## A. GAS TURBINE DEVELOPMENT BY B.M.W.

### 1. Introduction

This report is based on interrogation of members of the B.M.W. organisation, on examination of factories at Stassfurt, C-5/180, Heiligenroda, 26/79, Mittelwerk, 5/64, and Eisenach, 26/79, and on cursory inspection of various drawings and documents recovered from these targets.

### 2. Organisation of Gas Turbine Work at B.M.W.

#### 2.1 Personalities.

The chief personalities are as follows:-

| | |
|---|---|
| Dr. Schaaf, | Managing Director of the whole organisation, now at Eisenach. |
| Dr. Stoffregen, | The Director in charge of engine production, now at Stassfurt. |
| Dr. Bruckmann, 26/1 | The Director in charge of all development work, now presumed to be in Munich. |
| Dr. Oestrich, | Engineer in charge of jet engine development, now at Stassfurt. |
| Dr. Ulsamer, | Formerly concerned with development, now working on the production side. Presumed to be in Munich. |
| Oberst Knemayer, | In charge of jet engine development at R.L.M. |

Drs. Schaaf, Oestrich, and Stoffregen were interrogated and were quite ready to answer questions and to speak about their work. In technical matters, Dr. Oestrich was the most valuable witness and it is suggested that he be brought over to U.K. for more detailed interrogation than was possible in the course of this examination. (Being done by A.D.I. (K)).

## 2.2 Location of Plants.

All the B.M.W. gas turbine work both development and production was originally centred in Berlin - Spandau, and in spite of subsequent dispersal, a good deal of plant remains there. When the heavy bombing of Berlin started, the development work was moved to caves at Wittringen, near Saarbrucken, but the liberation of France in 1944 made this position too exposed before the plant ever came into operation, and further removals became necessary which finally brought the experimental centre to

"Kalag"
Shafts 6 and 7
Neu Stassfurt.

This is a disused salt mine which provides space for some 20 underground workshops averaging 200 x 100 ft. and with ample head room. A large number of machine tools are installed and other underground rooms are fitted out as stores, drawing office, laboratory etc. Testing was to have been done on a test bed mounted at the head of shaft 6.

Production was dispersed to the following sites

(a) Zülsdorf near Oranienburg.
It is here that all the existing 003 engines have been made.

(b) Heiligenroda near Dorndorf. (Eisenach)
This was also to have been capable of producing complete engines but was only in partial operation when captured. It is another salt mine with 40,000 sq.metres of floor space available for production.

(c) Abterroda.
Another salt mine near Heiligenroda, but much smaller. Intended for the production of parts such as oil cooler.

(d) Ploemintz.
Another underground plant in a salt mine near Baalberge, Bernburg. Used chiefly for machining of large parts such as compressor casings, etc.

(e) Kalag.
Some production was also going on in the development factory at Neu Stassfurt.

(f) Bad Salzungen.
Another salt mine, intended for assembly but never used.

Independently of these B.M.W. plants, production of 003 engines was also being started at Mittelwerk, Nordhausen. Here there is an assembly line in the main tunnel B (just beyond the V.1 assembly line). It is understood that most of the components were to have been made outside.

Apart from some experimental blade manufacture at Stassfurt, all blades for compressor and turbine are obtained from

Würtembergische Metallwarenfabrik
Geisslingen, Near Stuttgart.

## 3. History of the 003 engine.

### 3.1 Development.

Preliminary work on jet propulsion was started in 1934 and work on the 003 project began in 1939. The aerodynamic design was based on work at Göttingen and a thrust of 600 Kg. was aimed at. This engine ran in August, 1940 giving the following approximate performance.

| | |
|---|---|
| Thrust | 450 Kg. |
| Weight about | 750 Kg. |
| Sp. Cons. | 2.2 lb/hr. / lb. |
| Air Flow | 16 Kg/Sec. |

Like later models this had a seven stage axial compressor, single stage turbine, annular combustion chamber with 16 jets. Hollow turbine blades were used from the start primarily for the sake of the blade cooling, but also to economise in material.

Later designs were based on the firms own experimental work and the substitution of the new blading gave an immediate improvement in performance.

The results were approximately

| | |
|---|---|
| Thrust | 600 Kg. |
| Sp. Cons. | 1.6 lb/hr / lb. |
| Weight | 550 Kg |

Further improvement in component efficiency and increase in air mass flow have since been achieved but weight has tended to increase as a result of added auxiliaries, increase in gauge of metal to avoid failures, etc.

The chief difficult encountered in the development work was with compressor blade failure through vibration, but this has now been overcome and the weakest component of the present engine is the turbine blading which is likely to require replacement after 50 hours.

According to Dr. Schaaf the first flight in a jet propelled aircraft, using a power plant by Heinkel-Hirth, was achieved some time before the war, about 1937.

The Luftwaffe and R.L.M. showed little enthusiasm for jet propulsion until about 18 months ago when the priority was raised. Junkers were then instructed to get into production at once with 004 even if the resulting engines were inefficient and required large quantities of alloy steels (solid turbine blades). B.M.W. were to carry their development a stage further aiming to get a somewhat higher efficiency and to minimise the use of alloy steel. The success achieved in the latter respect is illustrated by the fact that the present 003 engine contains only 0.6 Kg. nickel.

It was claimed that in the development of this engine the firm had received no significant help from national research organisations whose work in this field was considered ineffective. The firm had done some research on its own but the main emphasis, especially in the last 2 years, had been on the immediate development problems.

Mass production of 003 is said to require 600 man hours* made up as follows:

| | |
|---|---|
| Machining | 220 hours |
| Sheet metal work including turbine blading | 160 hours |
| Assembly | 60 hours |
| Starter, Governor, etc. | 60 hours |
| Misc. | 100 hours |

*These figures were obtained through Cdr. Haskell, U.S. Navy.

### 3.2 Design and performance 003

For design details reference must be made to the drawings, but for convenience the main features of the design are summarised below, with notes on materials and performance.

## A. Description of Engine.

A straight through axial compressor engine with 7 compressor stages, annular combustion chamber, single stage turbine having both stator and rotor blades hollow and air-cooled. Adjustable propelling nozzle with internal cooling.

| | |
|---|---|
| Overall length | 11.7 ft. |
| Max. diameter | 2.25 ft. |
| Weight | 1360 lb. |

Compressor Disc construction. Cooling air for turbine drawn from 4th stage.

Combustion system. Annular. 16 individual burners each with stabilising baffle. "Sandwich" mixers.

Turbine. The hollow rotor blades have an internal sleeve to direct cooling air flow along surface.

Auxiliaries. Certain auxiliaries are the same as on 004, e.g. 2 stroke starter, fuel pump.

## B. Materials.

Large castings such as -

| | |
|---|---|
| Compressor housing | Elektron |
| L.P. stages compressor blading | Elektron |
| H.P. " " " | Dural |
| Combustion chambers. | M.S. aluminium sprayed except mixers which are "Sicromal 10" |
| Turbine stator blades | "Sicromal 10" |
| Turbine disc | Carbon steel. |
| Turbine rotor blades | 15% Nickel steel (C less than .1%, Cr 16-18%, Ni 15%, Si 1%, Mo 2%). |
| Propelling nozzle | M.S. except for spider which is "Sicromal 10". |

Note: Sicromal 10 used in various components has the composition C .1% Cr 12-14%, Al 1.5-2%, Si 1-1.5%. This material has also been used for rotor blades as has a new material No. 1435 which has C 0.1%, Cr.10-13%, Mn 17-19%.

C. Performance.

Static thrust    800 Kg = 1760 lb.

This is an endurance condition (Dauerschub) and on the instructions of R.L.M. no attempt has been made to step up the perfotmance for take-off or combat. It is virtually a single speed engine.

| | |
|---|---|
| Specific consumption | 1.35 - 1.4 $\frac{lb/in.}{lb.}$ |
| Air mass flow | 19.3 Kg/sec = 42.5 lb/sec |
| Compression ratio | 2.7:1 |
| Engine speed | 9500 r.p.m. |
| Idling speed | 3000 r.p.m. |
| Idling thrust | 50 Kg = 110 lb. |
| Component efficiencies: | Compressor 80% |
| | Combustion (g.l.s. full speed) 90-95% |
| | Turbine 75 - 80% |

These results are based on analysis of engine tests. No separate component tests have been done as yet except for atmospheric combustion rig work.

3.3 Manufacture and application.

About 6 or 700 003 engines have been made, all at Zülsdorf and all of the Mark I design, 003 (A1). The A2 design differs only in constructional and manufacturing detail. Plans had provided for the following scale of production.

| | |
|---|---|
| Berlin Spandau and Zülsdorf | 2000 a month. |
| Heiligenroda, Abterroda, Ploemintz, Stassfurt | 2000 a month. |
| Mittlewerk | 2000 a month. |

Great difficulty was however being experienced in establishing production on this scale and the plans had been written down first to 1500 a month then lower still.

The engine was originally intended as an alternative to 004 for Me.262 but this application was later given up in favour of the Volksjäger. The development of the latter aircraft has been held up by airframe difficulties which required the redesign of the wing.

Other applications of the 003 engine which had been considered were

A. Arado 234.

The use of 4 x 003 engines on the Arado 234 was expected to produce an aircraft of very high performance with a top speed of 880 km/hour at 10,000 meters and a range of 1400 km. A prototype had been completed and had done flight tests at Lünnewitz. Figure 4 attached.

B. Ju. 287

To be powered with 6 x 003 engines. No particulars available.

C. Ju. 88

As auxiliary power plants 2 x 003 engines would give an additional 140 km/hr.

D. Me. 262.

See section 5.

4. <u>018. 028 and other engine projects.</u>

4.1 <u>018 Engine.</u>

Work on this project had not got very far mainly because of the interruption to the work which resulted from strategic bombing and from the liberation of France and which necessitated the removal of the experimental group four times over. R.L.M. ordered work on the project to stop about 6 months ago as it was regarded as a long term development for which no airframe was available anyhow. A good deal of design work has been done which is best expressed in the substantially complete drawings and the compressor design data (see Appendix 1) which have been recovered from Stassfurt. A compressor was built but never tested, and this was blown up before the capture of the target. Parts of the destroyed compressor have been recovered.

The engine is briefly described and the design performance outlined in the following notes.

A. Description of Engine.

A straight through, simple, axial compressor engine with 12 compressor stages, annular combustion system with 24 burners, 3 turbine stages, adjustable propelling nozzle.

| | |
|---|---|
| Overall length | 16.2 ft. |
| Max. diameter. | 4.06 ft. |
| Weight | 6400 lb. |
| Compressor | Disc construction. First 5 discs dural, rest steel. H.P. blades steel. No blow-off. |
| Combustion system. | Annular and similar to 003, but with 24 burners. |
| Turbine | Hollow blades throughout. |

B. Estimated performance.

| | |
|---|---|
| Static thrust | 3400 kg = 7500 lb. |
| Pressure ratio (static) | 6.6:1. |
| Rotational speed. | 5000 r.p.m. |
| Specific consumption | 1.08 $\frac{\text{lb/hr.}}{\text{lb.}}$ |
| Air mass flow | 180 lb/sec |
| Heat release in c.c. | 69,200,000 $\frac{\text{k cal}}{\text{m}^3\text{ hr}}$ = 0.65 x $10^6$ $\frac{\text{C.H.U.}}{\text{cu.ft.hr.atm.}}$ |
| Gas temperature at turbine. | 800°C. |
| Power developed in turbine. | 40,000 H.P. |
| Component efficiencies: | |
| Compressor | 79% |
| Combustion (g.l.s. full speed) | 90-95% |
| Turbine | 75% |

For further details see document A4, Appendix 1.

Application of this power plant to a projected bomber Henschel P.122 had been considered. This was estimated to give top speed at ground level of 1010 km/hr. (635 mph) and at 10,000 metres 935 km/hr. (580 mph); max. range at 17000 metres 2000 km.

As far as the power plant was concerned effective operation up to 18,000 metres was expected. See figure 5 attached.

4.2 <u>028 Engine.</u>

This was a project for an 018 engine modified to drive a contra-rotating propeller, it was still in the design stage. A few drawings of individual components were received but the only GA available is the miniature one in reference A1 of Appendix 1, Figure 2 attached.

The engine and its estimated performance are summarised below :

The 018 engine was modified by the addition of a further turbine stage, the drive to the propellers being taken through the main compressor shaft and transmitted by planet gears.

| | |
|---|---|
| Overall length | 19.5 ft. |
| Max. diameter | 4.06 ft. |
| Weight (excl. prop) | 3500 kg.<br>7540 lb. |
| H.P. delivered to airscrew | 7700 |
| Prop. speed. | 900 r.p.m. |
| Fuel consumption | 3700 kg/hr |
| Equivalent H.P. developed at 800 k.p.h. | 14000 H.P. |

4.3 <u>Other projects.</u>

Oestrich had other plans on which no detailed work had been done.

A. Further development of 003.

The aerodynamic design of this engine was fixed almost 4 years ago and it is considered that by redesign a 50% increase in output could be obtained.

B. A new simple axial engine using a greater proportion of sheet metal construction.

| | |
|---|---|
| Diameter | 2.75 ft. |
| Weight | 900 kg. |
| | 2000 lb. |
| Thrust | 1700 kg. |
| | 3750 lb. |
| Sp. cons. | 1.3 lb/hr. / lb. |

C. A lightened propeller engine having a specific weight comparable with that of a simple jet engine and giving a specific consumption at 800-900 k.p.h. of about 1.

D. An expendable power plant using sheet metal construction to the greatest possible extent.

| | |
|---|---|
| Thrust | 500 kg. |
| Compressor | 5 or 6 stage axial. |
| Specific cons. | 1.5 lb/hr. / lb. |
| Production time | 100 man hours. |

5. Rocket development and 003R engine.

B.M.W. have a group in Munich working on rocket propulsion under Zborowski. This group has developed a biliquid rocket using nitric acid as oxygen carrier and a mixture "Tonka" as fuel. No one in Stassfurt or Eisenach seems to know exactly what Tonka contains but it is said to be based on a heavy hydrocarbon with additions of various substances to make it react spontaneously with the nitric acid. It is not aniline. The mixture has been changed very often but development is well advanced and the system has been applied not only to 003R but also to certain guided missiles "Schmetterling" and X4. The specific thrust obtainable with the system is 170-200 lb / lb/sec. Zborowski was in the S.S. and will probably have disappeared; detailed information on this work is most readily available from Dr. Bruckmann in Munich.

003R is a 003 engine with a drive taken out through a modified gearbox and transmitted through a long shaft to the rocket fuel pumps which require 200 H.P. (See Figure 3 attached). The rocket is mounted close to the main jet from the engine, and gives a thrust of 1250 kg (2750 lb) with an endurance of 3 minutes. The rocket can be switched on and off at will by virtue of the spontaneous reaction of the two liquids.

This power plant has been fitted to an Me.262 and has flown at Lechfeld. Flight test results are not known but estimates were as follows: -

| | |
|---|---|
| Speed at 9000 m | 900 km/hr. |
| Rate of climb | 85 m/sec. |
| Time of climb to 10,000 m | 115 sec. |
| Time of climb to 13,000 m | 140 sec. |

(Rocket turned on at 700 km/hr. at 0 ft.)

## APPENDIX I

**Note on documents, drawings and engine parts recovered recovered from the targets.**

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Orders for the destruction of secret and top secret papers had been carried out, but searches at Kalag revealed various reports and drawings which had been overlooked. Thanks to the help of various U.S. Army Guards and of a Belgian D.P., I was also able to locate and recover a buried steel box containing complete drawings of the 003 and 018 engines.

1. Documents from Neu Stassfurt.

A. B.M.W. papers.

1. B.M.W. gas turbine engines, by H. Oestrich.
2. 018 compressor.
   Design data for 018 compressor.
3. Notes on compressor design.
4. Summary report No. 114/44. Design data for 018.
5. Notes for a report on the design of 018 compressor by Fickert.
6. Manuscript notes on pressure and temperature rise in the stages of the 018 compressor. by Loffler.
7. Characteristics of 003 compressor.
8. Characteristics of 003 compressor.

B. Papers by various research organisations.

The following research reports, which though not directly relevant to the B.M.W. engines are of general aerodynamic interest.

B9. Technische Hochschule.
Stuttgart. Berichssbrief No.70.

B10-15 D.V.L. reports 1910
1910/2
1910/4

1910/5
1910/6
1490

B16, 17. Focke Wulf G.m.b.H.
Reports 1436
8003

B18 Lillienthah Gesellschaft.
Paper by Antonio Ferri.

B19-25 Göttingen
(Aerodynamische Versuchstnstalt)
Reports 6616
1955
3123
3051
3147
3200
42/A/19

B.26 Brunswick.
(luftfahrtforschungsanstalt.
H. Göring)
Reports 1924
1983
1816

2. Drawings from Neu Stassfurt.

No detailed list has been made, but the following is a rough guide.

003 engine. A complete set of drawings of the Mark 2 engine.
(recovered from buried box in woods near Stassfurt.)

018 engine. A substantially complete set of drawings from the same source. Also other drawings recovered from the mine at Stassfurt (partly redundant).

028 engine. A few drawings from the mine. Miniature GA in Ref. Al.

3. Engine parts recovered from Stassfurt and Eisenach.

3 incomplete 003 engines have been shipped from Kalag
by 5th Air Disarmament Group,
(Capt. Chilcote),
A.D. Division,
U.S.S.T.A.F.

I understand that complete engines are available from Volkenroda. There were no complete engines at any of my targets.

The following components have been brought from Stassfurt and Eisenach.

1. Parts of wrecked 018 compressor.

2. Experimental turbine wheel (003).

3. 018 compressor blades in course of manufacture.

4. Fuel jets for 003 engine.

5. A set of turbine blades (003) illustrating process of manufacture.

## APPENDIX II

### Nomenclature

The German nomenclature for jet propulsion systems has appeared in various intelligence reports but has not to any knowledge been fully explained. The nomenclature was worked out in R.L.M., early in the war.

| | | |
|---|---|---|
| R | = | Rakete = Rocket. |
| TL | = | Turbine - Luftstrahl = Turbo jet. |
| PTL | = | Propeller-Turbine-Luftstrahl = Propeller turbine engine. |
| TLR | = | Turbo jet with rocket. |
| L | = | Luftstrahl = Propulsive duct (N.B. B.M.W. know of no work done or being done in this field.) |
| IL | = | Intermittierendes Luftstrahl = Argusrohr or V1. |
| RL | = | Rakete-Luftstrahl. |
| | = | Rocket with augmentor. |

Hence, jet propulsion by turbo jet is referred to me TL-Antrieb, and a jet engine as TL Triebwerk or TL Gerät.

As regards the code number 003, 018, etc., Dr. Franzmof Junkers says that beginning with the 011 engine, the last numberal was to indicate the manufacturer, thus 1 Heinkel-Hirth, 2 Junkers, 8 B.M.W. There is therefore no reason to suspect the existence of engines corresponding to the missing numbers 013, 014, etc.

## B. GAS TURBINE DEVELOPMENT BY DAIMLER BENZ.

### 1. Introduction.

This note records information obtained during investigation of a target at Eckertal, near Bad Harzburg where Prof. Leist, formerly associated with Daimler-Benz, is now working. This information was obtained exclusively by interrogation since no documentary evidence bearing on the Daimler-Benz project was found. Completion of the story requires the examination of the material evidence, i.e. documents and hardware, which should be available at Daimler-Benz, either in Stuttgart or in a dispersal plant.

### 2. History of the project.

Prof. Leist went to Daimler-Benz in 1939 after having been for 5 years at the D.V.L. where he was concerned first with exhaust gas turbines and later with general theory of jet propulsion by propulsive duct and turbo jet. With Daimler-Benz, Leist started the development of a so-called ZTL Triebwerk, which is described in the next section. One of these engines was built and ran up to full design speed in the autumn of 1943. It was run without propelling nozzle and for the purpose of mechanical testing only. While the development was at this stage, all work on the project was stopped by order of RLM, not because of any faults shown up by the preliminary tests but because the design was more complex than those under development by Junkers, Heinkel-Hirth and B.M.W. and was considered a long-term objective. Daimler-Benz were directed to work on the Heinkel-Hirth project and Leist went to Brunswick Technische Hochschule.

### 3. Description of the engine.

Z.T.L. means Zweikreis - Turbine - Luftstrahl, literally Two-circuit - turbo-jet engine, or turbo-jet engine with augmentor. The two circuits are in fact (a) the air flow through the main compressor, combustion system turbine and jet, (b) the secondary air flow through the ducted fan. But the design, which is diagrammatically illustrated in the attached figure 6, had several special features. The compressor and ducted fan were mounted on two contra-rotating drums, the inner drum directly driven by the turbine and the outer drum driven through gears at about ½ speed. The inner drum carried 9 stages of compressor blading while the outer drum carried 8 stages of compressor blading internally and 3 stages of fan blading externally. The turbine was cooled by partial admission over 30% of its circumference of air drawn from the ducted fan circuit, the remaining 70% receiving the working gases. With this technique (cf. "Probleme des Abgasturbinenbaues" by K. Leist, Luftfahrtforschung 15 p.481 1938) it was expected that working gas temperatures of 1100°C. would be possible. Finally, the main air supply from the ducted fan was mixed with the turbine exhaust gases in a common jet pipe.

Four tubular combustion chambers were used, though provision was also made for a fifth in case it were found possible to reduce the amount of turbine cooling air. Each chamber was about 70 cm. long x 25 cm. diameter with upstream injection against a swirl plate as in the Junkers engine and secondary mixing by opposed swirl.

The only design data which could be obtained was as follows: -

| | | | | |
|---|---|---|---|---|
| Overall diameter | = | about 900 mm. | = | 2.[illegible] ft. |
| Overall length | = | about 5 m. | = | 15.2 ft. |
| Weight | = | 1300 kg. | = | 2870 lb. |
| | | (No attempt was made at a light construction). | | |

Design condition was 900 km/hr. at [illegible] metres, and at this condition -

| | |
|---|---|
| Power developed | = [illegible] |
| Air mass flow through compressor | = [illegible] |
| | = [illegible] lb/sec. |
| Air mass flow through fan | = 16 kg/sec. |
| | = 35.2 lb/sec. |
| Pressure ratio | = [illegible] |
| Fuel consumption | = 370 gm/thrust [illegible] |
| | = [illegible] |
| Speed of turbine and inner compressor rotor | = [illegible] r.p.m. |

C. GAS TURBINE DEVELOPMENT BY JUNKERS.

1 Introduction

The information contained in this note was obtained by interrogation of Dr. A. Franz, head of technical development at Junkers, at his home in Allanstedt, Harz on May 16th.

Early experiments.

2. Franz joined Junkers in 1936. The firm was at that time considering variants of the free piston (Pescara) engine but it was soon concluded that there would be great difficulty in getting the required performance with such systems with any reasonable weight and the work was stopped. Some preliminary work on jet propulsion turbine engines was done in the Magdeburg branch of the firm in 1937, but this was a half-hearted effort and made no significant progress.

In 1939 the idea of jet propulsion by gas turbine was seriously taken up at Dessau, 5/13, and the first step was the design and manufacture of a miniature experimental unit, small enough to allow independent testing of components with the poor power available. The compressor was to absorb some 400 HP. at a rotational speed of something over 30,000 rpm. This project was a failure. The complete power plant was no good because of the inadequate performance of the scaled down combustion system, and the independent compressor tests gave little information because the unit was wrecked by blade failures.

3. History of the 004 engine.

3.1 004.A development.

At the end of 1939 a start was made on the designing of a full sized jet propulsion turbine engine. This was known as 004.A, a straight though axial compressor engine with 8 compressor stages, 6 combustion chambers and single stage turbine, in fact the precursor of the present Junkers engine which is 004.B.

In designing this engine the compressor blading was based on data provided by Gottingen. Although the firm has since done aerodynamic research on its own, contact has been maintained with Gottingen throughout. In contrast, the co-operation with Brown Boveri Co. which was initiated by R.L.M. proved fruitless.

Construction of 004.A was begun early in 1940 and the first engine was run at Christmas 1940 without propelling

The performance has been worked up to 930 Kg static thrust (2050 lb) and with hollow air cooled turbine blades, by using higher gas temperatures, 1000 Kg or 2200 lb. is possible. Junkers have not found it necessary, in their hollow blades, to use the inner sleeve favoured by BMW.

Component efficiencies measured by independent test (compressor and combustion) and deduced from engine performance (turbine) are as follows:

| | |
|---|---|
| Compressor (tested with throttled entry driven by 1500 Kw motor) | 78% at design point<br><br>83% at peak of characteristic. |
| Combustion system | 93% combustion efficiency at gls. full speed.<br><br>Pressure drop 0.1 - 0.15 stm. |
| Turbine | with solid blades 85%. Cooling air reduces efficiency in proportion to amount used which is 2 - 3%, but the hollow blades are of improved design, masking this effect. |

The engine requires overhaul after 25 hours for metallurgical tests on the turbine. If this passed the test it is refitted for a further 10 hours running but 35 hours life is the absolute limit for the turbine wheel. Combustion chamber parts are expected to need replacement at the 25 hour overhaul. It was intended to work up to a useful life of 50 hours with the aircooled turbine blades.

The chief weakness in the combustion system is the instability which becomes marked at 10 Km altitude (33,000 ft) and as relighting in flight is impossible this is a significant limitation. The greatest altitude reached with Me.262/004.B is 12.7 Km or 42,000 ft. and this required very careful nursing of the engine. To get over this weakness experiments have been going on with a duplex burner having the main and auxiliary jets mounted side by side on the burner stem. The resultant asymmetry did not have any marked effect on temperature distribution.

## 4. Other projects.

### 4.1 012 engine.

The 012 engine was intended for a fast bomber, specification (Ju.287) and design data were as follows:

Thrust 2700 - 2900 Kg = 6000 - 6400 lb.

Weight c 2000 kg. = 4400 lb.

Length about 5.3 metres = 17.1 ft.

Diameter about 1.15 metres = 3.75 ft.

Static pressure ratio 6 : 1

Compressor 11 stage axial with provision for blow off, if required, after 5th or 6th stage.

Turbine 2 stage

Specific consumption 1.2 $\frac{lb/hr.}{lb.}$

Air mass flow: Something over 50 kg/sec.

Rotational speed 6000 rpm.

10 engines to this design were on order and parts for three were being made but no engine or component tests had been run

### 4.2 022 engine.

This was to be 012 with drive to a contra rotating propeller but had not got beyond the project stage.

in this connection Franz says that beginning with the 011 engine the last numeral in the code number was to indicate the manufacturer, thus 1 Heinkel Hirth, 2 Junkers, 8 BMW. There is therefore no reason to suspect the existence of engines 013, 014 etc.

### 4.3 Other plans

The 004 Engine had been given a long jet pipe to allow for reheat from which 20% improvement in thrust was expected. In practice it was found that 13 - 14% was the most obtainable without excessive jet pipe temperature and deterioration of the structural work. Two methods of fuel injection were tried:

(a) Upstream injection with no baffling immediately in the wake of the turbine. This did not give perfect stability but was preferred to method (b) because it did not affect the turbine temperature.

(b) Injection at the level of the turbine nozzles. This gave perfect stability (on the test bed - no flight tests done) but gave the turbine blading a bad time.

There was also a plan for a beefed up 004 engine within the same dimensional limits but completely redesigned and aiming at a thrust of 1500 kg. Only in the project stage.

Franz had been asked to undertake work on propulsive ducts but had been unable to do this and was not aware of any work in this field.