The first set of valves failed in a short time under cycling conditions and the second set was constructed of a thicker material with resulting longer life. The valve section is being redesigned to incorporate an improved valve design based on the results of valve tests by other groups.

Mr. Rothrock stated that a combustion or possibly detonation of an explosive fuel-hydrocarbon type of fuel was scheduled for investigation.

Mr. Rothrock stated that Mr. Worth of Wright Field is working on a fuel program involving ram jets to be submitted by the Army to the NACA. Mr. Rothrock stated that consideration was being given to the burning in the shock wave in a steady-flow ram jet.

Mr. Pinkel stated that the second burner design for the steady-flow ram jet unit would consist of two annuli with annular shielded zones and fuel nozzles injecting into the shielded zones. The burner had 40% reduction in free flow at the burner section area and holes in the shields for the introduction of primary air for the burning process. When operating with twenty-one pounds of air per second at an air-fuel ratio of 30, a combustion efficiency of 82% with a pressure drop of 1 q was obtained. The flame length was 3 feet. The 1 q pressure drop is equal to approximately four inches water at the conditions.

The Chairman stated that it would be desirable to install the burner for the steady-flow ram jet unit if it was in shape to run. Mr. Pinkel stated that the burner could be installed but that he would like to obtain additional test results on the burner. It was agreed that the burner would be installed immediately and that Mr. Pinkel's group would cooperate in obtaining additional burner information as the tests progressed. It was further agreed that reports on the steady-flow ram jet performance would be prepared by the Engine Installation Research Division and reports on burner performance would be prepared by the Thermodynamics Division.

Mr. Pinkel stated that there was a favorable interference between the pressure drop due to area reduction at the burner and the pressure drop caused by combustion. It was noted that the pressure drop under operating conditions was less than the cold pressure drop plus the calculated momentum pressure drop from burning.

The Chairman stated that it would be very desirable for the laboratory to get out results on the steady-flow ram jet ahead of Professor Hottell of the Massachusetts Institute of Technology who is working on a ram jet project for the Army. Mr. Silverstein stated that with the first burner installation two of the burners didn't work but the pilot alone worked on all burners. Mr. Pinkel stated that with this type of burner if the burner was not working it was almost certain that the pilot flame was out.

Mr. Silverstein stated that it was planned to run individual lines to each burner unit and then try adding sheltered zones at the burner entrance. Mr. Pinkel noted that the sheltered zones resulting from the fuel lines had been streamlined out when the installation was made. Mr. Pinkel stated that the burner developed for the NACA jet-propulsion unit appeared to be a good design for use in the steady-flow ram jet. Mr. Silverstein described the burner developed by Professor Hottell with fuel injection normal to the stream in a flame stabilizer downstream from the fuel injection.

The data from the Ford-built unit was shown to the group by Mr. Pinkel at this time. The data showed that maximum thrust of 647 pounds was obtained with 20° inlet ram, 50,000 pounds of air per hour, and 2400 pounds of fuel resulting in a fuel air of .048. The unit operated at forty cycles per second. Mr. Pinkel stated that the unit operated satisfactorily except for shaking the instruments.

Mr. Schey reviewed the work that had been carried out on valves. A valve had been developed that was twice the height of the German valve and operated successfully for three hours at 40 cycles. The design to incorporate this valve into the Ford-built unit was completed and is ready to go into the shop. The committee approved the construction and tests of this grill design in the Ford unit.

Mr. Schey reported that the hinged-type valve had very short life in the reciprocating piston apparatus. Mr. Silverstein pointed out that the changes made in the spring details may have resulted in the short life.

Mr. Schey showed a new valve design made up with a curved and straight piece riveted together that had been constructed. He stated that other valve developments are also in progress.

Mr. Rothrock stated that two groups were working on the general combustion problem. One group, under Mr. J. C. Sanders, was working on a problem of fuel properties required for jet-propulsion units. A second group, under Mr. I. Irving Pinkel, was working on the fundamentals of combustion turbulence and pressure effect at altitude. Doctors Hicks and Simon are working on the problem of mixing fuel and air and Mr. C. D. Miller was working on the problem of mixing utilizing photographic methods.

Mr. Rothrock stated that Colonel Wansel and Mr. Worth discussed a project request for basic research on combustion in which Mr. Worth stated that emphasis should be placed on ram jets.

The following list of questions to be answered as results of this work were proposed by Colonel Wansell and Mr. Worth:

1. What is max. heat release /cu ft/ unit time.
   What increase possible for hydro carbon fuels — other fuels.
2. What is the max. mix velocity or flame speed for hydro carbon fuels.

3. What is the limit of mixture ratio for H.C. fuels.

4. What is velocity head loss for burning.

5. What is velocity head loss for mixing fuel and air. Comments on liquid spray, air aspirated mixing, pre carb. mix.

6. What is meaning or correlation of flame color to rate of heat release.

7. Available energy of heat release as affected by condition of burning of the fuel (detonation wave pressures, etc.)

8. What is the relation between flame visibility and heat release.

9. What is the difference of flame travel in stationary fuel mixture as compared to stationary flame in moving fuel mixture assuming turbulence of same degree in both cases.

10. Is there a radiant energy transfer from the burning front to the yet unburned fuel.

11. Are there catalysts or additions for hydro carbon fuels which will cause higher burning rates.

12. What are the condition parameters to promote detonation.

13. What is a good yardstick for measuring the desirability of a jet fuel.

14. How can the B.T.U./unit volume be increased.

15. What basic parameters should the fuel characteristics be described with for a jet fuel.

Mr. Rothrock stated that one group of chemists in the Fuels and Lubricants Division have started an investigation on the use of catalysts in combustion.

The meeting adjourned at 4:00 p.m.

Jesse H. Hall
Secretary, Ram Jet Committee.

JHH:lmk

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RAM JET CONFERENCE

April 15, 1945

The Committee met in the Executive Conference Room at Cleveland on April 15, 1945, at 2:00 p.m.

Present:

Abe Silverstein, Chairman
B. Pinkel
K. M. Rothrock
O. W. Schey
J. H. Hall, Secretary

The reading of the minutes of the last meeting on February 13, 1945 was dispensed with. The chairman reviewed the discussion that had taken place with Doctors Goss, Miller, and Tatum during a recent visit to the laboratory concerning the "Bumblebee" project. The project is under the direction of Dr. Tuve's group at the Johns Hopkins Applied Physics Laboratory in Silver Spring, Maryland. It is being carried out for the Navy Department, Bureau of Ordnance. The project is for the development of a ship to air missile using a steady-flow ram jet as the power plant. The chairman stated that the drag as obtained on the "Bumblebee" project gave results similar to those obtained at Langley Field. It was pointed out that cold models had already been tested using telemetering instrumentation and rocket launching. Two problems expected to give some difficulty on the project are the starting problem and the fuel system. It was pointed out that the fuel system utilizing the pressure rise across the diffuser might work in opposite direction when the missile goes slightly off the design conditions to bring the unit back to the design conditions. Mr. Schey suggested the possibility of adjusting the fuel flow to the rich range so that leaning out would increase the thrust. Mr. Pinkel stated that compensated fuel controls appeared necessary.

The Chairman made a strong recommendation for more emphasis on the missile program at this laboratory because of the intense interest evidenced by both the Army and Navy. The question was raised as to whether the laboratory could drop other projects to allow the increased work on missiles. Mr. Rothrock stated that the laboratory projects would be reviewed with this thought in mind.

The chairman stated that the design of supersonic compressors offered considerable promise if an efficient design could be worked out. He stated that Mr. Kantrowitz at NACA had done some work along this line. Mr. Pinkel suggested that the laboratory should carry the steady-flow ram-jet project through flight tests. The chairman pointed out that NACA was working on setting up a fuel station for such flight tests.

The chairman stated that the NACA Special Committee on Self-Propelled Guided Missiles was scheduled to meet on April 18 and that he would like to present a progress report covering NACA work to date and the program of the work to be carried out. It was requested that each member of the team write up the work under his direction by Monday, April 15, 1945.

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Mr. Rothrock stated that the Army has been given a directive to develop rocket prime movers for aircraft. The Fuels and Lubricants Division is carrying out work on fuels and combustion for rockets but there are other problems that should be carried out at the same time, such as development of turbulence pumps for liquid fuels, nozzles and heat resisting materials for cooling systems.

Mr. Sohey stated that he would investigate the use of ceramics for rocket-motor nozzles.

The chairman asked for a progress report on the work accomplished since the last meeting.

Mr. Rothrock stated that tests were under way on the combustion chamber units. He stated that a setup had been made of a combustion chamber of the transparent number and small nozzle for an exit to study the effect of turbulence on combustion. An apparatus is being set up to study the mixing process for fuel in air and effective turbulence. Another apparatus is being set up for studying the steady-combustion process by means of high-speed photography. A program is being carried out to prepare or synthesize new fuels considered to be of interest in the ram jet and rocket programs. A small-scale intermittent combustion chamber is being set up to study the combustion problem. The chairman suggested that the Fuels and Lubricants group look into the possibility of using the intermittent combustion-chamber test apparatus of the Thermodynamics Division for fuels tests and to get the two groups together to coordinate fuels and combustion work. The chairman also suggested that the Fuels and Lubricants group consider the use of tracers for ignition in ram jets. It was also suggested that the use of sensitizers for reducing fuel autoignition temperatures be looked into.

The chairman stated that a visit by Army and Navy groups interested in ram jet work had been discussed in a telephone conversation between Mr. Kemper and Dr. Lewis and asked for comments as to a suggested date. After some discussion it was decided that April 26, 1945 would be the most advantageous date. The chairman requested that proposed items to be included in the agenda for the meeting should be turned in by Monday, April 16, in order to discuss the program with Dr. Lewis who is expected on Tuesday, April 17.

Mr. Pinkel reported on progress on the buzz bomb work since the last meeting. He stated that tests using the first grid had been completed and the second grid was being installed. Mr. Pinkel stated that the second grid was different in that it had venturis downstream from the nozzle. After the meeting, Mr. Pinkel informed the secretary that actually both grids had the venturis. The third grill to be tested will be the grill designed and built by the Supercharger group. Mr. Pinkel stated that with ram increased from 40" to 60" water the increase in thrust by increasing ram was tapering off in this range. He stated that it was observed that at 40" water ram the effective jet velocity was indicated to be a little higher than at 60" water. A thrust of 760 pounds net was obtained at a simulated speed of 350 miles per hour and with a fuel consumption of 3200#/hr.

It was stated that the pressure time record from a quartz crystal pick-up had not been very satisfactory because of severe vibration. The maximum and minimum pressure instrumentation was also found to be not too satisfactory.

The high-speed motion pictures obtained with the intermittent-combustion apparatus showed uneven cycles. A surge tank has been installed in the entrance which, it is believed, has improved the uniformity of the combustion cycles. More evidence will be available when the high-speed motion pictures have been developed and can be observed. Mr. Pinkel stated that the apparatus was very hard on valves since the surge chamber had been put in which indicated higher maximum pressures and a higher rate of pressure rise resulting from combustion. Indicator records are being taken on the apparatus but the Piezo electric crystal and trap pressure instruments have not been working too well. Mr. Pinkel stated that the resopulse drawings had been completed.

Mr. Pinkel stated that Mr. Parker at Annapolis has shown him captured German documents of the Smidding Company reporting on all sorts of aeropulse ideas.

Mr. Schey reported that all grill castings for the buzz bomb will be developed within a week and machining of the castings will start immediately.

Mr. Schey stated that the group working on valves had obtained designs with a life of three hours with considerable improvement, from a pressure-drop standpoint, over the German valves. Mr. Schey stated that the Ford-built grill equipped with an NACA two-piece valve will be completed in about a week at the best. He stated that little testing was being carried out at the present and the work would increase pending the outcome of tests on the full-scale unit.

The chairman asked that a list of all reports on ram jets being worked on by the group be sent to the secretary and that the list be circulated for the information of the members.

The meeting adjourned at 4:30 p.m.

Jesse H. Hall,
Secretary, Ram Jet Committee.

JHH:imc

Address reply & ENVELOPE

COPY

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Commanding General
AAF Materiel Command
Engineering Division
Reference: Dept. 50
Wright Field, Dayton, Ohio

ARMY AIR FORCES
Materiel Command
Office of the Commanding General

Capt. J. P. Auwerter
pjg Ext. 2-3103

National Advisory Committee for Aeronautics
1500 New Hampshire Avenue, N.W.
Washington, D. C.

Attention: Dr. G. W. Lewis, Director
of Aeronautical Research.

Dear Dr. Lewis:

The Materiel Command is at present making a thorough study of the development of long range, ground launched, pilotless, controlled missiles. Of immediate importance is the design of a preset guided missile of 100 to 150 miles range.

The Army Air Forces desires, however, to develop in the minimum period of time a pilotless guided missile, ground launched, which would have a range of 100 miles with the application of remote control for the accurate hitting of military objectives. The requirements for this new type missile have been prescribed, and are as follows:

(1) Range - 100 miles
(2) Pay Load - 1,000 lb. demolition bomb
(3) Speed - 550 mph.
(4) Control - Remote or target seeking

The general requirements dictate that this missile be of the simplest construction and minimum size. It is further desired to propel this missile by means of jet propulsion. However, due to the urgency of the program, the type of motor to be used must be limited to one of the existing types or a new design which would be readily available.

In order to accomplish the development of such a missile it is felt that the program should be divided into three parts, namely (a) the vehicle itself, (b) the jet power supply, and (c) the remote control devices and launching mechanisms.

It is requested that the NACA undertake a program in cooperation with the Materiel Command to develop parts (a) and (b). If such a proposal is agreeable to the NACA it is requested that the following action be taken:

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Dr. G. W. Lewis
11 August 1944

a. The laboratories of the NACA immediately begin a preliminary design study of the possible vehicles and propulsion systems to accomplish the general experiments as stated above.

b. That at the earliest possible date a conference between representatives of the NACA and the Materiel Command be held at which time the design studies would be evaluated.

c. The comments of the NACA in regard to such a development program are requested.

Very truly yours,

(signed) H. Z. Bogert

F. O. CARROLL
Brig. General, U.S.A.
Chief, Engineering Division.

cc: Materiel Division, Asst. C/AS, MS,
Washington, D. C.
Materiel Command Liaison Office,
NACA Lab., Langley Field, Va.
Materiel Command Liaison Office
AAL, Moffett Field, Calif.
Materiel Command Liaison Office
NACA AERL, Cleveland, Ohio

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RAM JET CONFERENCE

July 24, 1944

The Committee met in the Executive Conference Room at AERL on July 24, 1944 at 1:30 p.m. Present:

L. M. Jacobs, Chairman
Benjamin Pinkel
L. Richard Turner
Abe Silverstein
Robert E. English
A. D. Johnson
W. Mutterperl
Carlton Kemper
Jesse H. Hall, Secretary

1. Mr. Jacobs discussed the robot bomb currently being used by the Germans. A detailed description was given of the ram-jet installation, as well as a general description of the robot bomb and its effectiveness as a military article. Mr. Jacobs pointed out that the basic construction of the robot bomb was extremely simple but that the controls were very complicated. He stated that the robot bomb was equipped with electrical-, pneumatic-, and hydraulic-type controls. The design and construction of the controls are excellent indicating considerable effort by the Germans on this phase in contrast with the extremely simple basic construction of the robot bomb. A general discussion followed on the detail of construction used in the ram-jet robot bomb by the Germans.

2. Mr. Turner and Mr. Mutterperl presented curves on performance and efficiency based on theoretical calculations for the intermittent- and steady-flow types of ram jets. The analysis from the theoretical studies indicates that the intermittent-flow ram jet is capable of higher efficiencies than the steady-flow type up to a range of 900 miles per hour.

3. Mr. Jacobs brought up the question of possible uses for ram-jet units and what line of attack could be followed in the laboratory's research on the ram-jet unit as a power plant. Suggested uses of the ram-jet units were for assisted take-off, long range projectiles, and for use as a primary power plant. It was agreed that ram-jet units should be considered as power plants for aircraft and, as such, should be thoroughly explored by the laboratory.

4. Mr. Johnson and Mr. English exhibited several valve designs that had occurred to them for possible use in ram-jet units. In discussing these valve designs, Mr. Jacobs pointed out that if complicated valves and drives were used, the fundamental advantage of simplicity of the ram-jet units would be lost to some extent. It was agreed that the first theoretical-flow ram-jet unit to be considered should have automatic inlet valves and no exit valves. Exit valves and inlet valves involving valve-drive systems would be considered later. It was decided that the laboratory should go ahead with the design and

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construction of an intermittent-flow ram-jet unit utilizing the information available on the German unit and improving on the German design wherever possible. Work on steady-flow ram-jet designs will follow later. One of the units to be built by the Ford Motor Car Company for the Army Air Forces will be requested for test as soon as these units become available.

5. Work of the group for the coming week was discussed. It was agreed that the first problem to be attacked is the design of the automatic inlet valve. Members of the group were requested to work on this problem during the following week and bring their designs to the next meeting in appropriate form for including in the minutes of the meeting. Considerations are to be given to the design of automatic valves that will allow filling the combustion chamber at full ram pressure and clearing the combustion chamber of burnt gases between cycles.

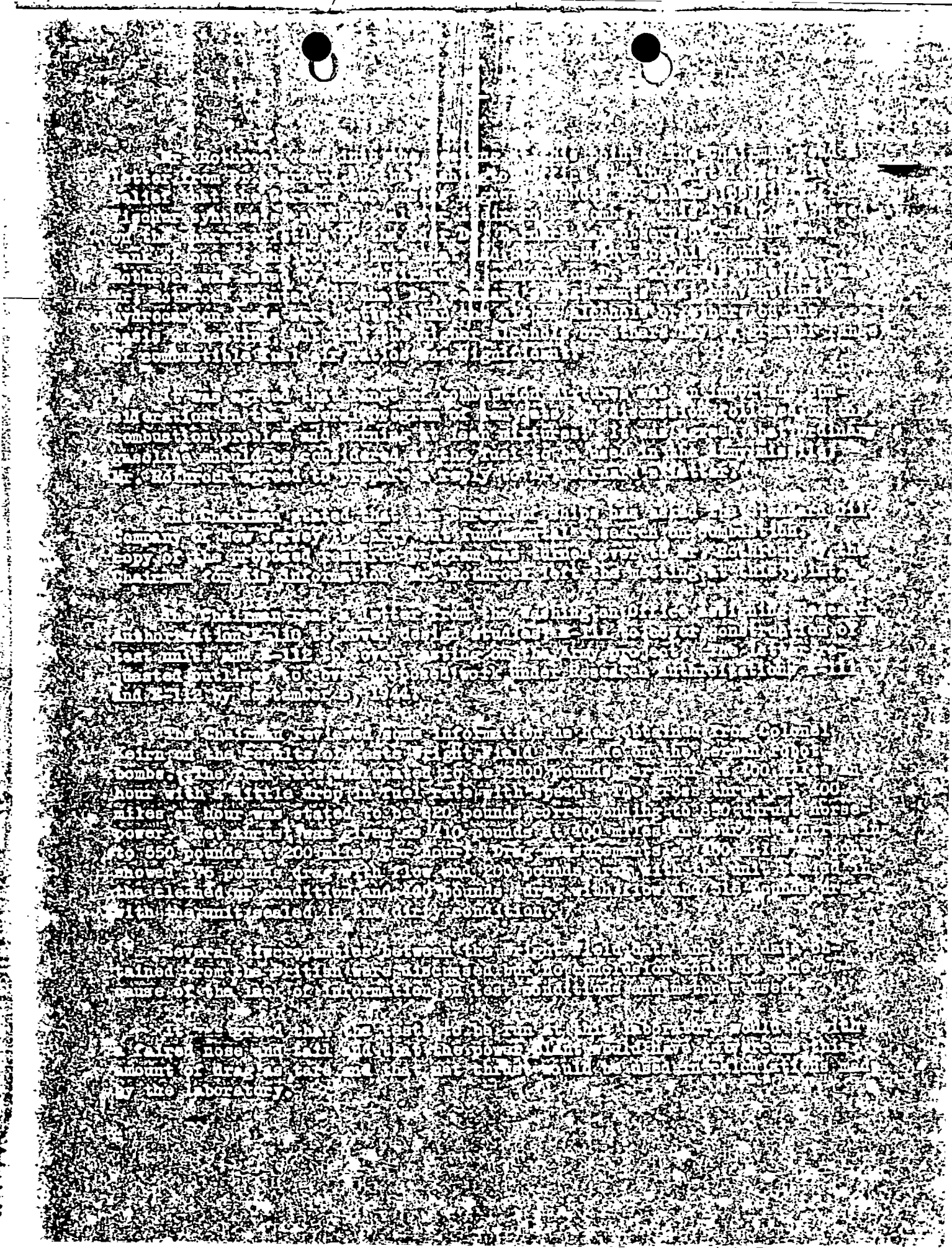
6. The next meeting was scheduled for 9:00 a.m., Tuesday, August 1, 1944, and subsequent meetings will be held each Tuesday at 9:00 a.m.

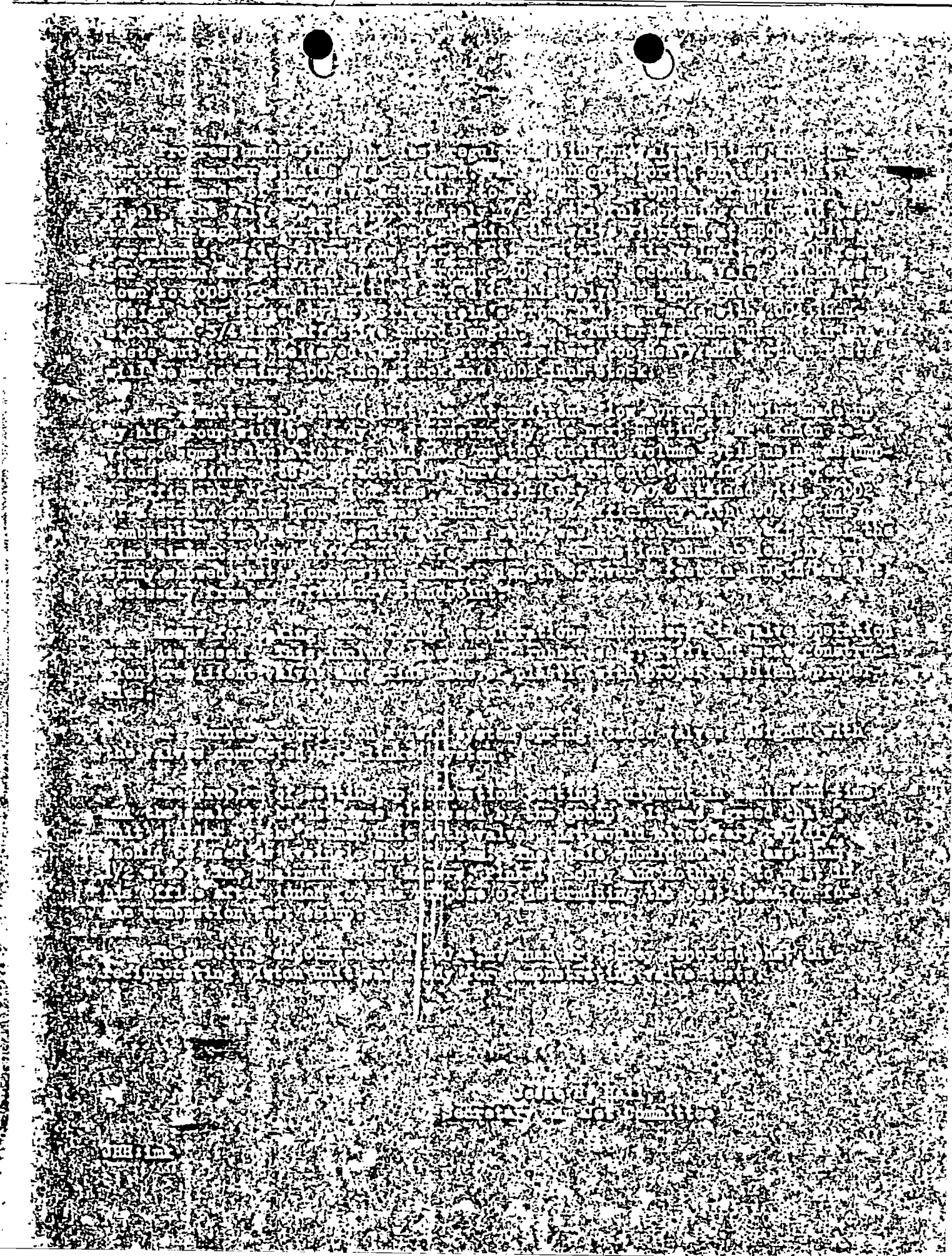
7. The meeting adjourned at 3:30 p.m.

Jesse H. Hall

Jesse H. Hall,
Secretary, Ram-Jet Committee.

JHH:db





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Dr. Lewis inquired as to what was desirable in a seat material and the possibilities of the material under consideration for meeting these requirements. The Director expressed doubt that some of the material that had been mentioned, for seat construction, would be satisfactory from a heat standpoint. Mr. Jacobs noted that the valves he had observed in one of the German units did not indicate that the valves had been subjected to high temperatures.

Mr. Sobey noted that the valves may receive heat through the grill and other paths in addition to direct transfer from the combustion gases.

Dr. Lewis inquired as to what seat material was used in the German unit. Mr. Jacobs stated that the valves seated on the aluminum alloy grill along the side but that he was not sure about the seating at the tip.

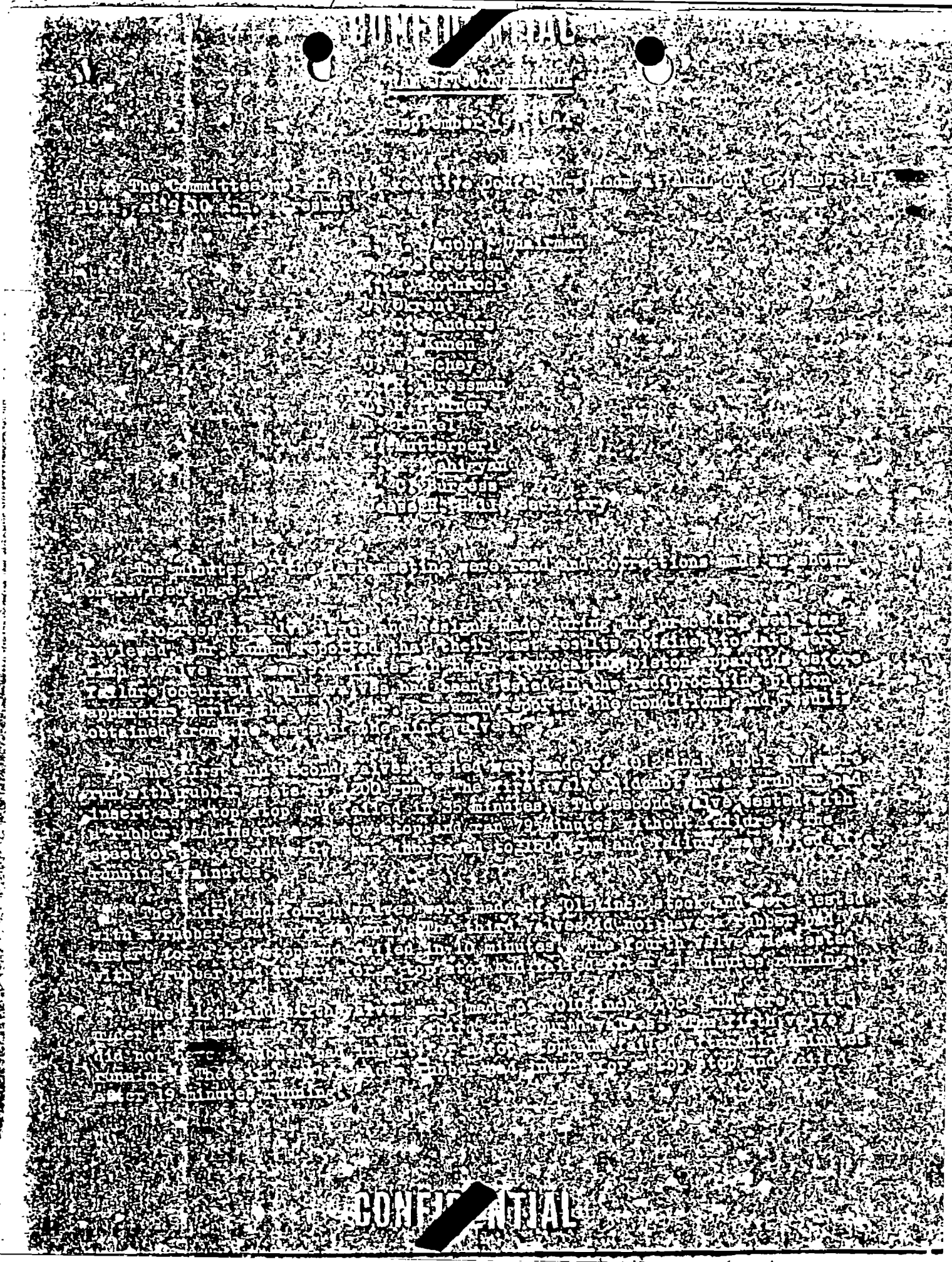
Mr. Silverstein entered the meeting at this point.

The results of tests at Wright Field on the German unit in the wind tunnel were discussed. Mr. Silverstein stated that the test results showing less drag in the sealed condition than was obtained with flow through the valves was to be expected. Mr. Silverstein noted that it might be possible to calculate the approximate valve opening from the drag increase caused by flow through the inlet.

Dr. Lewis inquired as to what might be called the optimum valve opening. The Chairman stated that it was the objective of the group to obtain a valve that would open fully. In the discussion of the valves Mr. Turner noted that tests had been run with double size valves at 1200 rpm but that the next step would be to test the valves at actual size at full speed.

The Chairman asked for a progress report from Mr. Pinkel's group on combustion work accomplished since the last meeting. Mr. Turner stated that Dr. Williams of the Fuels and Lubricants Division had obtained some interesting results in combustion tests he is running on another project. In tests of a conical combustion chamber with rear ignition, central ignition had been tried and the explosion report was of much higher intensity than with the regular rear ignition. This indicated that probably [illegible] central ignition would result in greater powers than rear ignition in intermittent ram jet installations.

Mr. Turner sketched on the blackboard the layout of equipment his group was constructing for combustion tests. The air supply was from a 7,000 C.F.M. capacity blower and pressures up to approximately 40" water should be attained. The duct in which the valves were located was 9" square. The blower capacity would allow velocities up to 200 ft/sec in the combustion chamber. A glass window is to be incorporated in the top of the test unit to provide means for observing the valve action. The length of the combustion chamber is to be full size and the area is to be 1/4 full size, to obtain the half scale combustion chamber previously agreed on.



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RAM-JET CONFERENCE

October 3, 1944.

The Committee met in the Executive Conference Room at AERL on October 3, 1944, at 9:05 a.m. Present:

B. H. Jacobs, Chairman
J. K. Nahigyan
L. R. Turner
D. M. Sohey
D. Okrent
B. Pinkel
A. Hitterpol
C. C. Burgess
J. R. Brossman
J. C. Sanders
M. Wolfenstein
R. H. Hall, Secretary

The minutes of the previous meeting were read and approved as read.

A valve assembly taken from a German robot bomb was shown to the group. Mr. Sohey stated that Dr. Lewis had asked for the valve to be returned at an early date in its original condition as he intends to use the valve at a meeting of the Budget Committee. Measurements desired should be taken as soon as possible so that the valve assembly might be returned in accordance with the request of Dr. Lewis.

The construction details were examined and discussed by members of the group. Mr. Brossman reported that the valve-test program on the large valves as installed in the reciprocating-piston apparatus had been completed. The results of the test work on the large valves were reviewed. Included in the investigation were the effect of valve thickness, seat material, speed, and stop construction on valve life.

The method used for forming the valves which had been tested was discussed. The current method of forming the valve by means of a sheet-metal brake was believed to be undesirable from a stress standpoint. Suggested methods for forming included laying the material on a form and shot blasting, wrapping the material on a roll to obtain the proper curvature, and annealing the material on a form followed by heat treatment.

Mr. Burgess reported on results of the valve tests conducted during the preceding week in the intermittent-flow apparatus in the Duct Laboratory. A comparative test had been made of Inconel and Swedish-steel stock. The Inconel material gave considerably longer life, but it was pointed out that the single test could not be considered conclusive. Steel valves made up with the rolling direction of the material in span and chordwise were compared. The valve with

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	Propane	Propane	Methane
Temperature of storage, °F	-44	120	-258.5
Type of tank	Freely vented insulated 2" cork	Pressure 200 psi not insulated	Freely vented insulated 2" cork
Weight of fuel, pounds	2420	2116	732.6
Length of 1.63 radius tank, feet	10	16.6	10
Thickness of wall—steel, inches	1/8	1/4	1/8
Thickness of wall—aluminum, inches	1/8	7/16	1/8
Weight of tank—steel, pounds	508	1607	509
Weight of tank—aluminum, pounds	182	1165	182
Weight of insulation (cork), pounds	156	0	156
Loss of fuel, pounds per hour	[illegible]917 ([illegible]036%)	0	1.94 ([illegible])
Purge	Necessary	Unnecessary	Necessary
Temperature effect on metal	None	None	Terrific
Tank pressure, pounds per sq. in.	14.7	85.5	14.7

Mr. [illegible] also submitted curves showing the suitability of different types of fuel. Messrs. Rothrock and Jacobs agreed that the use of gaseous fuel in the intermittent duct seems to be very promising.

Mr. Rothrock sketched on the blackboard the test rig for studying the vaporization of liquid fuels. Plans are made to compare the vaporization of different fuels, including gasoline, fuel oil, and kerosene. Mr. Rothrock stated that a demonstration would be held as soon as the safety mechanism is installed on the rig.

Mr. Mahlegan reported that the fabrication of the gasoline burners is progressing and that a demonstration can probably be held on November 7, 1944. Mr. Mahlegan also reported that the rig for the robot bomb installation is progressing. Parts are scheduled to start coming in on November 8, 1944.

Mr. Jacobs sketched on the blackboard for the information of the Committee the method of launching robot bombs that were used in France. The bombs run on a track and are pushed by a piston which is actuated by explosives. The slot provided in the cylinder for connecting the piston to the bomb is sealed by rubber.

Mr. Jacobs stated that the Committee is now in a position to design a continuous-flow unit for the Navy missile.

It was generally agreed by the Committee that the work being done by the shops is moving unreasonably slow. Mr. Burgess suggested that if a shaper and lathe were placed in the wind tunnel, 95 percent of their work could be taken out of the shop. This policy, however, is frowned upon because the machines stay idle part of the time. Mr. [illegible] suggested that the Committee contact the shop in order that the shop appreciate the high priority of this job. It was agreed that pressure should be brought to bear on the shops in order to [illegible] work.

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RAM-JET CONFERENCE

October 17, 1944

The Committee met in the Executive Conference Room at AERL on October 17, 1944, at 9:10 a.m. Present:

B. [illegible] Jacobs, Chairman
A. [illegible] Rothrock
A. [illegible] Kunen
[illegible] Turner
D. [illegible]
[illegible] Kalligyan
[illegible]
A. Silverstein
[illegible] Sanders
[illegible] Bohey
[illegible]
[illegible] Burgess
[illegible] Buckner, Acting Secretary

The minutes of the previous meeting were read and approved as read.

Mr. Kunen reported that the grill used for testing had been revised and now [illegible] Swedish-blue steel, brass, low-carbon steel, and bronze valves have been tested. Swedish-blue steel valves of 0.006-inch thickness [illegible] 18 minutes and [illegible] minutes at 1500 and 1200 rpm, respectively. The valves of 0.008-inch thickness were improperly made and consequently lasted only about 2 minutes. The valves of 0.010-inch thickness failed after 25 minutes of operation at an engine speed of 1500 rpm. The brass, the low-carbon steel, and the bronze valves gave very poor results. Mr. Kunen stated [illegible] planning to run tests to give a curve of valve life versus closing [illegible].

Mr. Kunen passed the valves around for inspection. From the examination of the valves it was apparent that the failure was caused by the end of the valve [illegible] the seat. Several recommendations were made to avoid this type of failure. Mr. Silverstein suggested that the ragged end of the valves be [illegible] and that the end of the valve be stiffened by some method. Mr. Rothrock suggested that a spring sheet be located at the end of the valve seat to [illegible] more gradually and Mr. Kalligyan made design revisions in [illegible]. [illegible] recommended that the edge of the valve be curled. Mr. [illegible] suggested that the [illegible] edge of the valve seat be made wider in order to provide a [illegible] cushion and to distribute the stress over a larger area. Mr. [illegible] suggested that [illegible] the valve seat be [illegible]. Mr. Kunen [illegible] consider these recommendations in laying out future test work. It [illegible] agreed that [illegible] of shock absorber should be provided to [illegible].

[illegible] Burgess pointed out [illegible] to date direct comparison of valves is not [illegible]. Mr. Kunen added

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[illegible] CONFERENCE

October [illegible], 194[illegible]

[illegible]

The committee met in the [illegible] conference room [illegible] on October [illegible], 194[illegible], at 9:00 a.m. Present:

[illegible] Jacobs, Chairman
[illegible] Holms
[illegible] Kemper
[illegible] Bobey
[illegible] Silverstein
[illegible] Sharp
[illegible] Schroeder
[illegible] Pinkel
[illegible] Mahlgren
[illegible] Sanders
[illegible] Bolz
[illegible] Brossman
[illegible] Kunen
[illegible] Rittersport
[illegible] Burgess
[illegible] Durant
[illegible] Ornstein
[illegible] Hall, Secretary

The minutes of the previous meeting were read and corrections made as shown on revised pages 2 and 3.

The chairman asked that a brief review of progress to date precede the regular progress reports of the various groups for the information of Mr. [illegible] Holms. The progress made to date by Mr. Bobey's group on valve designs was reviewed by Mr. Kunen. He stated that several types of valves had been tested with the objective to obtain a minimum of 1-hour life with satisfactory results. Valve life exceeding the 1-hour minimum had been obtained on the reciprocating piston apparatus at 1200 rpm with the large size valves and at 1500 rpm with a smaller size valve.

Mr. Holms asked if there were any size limitations being used by the group. Mr. Kunen stated that larger valves than those being used by the Germans were tested in view of the possibility of obtaining lower pressure drop through the valve.

Mr. Bobey stated that the objective of the valve work was to obtain a valve that would open fully and have minimum losses.

Mr. Brossman reviewed the results obtained on the reciprocating piston apparatus during the preceding week. One of the nine grills and valves being made by the shop had been completed and tested. This grill which had a straight

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PROGRESS REPORT ON RAM JETS
BUREAU OF AERONAUTICS
October 25, 1944

The Bureau of Aeronautics has under its cognizance a number of ram jet developments. The general status of these projects is as follows:

A. Continuous-Flow Ram Jet Units.

1. Bureau of Standards (see Enclosure A)

The Bureau has been working during the past six months on a burner for a ram jet unit. At the present time, preliminary tests are being carried out on a quarter section of a 10 inch diameter burner. These tests indicate that steady running has been achieved at chamber inlet velocities of 200 feet per second and a discharge temperature of about 3800° F. (Successful runs were made at inlet velocities up to 300 feet per second in a one-inch tube.) The pressure drops are only slightly above the theoretical drop associated with combustion. (The exact values are shown in Enclosure A. These values may be subject to a small correction since it was found that the cross sectional area of the chamber changed during the test, and thus some of the pressures reported may be subject to correction.) The combustion efficiencies obtained were of the order of 95 to 99 %.

It appears that the development of the Bureau of Standards combustion chamber has proceeded far enough to warrant the construction and test of a full size ram jet unit. The Bureau of Aeronautics is negotiating with Fleetwings Aircraft for the construction of such units.

2. The Massachusetts Institute of Technology (see Enclosure B)

M.I.T. has also been working for about six months on the development of a suitable ram jet combustion chamber. Initial experiments were on the gas turbine type chamber with air-atomized gasoline. However, experience showed the apparent superiority of pressure-atomized gasoline injected upstream. A small combustion chamber is being built and [illegible]

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RAM JET CONFERENCE

November 7, 1944

CONFIDENTIAL

The Committee met in the Executive Conference Room at AERL on November 7, 1944, at 9:05 a.m. Present:

E. N. Jacobs, Chairman
O. W. Schey
J. R. Bressman
R. J. Bolz
E. F. Dahlgren
L. R. Tinney
C. O. Sanders
A. O. Burgess
L. [illegible] Dunan
A. Silverstein
B. Pinkel
D. [illegible]
S. Ornstein
F. Wattendorf
R. J. Littell
E. M. Hall, Secretary

The minutes of the previous meeting were read and corrections made as shown on revised page 3.

Mr. Bressman reported that two aluminum grills for curved valves had been completed. Tests with valves of .010-inch steel with a good fit on the seat resulted in failures in 2 or 3 minutes at 1500 rpm with a rubber top stop. A valve made with approximately 1/16-inch clearance at the mid chord point when the tip rested on the seat lasted for 2 hours and 15 minutes at 1500 rpm before failure occurred. The failure was in flexure and appeared to have been caused by too sharp a bend in forming.

Mr. Tinney stated that in observing operation of this valve the valve tip hit first and the valve then flattened to fit the seat. The Chairman suggested that the valves being made for the combustion apparatus should have clearance of 1/16-inch as used in tests of valves in the reciprocating piston apparatus.

Mr. Bressman stated that a curved valve made of .010-inch stock had been run at 1600 rpm and failed after 31 minutes running. Mr. Bressman reported that straight valves made of .006-, .010-, and .012-inch Swedish-blue steel stock had been tested. The .006-inch valve failed after 26 minutes at 1500 rpm. The .010-inch valve failed after 67 minutes at 1500 rpm, and the .012-inch valve failed after 103 minutes at 2100 rpm. Mr. Bressman noted that both straight and curved valves had a tendency to vibrate with steady airflow.

Mr. Dahlgren asked if the best valve designed should be tested in the Ford unit. The Chairman stated that it was the purpose of the group to design an NACA unit and that possibly some features of the German unit could be incorporated to advantage. The fuel system from the Ford unit could possibly be used on the NACA

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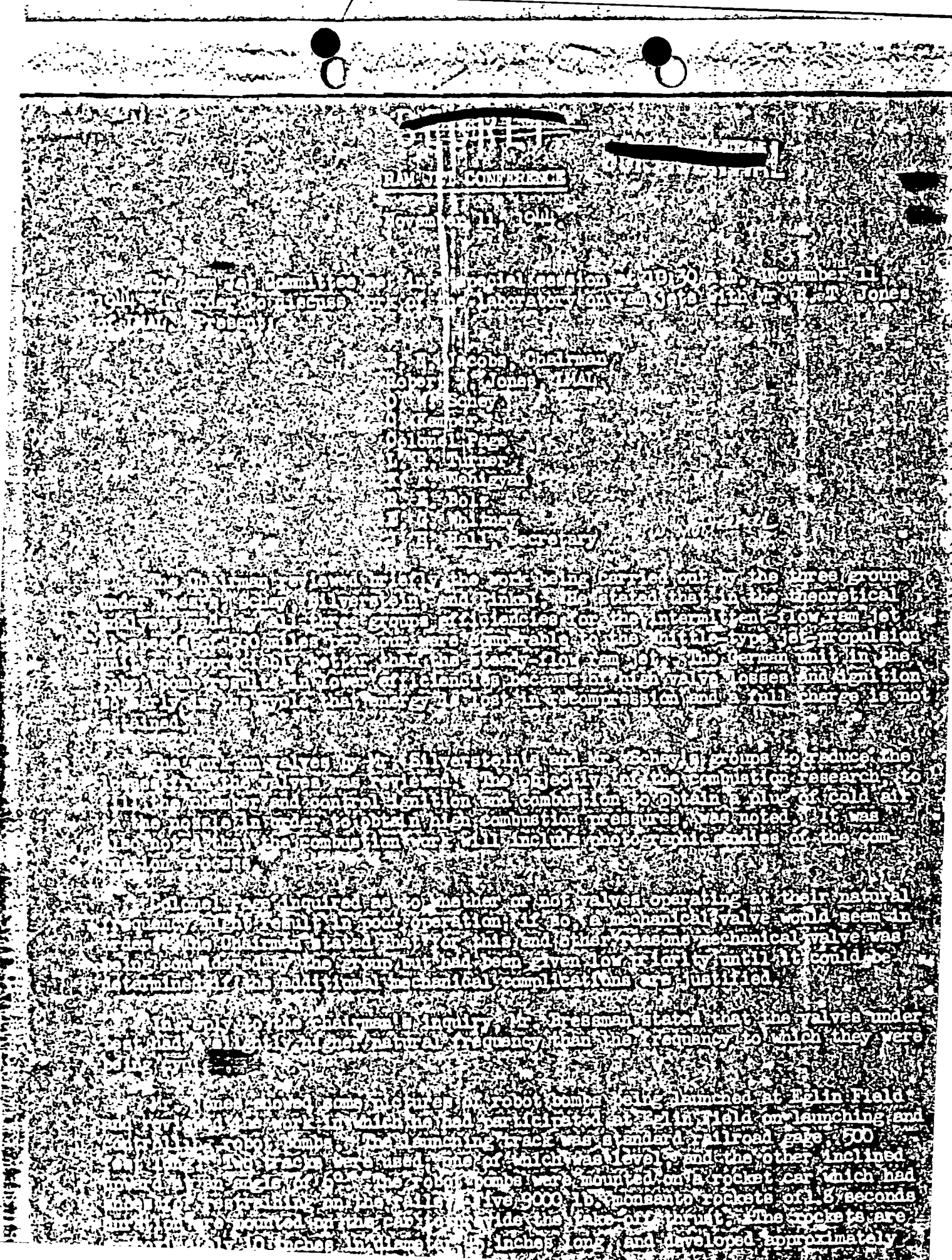

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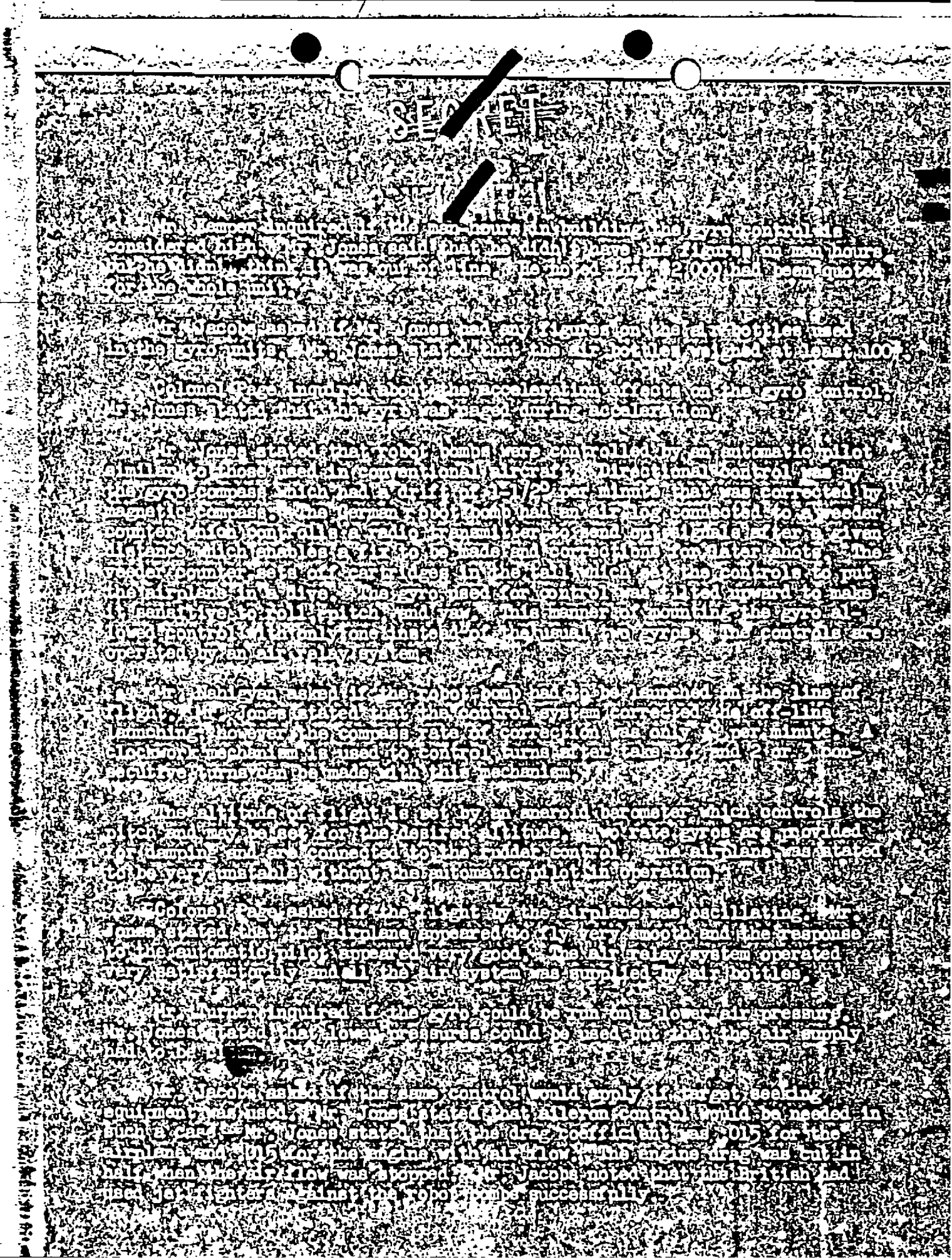

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RAM-JET CONFERENCE

November 14, 1944

The Committee met in the Executive Conference Room at AERL on November 14, 1944, at 9:05 a.m. Present:

E. N. Jacobs, Chairman
A. Silverstein
A. [illegible] Kunen
J. R. Bressman
L. R. Turner
[illegible] Bolz
W. Mutterperl
D. Okrent
[illegible] Burgess
K. K. Nahigyan
[illegible] Hall, Secretary

The minutes of the previous meeting were read and corrections made as shown on revised pages 1 and 2.

Mr. Bressman reviewed the results of the valve tests carried out during the preceding week on the reciprocating-piston apparatus. The best results to date with the curved valve was obtained with a .010-inch Swedish-blue steel valve which operated for 41 minutes at 50 cycles per second. The failures of valves tested during the week have, in every case, been failure in flexure at the same point.

The best results obtained to date with flat valves have been 103 minutes for a .012-inch Swedish-blue steel valve and 60 minutes for a .010-inch Swedish-blue steel valve, both of which were operated at 75 cycles per second. At 45 cycles per second the valves had lasted a maximum of approximately 8 minutes. A straight valve tapered from .015-inch thickness at the base to a .008-inch thickness at the lip has been operated for approximately 1 hour at 30 cycles per second. From the tests with tapered valves no gain in valve life is expected but a reduction in pressure drop should be obtained. The reflex of the top stop being used in current tests of the curved valves has a rubber insert to cushion the impact of the valve lip.

Mr. Mutterperl reported that a number of tests had been run on the impact machine but that the results obtained are as yet not conclusive. Low-carbon steel valves did not break when tested in the impact machine but did fail by taking a permanent set or curl. Mr. Mutterperl noted that the results of these tests indicate that a bimetallic valve with low-carbon steel on the face to absorb impact might offer some possibility.

Mr. Nahigyan reported that the burner being set up by his group had been running but still had some "bugs" to work out before a demonstration would be justified.

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[illegible] CONFERENCE

November 21, 1944

The Committee met in the Executive Conference Room at AERL on November 21, 1944, at 9:10 a.m. Present:

Abe Silverstein, Chairman
Dr. W. F. Durand - Washington Office
Carlton Kemper
L. R. Turner
[illegible] Shigyan
B. Pinkel
[illegible] Holbrook
D. [illegible] Schey
[illegible] [illegible]terperl
[illegible] Sanders
[illegible] Ornstein
[illegible] Burgess
[illegible] Bois
[illegible] R. Bressman
[illegible] Kunen
[illegible] Sharp
[illegible] Williams
[illegible] Hall, Secretary

The Chairman reviewed the program being carried out by the group in general terms for the benefit of Dr. Durand and asked that the group precede their progress reports for the week with a brief resume of results to date.

Mr. Kunen stated that with the large valves of approximately 7-inch span and 3-inch chord demonstration tests of over one hour had been run at 20 cycles per second but higher speeds fraying at the tip was encountered. With the smaller size valves demonstration tests of over one hour had been run at 25 cycles per second. When the radius of curvature of the valve was decreased to a smaller value than that of the valve seat the valves had been run as long as 2 hours and 10 minutes at 30 cycles per second. When the speed was increased to 35 cycles per second failure occurred in flexure after 1 hour and 40 minutes running time. Dr. Durand inquired if failure in flexure was typical. Mr. Bressman stated that failure in flexure was typical of valves that failed after considerable running [illegible].

Dr. Durand asked if the close spacing of the grill is necessary for support as larger spacing would result in lower pressure drops. Mr. Kunen stated that the maximum pressures that would be encountered when the full scale units were operated had not been determined and that the necessary support of the valves would depend on this maximum pressure. Mr. Kunen stated that pressure drops as small as 1/3 of that obtained in the German-type valves had been attained with steady-flow tests.

Mr. Turner stated that tests of the combustion apparatus as a single-shot device have indicated that the fuel charge was apparently stratified. The irregular firing encountered in the demonstration of the unit at the last meeting was stated to have been caused by vapor lock in the fuel system. Propane in gaseous form will be used when the apparatus is tested with continuous cycling operation.

Dr. Durand inquired if the electric ignition would be used when the unit was operated continuously. Mr. Turner stated that electric ignition would be used because of the much greater rate of pressure rise with point ignition as compared with plane ignition obtained when the fresh charge was ignited by contact with the retreating charge of the previous cycle.

Dr. Durand stated that he had been getting together a list of Army and Navy projects in which jet propulsion was used in one form or another. A total of 25 projects are being worked on including rockets, projectiles, etc. Dr. Durand stated that the English were tremendously interested in all phases of jet propulsion projectiles, bombs, and aircraft.

Mr. Silverstein inquired if Dr. Durand had information on the latest German weapons using rockets and jet propulsion. Dr. Durand stated that very extensive information was available on the V-1 as a number of the units have been captured. A few of the V-2's have been sufficiently undamaged when found to indicate the general design used. Theoretical studies by the British have indicated that the V-2 rocket reaches a height of 60 or 70 miles and has a striking velocity of around 3000 feet per second. The explosive charge was stated to be three or four tons. One of the drawbacks of this type weapon was the deep penetration caused by the high striking velocity which resulted in relatively small surface damage area.

Mr. Nahigyan drew a sketch of the test setup for testing the full-scale intermittent jet units. Two stages of blowers are to be used to obtain ram pressure simulating 400 miles per hour. A large surge chamber is incorporated ahead of the test unit to damp out pressure caused by the unit cycling. The thrust of the unit is to be measured by a linkage system somewhat similar to that used in static tests of jet propulsion units.

Mr. Silverstein inquired as to what accuracy might be obtainable with the thrust measuring system. Mr. Nahigyan stated that Dr. Hom of the Toledo Scale Company had gone over the system and was of the opinion that the measured thrust should be a good average. Dr. Durand noted that artificial damping could be incorporated in the setup.

Mr. Schey asked Dr. Durand what valve life would be satisfactory in his opinion. Dr. Durand stated that for the given range of 500 miles valves that would operate satisfactorily for 1-1/2 to 2 hours should give satisfactory service.

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December 5, 1944

The Committee met in the Executive Conference Room at Cleveland on December 5, 1944 at 2:00 p.m. Present:

Abe Silverstein, Chairman
Robert E. Littell, (Washington Office)
Addison M. Rothrock
Oscar W. Schey
Benjamin Pinkel
Carlton Kemper
Jesse H. Hall, Secretary

The Chairman reviewed the reorganization of the Ram-Jet Committee that had been carried out after the last meeting of the Committee. The work of the group has been divided as follows: analysis and theory under Mr. Nutterperl; design of the aero-pulse unit under Mr. Bressman; testing of complete aero-pulse units under Mr. Nahigyan; design of the steady-flow ram jet under Mr. Silverstein and Mr. Nutterperl; tests of the steady-flow ram-jet units under Mr. Perchonok; and the study of simple, cheap turbo-jet units for missiles under Mr. Schey. Meetings of the groups working on the several phases of the project will be held from time to time as desirable and the Ram-Jet Committee will meet at much less frequent intervals than has been the policy in the past.

The Chairman stated that the work on intermittent-flow ram jets was to follow two lines of attack. One, to improve the German-type unit as built by Ford; and two, to design a completely new unit for tests.

The Chairman inquired if there was any information as to why the aero-pulse unit had not been received from the Ford Motor Company. Mr. Kemper stated that it was his understanding that the fuel system on the Ford unit had not as yet been cleared. Mr. Littell stated that the NACA Liaison Office at Wright Field had informed him that Col. Keirn is a consultant on jet propulsion and not a project head. Col. Keirn had not passed the request for a Ford-built unit on to the project head at Wright Field promptly, which resulted in some delay. Mr. Pinkel stated that it would be two weeks before the apparatus will be completed for testing the aeropulse unit.

The Chairman stated that the test stand was ready for tests on steady-flow ram-jet units. A layout of the steady-flow ram-jet unit using a vaporizing-type burner unit was shown to the group. This unit is being assembled and will be ready to test in a week or ten days.

Mr. Littell inquired as to what the plans were for testing the steady-flow ram-jet units. The Chairman stated that the unit would be tested on a stand with a blower to supply ram air in order to work out combustion problems and it would later be tested in the wind tunnel.

Mr. Littell stated that the Navy group working on missiles was interested in an evaluation of the steady-flow ram jet and that the missile group would go ahead with a design of the missile as soon as sufficient information on performance was available. Speed is of utmost importance in the design of a missile as the missile must be faster than any of the enemy airplanes and also the greater the velocity of the missile the greater the accuracy of fire.

The Chairman noted that with the new pipe system to be installed in the 11-foot wind tunnel a Mach number of 2 can be obtained for high speed tests.

Mr. Pinkel reported that the combustion apparatus for steady combustion in the aeropulse unit had been improved to the point where good firing was obtained but the peak pressures were no where near the design pressures as shown by theory. Mr. Pinkel stated that the low peak pressures were apparently caused by slow combustion. Mr. Rothrock stated that it was his opinion that a photographic study of the combustion would be the best way to determine the cause of slow combustion.

Mr. Pinkel stated that the liquid injection burners for the steady-flow ram-jet unit were about ready.

Mr. Rothrock reported that very little progress had been made on burner tests in the past two weeks as burner tests became of lack of altitude air. Burning had been carried out successfully at velocities up to 150 feet per second and fuel-air ratios of .01. With the higher fuel-flow rates it was necessary to inject liquid propane because of the limited capacity of the fuel system. The system is being altered to provide higher flow rates of the propane in the gaseous state. The work on fuel vaporization was reported to be proceeding and fuel temperatures up to 750° had been used in the tests.

Mr. Schey reported that most of the cast work on the valves for the aeropulse unit had been completed and that it was believed that a satisfactory valve design had been achieved.

The Chairman asked for an opinion from the various members of the group on how much emphasis should be placed on the aeropulse in comparison with the ram-jet unit. It was agreed that the phase of the aeropulse program involving modifications of existing units would be pushed where-as the second phase involving construction of a unit designed by the NACA would be carried through to completion of tests of the unit but the program would not be extensive. The Chairman stated that he had heard that contractors had been called in for the purpose of discussing getting a contract for 1,000 aeropulse units in accordance with the design submitted by the NACA.

Mr. Schey showed a drawing of a jet unit incorporating a cast impeller and with a turbine to be made by casting or by other means to obtain an over-all pressure ratio of 4.

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RAM JET CONFERENCE

December 5, 1944

The Committee met in the Executive Conference Room at Cleveland on December 5, 1944, at 3:00 p.m. Present:

Abe Silverstein, Chairman
Robert R. Littell (Washington Office)
Addison M. Rothrock
Oscar W. Schey
Benjamin Pinkel
Carlton Kemper
Jesse H. Hall, Secretary

The chairman reviewed the reorganization of the Ram Jet Committee that had been carried out after the last meeting of the Committee. The work of the group has been divided as follows: Analysis and theory under Mr. Mutterperl; design of the aero-pulse unit under Mr. Bressman; testing of complete aero-pulse units under Mr. Nahigyan; design of the steady-flow ram jet under Mr. Silverstein and Mr. Mutterperl; tests of the steady-flow ram-jet units under Mr. Perchonok; and the study of simple, cheap turbo-jet units for missiles under Mr. Schey. Meetings of the groups working on the several phases of the project will be held from time to time as desirable and the Ram Jet Committee will meet at much less frequent intervals than has been the policy in the past.

The chairman stated that the work on intermittent-flow ram jets was to follow two lines of attack. One, to improve the German-type unit as built by Ford; and two, to design a completely new unit for tests.

The Chairman inquired if there was any information as to why the aero-pulse unit had not been received from the Ford Motor Company. Mr. Kemper stated that it was his understanding that the fuel system on the Ford unit had not as yet been cleared. Mr. Littell stated that the NACA Liaison Office at Wright Field had informed him that Col. Keirn is a consultant on jet propulsion and not a project head. Col. Keirn had not passed the request for a Ford-built unit on to the project head at Wright Field promptly, which resulted in some delay.

Mr. Pinkel stated that it would be two weeks before the apparatus will be completed for testing the aeropulse unit.

The chairman stated that the test stand was ready for tests on steady-flow ram-jet units. Layout of the steady-flow ram-jet unit using a vaporizing-type burner units was shown to the group. This unit is being assembled and will be ready to test in a week or ten days.

Mr. Littell inquired as to what the plans were for testing the steady-flow ram-jet units. The chairman stated that the unit would be tested on a stand with a blower to supply ram in order to work out combustion problems and it would later be tested in the Wind Tunnel.

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Mr. Littell stated that the Navy group working on missiles was interested in an evaluation of the steady-flow ram jet and that the missile group would go ahead with a design of the missile as soon as sufficient information on performance was available. Speed is of utmost importance in the design of a missile as the missile must be faster than any of the enemy airplanes and also the greater the velocity of the missile the greater the accuracy of fire.

The chairman noted that with the new pipe system to be installed in the Altitude Wind Tunnel a Mach number of 2 can be obtained for high speed tests.

Mr. Pinkel reported that the combustion apparatus for steady combustion in the aeropulse unit had been improved to the point where good firing was obtained but the peak pressures were no where near the design pressures as shown by theory. Mr. Pinkel stated that the low peak pressures were apparently caused by slow combustion. Mr. Rothrock stated that it was his opinion that a photographic study of the combustion would be the best way to determine the cause of slow combustion.

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Mr. Schey reported that most of the test work on the valves for the aero-pulse unit had been completed and that it was believed that a satisfactory valve design had been achieved.

The chairman asked for an opinion from the various members of the group on how much emphasis should be placed on the aeropulse in comparison with the turbo jet and steady-flow ram jet. It was agreed that the phase of the aero-pulse program involving modifications of existing units would be pushed whereas the second phase involving construction of a unit designed by the NACA would be carried through to completion of tests of the unit but the program would not be extensive. The chairman stated that he had heard that contractors had been called in for the purpose of discussing getting a contract for 1,000 missiles built in accordance with the design submitted by the NACA.

Mr. Schey showed a drawing of a turbo-jet unit incorporating a cast impeller and with a turbine to be made by casting or by other means to obtain as low an over-all cost as possible.

Mr. Schey stated that the unit as designed should provide 900 thrust horsepower at 550 miles an hour at 5,000 feet altitude and that the specific weight would be approximately 475 pounds per thrust horsepower. The over-all diameter of the unit was approximately 25 inches.

Mr. Schey noted that the Navy was very much interested in the cast impeller design. The chairman stated that it was his opinion that improvement in the Ford-built aero-pulse unit was the best change for the NACA to make a substantial contribution. The group concurred in this opinion. A new set of valves of NACA design will be tested in the Ford-built unit as soon as possible after the unit arrives.

The meeting adjourned at 4:00 p.m.

Jesse H. Ball,
Secretary, Ram Jet Committee.

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RAM JET CONFERENCE

November 21, 1944

The Committee met in the Executive Conference Room at AERL on November 21, 1944, at 9:10 a.m. Present:

Abe Silverstein, Chairman
Dr. W. F. Durand -- Washington Office
Carlton Kemper
L. R. Turner
K. K. Nahigyan
B. Pinkel
A. M. Rothrock
O. W. Schey
W. Mutterperl
J. C. Sanders
L. Ornstein
W. C. Burgess
R. E. Bolz
J. R. Bressman
A. E. Kunen
E. R. Sharp
D. T. Williams
J. H. Hall, Secretary

The Chairman reviewed the program being carried out by the group in general terms for the benefit of Dr. Durand and asked that the group precede their progress reports for the week with a brief resume' of results to date.

Mr. Kunen stated that with the large valves of approximately 3-inch span and 3-inch chord demonstration tests of over one hour had been run at 20 cycles per second. At higher speeds fraying at the tip was encountered. With the smaller size valves demonstration tests of over one hour had been run at 25 cycles per second. When the radius of curvature of the valve was decreased to a smaller value than that of the valve seat the valves had been run as long as 2 hours and 40 minutes at 30 cycles per second. When the speed was increased to 35 cycles per second, failure occurred in flexure after 1 hour and 40 minutes running time. Dr. Durand inquired if failure in flexure was typical. Mr. Bressman stated that failure in flexure was typical of valves that failed after considerable running time.

Dr. Durand asked if the close spacing of the grill is necessary for support as larger spacing would result in lower pressure drops. Mr. Kunen stated that the maximum pressures that would be encountered when the full scale units were tested had not been determined and that the necessary support of the valves would depend on this maximum pressure. Mr. Kunen stated that pressure drops as small as 1/3 of that obtained in the German-type valves had been attained with steady-flow tests.

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Mr. Mutterperl reported that tests in the impact machine had been run over a range of frequencies from 15 to 60 cycles per second. Preliminary results indicated that the total number of impacts before failure was a function of the velocities of impact as shown in the following curve:

These preliminary results indicate that valve life is relatively independent of frequency. Mr. Mutterperl noted that test results at the Watertown Arsenal indicated that the total number of impacts increased with the velocity of impact in contradiction to the results of the tests in the impact machine. Further tests will be made to substantiate the prelimipary results.

Mr. Ornstein stated that a plastic paddle had been used in the impact machine in place of the steel paddle resulting in an increase of valve life by 2-1/2 times. When the seat was also made of plastic valve life was further increased by 2-1/2 times.

Mr. Silverstein asked what maximum temperatures the plastic material would stand. Mr. Ornstein stated that the maximum service temperature for the material was given as 300° C. Mr. Pinkel noted that leaks in the valves would probably result in temperatures exceeding the service limit. Mr. Ornstein stated that the plastic material does not oxidize or burn readily. The material had been subjected to temperatures up to 600° F in the furnace. Mr. Ornstein stated that he would bring samples of material that had been subjected to furnace tests to the next meeting.

Dr. Durand inquired as to whether or not the temperature of the valve would be lower than that in a similar position with steady-flow ram jets. Mr. Schey stated that it was his opinion that the temperatures would be lower.

Mr. Rothrock noted that the conditions would be similar to that of valves in the reciprocating engine.

Mr. Turner stated that the turbine wheels tested in the intermittent-flow turbine had indicated lower temperatures than wheels operated in steady-flow turbines with the same mean gas temperatures.

Dr. Durand stated that an Italian prisoner of war reported that the Germans had built a turbine in which cold air jets were incorporated as a sector of the nozzle ring. Gas temperatures as high as 2000° F were reported to have been used in this turbine.

Mr. Turner stated that tests of the combustion apparatus as a single-shot device have indicated that the fuel charge was apparently stratified. The irregular firing encountered in the demonstration of the unit at the last meeting was stated to have been caused by vapor lock in the fuel system. Propane in gaseous form will be used when the apparatus is tested with continuous cycling operation.

Dr. Durand inquired if the electric ignition would be used when the unit was operated continuously. Mr. Turner stated that electric ignition would be used because of the much greater rate of pressure rise with point ignition as compared with plane ignition obtained when the fresh charge was ignited by contact with the retreating charge of the previous cycle.

Dr. Durand stated that he had been getting together a list of Army and Navy projects in which jet propulsion was used in one form or another. A total of 15 projects are being worked on including rockets, projectiles, etc. Dr. Durand stated that the English were tremendously interested in all phases of jet propulsion projectiles, bombs, and aircraft.

Mr. Silverstein inquired if Dr. Durand had information on the latest German weapons using rockets and jet propulsion. Dr. Durand stated that very extensive information was available on the V-1 as a number of the units have been captured. A few of the V-2's have been sufficiently undamaged when found to indicate the general design used. Theoretical studies by the British have indicated that the V-2 rocket reaches a height of 60 or 70 miles and has a striking velocity of around 3000 feet per second. The explosive charge was stated to be three or four tons. One of the drawbacks of this type weapon was the deep penetration caused by the high striking velocity which resulted in relatively small surface damage area.

Mr. Nahigyan drew a sketch of the test setup for testing the full-scale intermittent jet units. Two stages of blowers are to be used to obtain ram pressure simulating 400 miles per hour. A large surge chamber is incorporated ahead of the test unit to damp out pressure caused by the unit cycling. The thrust of the unit is to be measured by a linkage system somewhat similar to that used in static tests of jet propulsion units.

Mr. Silverstein inquired as to what accuracy might be obtainable with the thrust measuring system. Mr. Nahigyan stated that Dr. Hon of the Toledo Scale Company had gone over the system and was of the opinion that the measured thrust should be a good average. Dr. Durand noted that artificial damping could be incorporated in the setup.

Mr. Gohey asked Dr. Durand what valve life would be satisfactory in his opinion. Dr. Durand stated that for the given range of 500 miles valves that would operate satisfactorily for 1-1/2 to 2 hours should give satisfactory service.

Mr. Mutterperl reviewed the work that had been carried out on the steady-flow ram jet for the benefit of Dr. Durand. The over-all dimensions of the unit were given as 20 inches in diameter and 9 feet long. Mr. Mutterperl stated that a coil-type preevaporizer burner was being worked out by Mr. Khanigyan and an annular-type burner incorporating an annular pilot was being worked on by Mr. Bols. Work on the burners and the steady-flow ram jet was reported to have progressed sufficiently so that test of the unit should be started in about two weeks.

Dr. Durand stated that the Navy was just a little disappointed in progress made on the steady-flow ram jet. Dr. Durand stated that a progress report giving the progress that had been made should satisfy the Navy in view of the progress that actually has been made.

Dr. Durand inquired if the combustion would be completed in the 3-feet long combustion chamber or if the flame would come out the tail. Mr. Bols stated that the flame length encountered with his burner was of the order of 5 feet.

Dr. Durand stated that from his experience the problem of mixing the fuel and air was one of the great difficulties in combustion.

Mr. Silverstein inquired what Dr. Durand thought of the relative merits of using vaporized or liquid injection. Dr. Durand stated that with liquid injection the fuel had to vaporize anyway. Mr. Silverstein suggested that penetration by the liquid particles would possibly give better distribution. It was found on tests of the Westinghouse unit that best combustion was obtained with injectors giving relatively large droplets; next best with injectors giving small droplet size; and the poorest combustion was obtained with gaseous fuel.

Dr. Durand stated that the results of the combustion work at the Esso Laboratory by the Bureau of Ships should provide valuable information on the subject of combustion.

Mr. Rothrock stated that his division was working on fundamental combustion problems. The fundamental work with combustion is concerned with two phases of the problem. First, the mixing process; second, the burning process. Combustion in small tubes is currently being studied. The vaporization and mixing process is being studied by tests with a 3-inch diameter tube. Droplet size measurements have been attempted but indirect methods were the only ones successful to date, such as light absorption.

Dr. Williams discussed the studies that had been made of using propane or a mixture of butane and propane as fuel to eliminate the compressed air bottles used by the Germans and thereby give an increased fuel capacity. Two main questions involved in the work are the possibility of developing a gyro that can be driven by propane gas, and in the case of high altitudes operation maintaining temperatures that would give sufficient vapor pressure.

Mr. Schey showed the group some results that had been obtained on tests of impellers made by casting. A pressure ratio as high as 6:1 would be obtained in a compressor using the cast impeller at altitudes of 40,000 feet at the operating-tip speed of 1750 feet per second. If a factor of safety of 1-1/2 was used pressure ratios of 4.25 would be obtained at 40,000 feet using a tip speed of 1475 feet per second. Pressure ratios of 2.75 would be obtained at 40,000 feet at a tip speed of 1200 feet per second and would give a factor of safety of 2. The advantage of the cast construction for impellers and turbine rotor would be a reduction of cost. Mr. Silverstein stated that if a sufficiently cheap conventional jet propulsion unit could be made the Aerojet would, in all probability, be ruled out of the picture, as its main advantage is a very cheap construction. Mr. Schey stated that a larger size impeller of the same type shown to the group had a capacity of 39 lb/sec.

The meeting adjourned at 10:50 a.m.

Jesse H. Hall,
Secretary, Ram Jet Committee.

JHH:imk

CONFIDENTIAL

[illegible] JET CONFERENCE

November 14, 1944

The Committee met in the Executive Conference Room at AERL on November 14, 1944, at 9:05 a.m. Present:

R. N. Jacobs, Chairman
A. Silverstein
A. M. Kuman
J. R. Bressman
L. R. Turner
R. E. Bolz
W. Mutterperl
O. Okrent
W. C. Burgess
K. K. Nahigyan
J. H. Hall, Secretary

The minutes of the previous meeting were read and corrections made as shown from revised pages 1 and 2.

Mr. Bressman reviewed the results of the valve tests carried out during the preceding week on the reciprocating piston apparatus. The best results to date with the curved valve was obtained with a .010-inch Swedish-blue steel valve which operated for 41 minutes at 30 cycles per second. The failures of valves tested during the week have, in every case, been failure in flexure at the same point.

The best results obtained to date with flat valves have been 103 minutes for a .012-inch Swedish-blue steel valve and 60 minutes for a .010-inch Swedish-blue steel valve, both of which were operated at 35 cycles per second. At 45 cycles per second the valves had lasted a maximum of approximately 6 minutes. A straight valve tapered from .015-inch thickness at the base to a .008-inch thickness at the tip has been operated for approximately 1 hour at 30 cycles per second. From the tests with tapered valves no gain in valve life is expected but a reduction in pressure drop should be obtained. The reflex of the top stop being used in current tests of the curved valves has a rubber insert to cushion the impact of the valve tip.

Mr. Mutterperl reported that a number of tests had been run on the impact machine but that the results obtained are as yet not conclusive. Low-carbon steel valves did not break when tested in the impact machine but did fail by taking a permanent set or curl. Mr. Mutterperl noted that the results of these tests indicate that a bimetallic valve with low-carbon steel on the face to absorb impact might offer some possibility.

Mr. Nahigyan reported that the burner being set up by his group had been running but still had some "bugs" to work out before a demonstration would be justified.

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Mr. Bolz reported that the burner setup of the Fuels & Lubricants group was in operation and a demonstration run could be made. A cone with holes had been installed at the down-stream end of the primary air duct and a screen had been installed just ahead of the pilot. Pulsating burning was still encountered with the setup under certain conditions.

Mr. Silverstein stated that a pilot had been put in the burner of the Westinghouse jet propulsion unit in the Wind Tunnel. The unit had not been tested as yet with the pilot but will be tested the night of November 14.

The meeting adjourned at 9:45 a.m. and the group went over to witness a demonstration run of the Fuels & Lubricants burner setup and the combustion apparatus set up by the Thermodynamics group.

Jesse H. Ball,
Secretary, Ram Jet Committee.

JHB:lmk

RAM JET CONFERENCE

November 11, 1944

The Ram Jet Committee met in a special session at 10:30 a.m., November 11, 1944, in order to discuss work of the laboratory on ram jets with Mr. R. T. Jones of IMAL. Present:

E. H. Lepoha, Chairman
Robert T. Jones, IMAL
O. W. Schey
C. Kemper
Colonel Page
L. R. Turner
K. K. Nahigyan
R. E. Bolz
J. G. Whitney
J. H. Hall, Secretary

The Chairman reviewed briefly the work being carried out by the three groups under Messrs. Schey, Silverstein and Pinkel. He stated that in the theoretical analyses made by all three groups efficiencies for the intermittent-flow ram jet at speeds of 500 miles per hour were comparable to the Whittle-type jet-propulsion unit and appreciably better than the steady-flow ram jet. The German unit in the robot bomb results in lower efficiencies because of high valve losses and ignition so early in the cycle that energy is lost in recompression and a full charge is not attained.

The work on valves by Mr. Silverstein's and Mr. Schey's groups to reduce the losses from the valves was reviewed. The objective of the combustion research, to fill the chamber and control ignition and combustion to obtain a plug of cold air to the nozzle in order to obtain high combustion pressures, was noted. It was also noted that the combustion work will include photographic studies of the combustion process.

Colonel Page inquired as to whether or not valves operating at their natural frequency might result in poor operation; if so, a mechanical valve would seem in order. The Chairman stated that for this and other reasons mechanical valve was being considered by the group but had been given low priority until it could be determined if the additional mechanical complications are justified.

In reply to the Chairman's inquiry, Mr. Bressman stated that the valves under test had a slightly higher natural frequency than the frequency to which they were being cycled.

Mr. Jones showed some pictures of robot bombs being launched at Eglin Field and reviewed the work in which he had participated at Eglin Field on launching and controlling robot bombs. The launching track was standard railroad gage, 500 feet long. Two tracks were used, one of which was level, and the other inclined upward at an angle of 6°. The robot bombs were mounted on a rocket car which had shoes for restraining on the rails. Five 9000 lb. monsanto rockets of 1.8 seconds duration are mounted on the car to provide the take-off thrust. The rockets are approximately 10 inches in diameter, 15 inches long, and developed approximately 8,000 horsepower at the end of the run.

To illustrate the friction to be overcome by the rockets Mr. Jones stated that 15 men were unable to push the rocket car down grade. Mr. Kemper inquired if any information was available on launching robot bombs from airplanes. Mr. Jones stated that he didn't have any information but believed that such procedure was feasible. Mr. Jones stated that a robot bomb had caught fire at Eglin Field and that such a fire would be hazardous if the launching were being made from an airplane.

Mr. Jacobs inquired as to what fuel was used in the rockets. Mr. Jones stated that the fuel was monsanto block, which was a dry fuel. The rockets developed 160#sec/#fuel and weight of fuel was approximately equal to the weight of the case.

In the tests at Eglin Field an A-20 airplane was used to photograph the robot bomb in flight and a P-51 was used to shoot it down. The engine was started 20 seconds before launching to make sure that operation is stable. The first robot bomb launched successful and the airplane was stable but at a nose down pitch which resulted in a flight of about 2 miles. In checking up it was found that the speed was 510 feet per second instead of 570 and the pitch was set too low. The front rockets were found to dissipate energy by discharging against the rear rockets.

In the next two launchings attempted the pitch was increased but the splash from the front rockets burned off the elevator. In the fourth attempt all five rockets were moved to the back. Before the engine got going the airplane caught fire and so was launched with the engine dead.

The next try at launching was successful and the airplane flew for 60 miles before it was shot down.

Mr. Futterperl asked Mr. Jones if there was any acceleration after launching. Mr. Jones stated that there was a very small acceleration but that the airplane had to be launched at flying speed. The most practical launching scheme would be one that did not require a track. It was pointed out that the rocket alinement with the center of gravity was very critical and should be within 1/2-inch of c.g. The rockets are mounted below and inclined inward and upward to get alinement with the center of gravity.

Two 40,000-pound rockets of 1-second duration could be used in place of the five 9,000-pound rockets. However, if the time was increased and the thrust reduced the angle of pitch would come too large. Launching speeds to the order of 600 feet per second would make launching without track difficult.

Mr. Jacobs noted that the V-2 was launched without a track and had considerably higher speeds.

Mr. Jones stated that the airplane could be stabilized during launching but that nothing had been tried along that line as yet.

Mr. Kemper inquired if the man hours in building the gyro control is considered high. Mr. Jones said that he didn't have the figures on man hours but he didn't think it was out of line. He noted that $2,000 had been quoted for the whole unit.

Mr. Jacobs asked if Mr. Jones had any figures on the air bottles used in the gyro units. Mr. Jones stated that the air bottles weighed at least 100#.

Colonel Page inquired about the acceleration effects on the gyro control. Mr. Jones stated that the gyro was caged during acceleration.

Mr. Jones stated that robot bombs were controlled by an automatic pilot similar to those used in conventional aircraft. Directional control was by the gyro compass which had a drift of 1-1/2° per minute that was corrected by magnetic compass. The German robot bomb had an air log connected to a veeder counter which controlls a radio transmitter to send out signals after a given distance which enables a fix to be made and corrections for later shots. The veeder counter sets off cartridges in the tail which set the controls to put the airplane in a dive. The gyro used for control was tilted upward to make it sensitive to roll, pitch and yaw. This manner of mounting the gyro allowed control with only one instead of the usual two gyros. The controls are operated by an air relay system.

Mr. Mahlgren asked if the robot bomb had to be launched on the line of flight. Mr. Jones stated that the control system corrected the off-line launching; however, the compass rate of correction was only 3° per minute. A clockwork mechanism is used to control turns after take off and 2 or 3 consecutive turns can be made with this mechanism.

The altitude of flight is set by an aneroid barometer which controls the pitch and may be set for the desired altitude. Two rate gyros are provided for damping and are connected to the rudder control. The airplane was stated to be very unstable without the automatic pilot in operation.

Colonel Page asked if the flight by the airplane was oscillating. Mr. Jones stated that the airplane appeared to fly very smooth and the response to the automatic pilot appeared very good. The air relay system operated very satisfactorily and all the air system was supplied by air bottles.

Mr. Turner inquired if the gyro could be run on a lower air pressure. Mr. Jones stated that lower pressures could be used but that the air supply had to be clean.

Mr. Jacobs asked if the same control would apply if target seeking equipment was used. Mr. Jones stated that aileron control would be needed in such a case. Mr. Jones stated that the drag coefficient was .015 for the airplane and .015 for the engine with air flow. The engine drag was cut in half when the air flow was stopped. Mr. Jacobs noted that the British had used jet fighters against the robot bombs successfully.

Mr. Kemper asked what length of time was required to launch one of the robot bombs. Mr. Jones stated that approximately 20 minutes was required to launch a robot bomb. Mr. Jones noted that tactical use had been suggested in view of the accuracy attained up to distances of 75 miles.

Mr. Jacobs stated that a steady-flow ram jet was being set up in the Altitude Wind Tunnel and two of the groups were working on the combustion problem for this unit. He stated that it was his personal belief that speeds of 550 miles an hour for the steady-flow ram jet would be better than the German unit. Mr. Mutterperl stated that launching speeds of around 400 miles an hour would be required for the steady-flow ram jet. Mr. Jones stated that the robot bomb requires about 240 miles per hour launching speed and that 400 miles per hour would complicate the problem. Mr. Jones stated that it was his opinion that the rocket launching scheme used in this country was better than the German slotted cannon. Rocket launching without rail ramp would be feasible if speeds were obtained in one second. 350 feet per second in one second appears feasible but Mr. Jones stated that he didn't know of any rockets that would provide a speed of 600 feet per second in one second. Approximately 20 g acceleration would be required. Mr. Jacobs asked if the instruments would stand 20 g acceleration. Mr. Jones stated that he thought so but that some trouble may be encountered with the fuel system. In one case 400 feet per second attained in 1.8 seconds blew out the engine before the end of the ramp was reached. Mr. Jones stated that his chief interest was in the design of automatic pilot for stability.

Mr. Jacobs inquired if there was any interest in the use of target seeking controls. Mr. Jones stated that there was interest and that he had been working on a missile with such a control to attack robot bombs.

The V-2 German rocket was discussed by the group. Mr. Jacobs stated that a 500 horsepower fuel pump was used and that the missile was launched like a sky rocket. He stated that one of the missiles had landed in Sweden without explosives and appeared to have a group of rockets at the tail.

Mr. Kemper asked if Mr. Jones had any information on the use of robot bombs by the Japs. Mr. Jones said he thought he had read somewhere that the Japs had been given information on the robot bombs by the Germans but that he wasn't certain. He stated that television had been developed along with radar and heat seeking equipment for control of missiles. Small size sets are already developed.

Mr. Kemper inquired if any results were available on jamming radar. Mr. Jones stated that work being carried out on the use of tinfoil and aluminum powder for radar jamming.

Mr. Turner asked if any difficulty had been encountered with fuel control. Mr. Jones stated that each engine was checked for fuel flow. The fuel flow is controlled by impact air pressure.

Mr. Mutterperl asked if Mr. Jones had noted any trends in requirements of the services. Mr. Jones stated it appeared to be of definite interest in the smaller size having approximately 1/2 the thrust of the current units.

The meeting adjourned at 12:20

Jesse H. Hall
Secretary, Ram Jet Committee

JHH:lmk

RAM-JET CONFERENCE

November 7, 1944

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The Committee met in the Executive Conference Room at AERL on November 7, 1944, at 9:05 a.m. Present:

E. N. Jacobs, Chairman
O. W. Schey
J. R. Bressman
R. E. Bolz
E. E. Nahigyan
L. R. Turner
J. C. Sanders
W. C. Burgess
A. E. Kunen
A. Silverstein
B. Pinkel
D. Okrent
L. Ornstein
W. Mutterperl
R. E. Littell
J. H. Hall, Secretary

The minutes of the previous meeting were read and corrections made as shown on revised page 3.

Mr. Bressman reported that two aluminum grills for curved valves had been completed. Tests with valves of .010-inch stock with a good fit on the seat resulted in failures in 2 or 3 minutes at 1500 rpm with a rubber top stop. A valve made with approximately 1/16-inch clearance at the mid chord point when the tip rested on the seat lasted for 2 hours and 15 minutes at 1500 rpm before failure occurred. The failure was in flexure and appeared to have been caused by too sharp a bend in forming.

Mr. Kunen stated that in observing operation of this valve the valve tip hit first and the valve then flattened to fit the seat. The Chairman suggested that the valve being made for the combustion apparatus should have clearance of 1/16-inch as used in tests of valves in the reciprocating piston apparatus.

Mr. Bressman stated that a curved valve made of .010-inch stock had been run at 1500 rpm and failed after 41 minutes running. Mr. Bressman reported that straight valves made of .008-, .010-, and .012-inch Swedish-blue steel stock had been tested. The .008-inch valve failed after 25 minutes at 1500 rpm. The .010-inch valve failed after 67 minutes at 1500 rpm; and the .012-inch valve failed after 103 minutes at 2100 rpm. Mr. Bressman noted that both straight and curved valves had a tendency to vibrate with steady airflow.

Mr. Nahigyan asked if the best valve designed should be tested in the Ford unit. The Chairman stated that it was the purpose of the group to design an NACA unit and that possibly some features of the German unit could be incorporated to advantage. The fuel system from the Ford unit could possibly be used on the NACA unit.

The Chairman asked if the combustion apparatus being set up by Mr. Pinkel's group could be used for cycling operation. Mr. Turner stated that the apparatus would be limited to single shot operation until the cycling valve is complete. The shop is planning to form cut the cycling valve and the valve may not be completed until December 7. The Chairman stated that shop work on the combustion apparatus should be done in our own shop if possible and should be pushed on through to completion. The Chairman agreed to assist in expediting the shop work on this phase of the project providing Mr. Pinkel's group follows through in setting up the apparatus for tests.

Mr. Bols stated that combustion tests had shown that a pilot was necessary in obtaining combustion at 130 ft/sec as attempts to obtain ignition from a spark was not successful. The Chairman stated that it is his belief that with velocities of the order of 200 ft/sec being considered for the ram jet units attempts to obtain ignition from a spark would be unsuccessful and suggested that the group working on combustion consider making provisions for a pilot.

Mr. Mutterperl suggested the use of a venturi to smooth out the large scale turbulence in the air stream for combustion considerations. The Chairman noted that the German's used venturis immediately downstream of the valves. Mr. Mutterperl suggested that the scale of turbulence was important in relation to flame propagation and blowing out the flame.

Mr. Bols stated that with tests in the combustion pipe the burning was not satisfactory until the flame snapped back to the fuel injection valves. The Chairman suggested that when burning started the flame snaps back because of flow stoppage and compression wave being reflected back.

Mr. Mutterperl reported on results of valve materials tested in the impact machine. The .005-inch Swedish-blue steel stock ran for approximately 13 minutes before failure and the .008-inch stock ran from 9 to 10 minutes before failure. Adjustments are being made to the machine to obtain more consistent results among the valves being tested simultaneously. An X-ray photograph of .005-inch Swedish-blue steel which showed uniform distributed inclusions was shown to the group. Of the material to be tested in addition to the Swedish-blue steel there are included: inconel, heat-treated Swedish-blue steel, and low-carbon steel. After discussion by the group it was agreed that high-carbon steel should be tested in place of the low-carbon steel.

Mr. Silverstein suggested that tests should be made of the toughest steels known. Mr. Kamen noted that Swedish-blue steel was best from a fatigue standpoint.

Mr. Ornstein inquired as to what velocity of impact had been observed in the reciprocating piston apparatus. Mr. Kamen stated that the impact velocity was approximately 50 ft/sec at 1200 rpm.

Mr. Turner reported that the valve section for the combustion apparatus should be completed by November 5th and that approximately 2 days would be required to install. The Chairman asked if the apparatus would be ready to demonstrate by the next meeting. Mr. Turner stated that the equipment should be ready to demonstrate by that time.

Mr. Bols reviewed the work on combustion accomplished since the last meeting. After unsuccessful arrangements of ignition source and pilot, combustion was obtained with the sudden enlargement to twice the area in the primary air passage just ahead of the pilot. Good combustion was obtained with this arrangement but sometimes when the apparatus was operated pulsating combustion was obtained for some unknown reason.

The next scheme to be tried will be a cone enlarging the primary air pipe to twice the area at the pilot with holes cut in the cone.

The fundamentals of combustion and flame propagation and the effect of turbulence was discussed by the group. It was agreed that large scale turbulence should be reduced to a minimum but that small scale turbulence was desirable from a combustion standpoint. The chairman suggested the use of honeycomb just ahead of the pilot to reduce large scale turbulence. Mr. Mutterperl suggested that a wire be inserted at the point where the flame goes out to introduce turbulence at that point to find out if the flame could be extended. Mr. Silverstein suggested the use of a screen for a 50% opening just ahead of the pilot.

Mr. Littell read the summary of the Bureau of Aeronautics Progress Report on Ram Jets, dated October 23, 1944. (Appendix A)

Mr. Nahigyan stated that the burners were approximately 2/3 complete and that the setup for tests of Ford-built robot bombs was under way.

Mr. Rothrock stated that tanks for gaseous fuel, when designed on the basis of aircraft practice, weighed approximately 100 pounds for a 500 gallon tank instead of the 1000 pounds previously reported. Mr. Bols stated that calculations for a 500 gallon tank working at 100 pounds per square inch pressure designed with a factor of safety of 1-1/2 based on the yield strength resulted in a weight of 80 pounds for aluminum, 85 pounds for magnesium, and 110 pounds for steel.

Mr. Mutterperl reported that the ducting was 50% complete for the steady-flow ram jet installation. The support structures for the test stand were about ready to go into the shop.

Meeting adjourned at 11:25 a.m.

Jesse H. Hall,
Secretary, Ram Jet Committee.

JHH:ink

PROGRESS REPORT ON RAM JETS
BUREAU OF AERONAUTICS
October 25, 1944

The Bureau of Aeronautics has under its cognizance a number of ram jet developments. The general status of these projects is as follows:

A. Continuous-Flow Ram Jet Units.

1. Bureau of Standards (see Enclosure 1)

The Bureau has been working during the past six months on a burner for a ram jet unit. At the present time, preliminary tests are being carried out on a quarter section of a 10 inch diameter burner. These tests indicate that steady running has been obtained at chamber inlet velocities of 200 feet per second and discharge temperature of about 3000° F. Successful runs were made at inlet velocities up to 800 feet per second in a one-inch tube. The pressure drops are only slightly above the theoretical drop associated with combustion (the exact values are shown in Enclosure A). These values may be subject to a small correction since it was found that the gross sectional area of the chamber changed during the test, and thus some of the pressures reported may be subject to correction. The combustion efficiencies attained were of the order of 95 to 99.6%.

It appears that the development of the Bureau of Standards combustion chamber has proceeded far enough to warrant the construction and test of a full size ram jet unit. The Bureau of Aeronautics is negotiating with Fleetwings Aircraft for the construction of such units.

2. The Massachusetts Institute of Technology (see Enclosure 2)

M.I.T. has also been working for about six months on the development of a suitable ram jet combustion chamber. Initial experiments were on the gas burning type chamber with air-atomized gasoline. However, experiments showed the apparent superiority of pressure-atomized gasoline injected up-stream. A small combustion chamber has been built and run.

The data for typical runs is given in Enclosure B. Inlet-air velocities up to [illegible] feet per second were obtained with stable burning. The velocity was limited by the air supplied and not by flame instability.

A larger air supply was obtained in a scaled up version of combustion chamber [illegible] which was built and run. This combustion chamber B-14 shown in Enclosure B, is 8 inches in diameter. Stable burning at velocities as high as 240 feet per second has been obtained. This velocity is not limited by stability but is the limit of velocity so far tried with the new air supply. Combustion efficiency has not been measured, but it is estimated at 90%. (See Enclosure B for the detailed information.)

The Bureau of Aeronautics is negotiating with Fleetwings Aircraft for the construction and testing of full-scale ram jet engines built around the design of the M.I.T. combustion chamber.

3. N.A.C.A.

On June 30, 1944, the Bureau of Aeronautics requested the N.A.C.A. to undertake the design, construction, and test of the continuous-flow ram-jet unit. No report of progress has been received to date.

D. Intermittent-Flow Ram Units (Aeropulse Motors)

1. Reaction Motors, Incorporated. (Enclosure C)

Reaction Motors has constructed and tested an intermittent type of ram-jet unit. The unit operated successfully with 100 octane gasoline as well as on Diesel oil. A report on the tests of this unit is attached (See Enclosure C).

2. Engineering Experiment Station, Annapolis.

Preliminary experiments have been carried out at the Engineering Experiment Station at Annapolis on intermittent types of ram-jet units varying in size from 6 inches diameter to 18 inches diameter. Different types of inlet valves have been studied, including such types as Eichelberg valves, poppet valves, rotary valves. Some tests have also been carried out on intermittent combustion units without valves. A report on these tests is being prepared.

3. Aerojet Engineering Corporation

Aerojet has been making a thorough theoretical investigation of the performance parameter with a view to increasing the efficiency of the Aeropulse unit. Only preliminary experiments have been run thus far. A comprehensive report is being prepared.

4. N.D.R.C. Mathematics Panel

A project has been set up with the N.D.R.C. Mathematics Panel to assist the Bureau of Aeronautics' contractors in the further theoretical analysis of the pressure wave phenomena occurring during the cycle of operation of the Aerojet unit.

5. Lycoming Engine Division,

The Bureau of Aeronautics has a contract with the Lycoming Engine Division for the further development of engines of the intermittent-flow ram-jet type. The purpose of the contract is to improve the specific fuel consumption of these engines sufficiently so that they might compete with the turbo-jet engines. As a first step, Lycoming will make careful measurements and an analysis of the performance of the intermittent-flow ram-jet units being built by Post Motors under a contract with the AAF. This work has just begun started. Five units are scheduled for delivery to Lycoming by November 1, 1944.

6. MIT

On June 30, 1944, the Bureau of Aeronautics requested the NDRC to undertake the design, construction and test of an intermittent-flow ram-jet unit. A preliminary analysis of the behavior of these units has been started. No experimental progress has been reported to date.

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RAM JET CONFERENCE

October 31, 1944.

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The committee met in the [illegible] Conference Room at AEL on October 31, 1944, at 9:00 a.m. Present:

R. I. Jacobs, Chairman
C. E. Holms
O. Kemper
O. F. Mohey
A. Silverstein
E. R. Sharp
A. M. Rothrock
B. Pinkel
K. K. Nahigyan
J. C. Sanders
L. R. Dolz
J. R. Dressman
A. L. Kunen
W. Matterperl
W. C. Burgess
D. Ouvrat
L. Ornstein
J. E. Hall, Secretary

The minutes of the previous meeting were read and corrections made as shown on revised pages 2 and 3.

The chairman asked that a brief review of progress to date precede the regular progress reports of the various groups for the information of Mr. C. E. Holms. The progress made to date by Mr. Mohey's group on valve designs was reviewed by Mr. Kunen. He stated that several types of valves had been tested with the objective to obtain a minimum of 1-hours life with satisfactory results. Valve life exceeding the 1-hour minimum had been obtained on the reciprocating piston apparatus at 1200 rpm with the large size valves and at 1500 rpm with a smaller size valve.

Mr. Holms asked if there were any size limitations being used by the group. Mr. Kunen stated that larger valves than those being used by the Germans were tested in view of the possibility of obtaining lower pressure drop through the valve.

Mr. Mohey stated that the objective of the valve work was to obtain a valve that would open fully and have minimum losses.

Mr. Dressman reviewed the results obtained on the reciprocating piston apparatus during the preceding week. One of the nine grills and valves being made by the shop had been completed and tested. The grill which had a straight

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valve seat and curved back stop was shown to the group. The valve seat was at a 60° angle from the vertical and the curved back stop was designed so that the bending stress in the valve would not exceed 65,000 lbs/sq in. in the full open position. A valve made of .008-inch Swedish-blue steel stock failed after 45 minutes, at 1500 rpm. The valve made with .010-inch Swedish-blue steel stock was still in satisfactory condition after 181 minutes of running at 1500 rpm. A second test was made with a valve of .010-inch Swedish-blue steel stock with the rolling grain spanwise and the valve was in good condition after three hours' running at 1500 rpm. A valve of .010-inch Swedish-blue steel stock was tested at 1800rpm and a small piece broke out of the corner of the valve after 51 minutes running. A valve of .010-inch stock was tested under the same conditions and failed after 57 minutes running time at 1800 rpm. A valve was tried with the tip over-hanging the grill by a small amount with no apparent difference in results. It was noted that the valves currently being tested by the group have been made with rounded corners and the tip polished with emery cloth.

Mr. Nutterperl reviewed the valve tests that had been conducted to date by Mr. Silverstein's group. It was noted that valve life of 64 minutes and over had been obtained with the valve operating from 40 to 56 cycles per second. Various materials had been tried in the valve test apparatus for the purpose of arriving at the best combination.

Mr. Ornstein of the Metallurgical group reviewed the metallurgical work that had been carried out in conjunction with the valve test work of the Wind Tunnel group. Mr. Ornstein stated that examination had shown that the structure of Swedish-blue steel varied with the thickness of the stock. It was noted that with increase in thickness the grain structure changes were such that increased thickness should result in increased resistance to impact. The variation in grain structure with thickness was attributed to the variation in effective heat-treatment with thickness. The fractures in the valve that had been examined were noted to be through the grain which is typical of fracture from impact. A chemical analysis had been made of the Swedish-blue steel currently being used for valve tests and elements were found in addition to those used in Swedish-blue steel manufactured before the war. It was noted that in the valve failures which had been investigated the fractures followed a straight line which indicated that rolling seams or preferred orientation were possible causes.

A specimen which had been heat-treated at 1100° F showed crystal structure changes that appeared to be better from an impact standpoint. Mr. Ornstein stated that it was his opinion that the valve should have spring properties as a result of heat-treatment, instead of cold rolling with the resultant residual stresses.

It was pointed out that variation in hardness within reasonable limits did not change the modulus of elasticity of the material and that the softer material would have better impact resistance. Specimens had been prepared on the basis of the work of the Metallurgical group and will be tested in the impact machine which is scheduled for completion on November 1.

The results of a report by the Watertown Arsenal on high velocity impact tests was reviewed.

The use of the impact machine and the question of whether or not the results may be directly applicable to valve design was discussed.

Mr. Kutterpel noted that the reasons for valve failures were not known by the group and the impact machine may be used in obtaining information on the cause of failure.

Mr. Kemper noted that if simple valves were used tests could possibly be made just as rapidly in the valve test apparatus with results that were of direct value.

Mr. Burgess stated that the variation of structure with thickness would make tests with varying valve thickness an inexact evaluation of the effect of material thickness.

Mr. Silverstein noted that meeting the minimum requirement of 1-hour-life valve tests was no particular improvement over the German design. It was pointed out that with the valve designs being tested and with lower cycling frequencies lower pressure drops through the valves should be obtained than with the German valves.

The question of what cycling frequency should result in optimum performance was discussed. Mr. Turner stated that with the combustion apparatus 50 cycles per second would be obtained.

Mr. Turner sketched on the blackboard the single shop combustion apparatus being constructed by Mr. Pinkel's group. The first test with the apparatus will be made using liquid propane and later tests with gaseous propane. The fuel valve for operation is designed to allow a slug of fresh air to enter the combustion chamber before the injections start. It is hoped to get a combustion process that will allow a slug of fresh air to fill the nozzle at the time the inlet valves close for the purpose of increasing the rate of combustion and pressure rise.

Mr. Helms inquired as to when the combustion apparatus would be ready for tests. Mr. Turner stated that the shop had promised completion by November 7, and that tests should begin in about 10 days.

Mr. Sanders inquired as to what rate of flame propagation was anticipated in the combustion apparatus. Mr. Turner stated that the transverse flame propagation rate was expected to be approximately 25 feet per second but that this rate would probably be increased considerably by turbulence.

Mr. Turner stated that the photographic studies of the combustion process should give the information necessary for designing a satisfactory combustion chamber.

Mr. Helms stated that 1,000 robot bombs were on order by the Army from Ford and that the next order was expected to be for 2,000. No changes will be made in the robot bomb design unless data is gotten out to show how improvements can be made.

The chairman noted that progress of shop work was comparatively slow on the ram jet projects. Mr. Schey said he felt the slow progress in the shops was serious. Mr. Holmes stated that priority on the ram jet projects should be exceeded only by turbine and jet projects.

Mr. Silverstein stated that the continuous-flow ram jet to be made by converting the Westinghouse installation now in the tunnel is to be tested by using a blower to arrive at a satisfactory combustion chamber. Wind tunnel tests will be made when a satisfactory combustion chamber design can be made.

Mr. Bolz sketched the burner installation that has been made up to simulate combustion in the steady-flow ram jet. Test work on the burner had been interrupted after 1-day's running by the fuels test engine, which is installed in the same test room, going back into operation. Mr. Rothrock stated that schedules would be arranged so that the burner tests could be carried out without undue interference from the fuel test engine.

Mr. Pinkel stated that it was his understanding that liquid fuel would be used for the ram jets. Mr. Rothrock stated that further estimates are being made on the comparison of the relative merits of liquid and gaseous fuels for use with ram jets.

Mr. Kumm inquired as to the increase in fire hazard with the storage of liquefied gases on shipboard. It was generally agreed that the fire hazard would be an important consideration.

Mr. Mahigyan reported that the gasoline burners being made by his group were in the last stage of assembly and a demonstration run should be possible by the next meeting. Mr. Mahigyan inquired as to what pressure losses would be allowable in the burners. The chairman stated that losses equal to 10% or the loss due to combustion should not be excessive.

Mr. Mahigyan reported that the test set up for the robot bomb which had been scheduled for completion by November 3 had been delayed 2 weeks by a delay in contract negotiations.

The meeting adjourned at 10:50 a.m.

Jesse H. Hall,
Secretary, Ram Jet Committee.

JHH:lmk

RAM [illegible] CONFERENCE

October 24, 1944

CONFIDENTIAL

The Committee met in the Executive Conference Room at AERL on October 24, 1944, at 9:10 a.m. Present:

E. N. Jacobs, Chairman
Colonel F. R. Page
A. M. Rothrock
R. E. Bolz
L. Simon
K. K. Nahigyan
D. Pinkel
O. W. Schey
J. H. Dressman
A. E. Kunan
F. C. Burgess
W. Mutterperl
D. Okrent
L. R. Turner
J. H. Hall, Secretary
E. A. Beckner, Acting Secretary

The minutes of the previous meeting were read and with several changes were approved.

Mr. Kunan gave a short summary of his test program to date and presented a chart showing the different types of valves that had been tested. He reported that he has 9 grills and a number of valves being made up in the shop at the present time. A valve with the trailing edge sealed by silver solder failed after several minutes. A valve with the end sealed by shot blasting is to be tested in the near future. An .008-inch Swedish-blue steel valve failed after combined operation at 1600 rpm for 46 minutes and at 1800 rpm for 2 minutes. Another valve of the same material which had a smaller radius of curvature than the valve seat and a thickness of .010-inch failed after 15 minutes of testing because the valve had been bent sharply at one place. Straight valves of .008-inch thickness failed in the same manner as the curved valves after 46 minutes of testing.

At this point, Mr. Kunan asked for a definition of the objective of the test program. Mr. Jacobs stated that the objective of finding a valve which would run for one hour came from the Army. This type of valve is to be used in a missile which is to have a range of 400 miles and a speed of 550 miles per hour. There was some question as to whether the test program should be planned to find valves with a longer life at the low frequencies now under investigation or to attempt to find valves that would last for one hour at higher frequencies. Since there was no definite decision made by the Committee, Mr. Kunan stated that he would investigate both possibilities.

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Mr. Turner reported that the large valve and other test unit parts now being fabricated in the shop are long overdue. These parts were due on October 15, 1944, and progress is still slow. Mr. Turner also reported that the nozzle mount for the combustion study rig is nearly complete and the valve housing should be completed in about a week.

Mr. Mutterperl reported that the impact machine is approximately 20 per-cent completed. He stated that it is planned to test on the impact machine all of the shock absorber ideas of the last meeting. Tests have been made to find the effect of valve seat condition on valve life. Mr. Mutterperl submitted a plot of valve life versus the number of tests made on the valve seat without refacing between tests for .005-inch Dine-steel valves. This plot showed the valve life to decrease rapidly with the number of tests made on a valve seat without refacing. It was agreed that this plot made a great deal of the data previously obtained very doubtful. Mr. Mutterperl sketched on the blackboard a peculiar crystalline structure found after a valve dipped in tin had been tested. Mr. Burgess reported that the photomicrographs promised last week were not ready yet but would be submitted at the next meeting. Mr. Burgess stated for the information of the Committee that an Aramcal representative had given him data showing that impact strength generally rises with striking velocity to a peak and then drops off suddenly.

Colonel Page stated that he had inspected a German robot bomb at Wright Field and believed this bomb to be different from the one known to the Committee. Colonel Page stated that the bomb he examined had two sets of valves. The first set of valves were smaller than the second set. Colonel Page stated that he believed the trailing edge of the valves did not strike the seat but struck each other. Mr. Turner submitted photographs of the German valves sent there by Dr. Lewis and Colonel Page stated that he believed that the ones he examined were different. Colonel Page stated that he would call Wright Field and attempt to borrow the robot bomb in order that the Committee might examine it. Mr. Jacobs asked when the Ford bomb would be delivered and Colonel Page stated that it should arrive soon.

Mr. Mutterperl reported that the fabrication of the ram jet is progressing and provisions are being made to install the unit in the wind tunnel.

Mr. Bols reported that the gas burner for the ram jet had been fired and some difficulties were experienced with combustion. The highest velocity at which the unit would support combustion was 20 feet per second. At this velocity the flame was yellow and a peculiar pulsating flow was noted. Mr. Jacobs suggested that the difficulty was due to backwash. Mr. Bols stated that changes will be made in the burner in order to get better combustion and to support combustion at higher velocities.

Mr. Rothrock and Mr. Simon reported on the results of their study of storing gaseous fuels. Mr. Simon stated that the most promising method is the storage of propane under pressure. He gave the following tabular data for the storage of 500 gallons of low pressure gas:

	Propane	Propane	Methane
Temperature of storage, °F	-44	20	-258.6
Type of tank	Freely vented insulated 2" cork	Pressure 200 psi not insulated	Freely vented insulated 2" cork
Weight of fuel, pounds	2420	2116	1732.6
Length of tank, feet	10	16.6	10
Thickness of wall - steel, inches	3/8	3/4	3/8
Thickness of wall - aluminum, inches	1/8	9/16	1/8
Weight of tank - steel, pounds	509	1607	509
Weight of tank - aluminum, pounds	182	1165	182
Weight of insulation (cork), pounds	166	0	166
Loss of fuel, pounds per hour	917 (.038%)	0	1.94 (.112%)
Pump	Necessary	Unnecessary	Necessary
Temperature effect on metal	None	None	Terrific
Tank pressure, pounds per sq. in.	54.7	85.5	14.7

Dr. Simon also submitted curves showing the suitability of different types of fuel. Messrs. Rothrock and Jacobs agreed that the use of gaseous fuel in the intermittent unit seems to be very promising.

Mr. Rothrock sketched on the blackboard the test rig for studying the vaporization of liquid fuels. Plans are made to compare the vaporization of different fuels, including gasoline, fuel oil, and kerosene. Mr. Rothrock stated that a demonstration would be held as soon as the safety mechanism is installed on the rig.

Mr. Kahlgren reported that the fabrication of the gasoline burners is progressing and that a demonstration can probably be held on November 7, 1944. Mr. Kahlgren also reported that the rig for the robot bomb installation is progressing. Parts are scheduled to start coming in on November 8, 1944.

Mr. Jacobs sketched on the blackboard for the information of the Committee the method of launching robot bombs that were used in France. The bombs run on a track and are pushed by a piston which is actuated by explosives. The valet provided in the cylinder for connecting the piston to the bomb is sealed by tubes.

Mr. Jacobs stated that the Committee is now in a position to design a noncontinuous-flow unit for the Army missile.

It was generally agreed by the Committee that the work being done by the shops is moving unreasonably slow. Mr. Burgess suggested that if a shaper and lathe were placed in the wind tunnel, 95 percent of their work could be taken out of the shop. This policy, however, is frowned upon because the machines stay idle part of the time. Mr. Gehman suggested that the Committee contact the shop in order that the shop appreciate the high priority of this job. It was agreed that pressure should be brought to bear on the shops in order to expedite the work.

There being no further business to come before the meeting, the meeting adjourned at [illegible]

Respectfully submitted,

Howard A. Dunham, Jr.,
Acting Secretary, Ram Jet Committee.

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PULSE-JET CONFERENCE

October 17, 1944

The Committee met in the Executive Conference Room at AERL on October 17, 1944, at 9:10 a.m. Present:

E. N. Jacobs, Chairman
A. M. Rothrock
A. E. Kunen
L. R. Turner
D. Okrent
K. K. Nahigyan
B. Pinkel
A. Silverstein
J. C. Sanders
O. W. Schey
W. Mutterperl
W. C. Burgess
H. A. Buckner, Acting Secretary

The minutes of the previous meeting were read and approved as read.

Mr. Kunen reported that the grill used for testing had been revised and now has a reflex top. Swedish-blue steel, brass, low-carbon steel, and bronze valves have been tested. Swedish-blue steel valves of 0.006-inch thickness lasted 18 minutes and 3 minutes at 1500 and 1200 rpm, respectively. The valves of 0.008-inch thickness were improperly made and consequently lasted only about 2 minutes. The valves of 0.010-inch thickness failed after 25 minutes of operation at an engine speed of 1500 rpm. The brass, the low-carbon steel, and the bronze valves gave very poor results. Mr. Kunen stated that he is planning to run tests to give a curve of valve life versus closing time.

Mr. Kunen passed the valves around for inspection. From the examination of the valves it was apparent that the failure was caused by the end of the valve striking the seat. Several recommendations were made to avoid this type of failure. Mr. Silverstein suggested that the ragged end of the valves be sealed and that the end of the valve be stiffened by some method. Mr. Rothrock suggested that a spring shoe be located at the end of the valve seat to decelerate the valve more gradually and Mr. Nahigyan made design revisions in this method. Mr. Pinkel recommended that the edge of the valve be curled. Mr. Schey suggested that the trailing edge of the valve seat be made wider in order to provide an air cushion and to distribute the stress over a larger area. Mr. Burgess suggested that the ribs in the valve seat be run spanwise. Mr. Kunen agreed to consider these recommendations in laying out future test work. It was generally agreed that some type of shock absorber should be provided to eliminate this type of failure.

Mr. Burgess pointed out that to date direct comparison of valves is not possible because of the changing condition of the valve seat. Mr. Kunen added that the refacing of the valve seats and the fabrication of the valves holds

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up the test program an unreasonable length of time. It was agreed that the Committee should give thought to means of fabricating quickly and cheaply a large number of these valve seats.

Mr. Burgess reported that photomicrographs of the frayed edges of valves that have failed will be submitted at the next meeting. Mr. Hutter reported that no valve tests had been made during the past week, but work is proceeding on the fabrication of the impact machine and the test unit for the wind tunnel. Mr. Silverstein stated that liquid fuel would have to be used for the unit when tested in the wind tunnel because of the supply problem. Mr. Rothrock agreed to look into the possibility of using high-pressure storage tanks for gaseous fuels and report on the results at the next meeting.

Mr. Turner reported that the shop did not complete the work for his test rig on schedule and, consequently, the test rig will not be ready to run before October 24, 1944.

Mr. Mahigyan reported that the fabrication of the gasoline burner for the wind tunnel unit is progressing. This burner will be installed in a rig connected to an air system preliminary to installation in the unit for wind-tunnel tests. The unit is scheduled to be ready for installation in the wind tunnel by November 7, 1944.

Mr. Mahigyan also reported that the setup for testing the robot bomb is nearing completion and that it appears that the development of the valves will hold up the project. All parts should be completed by approximately November 14, 1944. The unit will be installed in the Engine Propeller Research Building, cell number 4, where air can be furnished at the rate of 130 pounds per second and at simulated airspeeds of 400 miles per hour.

Mr. Rothrock reported that the setup for studying fuel sprays should be ready to run some time this week.

Mr. Turner called to the attention of the Committee a combustion system in which burning takes place within the liquid and suggested that a similar process might be feasible for vaporizing fuel. It was agreed that the Committee should give further thought to this process.

The Committee decided that it should act in an advisory rather than a directory capacity in regards to work being performed by the members.

The meeting adjourned at 11:15 a.m.

Howard A. Buckner, Jr.

Howard A. Buckner, Jr.,
Acting Secretary, Executive Committee.

HAB:et

RAM JET CONFERENCE

October 10, 1944

The Committee met in the Executive Conference Room at NACA on October 10, 1944, at 9:45 a.m. Present:

S. H. Jacobs	Chairman
I. I. Mahigyan	
R. R. Turner	
O. W. Bobey	
A. M. Mathrook	
D. Okrent	
W. Matterperl	
T. O. Burgess	
A. B. Zumen	
J. R. Bresman	
J. O. Sanders	
H. A. Bualmer	Acting Secretary

The minutes of the previous meeting were read and approved as read.

Mr. Bresman reported on the results of the Swedish-blue steel valve tests of his group and passed the valves around for inspection. These results are shown in the following table:

Valve thickness (in.)	Grill details	Life before frying (hr)	Engine speed (rpm)
0.012	Aluminum seat and top	4	1200
.010	Aluminum seat and top	12	1500
.010	Aluminum seat and top	18	1800
.008	Rubber top	45	1200
.008	Rubber top	25	1500
.015	Reflex top	5	1500
.015	Rubber top	9	1500

All these failures were believed to be due to impact. Mr. Bobey asked if the test rig was not harder on the valves than actual operating conditions. Mr. Bresman stated that the opening is about the same, but the closing is different. Mr. Bobey suggested spring steel as a material because it has a tensile strength of about 200,000 pounds per square inch as compared with 125,000 to 150,000 for Swedish-blue steel. Mr. Bresman stated that the grill is being reshaped and 0.006-inch valves are being made. Mr. Jacobs stated that the tests are showing that the trend should be toward smaller and thinner valves. A discussion followed on the advisability of making tests of German valves to compare with our test results, but no action was agreed upon.

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Mr. Burgess reported on his tests of straight valves on curved seats and passed the valves around for inspection. The 0.005-inch steel valve, when tested at 50 oscillations per second and a steady-flow grid velocity of 250 feet per second (145 feet per second average for intermittent flow), failed after 44 minutes. The grain of this valve ran spanwise. The same thickness valve with the grain chordwise and with an inconel backing lasted 55 minutes. Mr. Burgess stated that the inconel backing had practically no motion relative to the valve. A 0.005-inch steel valve dipped in tin failed after 5 minutes of testing. Valves made from brass spring stock of 0.007-inch and 0.008-inch thickness failed after 9 minutes and 55 minutes, respectively.

Mr. Turner reported that the burner elements for his rig are in the shop and would probably be finished by October 15, 1944. The setup is progressing and it is planned to use as fuel either propane or propane and butane from bottles. Mr. Turner stated that the unit could probably be fired without the glass on October 17, 1944. Mr. Turner also reported that his calculations indicate that an application of the intermittent-flow burner to the existing jet-propulsion unit components would theoretically increase the efficiency 20 percent and the power output as much as 80 percent.

Mr. Rothrock stated that the setup of test equipment on his burner rig is proceeding satisfactorily.

Mr. Nahigyan reported that he had two gasoline burner designs being fabricated in the shop at the present time.

Mr. Mutterperl reported that the tests of his combustion rig are about ready to start. The rig consists of a rectangular duct mounted inside a circular duct connected to the altitude exhaust. The rectangular duct has a quarter-inch lip to support a pilot light. These tests will be made before the complete unit is tested in the wind tunnel. Mr. Mutterperl stated that it was planned to use liquid fuel, but it was pointed out that it had been decided previously to use gaseous fuel in order to expedite the tests to check the theory.

Mr. Mutterperl submitted a blackboard sketch of a simple apparatus for testing metals for impact. The apparatus consists of a rotating shaft with two strikers that hit the edge of the valves being tested. It was agreed that tests should be made to find how the data obtained on this rig correlate with other valve test data.

Mr. Jacobs stated that the group, with its present experience, is in a position to design valves for a 15-cycle unit which will run over an hour before failure. This unit would be approximately 6 feet long.

The meeting adjourned at 11:00 a.m.

Howard A. Buckner Jr.

Howard A. Buckner, Jr.,
Acting Secretary, Ram Jet Committee.

HAB:et

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October 5, 1944

The Committee met in the Executive Conference Room at AERL on October 5, 1944, at 9:05 a.m. Present:

E. W. Jacobs, Chairman
K. K. Kachigyan
L. B. Turner
O. W. Bohey
D. Okrent
B. Pinkel
W. Mutterperl
W. C. Burgess
J. B. Breesman
J. C. Sanders
L. Wolfenstein
J. H. Hall, Secretary

The minutes of the previous meeting were read and approved as read.

A valve assembly taken from a German robot bomb was shown to the group. Mr. Bohey stated that Dr. Lewis had asked for the valve to be returned at an early date in its original condition as he intends to use the valve at a meeting of the Budget Committee. Measurements desired should be taken as soon as possible so that the valve assembly might be returned in accordance with the request of Dr. Lewis.

The construction details were examined and discussed by members of the group. Mr. Breesman reported that the valve-test program on the large valves being tested in the reciprocating-piston apparatus had been completed. The results of the test work on the large valves were reviewed. Included in the investigation were the effect of valve thickness, seat material, speed, and stop-stop construction on valve life.

The method used for forming the valves which had been tested was discussed. The current method of forming the valve by means of a sheet-metal wrap was believed to be undesirable from a stress standpoint. Suggested methods for forming included laying the material on a form and shot blasting, wrapping the material on a roll to obtain the proper curvature, and annealing the material on a form followed by heat treatment.

Mr. Burgess reported on results of the valve tests conducted during the preceding week in the intermittent-flow apparatus in the Duct Laboratory. A comparative test had been made of Inconel and Swedish-steel stock. The Inconel material gave considerably longer life but it was pointed out that the single test could not be considered conclusive. Steel valves made up with the rolling grain of the material spanwise and chordwise were compared. The valve with

spanwise-rolling grain gave considerably longer life. The valves with spanwise- and chordwise-rolling grain were made of .005-inch stock. A valve with spanwise grain made of .008-inch stock ran for a longer time before failure than the .005-inch-thick valve but did not open fully. Mr. Pinsl noted that the spanwise-grain valve should be better from the standpoint of fraying in the tip.

Mr. Dressman stated that their tests had shown opposite results but since the failure of the valves in their tests had been by tearing, the indicated better-fraying resistance noted in the test of the smaller disc valves in the Duct Laboratory may be significant. In order to determine the impact resistance of materials being considered for valve construction, tests are being planned by Mr. Silverstein's group for studying impact resistance in a simplified test apparatus. This work will precede further tests of valves and is being set up on a simplified test apparatus in order to make a large number of tests in the minimum time.

Mr. Sanders reported on results of further calculations he had made for supercharging the intermittent ram jets. These calculations had been made on the basis of a pressure ratio of 1.6. The results indicated a fuel consumption of 1.2 lbs/hp hr at a fuel-air ratio of .015.

The inlet temperature to the turbine turned out to be higher than the previous limit. Additional calculations will be made for temperatures at and below the previous set limit of 1000° F.

Mr. Turner discussed calculations he had made on the application of the intermittent-flow burner to a Whittle-type unit. The calculations made were based on attempting to attain an optimum installation. Further calculations will be made based on application of the intermittent-flow burner to the existing jet-propulsion unit components.

Mr. Wolfenstein showed a sketch that he had made for supercharging the intermittent-flow ram jet by use of an axial-flow compressor ahead of the valves driven by a gas turbine through which part of the gas passed, the balance of the gas being carried out through a nozzle directly.

Mr. Turner reported on the status of the combustion apparatus. The estimated completion date for the apparatus was stated to be October 15, 1944.

Mr. Butterperl reported on the status of the steady-flow ram-jet installation for tests in the wind tunnel. The design work on the installation, except for the burner, was reported to be complete. It was noted that the unit must be ready to go into the tunnel for tests in about one month if it is fit into the tunnel schedule.

The burner design for use in the steady-flow ram-jet installation was discussed. Messrs. Mahlgyan and Bols sketched proposed burner arrangements on the blackboard. Mr. Mahlgyan stated that his group could design and test a cone-type burner using gasoline as the fuel within the time limit set, provided priority could be given this job over others currently being worked on by his group. The question of priority to enable this design to go forward will be looked into after the meeting.

The Chairman asked Messrs. Mutterperl and Boli to meet with him for a few minutes after the meeting of the group had adjourned to discuss the impossible design for gas burners.

The meeting adjourned at 11:45 a.m.

Jesse H. Hall

Jesse H. Hall,
Secretary, Rm Jet Committee.

JHH:lmk

RAM JET CONFERENCE

September 26, 1944

The Committee met in the Executive Conference Room at AERL on September 26, 1944, at 9:10 a.m. Present:

E. M. Jacobs, Chairman
D. Okrent
L. R. Turner
J. C. Sanders
W. Mutterperl
W. C. Burgess
C. R. Breesmann
A. K. Kunen
J. H. Hall, Secretary

The minutes of the previous meeting were read and corrected as shown on revised page 2.

Progress made during the preceding week in valve tests and design was reviewed. Mr. Breesmann reported the results of tests of five valves in the reciprocating piston apparatus. All of the valves were tested with a full rubber mat as a top-stop. The first valve was made of .010 inch stock and was tested with an aluminum grill at 1200 rpm. The valve failed after 14 minutes running.

The second valve tested was made of .008-inch stock and failed after 11 minutes running with an aluminum grill at 1200 rpm.

The third valve tested was made of .012 inch stock and failed after 33 minutes running with a bakolite grill at 1200 rpm.

The fourth valve tested was made of .015 inch stock and was still in good condition after 101 minutes of running with an aluminum grill at 1200 rpm.

The fifth valve was made of .012 inch stock and failed after 2 minutes running with an aluminum grill at speeds between 1600 and 1800 rpm.

The tests by Mr. Schey's group on the large size valves were scheduled for completion by September 27.

The Chairman noted that the work in the shop for Mr. Schey's group on valve construction and Mr. Pinkel's group on the combustion apparatus would have to be given relative priority. It was agreed that the combustion apparatus would have priority until the tests of the large valves are completed, at which time one man from the combustion apparatus job can be taken off to continue the valve construction work.

The aluminum grill for testing the next smaller size valves by Mr. Schey's group was shown. The range of valve sizes to be tested in the reciprocating piston apparatus was discussed. It was agreed that two of the small size valves should be tested in the reciprocating piston apparatus in a side by side arrangement. These valves are to be made up as an addition to the order for valves being made up for Mr. Pinkel's group for the combustion apparatus.

Mr. Mutterperl showed drawings that he had made up of a new valve design that had been made by Mr. Silverstein's group. The valves were designed to utilize a flat valve with the valve seats and top-stop curved to reduce operating stresses. The ribs in the grill were designed so that thickness and spacings could be varied. Valve thicknesses from .004 to .012 or possibly .015-inch will be tested in the new design.

Mr. Turner reported on the status of the combustion apparatus being set up by Mr. Pinkel's group. The valve seat grill for the combustion apparatus is scheduled for completion by October 9. The fuel injection equipment still appears to be the controlling factor as to when the combustion apparatus would be ready for operation. A simplified plunger-type injection pump for injection of the propane is being considered as the best method of getting the combustion apparatus operating at the earliest possible date.

Mr. Rothrock reported that the vaporization setup for liquid fuel tests should be running in about one week. Continuous injection of the fuel will be used first but the apparatus can be changed for intermittent injection tests.

Mr. Sanders reported on the progress he had made in calculations for supercharging ram jets. Mr. Sanders stated that his calculations were not sufficiently completed to obtain any conclusions.

The physical arrangement for the turbine blower and bleed valves for the supercharging system utilizing the peak pressure and the intermittent-flow ram jet for turbine was discussed. The Chairman suggested that Mr. Sanders consider pressure ratios considerably lower than the 2:1 pressure ratios used in the initial calculations, and lean mixtures of the order of .015 fuel air ratios.

The Chairman suggested that the group give some thought to suitable bleed valve designs for operation at high temperatures. It was suggested that the valves should be automatic if possible and that 1000° F would be the upper temperature limit in the valve designs. The discussion of valve designs for high temperature work indicated doubt that automatic valves could be made to operate satisfactorily in the high temperature range.

Mr. Silverstein reported on progress made toward getting a steady-flow ram jet installation tested in the Altitude Wind Tunnel. Mr. Silverstein sketched the steady flow ram jet installation currently being considered for tests in the Altitude Wind Tunnel. The setup consisted of the Westinghouse jet propulsion installation with the burner and turbine removed and modified to obtain the proper passage for a steady-flow ram jet installation. Mr. Silverstein pointed out that reduction of losses to an absolute minimum was very important in steady-flow ram jet operation. The burner arrangement to obtain the minimum pressure loss for use in the steady-flow ram jet installations was discussed.

The meeting adjourned at 11:00 a.m.

Jesse H. Hall,
Secretary, Ram Jet Committee.

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R[illegible] JET CONFERENCES

September 19, 1944

The Committee met in the Executive Conference Room at AERL on September 19, 1944, at 9:10 a.m. Present:

E. N. Jacobs, Chairman
Wm. Reiereisen
A. M. Rothrock
D. Okrent
J. C. Sanders
A. E. Kunen
O. W. Schey
J. R. Bressman
H. R. Turner
B. Pinkel
W. Mutterperl
K. K. Nahigyan
W. C. Burgess
Jesse H. Hall, Secretary

The minutes of the last meeting were read and corrections made as shown on revised page 1.

Progress on valve tests and designs made during the preceding week was reviewed. Mr. Kunen reported that their best results obtained to date were with a valve that ran 93 minutes in the reciprocating piston apparatus before failure occurred. Nine valves had been tested in the reciprocating piston apparatus during the week. Mr. Bressman reported the conditions and results obtained from the tests of the nine valves.

The first and second valves tested were made of .012 inch stock and were run with rubber seats at 1200 rpm. The first valve did not have a rubber pad insert as a top stop and failed in 35 minutes. The second valve tested with a rubber pad insert as a top stop and ran 79 minutes without failure. The speed of the second valve was increased to 1500 rpm and failure was noted after running 4 minutes.

The third and fourth valves were made of .015 inch stock and were tested with a rubber seat at 1200 rpm. The third valve did not have a rubber pad insert for a top stop and failed in 10 minutes. The fourth valve was tested with a rubber pad insert for a top stop and failed after 21 minutes running.

The fifth and sixth valves were made of .010 inch stock and were tested under the same conditions as the third and fourth valves. The fifth valve did not have a rubber pad insert for a top stop and failed after nine minutes running. The sixth valve had a rubber pad insert for a top stop and failed after 19 minutes running.

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The seventh and eighth valves tested were run under the same conditions as the third and fourth valves and were made of .008 inch stock. The seventh valve, which had no rubber pad insert for a top stop, failed after 2 minutes running. The eighth valve, which had a rubber pad insert for a top stop, failed after 7 minutes running.

The ninth valve tested was made of .012 inch stock and had an aluminum seat and a rubber top stop. The grill was made of aluminum alloy, furnace brazed. The valve was run for 95 minutes at 1200 rpm and was found to be in good condition at the end of the test. The speed was increased to 1700 rpm and failure occurred after 2 minutes running.

Further tests are planned for valves made with the .008 inch and .010 inch stock with a full rubber matt for the top stop. Other tests to be conducted will be with the rubber insert as the top stop with steel seats.

The Chairman suggested the use of aluminum top surface for tests and it was agreed that such tests would be conducted in the near future. The results of the tests were discussed by the group with respect to the valve thickness. It was suggested that bakelite seat material be tried in the reciprocating piston apparatus. It was decided that .012 inch stock would be used for all seat materials tested and that tests would be run at 1200 rpm. The speed will be increased to 1800 rpm for the best combinations.

Mr. Turner discussed an analysis he had made on the effect of valve thickness when the valve size is scaled down.

Mr. Mutterperl reviewed progress made by Mr. Silverstein's group on valve tests. It was reported that most of the work done during the past week was toward getting the intermittent flow apparatus operating satisfactorily. Several valves made of .002 and .004 inch stock, which had been tested to destruction, were shown to the group. Mr. Mutterperl stated that considerable trouble was encountered in synchronizing the intermittent and steady flow air streams. The test section used in the apparatus, which was equipped with a steel grill, was shown to the group. Mr. Turner noted that the valves had apparently been cut out by shears and suggested that the edges be ground to eliminate the stress set up in the shearing process.

Mr. Mutterperl reported that no further action had been taken by his group with respect to the continuous flow ram jet. He stated that a report entitled "Design Study of High-Speed Long-Range Guided Missile" has been prepared by his group. The Secretary will obtain a copy of the report and circulate it to members of the group.

Mr. Sanders reported on four schemes that he had considered for possible use as a means for supercharging ram jets. The first scheme investigated was the use of the turbine which utilised peak pressures, bled off the combustion chamber, to drive the blower. The second scheme considered was the use of a blow down type turbine connected to a unit with multiple combustion chambers. The third

method considered was the use of constant pressure turbine for a blower, the fourth scheme which was given very little consideration was the use of an engine driven blower. The schemes were discussed by the group and the first scheme appeared to be the most promising. For further analysis of the problem Mr. Sanders will place more emphasis on the first scheme.

The Chairman asked for any further results on the use of aeropulse unit as a burner for the Wulff type unit. Mr. Pinkel stated that his group would make a short analysis to survey the problem.

Mr. Turner reported on progress made in getting the single shot burner apparatus in operation. The design of the fuel valve turned out to be one of the most difficult parts of the apparatus; however, all parts including the valve sections will be completed or in the shop within 4 or 5 days.

The meeting adjourned at 10:50 a.m.

Jesse H. Hall,
Secretary, Ram Jet Committee

JHH:lmk

Revised Minutes
RAM JET CONFERENCE
September 12, 1944

The Committee met in the Executive Conference Room at AERL on September 12, 1944, at 9:15 a.m. Present:

H. H. Jacobs, Chairman
Wm. Peterson
O. W. Bohey
Richard Turner
A. B. Kumen
J. R. Breesman
W. Mutterperl
J. H. Hall, Secretary

The minutes of the last meeting were read and corrections made as shown on revised page 2.

The Chairman asked for a progress report on the various groups on valve designs and tests since the last meeting. Mr. Mutterperl stated that they were considering the use of nickel steel in their designs of valves. Tests had been made of valves made up in accordance with Mr. Jacobs' proposal using .008 inch stock. The valves tested in the intermittent-flow apparatus designed by Mr. Silverstein's group did not open sufficiently to contact the upper wall.

Mr. Breesman reviewed the results of the valve tests made by Mr. Bohey's group in the reciprocating piston test apparatus. The three valves tested were shown to the group. The first valve was run 56 minutes at 720 rpm and 38 minutes at 909 rpm. The valve failed in the nip section during the last 5 minutes of running. The valve was made with .012 inch stock with a Rockwell C-26 hardness at the tip. It was tested with a rubber seat and at atmospheric exhaust which resulted in a very small air flow.

The second valve was run for 55 minutes at 1200 rpm and failed during the last 11 minutes of running. The second valve was made of .012 inch stock, not annealed and was tested with a rubber seat and altitude exhaust.

The third valve failed during the last 4 minutes of a 30-minute test run. The valve was made of .016 inch stock and was tested with a rubber seat and with altitude exhaust.

Valves made with .010 inch stock are currently under tests by the group and valves made with .008 inch stock were scheduled for tests following the .010 inch valves.

Smaller valves than the ones currently under tests, as well as the current test size, will be tested with an aluminum alloy grill and soft seat material. Three valves were reported under construction by Mr. Bohey's group.

The Chairman noted that with the grill built up by welding the 62-S alloy being used would be annealed by the heat from welding.

Mr. Schey raised the question as to whether or not the method used to form the seat stock into the curved profile of the valve would affect the serviceability of the material under high stresses.

Mr. Kunen reported that the Metallurgical Laboratory group had tried annealing the seat stock and then heat-treating it back to the original state but had obtained poor results and had given up the work. Various means for bending the valves, annealing and heat-treating were discussed by the group. Mr. Bressman stated that inconel seat material was being considered for tests because of its high impact strength.

Mr. Kunen showed charts of valve position plotted against piston position obtained with the reciprocating piston test rig. A chart was also shown of pressure plotted against piston position that had been obtained.

Mr. J.C. Sanders entered the meeting at this point.

Mr. Schey inquired as to the adequacy of tests of valves larger than the size to be used in the actual design and tested at slow speed. It was the opinion of the group that tests using large valves at slow speed should give accurate results from a comparative standpoint and may possibly be more severe than tests of valves of the smaller size.

Mr. Schey stated that it was his opinion that the valve tested by this group indicated failure by impact on the flat surface and suggested that a rubber seat on the top surface be tried.

Mr. Kunen stated that tests were planned for a rubber seat at the top only and comparative tests with a rubber seat at the bottom only.

Mr. Turner suggested that the impact stresses could be reduced by increasing the seat area. He noted, however, that increasing the seat area would reduce the area for air flow but that if a workable valve can be attained in this manner the loss should not be too serious.

Mr. Mutterperl sketched a valve design his group had worked out in which the valve in the full open position was faired in. The tip of the valve was made with slight clearance so it would not strike the fairing if it opened past the full open position.

The test program to be followed to arrive at satisfactory valve designs was discussed. It was agreed that tests should proceed as planned to determine the effect of thickness and seat material effects on valve life.

The Chairman inquired as to what had been done toward getting a continuous flow ram jet test started in the wind tunnel. Mr. Mutterperl stated that some thought had been given to following up the Westinghouse jet propulsion unit tests with the unit operating as a ram jet by removing the turbine and compressors. The Chairman stated that it was his opinion that the conversion did not appear as

likely to give good results as a new design made for the specific purpose of steady-flow ram jet.

Mr. Turner stated that the ejector effect of the vaporizing fuel in the fuel spray might be used for overcoming pressure drop in the burner system of ram jet and other similar installations.

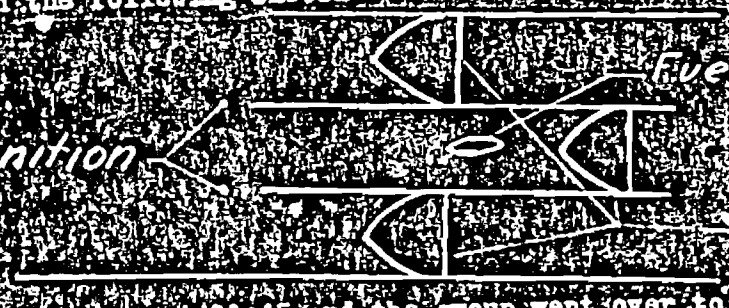
Mr. Sanders read the summary of a report he had written, entitled "A Preliminary Evaluation of the Explosion Jet-Propulsion Engine" and briefly reviewed some of the results he had obtained.

The Chairman asked Mr. Sanders to make a study of methods of obtaining a small amount of boost for ram jets with the simplest possible machinery. The purpose of the boost is to obtain good starting and ground running characteristics.

The Chairman stated, for Mr. Sanders' information, that the principal interest of the group is in the intermittent-flow ram jet and also the objective of the research being carried out on ram jets for the Navy and the missile for the Army.

The group discussed the possibilities of using the intermittent-flow ram jet as a burner for the Whittle type unit for increased power and efficiency. It was agreed that such an application of the intermittent-flow ram jet system offered considerable promise but that future work along that line should await successful results on the intermittent-flow ram jet installations now under consideration. The Westinghouse and General Electric jet propulsion units with the necessary high frequency valve operation would be considered at that time.

Mr. Turner reported on progress made by Mr. Pinkel's group in setting up the combustion test apparatus. The scheduled completion date was given as September 10. The fuel system to be used in the apparatus was sketched on the blackboard by Mr. Turner as shown on the following sketch:



The meeting adjourned at 11:45 and the group went over to observe operation of the intermittent-flow apparatus set up by Mr. Silverstein's group for valve tests.

Jesse H. Hall
Secretary, Ram Jet Committee

JHH:ink

Minutes

CONFERENCE

September 5, 1944

The Committee met in the Conference Room at AERL on September 5, 1944, at 9:10 A.M. Present:

[illegible]acobs, Chairman
[illegible]oney
[illegible]ard Turner
[illegible]orelson
[illegible]Rathbrock
[illegible]Bressman
[illegible]Kuhnen
[illegible]Muttorperl
[illegible]. Johnson
Dr. George W. Lewis
Carlton Kemper
Edward L. Sharp
Abe Silverstein
Jesse H. Hall, Secretary

The minutes of the special session on August 24, 1944 were read and approved as read. The minutes for the regular meeting on August 29, 1944 were read and corrections made as noted on revised pages 1, 2, and 3.

The Chairman asked for a report of progress made on valve designs since the last meeting. Mr. Muttorperl stated that tests being made by his group had been interrupted by failure of the generator in the Engine Research Building. The intermittent-flow test equipment is expected to be ready for test runs by the next meeting.

Mr. Kuhnen reported that one straight and three curved valves designed along lines similar to the German design had been tested by his group in the reciprocating piston apparatus. The straight valve broke in a very short time because of high flexure stresses near the base. The curved valves opened to a full open position against a flat surface to reduce flexure stresses. The first curved valve tested failed by chipping at the tip. A second valve was tried with the tip in the annealed condition but chipped more extensively than the first. Mr. Bressman noted that there was some doubt as to whether or not the second valve was fully annealed. The third valve was cut with the rolling grain of the material perpendicular to the length of the valve. This valve split near the tip along the rolling grain lines, and chipped at the tips. Bakelite and Lucite seats were used in the tests and both seat materials failed. None of the four valves tested lasted more than a few minutes before failure. It is planned to use rubber seats in later tests.

Dr. Lewis, Mr. Kemper and Mr. Sharp entered the meeting at this point.

Dr. Lewis stated that he felt the group should get valves of the proper construction to be tested in the German type unit in the laboratory.

Mr. Bressman stated that valves of one and one-half inch length and three inches width were being made up.

The Chairman read excerpts from a British report concerning possible future improvement to be expected in the German robot bombs.

Dr. Lewis inquired as to what was desirable in a seat material and the possibilities of the material under consideration for meeting these requirements. The Director expressed doubt that some of the material that had been mentioned, for seat construction, would be satisfactory from a heat standpoint. Mr. Jacobs noted that the valves he had observed in some of the German units did not indicate that the valves had been subjected to high temperatures.

Mr. Schey noted that the valves may receive heat through the grill and other paths in addition to direct transfer from the combustion gases.

Dr. Lewis inquired as to what seat material was used in the German unit. Mr. Jacobs stated that the valves seated on the aluminum alloy grill along the side but that he was not sure about the seating at the tip.

Mr. Silverstein entered the meeting at this point.

The results of tests at Wright Field on the German unit in the wind tunnel were discussed. Mr. Silverstein stated that the test results showing valve drag in the sealed condition than was obtained with flow through the valves was to be expected. Mr. Silverstein noted that it might be possible to calculate the approximate valve opening from the drag increase caused by flow through the inlet.

Dr. Lewis inquired as to what might be called the optimum valve opening. The Chairman stated that it was the objective of the group to obtain a valve that would open fully. In the discussion of the valves Mr. Turner noted that tests had been run with double size valves at 1200 rpm, but that the next step would be to test the valves at actual size at full speed.

The Chairman asked for a progress report from Mr. Pinkel's group on combustion work accomplished since the last meeting. Mr. Turner stated that Dr. Williams of the Fuels and Lubricants Division had obtained some interesting results in combustion tests he is running on another project. In tests of a conical combustion chamber with rear ignition, central ignition had been tried and the explosion report was of much higher intensity than with the regular rear ignition. This indicated that probably central ignition would result in greater powers than rear ignition in intermittent ram jet installations.

Mr. Turner sketched on the blackboard the layout of equipment his group was constructing for combustion tests. The air supply was from a 7,000 C.F.M. capacity blower and pressures up to approximately 40" water should be attained. The duct in which the valves were located was 9" square. The blower capacity would allow velocities up to 200 ft/sec in the combustion chamber. A glass window is to be incorporated in the top of the test unit to provide means for observing the valve motion. The length of the combustion chamber is to be full size and the area is to be 1/4 full size, to obtain the half scale combustion chamber previously agreed on.

Mr. Turner stated that the first type combustion to be tested is by ignition at the front and allowing the flame sphere to drift down stream and when the first sphere reaches the nozzle it should be of sufficient size to fill the opening.

Dr. Lewis inquired as to whether an analysis had been made of the effect of resonance on flow in the German unit. Mr. Silverstein stated that the resonant frequency was of the same magnitude as the frequency of the German unit on the basis of assuming the unit acts as an organ pipe of the same length.

There was some discussion on the effect of simplifying assumptions in calculating the organ pipe frequency of the German unit.

Dr. Lewis stressed the importance of the time element in obtaining results for the Army and Navy projects. It was suggested that results obtained within two months would be of great interest but the results obtained in eight months might be too late to be of interest.

Mr. Turner gave a brief review of the construction status of the combustion test apparatus. Delivery of the glass window appears to be the greatest delaying factor but according to quoted delivery time, the glass should be available in a little over two weeks.

The tests to be run in the test cell of the Jet Propulsion Building on the Ford-built German type unit were discussed. It was noted that the air and fuel consumption of the unit were the most important factors according to Colonel Keirn.

Mr. Rothrock described some fundamental combustion tests carried out in the Fuels & Lubricants Division. Gaseous mixtures had been burned in a very short distance with low pressure drop. Combustion air was separated from the main air flow, mixed with the fuel, ignited, and then combined with the main air stream after combustion was completed.

One of the prime objectives of the combustion research was to determine means of vaporizing the fuel to a gaseous state in order to obtain better combustion.

The meeting adjourned at 10:45 a.m.

Jesse H. Hall
Secretary Ram Jet Committee

JHH:lmk

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Revised Minutes of

RAM JET CONFERENCE

August 29, 1944

The Committee met in the Executive Conference Room at AERL on August 29, 1944, at 9:15 a.m. Present:

G. N. Jacobs, Chairman
O. V. Echey
Abe Silverstein
V. Richard Turner
Wm. Pereraisen
B. Pinkel
A. E. Kunen
R. H. Kastis
H. D. Johnson
J. H. Hall, Secretary

The minutes of the previous meeting were read and corrections made as shown on revised page 2.

The progress made on the project for development of a missile since the special meeting on August 24, 1944 was reviewed. Mr. Silverstein sketched a design his group had worked out using a Whittle type unit mounted behind the war head and fuel tanks. The air was taken in at the nose and was ducted over the outside of the war head and fuel tank back to the power unit.

Mr. Silverstein pointed out that with this arrangement a greater length was available between the c.g. and the tail than was the case with the previous two designs considered and should result in better stability. The designs shown had a 25 foot overall length. Mr. Pinkel suggested the use of a glider fuel tank or dropable wing tips incorporating fuel tanks for increasing range. The suggestions were discussed and it was agreed that the use of dropable fuel tanks or glider tanks did not appear promising with the range given in the directive but should be given serious consideration if the range was increased to the order of 1,000 miles. Mr. Silverstein stated that his group would make some calculations on the use of dropable fuel tanks.

The Chairman at this point gave a brief review of the Jet and Turbine Power Plant Committee discussions concerning development of the missile for the Army at the August 23, 1944 meeting. As a result of action taken at the meeting Allis Chalmers, Westinghouse, and General Electric are investigating the possibilities of simplification of their jet propulsion units with the idea of increasing production. The Chairman stated that Colonel Keirn was scheduled to be at the laboratory on September 1 and that at that time a meeting of the Ram Jet Committee to include only members would be held for the purpose of arising the details so that the work on the mock up to be tested would proceed.

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Mr. Rothrock came into the meeting at this point, the Chairman read a letter from Dr. Barnard to the Washington Office stating that it was his belief that the Germans were using higher alcohols or ethers (possibly from Fischer synthesis) as the fuel for their robot bombs. This belief was based on the characteristics of the robot bombs that Dr. Barnard had observed from the fuel tank of one of the robot bombs that had been brought to this country. Mr. Rothrock was asked by the Chairman to comment on Dr. Barnard's observations. Mr. Rothrock replied that Dr. Barnard's statements that conventional higher alcohols or ethers on the basis of heating, but that the higher alcohols or ethers have a greater range of combustible fuel air ratios was [illegible].

It was agreed that range of combustion mixtures was an important consideration in the general program of research. A discussion followed on the combustion problem and burning at lean mixtures. It was agreed that ordinary gasoline should be employed as the fuel to be used in the Army missile. Mr. Rothrock agreed to prepare a reply to Dr. Barnard's letter.

The Chairman stated that the Bureau of Ships had asked the Standard Oil Company of New Jersey to carry out fundamental research on combustion. A copy of the proposed research program was turned over to Mr. Rothrock by the Chairman for his information. Mr. Rothrock left the meeting at this point.

The Chairman read a letter from the Washington Office assigning Research Authorization R-110 to cover design studies, R-111 to cover construction of test units and R-112 to cover testing on the Army project. The letter requested outlines to cover proposed work under Research Authorizations R-111 and R-112 by September 6, 1944.

The Chairman reviewed some information he had obtained from Colonel Zeirn on the results of tests Wright Field had made on the German robot bombs. The fuel rate was stated to be 2800 pounds per hour at 400 miles an hour with a little drop in fuel rate with speed. The gross thrust at 400 miles an hour was stated to be 820 pounds corresponding to 850 thrust horsepower. Net thrust was given as 410 pounds at 400 miles an hour and increasing to 650 pounds at 200 miles per hour. Drag measurements at 400 miles an hour showed 375 pounds drag with flow and 200 pounds drag with the unit sealed in the cleaned up condition and 440 pounds drag with flow and 315 pounds drag with the unit sealed in the dirty condition.

Several discrepancies between the Wright Field data and the data obtained from the British were discussed but no conclusion could be made because of the lack of information on test conditions and methods used.

It was agreed that the tests to be run at this laboratory would be with a faired nose and tail and that the power plant would have to overcome this amount of drag as tare and that net thrust would be used in calculations made by the laboratory.

-3-

Progress made since the last regular meeting on valve designs and combustion chamber studies was reviewed. Mr. Johnson reported on tests that had been made of the valve according to Mr. Jacob's proposal of .015 inch steel. The valve opened approximately 1/2 of the full opening and could be taken through the critical speed at which the valve vibrated at 2800 cycles per minute. Valve vibrations started at an entering air velocity of 200 feet per second and steadied down at around 240 feet per second. Valve thicknesses down to .008 of an inch will be tried in this valve design. The second valve design being tested by Mr. Silvertooth's group had been made with .004 inch stock and 3/4 inch effective chord length. No flutter was encountered in the tests but it was believed that the stock used was too heavy and further tests will be made using .005 inch stock and .002 inch stock.

Mr. Mutterperl stated that the intermittent-flow apparatus being made up by his group will be ready to demonstrat by the next meeting. Mr. Kunen reviewed some calculations he had made on the constant volume cycle using assumptions considered to be practical. Curves were presented showing the effect on efficiency of combustion time. An efficiency of 7.0% attained with a .002 of a second combustion time was reduced to 6.0% efficiency with .008 second combustion time. The objective of the study was to determine the effect of the time element of the different cycle phases on combustion chamber length. The study showed that a combustion chamber length of over 4 feet in length was not necessary from an efficiency standpoint.

Means for taking care of high decelerations encountered in valve operation were discussed. This included the use of rubber seat, resilient seat construction, resilient valves and grids made of plastic with proper resilient properties.

Mr. Turner reported on a twin system spring loaded valves designed with the valves connected by a linked system.

The problem of getting up combustion testing equipment in a minimum time and the scale to be used was discussed by the group. It was agreed that a unit similar to the German unit with valves that would close very rapidly should be used as a single shot system. The scale should not be less than 1/2 size. The Chairman asked Messrs. Pinkel, Schey and Rothrock to meet in his office after lunch for the purpose of determining the best location for the combustion test setup.

The meeting adjourned at 11:50 a.m. when Mr. Schey reported that the reciprocating piston unit was ready for demonstrating valve tests.

James H. Hall,
Secretary Ram Jet Committee

JHH:jmk

RAM JET CONFERENCE

August 24, 1944

The Committee met in the Executive Conference Room at ASNE on August 24, 1944 at 10:30 a.m. Present:

[illegible], Chairman
[illegible] Schey
[illegible] Kmen
[illegible] Mutterperl
Richard Turner
[illegible] Peterson
Benjamin Pinkel
[illegible] Mutterperl
[illegible] D. Johnson
[illegible] F. Hall, Secretary

The Ram Jet Committee added a special session for the purpose of discussing proposals to meet the Army's specifications for a missile.

The Chairman asked for a progress report concerning the results of the survey made by each of the three groups. Messrs. Pinkel and Turner stated that their survey showed that four German units could be used if the range is 400 miles or under. For most ranges over 400 miles it is their opinion that the Whittle type unit should be used.

Mr. Kmen stated that a survey he had made indicated that the Whittle type unit would be the most desirable if the range was 400 miles or over. Mr. Mutterperl stated that his calculations showed the Whittle-type unit as being best for most ranges and would come nearer to meeting high-speed specifications than any arrangement with the German type unit.

Mr. Silverstein stated that it was his opinion that 550 miles per hour may be a little high even with the Whittle unit.

Mr. Mutterperl presented a chart showing performance factors and means for meeting the performance factors, utilizing various power plants, including conventional engines, jet engines, and steady and intermittent flow ram jets.

Mr. Silverstein stated that his group was studying front and rear positions for the power unit installation.

Mr. Mutterperl showed a layout that he had made with the Whittle unit located at the rear using an annular inlet and axial jet. The second layout which he had started was shown with the Whittle unit located in front and the discharge made in the form of segments of an annulus. The location and arrangement of the discharge had not been completed on the layout. The possible losses and other factors involved in the discharge jets for this installation were discussed. The maximum diameter of the fuselage for the two layouts was 43 inches.

Estimated figures on the proposed design include 1,700 pounds fuel, 9,000 pounds gross weight, 12% overall thermal efficiency and 1.14 pounds fuel consumption per thrust horsepower hour and a range of 400 miles.

Calculations will also be made on the designs for ranges of 400, 700 and 1,000 miles. Mr. Mutterperl noted that in making the design study assumptions involving drag and take off were considered questionable.

The specific proposal to be submitted as a recommendation was discussed and it was agreed that the Whittle type unit was the most desirable propulsion unit in view of the specifications laid down and further studies would be made on the unit designed along the lines followed in the layout shown by Mr. Mutterperl.

The meeting adjourned at 11:15 a.m.

Jesse H. Hall,
Secretary, Ram Jet Committee.

JHH:imk

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RAM JET CONFERENCE

August 22, 1944

The Committee met in the Executive Conference Room at AERL on August 22, 1944 at 9:15 a.m. (Present:

R. N. Jacobs, Chairman
Dr. George W. Lewis
Edward H. Sharp
Oscar W. Schey
L. Richard Turner
Wm. Heiereisen
Abe Silverstein
Benjamin Pinkel
W. Mutterperl
R. E. Littell
Carlton Kemper
Jesse H. Hall, Secretary

The minutes of the previous meeting were approved as read. Mr. Mutterperl, however, had a correction to a statement he had made which was recorded in the minutes of the previous meeting. The value of 27 cycles per second frequency for Mr. Jacobs' valve design should have been given as 100 cycles per second.

The Director of Research reviewed projects received by the Committee from the Army and Navy for research on ram-jet installations. The Navy project had only one specification, which was to keep the diameter down to 20 inches. Steady-flow and intermittent-flow ram jets are included in the Navy request. The Army has requested research on a specific installation. The Army request is for research that will lead to development of a missile that will have a range of 400 miles at 650 mph, and will carry a 4000 pound war head. As a result of the Army request, Dr. Durand called a conference in Washington to discuss the proposed research. The research is to include power plants that obtain oxygen from the air and is, therefore, not to include rocket propulsion. The aerodynamic aspects of the Army project will be worked out by LMAL. Mr. Jones of LMAL has carried out research which has resulted in improvement of the stability and control of the missile.

The Director suggested that the first phase of the Army project should be a survey of the possibilities of attaining the specifications as laid down, and to determine the approximate size and cost of a missile that will meet the specifications. Dr. Lewis noted that the German robot bomb was estimated to cost $5000.00.

Dr. Lewis stated that he had recently talked with Mr. Coombs about tests of the German robot bomb at the Royal Aircraft Establishment. Mr. Coombs stated that the unit had overheated on ground tests. Mr. Jacobs stated that Wright Field had used a blower at the inlet for their tests which had an annular slot to give a jet of cooling air over the outside surface with satisfactory results.

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The Chairman asked for a progress report from the various groups. Mr. Mutterperl reported on some calculations he had made on the effect of loss of q in the inlet system. His calculations showed that with .885 percent q, and one slug of air per second, 1750 pounds thrust could be obtained, which would give 8.44 percent thermal efficiency at 500 mph. With 0 (zero) q, the thrust was reduced to 1350 pounds, and the efficiency to 6.65 percent. Corresponding fuel consumptions were 1.65 pounds per thrust horsepower-hour, and 2.07 pounds-per-thrust-horsepower-hour, with .85 q and 0 (zero) q respectively. A model of a valve, built in accordance with the design Mr. Mutterperl had shown at the meeting of August 15th, was shown. Mr. Kunen reviewed the progress that had been made on the design and construction of the reciprocating piston test unit for inlet valves. Two valve designs that had been worked out by Mr. Kunen's group during the past week were presented. In one of the valve designs, the valve was designed to bend during the high pressure period, and with a rapid decrease in pressure, the energy stored by bending would be released to assist in rapid opening of the valve. Mr. Pinkel stated that it was his belief that the pressure drop would be too slow to obtain good results with this design feature.

At this point, Mr. Schey inquired of the Director of Research as to what priority should be assigned to the ram-jet projects. The Director stated that the research should carry an A priority but should be considered along with other A priority projects.

Dr. Lewis stated that Colonel Keirn had just called and that the first Ford built unit would be ready in a day or two. It was suggested that it would be very desirable to get one of the Ford units for tests in the Altitude Wind Tunnel and for Colonel Keirn to visit the laboratory to discuss the tests. Mr. Silverstein noted that the tunnel was at present closely scheduled.

Mr. Turner reviewed progress that had been made on the twin system designed by his group. He stated that obtaining proper timing was a difficult problem. Attempts were being made to avoid low pressure suction in the system, but low pressure suction may be necessary at low speeds. Strenous efforts are being made in the design to get a full charge. Mr. Turner stated that long nozzles would be beneficial for slow speed operation. Mr. Jacobs inquired as to the extent of losses that might be anticipated with long nozzles. Mr. Turner stated that in tests he had conducted with long nozzles on single-cylinder exhaust pipes, there had been little loss in mean jet velocity with length. Mr. Kemper inquired as to what lengths had been used. Mr. Turner stated that lengths up to 4 feet had been tested. Mr. Turner noted that in the German design, the combustion-chamber-to-tail-pipe air area ratio was approximately 2, and that with 2000 ft/sec nozzle velocity, ram pressures could not maintain proper combustion chamber velocities. With an area ratio of 4:1, approximately two times the power should be obtained with only a small increase in overall diameter.

The Director raised the question as to whether the work was leading away from good ground operation to attain optimum operation at high speed. It was agreed that this point was well taken and the suggestion was made that a jettisonable tail pipe be used to improve ground operation. The Chairman

asked for quantitative statements on the improvements that appeared possible over the performance of the German unit. Mr. Pinkel stated that it appeared possible to get from 4 to 5 times the power at twice the efficiency. Mr. Mutterperl stated that efficiencies of the order of 8-1/2 percent appeared obtainable in comparison with 3 percent of the German unit. The Chairman stated that it was the objective of the group to get as close to the theoretical performance as possible by an experimental approach and in accordance with the general objective as previously stated. A specific installation had been requested on which to work and now had been received. The Chairman read the letter that had been written by the Washington Office to this laboratory concerning the research to be conducted on the proposed missile for the Army. A copy of the letter from the Army to the Washington Office, setting up the requirements, was also read. The Chairman reviewed several methods of attack on the power plant installation that could be used to meet the Army requirements. Types mentioned were the Whittle type, the continuous ram jet, and a Chinese copy of a German unit.

The next meeting of the group was set for Thursday at 9:00 a.m. The three groups were requested to survey the different possibilities of meeting the Army requirements and make sketches by the next meeting. Preliminary estimates for the group to work on included 9000 pounds gross weight with a thrust of 1200 pounds and possibly up to 1500 pounds needed to attain the 550 mph velocity requirement.

The meeting adjourned at 11:26 a.m.

Jesse H. Hall

Jesse H. Hall,
Secretary Ram Jet Committee

JHH:db:imk

RAM JET CONFERENCE

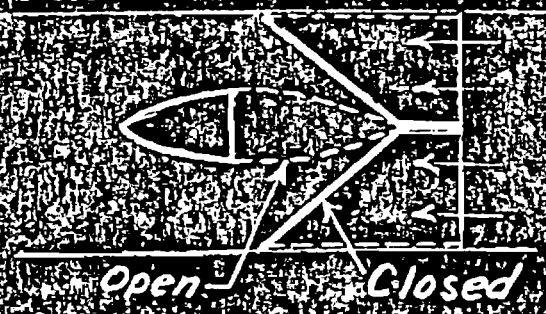
August 15, 1944

The Committee met in the Executive Conference Room at AERL on August 15, 1944 at 9:15 a.m. Present:

E. N. Jacobs, Chairman
Benjamin Pinkel
L. Richard Turner
O. V. Schey
W. Mutterperl
A. D. Johnson
A. E. Kunen
J. H. Bressman
Carlton Kemper
J. H. Hall, Secretary

The minutes of the meeting of August 8, 1944 were approved as read.

Progress made on valve designs and tests was reviewed. Mr. Mutterperl reported on the results of the test his group had made on their own design and the model supplied by Mr. Jacobs. The valve design made up by Mr. Mutterperl's group was destroyed by flutter early in the tests. The test results on the valves supplied by Mr. Jacobs showed comparatively high pressure losses. A valve design based on the two valves tested was sketched on the board as shown in the following sketch:



Mr. Mutterperl stated that a valve of this design would be made up and tested.

Mr. Kunen discussed the results of further calculations on the valve design he had shown at the previous meeting. The spring constant was found to be high because of the inertia of the valves used in the design and revisions were made to reduce the inertia of the moving parts, but the reduction in inertia by the revision was not considered sufficient to make the design promising. Mr. Jacobs suggested that valves should be designed to utilize the inertia effects to throw the valves open if possible.

A discussion followed on the possibilities of the use of a combination of valve frequency and inertia to accomplish better valve operation. The effects of losses in q and charge efficiency caused by inlet valves was discussed.

Mr. Turner showed drawings of a twin system using a common inlet and the linkage

system between two sets of valves. The explosion pressure from one combustion chamber in this design is used to open valves in the second combustion chamber. The explosion pressure is used to set springs in the linkage that are triggered by small motion of the valves on opening to rapidly complete the valve opening to the full open position. The group agreed that this valve system offered many advantages but that simple valves would be given first consideration. The construction of the more complicated valve system would proceed in order to be ready for test later in the program.

Mr. Johnson gave further details on the valve tests previously reported by Mr. Mutterperl. He described the type of flutter encountered in testing valve design submitted by Mr. Jacobs at all velocities of 80 ft/sec and 250 ft/sec. A frequency of 80 ft/sec was stated to be approximately 1650 cycles per minute. Mr. Kunen raised the question as to whether frequency of the order of 27 cycles per second in steady flow tests should be considered objectionable. It was agreed that a valve should not be thrown out on this score until it had been submitted to intermittent flow tests.

Mr. Kunen discussed the design, on which his group was working, of a valve test chamber mounted in place of the cylinder head on a single-cylinder engine to utilize the reciprocating piston of the engine for intermittent flow testing. The design included a throttle valve downstream from the rectangular test section. The valves under test were bolted on the front of the test section and glass windows were provided to observe valve motion.

Progress during the week on combustion chamber designs was next discussed. Mr. Mutterperl discussed an analysis he had made on a ram-jet system designed to handle one slug of air per second. Fifty cycles per second and 2000° F mean temperature were assumed. This resulted in a combustion chamber having a volume of 7 cubic feet, exit area of .62 square feet, inlet area of 3 square feet, and with dimensions of 24 inches diameter and 28 inches long. Combustion chamber velocity was 200 ft/sec. The performance of this unit at a fuel-air ratio of .032 was 1700 pounds thrust with a fuel consumption of 1.65 pounds per thrust horsepower hour at 500 mph and over-all efficiency of 8.4 percent. This compared with 1066 pounds net thrust and 6.84 percent efficiency for the Whittle-type unit.

The Chairman asked for a discussion as to what velocities would be desirable in the combustion chamber. A discussion followed on combustion chamber velocities and the effect of this velocity on combustion and efficiency of the cycle. It was agreed that compromises that serve to increase losses, in order to improve combustion, should not be made until proven necessary. Tests on combustion chamber designs would be made to determine limiting velocities that could be allowed from a combustion standpoint. Mr. Turner suggested that combustion should be started from a series of sparks along the axis of the combustion chamber. It was pointed out that flames started by a spark could move with the stream and still constitute satisfactory combustion. This was contrasted with the steady flame that must be maintained in the steady-flow type of ram jet.

The size of combustion chamber and its relation to exit area was discussed. Mr. Mutterperl stated that his group was considering an area ratio of 5:1, and Mr. Turner stated that his group was considering an area ratio of 4:1. In the discussion of the various velocities in the system, it was pointed out that entrance velocities of 200 ft/sec at 500 mph could be used and still maintain pressure recovery between 80 and 85 percent q_c. It was agreed that combustion chamber velocities should be of the order of 200 ft/sec or higher provided efficient combustion could be attained.

Mr. Pinkel showed a drawing of a test setup to study combustion chamber design. The setup consisted essentially of a mount for a complete unit with means for measuring thrust and a source of air at pressures up to 40 inches water with a surge chamber mounted just immediately upstream from the unit on the test. The unit would be mounted vertically and would, therefore, allow fuel to drop into the surge chamber in the event of leaks occuring when the unit was not in operation. The possibility of explosions occuring in the system and means for prevention or control of such an explosion to render it harmless were discussed at length. Mr. Pinkel is to submit the proposed setup to the Laboratory Safety and Security Committee for recommendations. The possibility of mounting the proposed test rig in a horizontal position is also to be looked into.

During the next week, the group is to continue work on combustion problems and is to study possibilities of using a single-shot system or other schemes that will allow getting combustion tests under way as soon as possible.

Jesse H. Hall

Jesse H. Hall,
Secretary,
Ram Jet Committee.

JHH:db

RAM JET CONFERENCE

August 8, 1944

The Committee met in the Executive Conference Room at ATSC on August 8, 1944 at 9:15 a.m. Present:

L. H. Jacobs, Chairman
Benjamin Pinkel
L. Richard Turner
O. W. Schey
A. M. Rothrock
W. Mutterperl
A. D. Johnson
A. E. Kunen
Wm. Peiereisen
J. H. Hall, Secretary

The minutes of the meeting of August 1, 1944 were approved as read.

Progress made during the preceding week on inlet-valve designs was reviewed. The discussion concerned the question of what is desirable in valve designs and drawings and models of proposed valves. Mr. Kunen stated that he felt that automatic valves should be considered first, but with spring-loaded automatic valves, the losses would likely be high. Mechanical designs to get around this loss were being considered by his group. Mr. Pinkel suggested that the spring-loaded valve offers too much restriction if operated from pressures existing during the charging part of the cycle. He pointed out that the valves should be operated by the explosion pressure, but that a time lag would be involved which indicated the need for energy storage. Mr. Turner stated that his calculations showed that an area greater than two-and-one-half times the exit nozzle area was required on the inlet side for good charging.

Mr. Mutterperl exhibited a model of an automatic valve which he stated would open with a q equivalent to three inches water existing at the leading edge. Mr. Kunen presented a drawing of a valve design consisting of air foils pivoting back of the leading edge and held shut by coil springs. Mr. Kunen stated that with his design after a small movement of the air foils had taken place, the airfoil lift assisted in opening, and when the velocities dropped, the loss of lift allowed the springs to close the valve. Mr. Turner pointed out that with sealing at two points with a pivot between, as used in Mr. Kunen's proposed valve, a difficult problem arose, because contact at one edge, with clearance at the pivot, would allow opening at the other edge. Mr. Schey stated that a small amount of spring action at the contact edges could be used to compensate for clearances.

At this point Mr. Jacobs briefly discussed the starting procedure of a German ram-jet unit which he had observed on a recent trip to Wright Field.

He stated that considerable difficulty was encountered in starting the unit and that the first explosion was very violent. From this observation, he stated that it was very apparent that valves to be used in this type unit must be mechanically strong to withstand the violent initial explosion.

Mr. Turner discussed calculations which he had made on valve acceleration impact. His calculations showed that valve motion with respect to acceleration and impact considerations attain optimum conditions in the range between 45 and 90° maximum movement. Mr. Turner presented drawings of two valve designs of the automatic type and stated that some work had been done on a mechanical design valve using Geneva type motion. Mr. Jacobs exhibited a model of a valve which was very similar to the German model except for a flap at the trailing edge made by bending the sheet stock used in the valve.

In the discussion of valve characteristics, Mr. Turner pointed out that full opening was needed to get good area ratio between inlet and exit. Mr. Mutterperl stated that full closure was necessary to prevent losses. In connection with the rapidity of pressure rise that might be attained for automatic valve closure, Mr. Jacobs said that pressure rises up to detonation were attainable.

At this time, Mr. Jacobs asked for comments as to which valves should be used in the first test. Mr. Schey suggested that simple valves should be tested first if these tests could be carried out rapidly and the designs ruled out if desirable. The group agreed with this suggestion.

In connection with the combustion part of the cycle, Mr. Jacobs stated that, in his opinion, the inlet valve should stay open until combustion started, to prevent loss in pressure between valve closure and start of combustion. He also stated that combustion should start at the back, or combustion should be completed very rapidly. The group concurred with these ideas. It was suggested that a twin system be used with ignition controlled by valve timing. Mr. Pinkel said this idea had been included in one of the designs by his group.

Work for the ensuing week by the various groups is to include further work to complete the valve designs believed most promising to the point where construction of the models could be started. Tests of valves are to be started as soon as the designs are completed and the valves can be constructed. The valves are to be static tested first to determine flow characteristics. After static tests are completed, tests will be made in a device utilizing a reciprocating piston downstream from the valves or other intermittent-flow schemes to simulate operating conditions.

The scale of the models to be used for flow tests was discussed. It was agreed that model sizes to be used in tests would be determined by the practical factors involved by the particular design, and that individual test groups would determine what size models to use with the general idea that actual operating conditions would be simulated as closely as practicable. Drawings and sketches of combustion systems are to be made by the various groups for presentation and discussion at the next meeting of the Committee. The Chairman emphasized the

need to get tests underway in order to get results as soon as possible. The ram-jet projects should be considered a full-time job for some junior staff members so that the projects will be kept moving.

The meeting adjourned at 11:30 a.m.

Jesse H. Hall

Jesse H. Hall,
Secretary, Ram-Jet Committee.

JHH:db

CONFIDENTIAL

RAM JET CONFERENCE

August 1, 1944

The Committee met in the Executive Conference Room at AERL on August 1, 1944 at 12:00 noon. Present:

A. H. Jacobs, Chairman
Benjamin Pinkel
L. Richard Turner
Abe Silverstein
A. D. Johnson
W. Mutterperl
O. W. Schey
A. E. Knuen
Carlton Kemper
Jesse H. Hall, Secretary

Visitors

Sir B. Melville Jones
H. S. Muir
B. Lockspeiser
R. K. Littell

1. The Ram Jet Committee met with Sir B. Melville Jones and Messrs. Muir and Lockspeiser as visitors in order to obtain any additional information that the British had available on the German robot development. Sir Melville discussed some of the work being carried out by the British on supersonic flight. He stated that a rocket with two cameras arranged to record the movement of the unit as it slowed down through the sonic range, had been built into a jet unit to obtain supersonic velocities. Another line of attack was to drop lead weights with small wings from 35,000 feet altitude with data being recorded by telemetering. The Miles Company is scheduled to build an airplane with thin wings and jet unit built by Power Jets, Ltd. Sir Melville stated that it was his private belief that the airplane would not attain speeds over 600 miles per hour but that some information would be obtained from the project.

2. Sir Melville stated that in order to get a ram jet in the air as soon as possible, a ram-jet unit was being installed in part of the cooling ducts of a Mustang. This project will be ready for test soon and may add 50 miles per hour to the top speed.

3. The Germans have laid down sites for launching robot bombs of the ten-ton size mentioned in the papers. Sir Melville stated that he had heard some talk of robot bombs as large as 80 tons. Mr. Muir read from his notes the information that he had obtained on the German robot bombs currently being used. He stated that some of the robot bombs were equipped with radio transmitters to enable the Germans to follow their course. The weight analysis made by the British showed 45 percent bomb load, 33 percent structure, and 22 percent fuel, power plant, and controls. The power plant was stated to weigh 400 pounds and the total weight 1,200 pounds. The wing loading was

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was calculated to be 57 pounds per square foot, and the stalling speed was estimated at 200 miles per hour from the calculated drag curves. The dive at the end of the flight was originally controlled by time clocks, but later models were believed to be equipped with an airlog on the nose to control the dive. Instead of coming in under power, some of the recent versions of the robot bomb glide in silently and then dive.

4. Information given on the ram-jet unit was that explosion pressure was between three and four atmospheres, the air flow from seven to nine pounds per [illegible] and the fuel consumption from three to four and one-half pounds per hour per pound of thrust. The thrust was estimated at 590 pounds at 400 miles per hour from calculated drag curves. The natural frequency of the valves was stated to be around 200 cycles per second, which was well above the operating range.

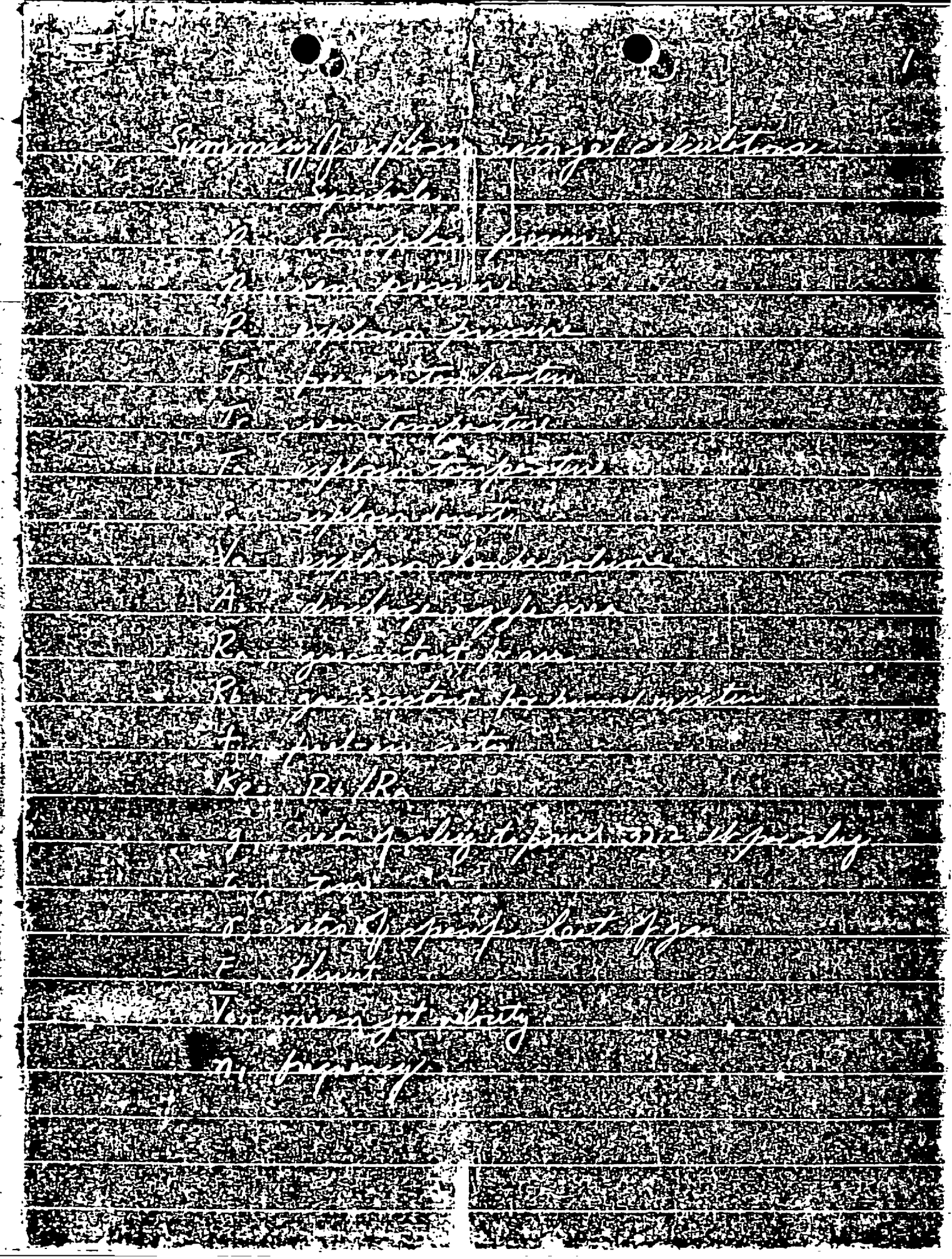
5. In combating the robot bombs, the British tried to shoot them down during the climb. The turn after takeoff occurs from three to four minutes after launching. About one-third of the units launched arrive in London. Quite a number are shot down by fighter planes and anti-aircraft, and recently, balloons have been used more effectively. In a ten day period, approximately 3600 were launched, of which approximately 1200 reached London, and approximately 2400 made land fall. Blast effect of the exploding bombs was said to be very bad, as the bombs were equipped with a very sensitive fuse, and would explode on contact with buildings well above the ground.

6. Mr. Jacobs stated that the laboratory was interested in the ram-jet cycle as a power plant installation, but would work on specific ram-jet installations for missiles if requested. Messrs. Turner, Hutterperl and Kunen discussed theoretical analyses which they had made on steady-flow and intermittent-flow ram-jet cycles. Mr. Jacobs noted after this discussion that if the theoretical performance is approached, the power and economy of the ram-jet approaches that of the Whittle type unit.

Jesse H. Hall

Jesse H. Hall,
Secretary, Ram-Jet Committee.

JHH:db



Combustion phase

Initial condition: air plus liquid fuel

Volume of fuel is assumed negligible

Initial temperature is at least room temperature plus any gain due to heat transfer from walls

T_a is given by a graphical solution of the equations of the first law of thermodynamics

$$e_a\Big|_{T_s}^{T} = -h_f f + \left[e_a + f\left(\frac{Am+B}{m+1}\right) + \{R_a - (1+f)R_b\}T \right]_{T_s}^{T_a}$$

where

e_a = internal energy of air

A, B = derived thermodynamic constants (Refineal)

m = hydrogen carbon ratio of fuel

For a combustion at constant pressure combustion

$$\frac{P_a}{P_s} = \frac{(1+f)K_2 T_a}{T_s}$$

the charging process being assumed to occur at fair air pressure and room temperature

Expansion phase or Flow phase

1) Expansion from combustion pressure to critical pressure for converging nozzle.

The thrust produced in this phase of the expansion is given by

$$I_1 = \frac{S_a V_a}{\gamma} \sqrt{\frac{2\gamma}{\gamma-1} g R_a T_a} \sqrt{\frac{\gamma-1}{\gamma+1}} \left\{ \frac{2\gamma}{\gamma-1} \left(\frac{\gamma+1}{2}\right)^{\frac{\gamma+1}{2(\gamma-1)}} \left(\frac{p_1}{p_0}\right)^{\frac{\gamma-1}{2\gamma}} - 2 - \frac{2}{\gamma-1} \left(\frac{\gamma+1}{2}\right)^{\frac{\gamma+1}{2(\gamma-1)}} \frac{p_1}{p_0} \right\}$$

2) Expansion from the critical pressure to some lower pressure.

The thrust impulse produced in the phase of the expansion is given by

$$I_2 = S_a V_a \sqrt{\frac{2\gamma}{\gamma-1} g R_a T_a} \left(\frac{p_0}{p_a}\right)^{\frac{\gamma-1}{2\gamma}} \int_{\left(\frac{p_c}{p_a}\right)^{\frac{\gamma-1}{\gamma}}}^{\left(\frac{p_0}{p_a}\right)^{\frac{\gamma-1}{\gamma}}} \sqrt{Z^2-1}\, dZ$$

The integral of this function is displayed in figure 1 for $\gamma = 1.13$ and 1.12 as a function of p/p_0.

3) Flow at the same pressure to empty and charge the combustion chamber.

The thrust impulse developed during the phase of the expansion is given by

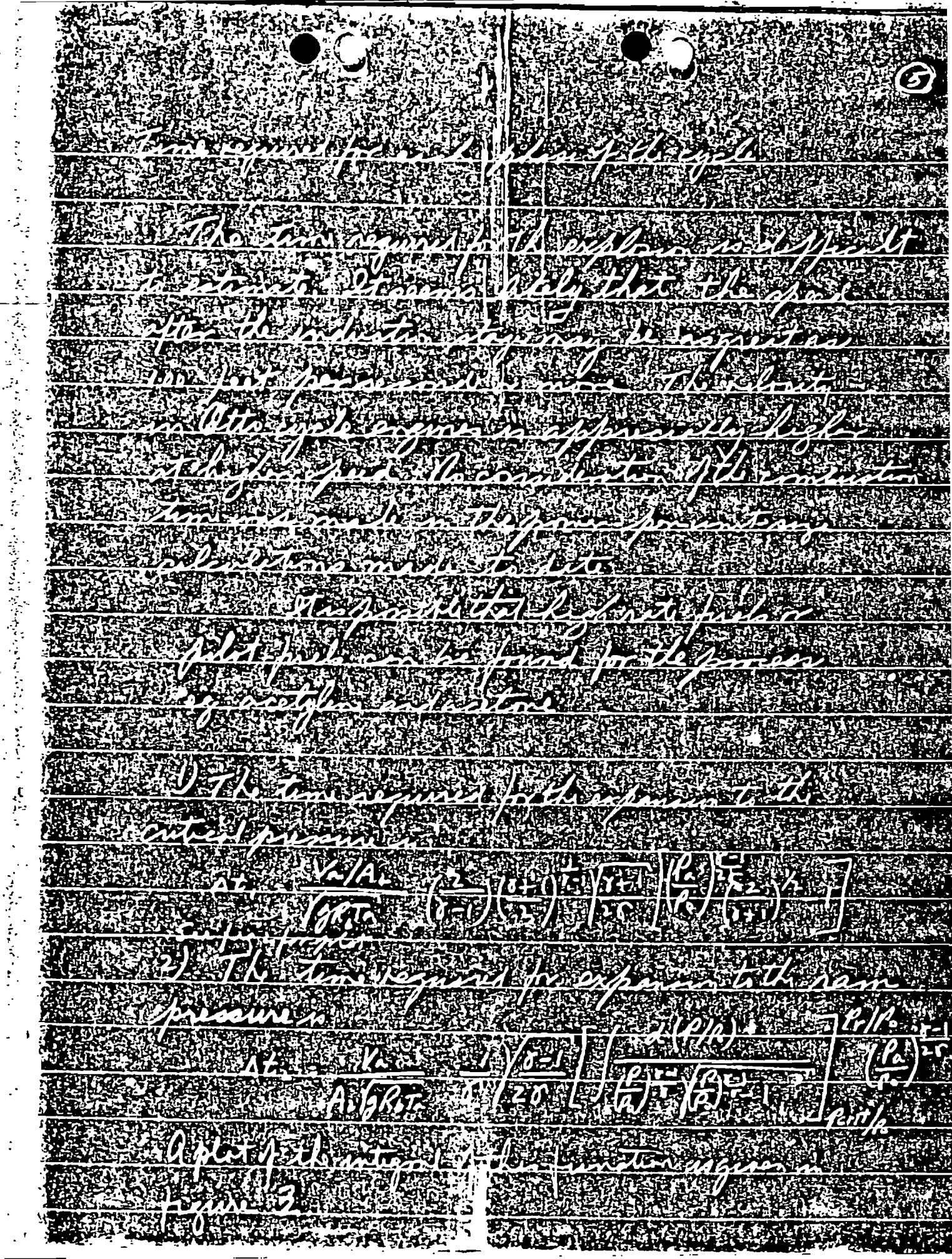
$$I_3 = S_a V_a \sqrt{\frac{2\gamma}{\gamma-1} g R_a T_a} \left(\frac{p_0}{p_a}\right)^{\frac{\gamma-1}{2\gamma}} \left(\frac{p}{p_0}\right)^{1/2} \sqrt{\left(\frac{p}{p_0}\right)^{\frac{\gamma-1}{\gamma}} - 1}$$

The mean jet velocity V_c is the total impulse $I_1 + I_2 + I_3$ divided by the total mass of V_a. In calculations it is convenient to divide each impulse term by the term $\sqrt{\frac{2\gamma}{\gamma-1} g R_0 T_0}$

For $\gamma = 1.3$

$$\frac{V_c}{\sqrt{\frac{2\gamma}{\gamma-1} g R_0 T_0}} = 0.5627 - 2.3463 \frac{p_a}{p_0} - 4.1145 \left(\frac{p_a}{p_0}\right)^{\frac{1}{\gamma}}$$

$$+ \left\{ \int_{(p_a/p_0)}^{\left(\frac{p_e}{p_0}\right)^{\frac{1}{\gamma}}} \sqrt{z^{\frac{\gamma-1}{\gamma}} - 1}\; dz + \left(\frac{p_e}{p_0}\right)^{\frac{1}{\gamma}} \sqrt{\left(\frac{p_0}{p_e}\right)^{\frac{\gamma-1}{\gamma}} - 1} \right\} \left(\frac{p_a}{p_0}\right)^{\frac{\gamma-1}{\gamma}}$$



The thrust is $M\Delta V$

$$\Delta V = (1+f)V_e - V_0$$

The thrust power in hp is then

$$thp = \frac{\varphi_0 A \sqrt{g \gamma B_0 T_0}}{N g R_a T_r}\left[(1+f)V_e - V_0\right]\frac{V_0}{375}$$

Valve timing of jet motor — Neglecting the time required for combustion the purging time divided by the total cycle time is given by

$$\frac{\Delta t_3}{\Delta t_1 + \Delta t_2 + \Delta t_3} = \frac{K_3}{\left(\frac{P_2}{P_a}\right)^{\frac{\gamma-1}{\gamma}} K_1 + K_2 + K_3}$$

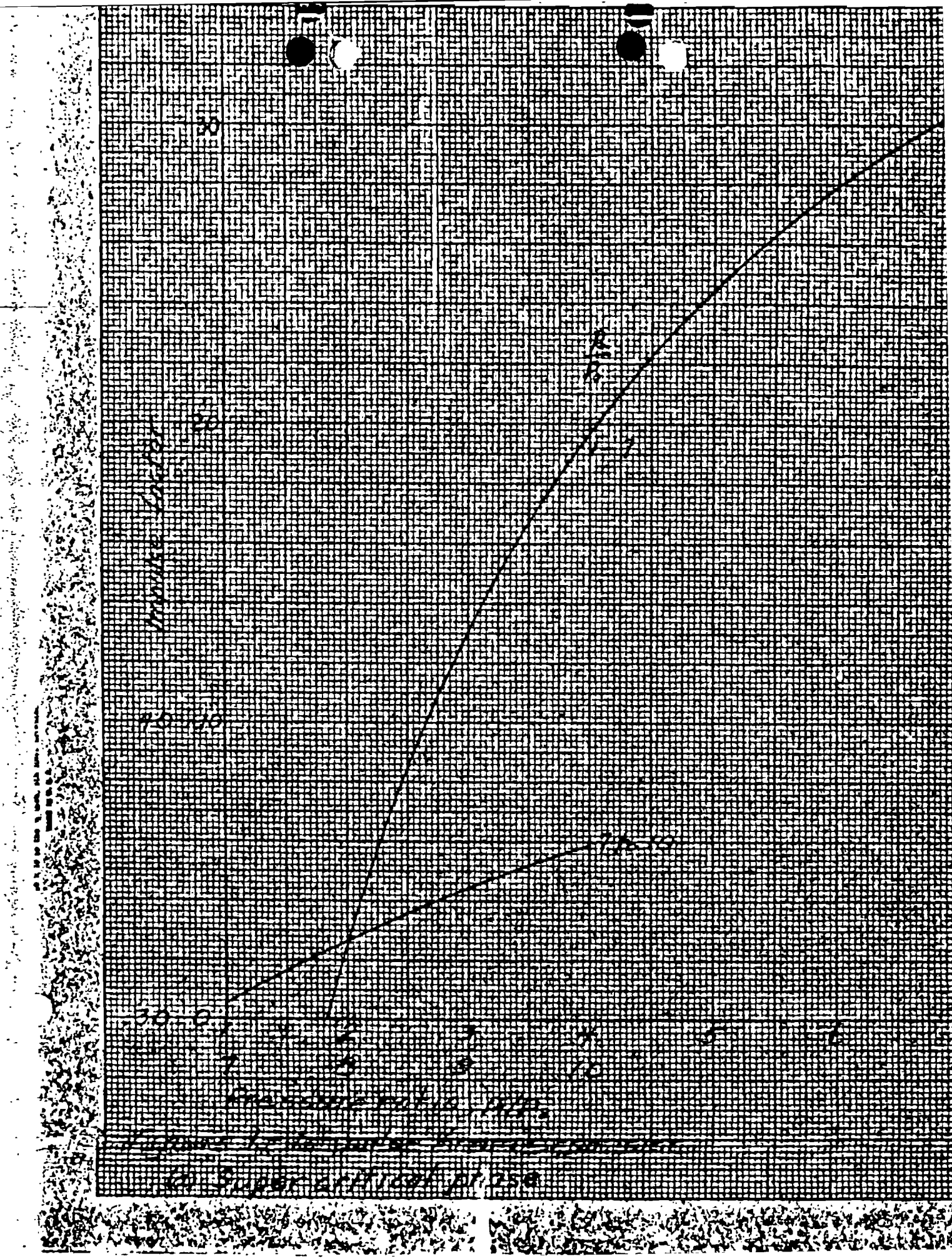
Where K_1, K_2 and K_3 are read from figures 12, 13 and 14 respectively.

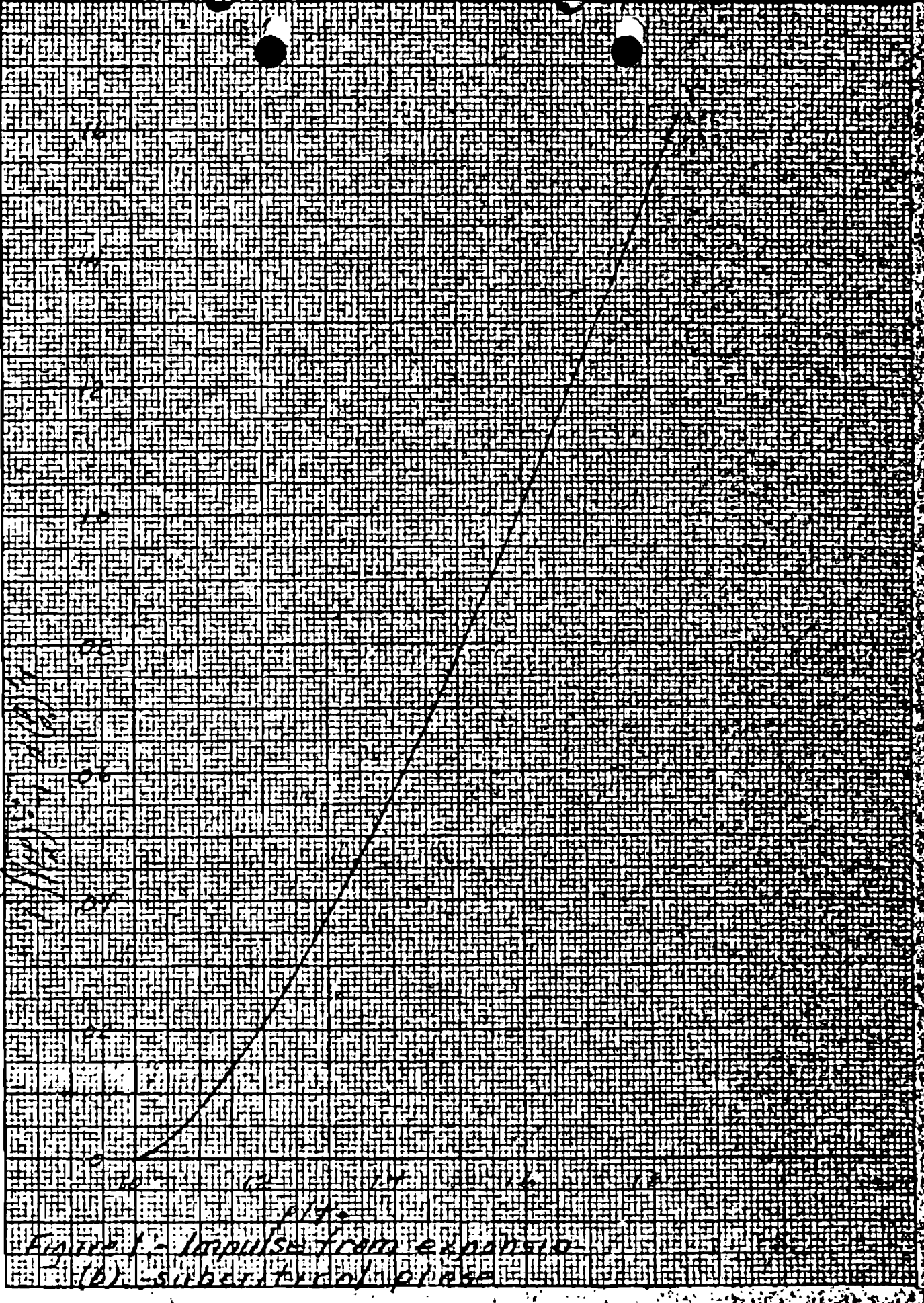
The ratio is shown in figures 5 for various values of [illegible] and [illegible]. The purging time is nearly independent of the [illegible] conditions rather than total cycle time except at very low air speeds. Apparently some means other than the ram will be required to at low speeds get satisfactory flow at lower air speeds.

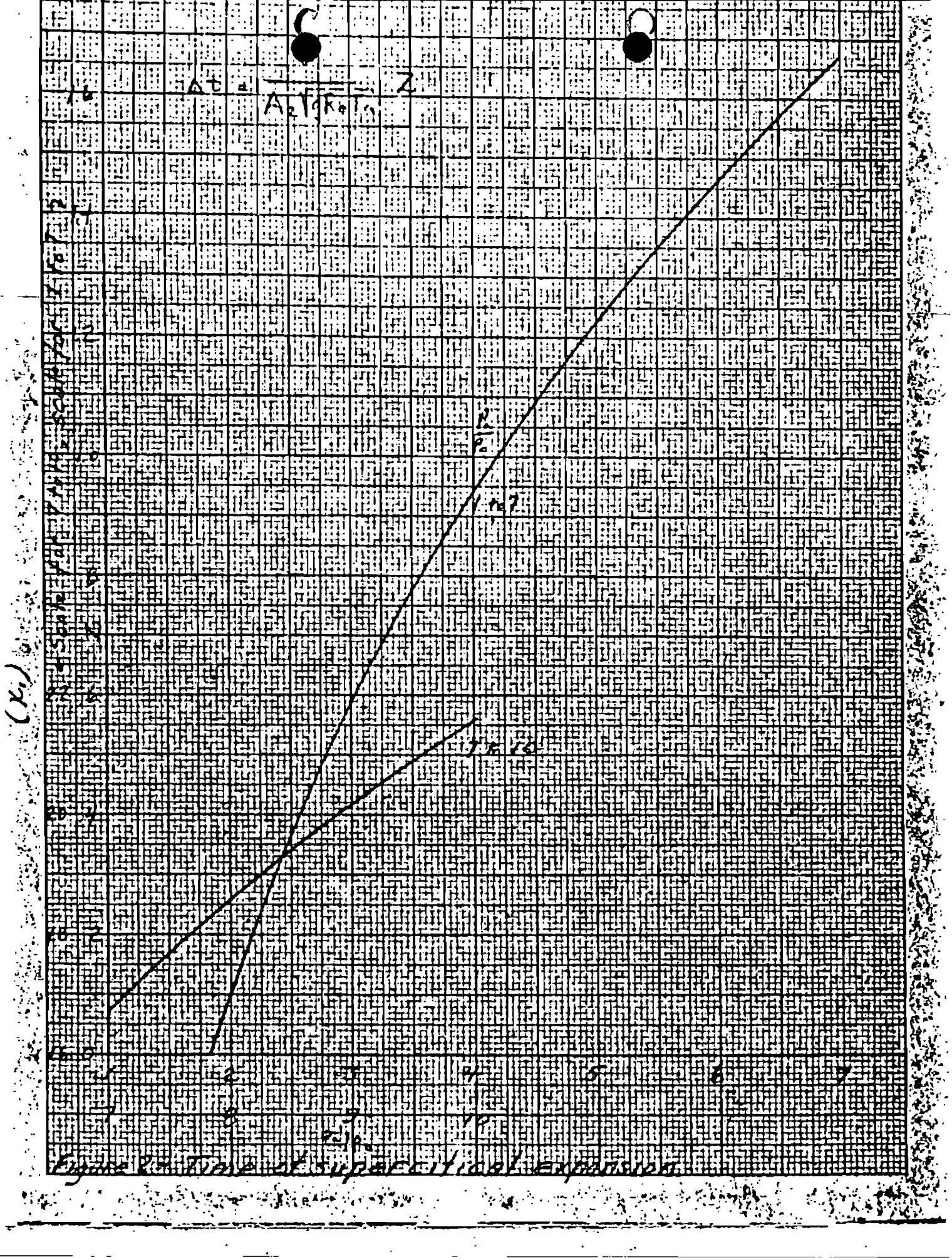
Figure 5 also shows the approximate capacity of the system. The volume capacity is of V at a constant fuel-air ratio which corresponds to nearly constant Ta and b.p. The frequency rises rapidly at low cruise speeds but is fairly constant above p.p. -1.2 which is approximately 400 mph.

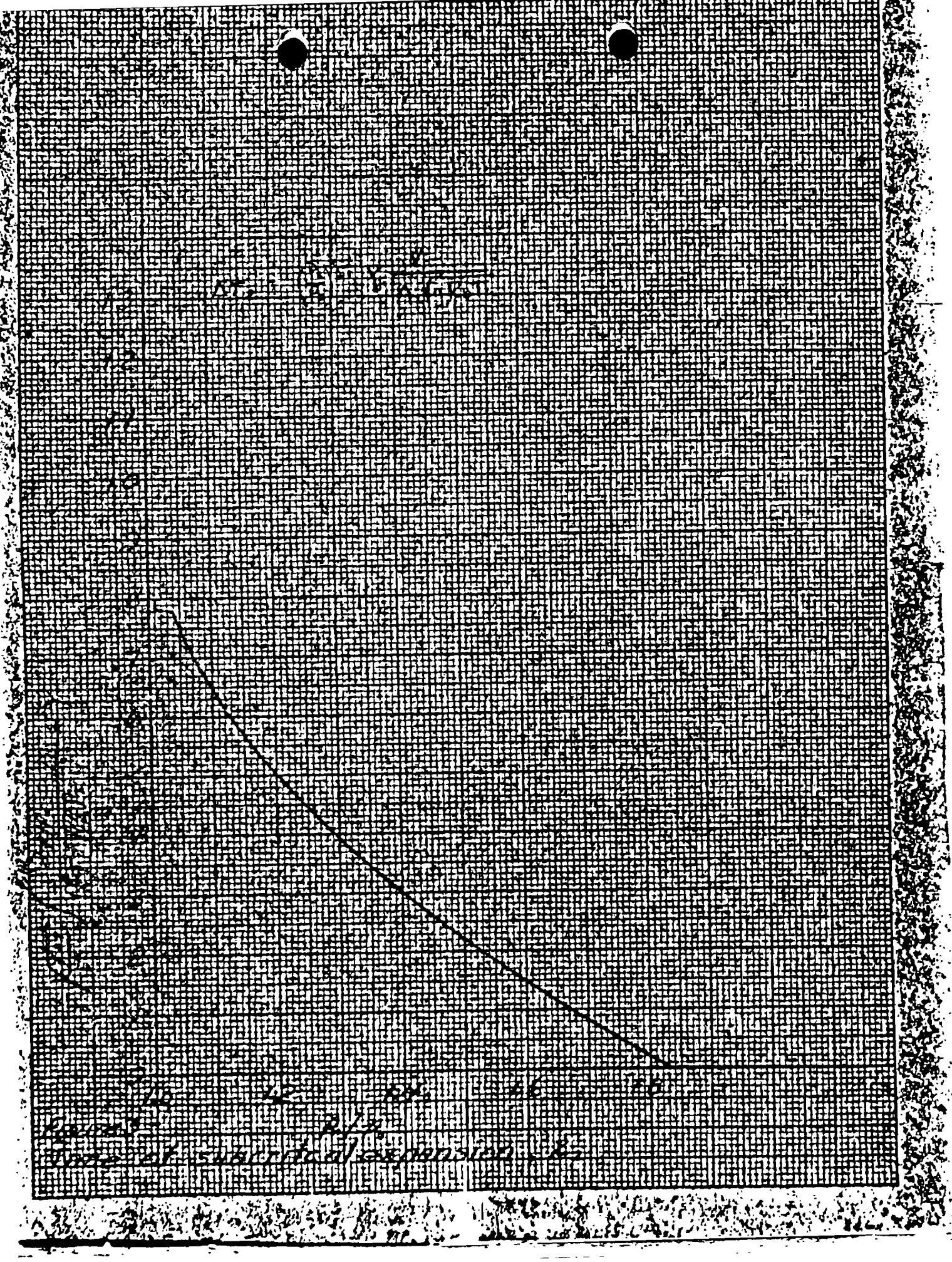
Therefore

The variation in frequency demands that a charging means be provided for low cruise speeds and that the valve system be substantially astatic.

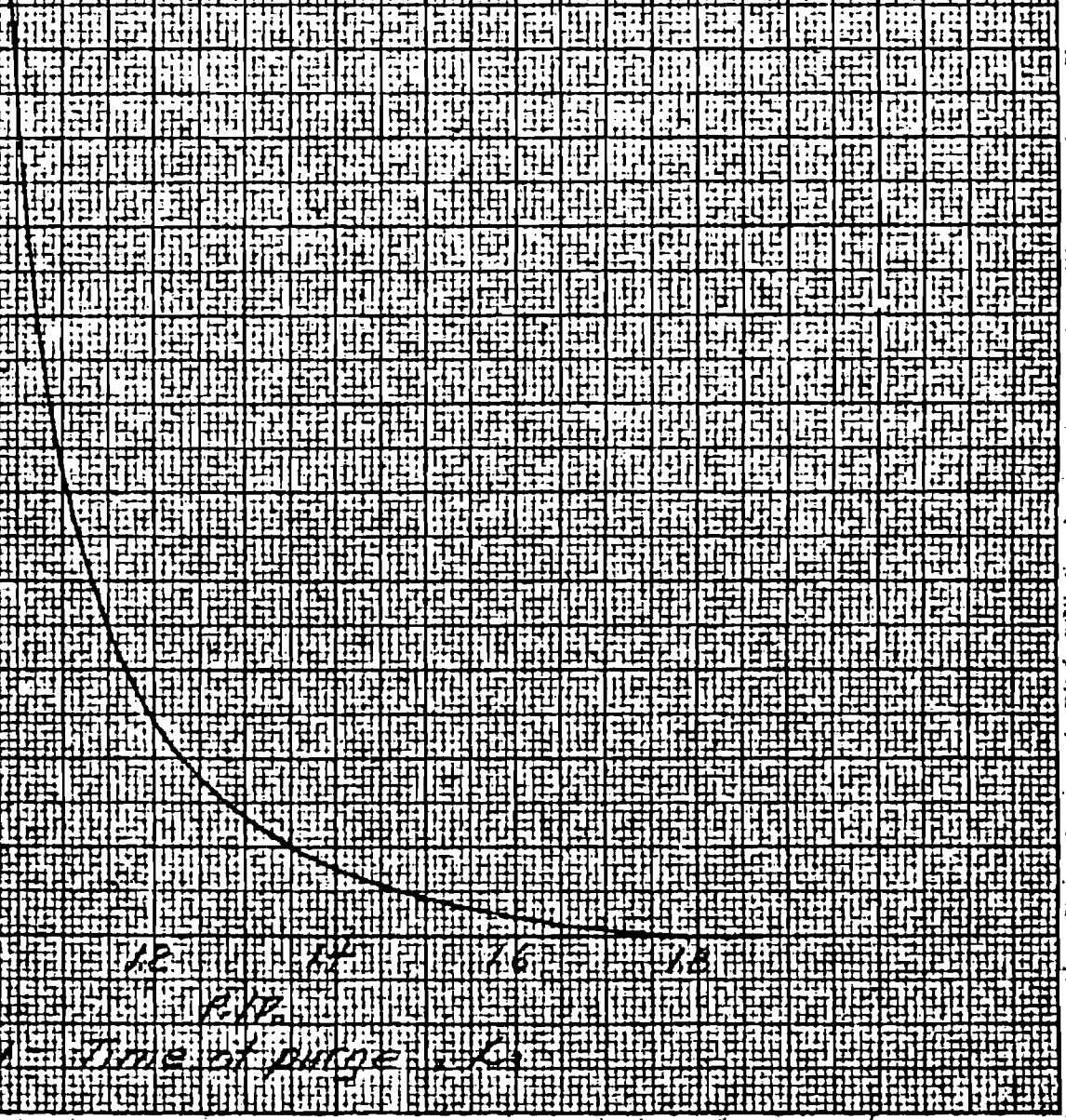








$$\Delta t_2 = \left(\frac{P_2}{P_0}\right)^{\frac{1}{\gamma}} W \frac{V}{A_t \sqrt{\gamma R T}}$$



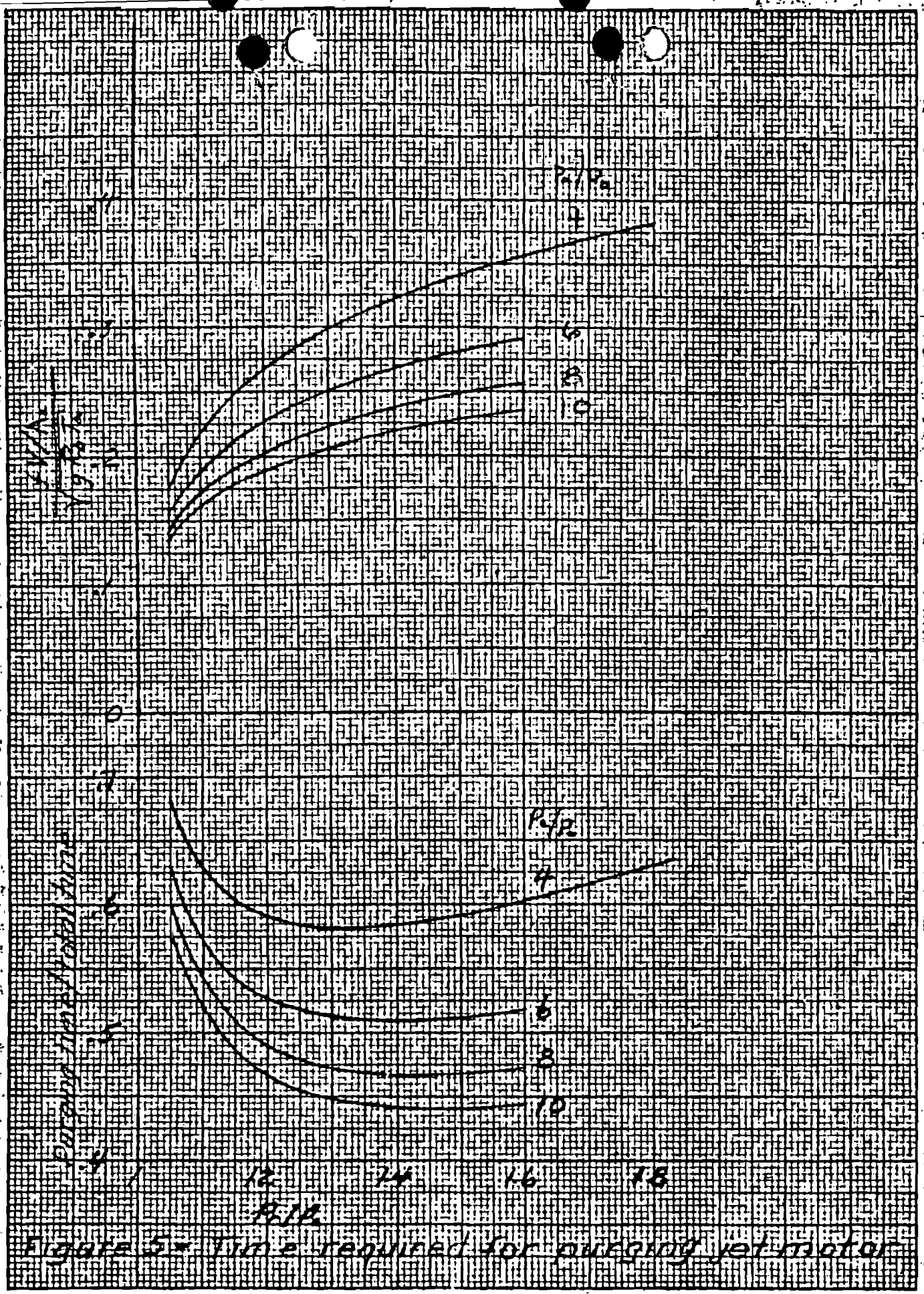


Figure 5- Time required for purging jet motor

Julius Rosenberg ET AL.

Referral

National

Aeronautics

And Space

Administration

No. 19

Appeal to: Mr. Miles Waggoner
Freedom of Information Officer
Nat'l Aeronautics & Space Admin.
Washington, D.C. 20546
Packet #19

REFERRAL

Reviewed by: esb / JSR

AGENCY Nat'l Aeronautics & Space Admin.

	Subject and File Number	Serial	Date	Document Description	No. of Pages Actual	Relea
1	Perl (HQ) 65-59312	416	5/19/51	HQ Letter to CV	2	2
2	Perl (HQ) 65-59312	431	6/4/51	CV LHM to HQ	9	9
3	Perl (HQ) 65-59312	444	6/7/51	NASA LETTER TO HQ	1	1
4						
5						
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TOP SECRET

~~SAC, CLEVELAND~~ May 19, 1951

DIRECTOR, FBI

32444

WILLIAM PERL, aka
William Mutterperl
ESPIONAGE - R
PERJURY

PERSONAL ATTENTION
STRICTLY CONFIDENTIAL

[redacted] B1

You are advised that with respect to the information appearing in reflet concerning the jet fighters, Mr. Robert Bell, Security Officer, NACA, has advised that his inquiries concerning this matter have developed that the information apparently refers to the P-80 fighter plane which was either in production or about to be placed in production as of August, 1944. It was suggested, however, that the information as indicated concerning these jet fighters may have appeared in a communication sent out by the Air Corps in 1944, at which time they were soliciting competitive bids for the production of a plane to meet certain specifications. It was pointed out that as a result of this invitation for competitive bids the P-80 jet fighter was subsequently built.

Mr. Bell stated that it would be rather difficult for them to locate any specific records concerning the P-80 without having additional identifying information. He suggested, however, that it might be possible to obtain more definite information through the Air Corps, and particularly to ascertain the data and specifications as set forth in their invitation for competitive bids with respect to this jet fighter. Accordingly, an effort is being made to obtain this additional information through the Bureau's liaison with the Department of the Air Force.

Mr. Bell also advised that with respect to the information concerning the air compression engine, according to the experts at the National Advisory Committee for Aeronautics this engine undoubtedly referred to the Westinghouse jet engine which was known as the J-31 or X-16 engine used in the XF-59 jet plane. It was pointed out that generally speaking the data concerning this air compression engine might have referred to other jet engines which are being used today, but that as of August, 1944, only the J-31 or X-16 engine was in existence.

ADVISED BY ROUTING SLIP (S) OF ___ DATE ___

RECEIPT ACKNOWLEDGED OTHERWISE

65-59312

RECORDED - 37 65-59312-416

MAY 22 1951

EX-30

cc: Buffalo
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JUN 4 1951

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DATE OF DECLASSIFICATION INDEFINITE

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Mr. Bell advised that this information pertaining to the J-31 or X-16 Westinghouse jet engine was available to subject Perl in view of the fact that he had been in charge of the testing of the XP-59 airplane which used this engine. According to the records of the NACA, the XP-59 had been completed for testing purposes prior to August, 1944. Further, it was definitely evidenced that Perl had a connection with this plane by reason of a memorandum which he submitted on March 19, 1945, recommending a raise in salary for one of the engineers who worked on the XP-59 plane under his supervision.

It might be noted here that the XP-59 airplane was produced by the Bell Aircraft Company, at which company Andrei I. Schevchenko, representative of the Soviet Government Purchasing Commission, was assigned in 1944. While it is indicated that the information concerning this air compression engine emanated from Schevchenko, this has not been conclusively established, for which reason additional investigation is presently being conducted on the possibility that Perl may have been the source of this information.

[redacted] B1

FS

This matter should receive expeditious attention.

Federal Bureau of Investigation
United States Department of Justice
900 Standard Building
Cleveland 13, Ohio
June 4, 1951

IN REPLY PLEASE REFER TO
FILE NO. 65-2730

STRICTLY CONFIDENTIAL

Director, FBI

Re: WILLIAM PERL, Aka.
ESPIONAGE - R; PERJURY
(Bufile 65-59312)

Dear Sir:

Rerep SA JOHN B. O'DONOGHUE, 5/17/51, Cleveland; Bulets dated 5/19/51 re the "Lexington Report" and re info concerning air compression engine (probably I-16 or J-31 engine).

[redacted] BI

The following persons were interviewed concerning this information:

AL W. YOUNG, Chief, Altitude Wind Tunnel Branch, Engine Research

MARTIN J. SAARI, Chief, Section B, Altitude Wind Tunnel

BEN PINKEL, Chief, Materials and Thermodynamics Research Division

G. MERRITT PRESTON, Chief, Flight Research Section

PRIATE AGENCIES
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65-2730

CCs: Buffalo 65-2003
New York 65-15387
Washington Field 65-5543
CV File 65-272[redacted]

CLASSIFIED BY [redacted] 2-22-78
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DATE OF DECLASSIFICATION INDEFINITE

65 JUN 13 1951

TOP SECRET

Director, FBI

According to the above mentioned persons, PERL worked on the P-59 doing theoretical compilations concerning the aerodynamics affecting the engine installation on the P-59. The P-59 utilized the I-16 General Electric jet engine (now known as the J-31) which was one of the earlier jet engines produced in this country. It was, however, preceded by the IA, a General Electric jet engine which was the first engine worked on at NACA Cleveland. The first IA was received at NACA, Cleveland in the Fall of 1943 and work on this engine was limited to a relatively small group. After PERL's arrival in Cleveland in December, 1943 he was assigned to assist on the experimentation of the propulsion system of the P-59. All agreed that PERL had access to any material he desired at that or any other time, including secret with the exception of Atomic Energy Commission data.

It was the concensus of opinion that the data concerning the experimental model of an air compression engine was generally accurate but appeared to be the statement of a layman who had seen a jet engine for the first time. As to Paragraph 1, each person contacted advised that the statement "...it was indicated the quantity of the chambers had something to do with the curtailment of combustible fuel..." was very confusing, and made little if any sense. The fact that the number of the chambers was considered optional and that there were to be ten combustion chambers was generally a true statement.

Paragraph 2 is entirely accurate insofar as it refers to General Electric jet engines which in 1944 were limited to either the I-16 or IA.

Paragraph 3 again would indicate an early jet since the present compression of air reaches approximately six atmospheres.

Paragraph 4, the temperature of 1760° Fahrenheit appears to indicate an early jet engine.

Paragraph 5 is a very general description of the combustion chambers of any jet engine.

Paragraph 6. None of those contacted were able to understand Paragraph 6 with the exception of G. MERRITT PRESTON, who advised a person with little or no engineering background might well describe the rear turbines in such a manner.

Director, FBI

It is pointed out that all the scientists contacted advised that by the Spring of 1944 PERL had an intimate knowledge of the workings of jet engines and would be able to describe one in complete detail at that time. They all stressed the information concerning the air compression engine as stated to them would appear to be a description proffered by a person with a limited or no engineering background.

Miss RUTH VANDERHOOF, Mail and Files Section Chief, made available abstracts to all General Electric and Bell Aircraft material on file in her section, and in addition furnished the complete preliminary data reports on the P-59.

[redacted]

Lexington Report and General Data Re PERL

BI

BEN PINKEL, previously described, has advised that he knew of no social acquaintances of PERL and regarded him as somewhat "stand-offish". He described PERL as one who appeared to be a "true scientist" whose one aim in life was the development and expansion of pure science. He recalled on several occasions that PERL had been invited to visit the homes of fellow employees but that PERL had in each instance refused.

According to PINKEL, PERL had no access to Atomic Energy Commission material, and it was pointed out by PINKEL that if anyone had given PERL the Lexington Report or other Atomic Energy Commission restricted data prior to November, 1949, it would necessitate a wrongful intent on the part of the person so doing. PINKEL explained this by stating that prior to November, 1949 no clearance had been requested for PERL and there would therefore be absolutely no reason to furnish PERL such data. He stated that after the request for clearance was made in November, 1949, it could well be that someone would have given PERL Atomic Energy Commission restricted data with the idea that PERL was, in their opinion, reliable and trustworthy, and that it was only a matter of days before he would get Atomic Energy Commission clearance. PINKEL stressed that he knew of no such instance, however, and offered the suggestion only for what it was worth.

PINKEL further advised that ALFRED BOBROWSKY was very unpopular and although he had no knowledge of any relationship between BOBROWSKY and PERL, he could hardly believe they would be compatible since they were direct opposites. The only persons

with whom PERL appeared to be closely acquainted in any degree were ABE SILVERSTEIN, Chief of Research, and MILTON KLEIN, who has since resigned from NACA.

Dr. ROBERT F. SELDEN was recontacted on May 21, 1951 and he advised it was possible that PERL and BOBROWSKY may have associated infrequently although he knew of no instance of such association.

SELDEN was asked to furnish some suggestion as to how PERL could have acquired a copy of the Lexington Report and he offered the suggestion that PERL was very close with ABE SILVERSTEIN and that a copy of the report had been charged out to SILVERSTEIN for some time. He stated he had no direct knowledge that anyone had ever permitted PERL to see the Lexington Report or any other Atomic Energy Commission data, but stated that copies could have been left around for some time and PERL might have gained access to a copy in an illegal manner.

Mrs. EVELYN FLEMING, nee Lasch, 27888 Osborne Road, Bay Village, Ohio, advised she served as secretary to ABE SILVERSTEIN from 1944 to 1950. She described PERL as a close friend of ABE SILVERSTEIN, and the only other apparent associates of whom she knew were MILTON KLEIN, MAURICE TUCKER, ARNOLD FRIEDMAN and LAWRENCE MARCUS.

Mrs. FLEMING stated that PERL had access to secret data and that while she had been secretary to SILVERSTEIN she had maintained records of all secret data maintained in SILVERSTEIN's office which was released to scientists at NACA. Before SILVERSTEIN became Chief of Research, FLEMING had no Atomic Energy Commission clearance, however, she had access to SILVERSTEIN's desk, file cabinets, and safe, but at no time did SILVERSTEIN maintain Atomic Energy Commission or NEPA data therein. It is her opinion that if SILVERSTEIN had such material in his possession he would either have to carry it on his person or return it to the Administration Building. She noted that SILVERSTEIN constantly kept a leather briefcase in his possession.

Mrs. FLEMING advised she did not get Atomic Energy Commission clearance until approximately two months before she left NACA in early 1950. She advised that the Lexington Report sounds familiar but is certain she would recall handling it and is positive she handled nothing which contained the Atomic Energy Commission restricted data classification.

She also advised that SILVERSTEIN was particularly

careful as to Atomic Energy Commission data as everyone at NACA was; all were deeply aware of the Atomic Energy Act of 1946.

Miss ALMA WILDY, secretary to Dr. J. C. EVVARD, Chief, Supersonic Propulsion Division, advised she had taken over the records maintained by Mrs. EVELYN FLEMING when Dr. EVVARD assumed his present position at the time ABE SILVERSTEIN became Chief of Research. Prior to that she had worked in the same office with Mrs. FLEMING as secretary to Dr. EVVARD and in Mrs. FLEMING's absence as secretary to ABE SILVERSTEIN. Miss WILDY advised she knew of no instance wherein PERL would have had access to the Atomic Energy material although she pointed out she herself had no access to such material. She stated that at no time did Mr. SILVERSTEIN maintain Atomic Energy material in his safe to her knowledge.

She did recall, however, that in March 1948 while ABE SILVERSTEIN was on annual leave in Florida, EVELYN FLEMING required access to SILVERSTEIN's safe. However, Mrs. FLEMING had either forgotten or had not had the combination to this safe and was forced to wire SILVERSTEIN in Florida for the combination. SILVERSTEIN advised FLEMING of the combination by return wire and this wire was then placed in the Mail and Files Section of the Lewis Flight Propulsion Laboratory. It was WILDY's opinion that only she, Mrs. FLEMING, ABE SILVERSTEIN, and one other person who had assisted Mrs. FLEMING in opening the safe were aware of this telegram with the exception of the clerk who filed it in the Mail and Files Section. She pointed out that PERL was then on leave without pay at Columbia University and would have no knowledge of this incident.

However, in May or June, 1949 Mrs. FLEMING went on a six-weeks leave and Miss WILDY during the course of her daily work required access to SILVERSTEIN's safe. She asked Mr. SILVERSTEIN for the combination but at that time he did not have it with him. She recalled the telegram and was able to secure it from Mail and Files. After opening the safe she advised she realized that this telegram presented a security problem and she instructed the Mail and Files Section to destroy it and later explained to Mrs. FLEMING what she had done. The combination to this safe remained the same until 1950 when it was changed while Miss WILDY was on leave some time between June 3 and July 10.

Miss WILDY advised she furnished the above information solely because of its peculiarity and stated there was never any indication that PERL had opened this safe himself or had any

knowledge of the combination thereto. She stated that during the day the safe was closed but was left on day lock which would necessitate a mere twist of the dial to open it.

Miss WILDY advised that the only people with whom she had seen PERL were HAROLD SHAMES, who is now in private business in New York, ABE SILVERSTEIN, and possibly MAURICE TUCKER.

Miss WILDY also furnished a list of secret documents which had been charged out to PERL as is reflected by her records. This list is set forth immediately hereinafter.

"S E C R E T"

"Compressibility Effects on Cascades of Low Cambered Compressor Blades, by Baily and Jefferson. R.A.E. (2-3-45)

"Preliminary Discussion on Impulsive Duct Engine Used for German Flying Bomb, by Howell, Richards, and Nock. R.A.E. (2-13-45)

"Examination of a German Rocket Motor Used for Assisted Take-Off, by Staffs of Engine Dept. and Metallurgy Div. Tech. Note EA 204, R. A. E. (2-13-45)

"Curve Sheets - MX-544 - Cleaned Up Run Test 32, Wright Field 20 Ft. Wind Tunnel (German Buzz Bomb). (1-25-45)

"Summary Report on Combustion Research - January 1943 to July 1944, National Bureau of Standards. (2-13-45)

"Report No. E. A. 224/13, TN No. Aero 1502 - Tests of FZG76 Flying Bomb Motor, by A. D. Baxter, D. E. Whaley, and C. Kell. R. A. E. (2-13-45)

"Jet Propulsion Combustion Chamber Research - Navy contract NOa(s) 5152 - Progress Report for Month of February 1945 - dated March 3, 1945 - by H. C. Hottel, MIT, Dept. of Chemical Engineering. (5-3-45)

"Progress Report on the Flow Phenomena at the Inlet of a Tube Travelling with Supersonic Velocity, Report No. Eng. Div. 18/44 - National Physical Lab. OSRD, Liaison Office. Ref. No. I-A-390, by G. H. Lean. (6-2-45)

"Supersonic Flow past Bodies of Revolution, by M. J. Lighthill, B.A. of the Aerodynamics Division, N.P.L. (Fluid Motion Panel, Aeronautical Research Committee) (6410-1030). (9-7-45)

Director, FBI

"Subsonic and Supersonic High Speed Tunnel Tests of a Faired Doubled Wedge Aerofoil, by W. F. Hilton, and F. W. Pruden of Aerodynamics Division, N.P.L. (Aerodynamics Subcommittee, Aeronautical Research Committee). (9-7-45)

"S E C R E T"

ISIDORE WARSHAWSKY, Instrument Service Section, advised he has known PERL since 1939 when PERL first became employed by NACA at Langley Field. According to WARSHAWSKY PERL, who then lived in a small home owned by the Chief of Police of Hampton, Virginia, SIDNEY HARMON, LAWRENCE MARCUS and his wife CELIA EPSTEIN and other persons whom he described as the "young, single, New York and Chicago Jewish people", associated to some extent at Langley Field during the period 1939-1942. He described this association as having meals together and occasionally holding dances and other "mild forms of entertainment". He pointed out that PERL was not particularly socially inclined and was more interested in pursuing his studies of physics and related problems. However, on occasion WARSHAWSKY visited PERL at his room in Hampton, Virginia where both listened to records.

WARSHAWSKY pointed out that he was transferred to Cleveland in 1942 and PERL came to Cleveland in late 1943. Their association at Cleveland has been very limited, and in general restricted to luncheon meetings at the NACA cafeteria. He pointed out that PERL usually had luncheon with MILTON KLEIN and that he would join them quite often although there was never any pre-arranged plan to their luncheon meetings. He also recalled that ALFRED BOBROWSKY was a late eater and perhaps on occasion did have luncheon with them although he could recall no specific instance. He also recalled that on occasion PERL had luncheon with a young girl whom he believed was employed in the 8' x 6' SSWT. He was unable to recall this girl's name but advised he was certain that PERL's relationship with this girl was merely a casual, workingtime acquaintance.

WARSHAWSKY advised PERL had access to secret data but not to Atomic Energy Commission data. WARSHAWSKY himself has had Atomic Energy clearance since June 8, 1948 but he pointed out that in all that time he has read only three Atomic Energy Commission documents, and these documents referred to instruments. He explained that he had clearance only for the purpose of being able to discuss problems with scientists who desired to purchase or have made new instruments necessary in their work in Atomic Energy matters. It was his capacity to approve or disapprove the purchase of such instruments.

Director, FBI

WARSHAWSKY advised he had not heard of the Lexington Report and it was his opinion that no one with Atomic Energy Commission clearance would furnish PERL Atomic Energy Commission restricted data unless the person did so maliciously. He did point out, however, that PERL's reputation as a mathematician was considerable and that it may well have been that someone working on the nuclear propulsion of aircraft problems could have requested PERL to do some theoretical analysis. He felt, however, that the problem could be given to PERL without disclosure of any restricted data, since such an analysis would of necessity involve only pure mathematics and/or physics.

WARSHAWSKY pointed out that he and BOBROWSKY had disagreed violently on many occasions while BOBROWSKY was working on shielding problems for the NEPA project but that despite this he felt it was not likely that BOBROWSKY would have furnished PERL any restricted data.

He noted that PERL was transferred to the Materials and Stresses Building in late 1949, and that while in that building he was engaged in a concentrated study of the physics of solids preparatory to becoming involved in the nuclear field. He stated it would be possible that PERL may have required some restricted data in adequately covering this field but he could see no reason for PERL having access to Atomic Energy Commission restricted data.

WARSHAWSKY advised that while he and PERL were employed at Langley Field he, WARSHAWSKY, used to visit New York at least once a year and definitely recalled being in New York City on December 7, 1941. He advised, however, that he was certain he had never made a trip to New York with PERL, nor does he ever recall seeing PERL while visiting New York City. WARSHAWSKY also advised he was a member of the CCNY alumni club at NACA Cleveland and he is certain that PERL has never participated in the activities of this club.

During the course of the interview WARSHAWSKY advised he had never been a member of the Communist Party nor any organization declared subversive by the Attorney General or House Un-American Activities Committee. He stated he recalled a great deal of talk concerning anti-Fascist organizations during the Spanish Civil War but was certain he had never attended any of their meetings nor had he ever contributed funds to these organizations.

Reference is made to Paragraph 2, Page 2 of Bureau letter dated May 19, 1951 concerning information furnished by Mr. ROBERT BELL in regard to the Lexington Report. Referenced letter indicates

Director, FBI

that copies #87A of the Lexington Report and 88A were, according to NACA records, charged out to ABE SILVERSTEIN during the same period.

Miss IRENE M. KIVES, secretary to the Director, Lewis Flight Propulsion Laboratory, NACA, Cleveland Airport, has advised that copy 87A was charged out to Dr. LAWRENCE O. BROCKWAY in October, 1948, exact date unknown; recharged to ABE SILVERSTEIN on November 2, 1948; and subsequently recharged to ALFRED R. BOBROWSKY during November, 1948, exact date unknown. There is pointed out that copy 88A was not charged out to SILVERSTEIN until November 29, 1948, and in all probability both copies were not in SILVERSTEIN's possession at the same time.

Miss KIVES, who furnished the records of charge-outs of the copies of the Lexington Report as is reflected in referenced report, is continuing her efforts to narrow the exact dates of charge-outs, and will furnish these at a future date.

Very truly yours,

R. J. ABBATICCHIO JR.
Special Agent in Charge

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
1724 F STREET, NORTHWEST
WASHINGTON 25, D. C.

TELEPHONE: LIBERTY 5-6700

June 7, 1951

Director
Federal Bureau of Investigation
U. S. Department of Justice
Washington 25, D. C.

Attention: Mr. Elmer F. Emrich

Dear Sir:

Attached is the copy of the report "Wind-Tunnel Tests of the Gorgon IIA and IIB Airframes. II - Power-Off Longitudinal and Lateral Stability and Control" which was inadvertently omitted from the attachments to Dr. Dryden's letter of June 6, 1951.

Very truly yours,

EXPEDITE PROCESSING.
JUN 9 1951

Robert L. Bell
Security Officer

NACA failed to send this report with its letter 6/6/51 - Report being kept with those submitted with NACA letter 6/6/51

Attachment

RECORDED - 81
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65-59812-444

JUN 9 1951
25

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133
56 JUN 15 1951

Julius Rosenberg ET AL.

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National

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And Space

Administration

No. 20

Appeal to: Ms. Miles Waggoner
Freedom of Information Office
National Aeronautics & Space Administration
Washington, D.C. 20546

REFERRAL

Reviewed by: wlw / wlw

Packet # 20

AGENCY NASA

Subject and File Number	Serial	Date	Document Description	No. of Pages Actual	No. of Pages Released
Per/(HQ) 6E-59:12	191	12/4/59	HQ TEL [illegible] TO CV, WFO	1	1

F RAL BUREAU OF INVESTIGATION
STATES DEPARTMENT OF JUS

CC-150

TOP SECRET

To: COMMUNICATIONS SECTION.

December 16, 1950

Transmit the following message to:

URGENT

SACs, CLEVELAND
WASHINGTON FIELD

WILLIAM PERL, ESP-R.

DATA OBTAINED THROUGH LIAISON WITH NACA, WASHINGTON, DISCLOSED THAT INFO FURNISHED TO MGB REPRESENTATIVE NYC RELATIVE TO G EIGHTY-SIX, [illegible] HIGH ALTITUDE JET FIGHTER PLANE APPARENTLY WAS OBTAINED FROM REPORT RECEIVED BY NACA JANUARY THIRTY FIRST, FORTY FOUR, FROM THEIR WEST COAST REPRESENTATIVE, COPY OF WHICH REPORT MADE AVAILABLE TO CLEVELAND LABORATORY OF NACA. FURTHER DISCREET INQUIRY BEING MADE BY NACA TO DETERMINE IDENTITY NACA OFFICIAL CLEVELAND HAVING CUSTODY THIS CONFIDENTIAL REPORT AND AVAILABILITY SAME FOR EXAMINATION BY PERL. CLEVELAND AND WFO MAY DISCONTINUE EFFORTS TO LOCATE XP EIGHT ONE DATA IN FILES NACA PENDING RESULT OF COMPLETE INFO FROM BUREAU RE ABOVE.

APPROPRIATE AGENCIES AND FIELD OFFICES ADVISED BY [illegible] SLIP (S) [illegible] DATE [illegible]

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EXEMPT FROM GDS, CATEGORY 2
DATE OF DECLASSIFICATION INDEFINITE

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DEC 28 1950

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Mr. Clegg
Mr. Glavin
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Mr. Tracy
Mr. Egan
Mr. Gurnea
Mr. Harbo
Mr. Mohr
Mr. Pennington
Mr. Quinn Tamm
Tele. Room
Mr. Nease
Miss Gandy

55 JAN 4 1951

TOP SECRET

TRANSMITTED VIA _____ M Per _____