be entirely unsatisfactory unless extreme precautions are taken to insure operation within the prescribed operating limits and particular care is exercised in the maintenance of air cleaner equipment installed in the airplane.

The specific difficulty with the piston ring assembly is that the lubricating oil control is partly maintained by the taper on the compression rings. This design is inherently unstable. As wear proceeds, the severity of the oil control decreases with the result that the oil consumption with this type of engine rapidly increases under the conditions of military service. This is interpreted as part of the objection raised by the complaint of rapid wear of the piston rings.

Another objection raised by the Government inspectors was the frequent occurrence of smoky cylinders during green run. This condition of smoke in the exhaust is due to excessive lubricating oil consumption which indicates unsatisfactory ring conditions, as described in the previous paragraph.

Another reason for smoke in the exhaust may be a slightly rich mixture for the particular cylinder in question. This condition is inherent with the mixture distribution characteristics of this engine and is not considered serious from the engineering standpoint.

Further reference was made by the inspectors to cylinders emitting a red exhaust flame. This condition is also attributed to either mixture distribution or lubricating oil consumption. The cylinders showing a suspicious exhaust in the green run should be noted by the inspector and if an unsatisfactory ring condition is found in these particular cylinders at teardown after the green run, the rings should be replaced and a penalty run given the engine.

The statement by Mr. Hoff that cylinders are inspected after the green run only by looking through the spark plug hole is entirely incorrect as the engine is completely disassembled for inspection after the green run. During the penalty run the cylinders which were equipped with new piston rings should be carefully observed for the condition of the exhaust flame. If the inspector is not satisfied with the exhaust from the replaced cylinders, a further inspection of the piston rings should be made.

5. USE OF PARTS FROM GREEN RUN ENGINES.

Statement of witnesses. - Mr. Hoff, a government inspector, stated that the practice of using parts removed from an engine following green run to replace failed parts on another engine without further penalty running is bad practice because of a number of master rod bearing failures and five sun gear failures in one engine. This practice is currently termed the use of "Kitty" parts.

Mr. Hollingsworth stated that master rod assemblies from the "Kitty" are used and passed without further test.

Comments. - The purpose of the initial (green) run of aircraft engines is to prove the satisfactory assembly of the engine and the compatibility of all surfaces subjected to wear. Therefore the use of parts removed from an engine following green run to replace failed parts from another engine is not considered entirely satisfactory. However, there are certain other parts which may be considered satisfactorily proven and run-in if they are operated with their complement parts.

Such items as are known to be critical from a service standpoint, i.e., master rod bearings, piston ring cylinder assemblies, supercharger drive gears, reduction pinion gears and other highly loaded parts which cannot be easily inspected after the penalty run-in, should not be interchanged at random after an engine has gone through the green run. Should it be necessary due to the failure of any one of the specific items as mentioned above to replace the part, the engine in question should be given a penalty run-in to definitely prove that the replaced part will operate satisfactorily.

The parts used or transferred from one engine to another engine during the period of September through March are listed in data included as Exhibit H.

To properly bring the unsatisfactory performance of these parts to the attention of inspection and manufacturing department personnel, it is recommended that these departments be properly bulletinized with information of this type.

6. SCHOOL ENGINES.

Statement of witnesses. - Testimony was submitted to the effect that school engines built of salvaged parts were operating more satisfactorily than standard production engines. Further testimony submitted by Mr. R.W. Clark indicated that fourteen school engines were produced out of the salvage of two years of operation.

Comments. - It is understandable from an engineering point of view that school engines which are built up of salvageable parts and hand fitted during assembly may perform equally as well as, or in some instances may perform more satisfactorily than, the standard production engines. Salvageable parts that are hand fitted to build up the school engines are those parts which are out of tolerances and which would affect interchangeability with the standard engines. The time and effort spent to assemble by hand fitting the parts could not conceivably be introduced into the production line.

It is pointed out that the parts used in a school engine have not been rejected from the production assembly line due to magnaflux indications, defective material or non-compliance with material and hardness specifications. School engines are for ground use only in training mechanics.

7. SUPERCHARGER CLUTCH.

Statement of witnesses. - Mr. Ray Clark stated that the Wright

type clutch fails even if in perfect tolerance because it is a very poor design and that it has sometimes operated better when outside of tolerance limits.

Comments. - The Materiel Command and the Wright Aeronautical Corporation are aware of the fact that the clutch assembly in this engine is not entirely satisfactory. Considerable engineering effort is being expended by both the manufacturer and the Materiel Command to effect an engineering solution to this problem. However, it is mandatory that the tolerances set up for the manufacturer of this assembly be strictly adhered to until an engineering change of design is instituted to correct the problem as a whole.

8. PENALTY RUNS AND ACCEPTANCE TESTS.

Statement of witnesses. - Mr. Ray Clark stated that a model test should be run on ever so many engines taken off the production line and that such a procedure has been suggested.

Comments. - Relative to the merit of performing a model test on an engine from the production line after a quantity of these engines have been produced is unquestionably desirable from a further production and inspection control point of view. It is pointed out that in the basic contract for the engines a provision is made whereby the Government can request one of the engines, selected at random from the production line, be submitted to a model test. This prerogative is exercised wherever service reports or penalty runs at a manufacturer's plant indicate that the quality of the production line engine is not up to standard.

9. RECORDS ON SERVICE DIFFICULTIES. - Summaries of records or reports from the service on R-2600-B series engines are attached as follows:

Army Air Forces - Exhibit I.
Navy Bureau of Aeronautics - Exhibit J.
Wright Aeronautical Corporation - Exhibit K.

10 COMMENTS ON ENGINE DIFFICULTIES. - The comments of the Army Air Forces on unsatisfactory reports received relative to the R-2600 series engines are included in Exhibit L. Comments by the Wright Aeronautical Corporation on service difficulties experienced with these engines are included in Exhibit M. Both manufacturing and service difficulties on these engines are discussed in detail by the Wright Aeronautical Corporation - Cincinnati, in Exhibit N.