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A.I.2(g) Report No.1768

GERMAN LIQUID ROCKET FUELS

The employment of the Hs 293 radio-controlled jet-propelled glider bomb against Allied shipping in the summer of 1943 first drew general attention to German work on liquid rocket fuels, although it was previously known that an assisted take-off rocket for heavy bombers had been developed and was believed to use liquid fuels. Combined investigation by several Ministries resulted in the identification of the two fuels - T and Z Stoff - used in the Hs 293 rocket motor as concentrated hydrogen peroxide and calcium or sodium permanganate solution (depending on temperature and climatic conditions) respectively.

2. Since that time German progress in the development of liquid rocket fuels has been additionally demonstrated by the operational employment of the Me 163 fighter, the A.4 long-range rocket, and the FZG 76 flying bomb (where T and Z Stoff are used for ground launching), while experimental work on a number of G.A.F. projects concerned with assisted take-off units for bombers and with controlled missiles for use against aircraft or shipping continues on a high priority. Liquid rocket fuels are also used in some new Naval weapons, e.g. in a rocket-propelled torpedo.

3. Recently, information from documents captured at the firm of Schmidding in Cologne has added considerably to knowledge of German liquid rocket fuel developments. The present report is intended to give a general basic picture of these liquid fuels, and includes information from various Intelligence sources on their development, manufacture and employment in G.A.F. and related equipment. It is to be expected that this information will be amplified from time to time as a result of investigation of German factories, establishments and documents.

Organisation of Rocket Propellant Development and Manufacture

4. Research and development of liquid (and solid) rocket propellants is carried out in Germany independently by the three Services in accordance with their particular requirements. Manufacture and supply, however, are controlled by the Ministry of Armament and War Production through its Armament Supply Office (Rüstungslieferungsamt, abbreviation: RLA) and through this organisation co-ordination and exchange of experimental experience naturally takes place. For Army requirements, Wa Prüf 11, a section of the German War Office, works largely through its well-known experimental establishment HAP 11 (the birthplace of the A.4 rocket) situated at Peenemünde Ost. Peenemünde West, adjoining HAP 11, is an Air Force experimental station and airfield controlled by the German Air Ministry; it carries out some rocket fuel research (under Dr. Demant) and is much concerned with the development of airborne controlled missiles, assisted take-off units, etc. utilising rocket motors.

5. Departments GL/C-E3 and GL/A-MII(E) at the German Air Ministry direct rocket fuel development as it affects Air Force interests. Their main liquid (and solid) rocket propellant research establishment is the Luftfahrtforschungsanstalt in Brunswick, where Prof. Lutz and Dr. Nöggerath are concerned with liquid rocket propellants and must be fully conversant with all German work on this subject.

Types and Properties of Liquid Rocket Fuels

6. The two main liquid rocket systems - monofuel and bifuel - are distinguished by the Germans as "monergol" systems in the former case, and "hypergol" or "non-hypergol" systems, depending on whether they are self-igniting or not, in the latter case.

7. The former makes use of a single fuel (or fuel mixture) containing sufficient combined oxygen to give complete or almost complete combustion;

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the latter uses two liquids, one an oxidant and the other a combustible fuel, which are led separately into the combustion chamber. The T Stoff/Z Stoff combination is not a typical representation of either class and is dealt with separately later in this report. Monofuel systems naturally require an initial ignition device; bifuel systems may be self-igniting (i.e."hypergols") when the two liquids come into contact or may need an igniter to start combustion.

8. The two systems require rocket motors of appreciably different design. For example, "monergol" fuels in most cases show remarkably rapid increase in burning speed with increased pressure and temperature, leading to detonation if unsuitable fuels or rocket designs are employed. On the other hand, the burning speed of "hypergols" is more essentially a function of the oxidant concentration, so that efficiency is obtained only with appropriate jet design to ensure intimate admixture of the two liquids and quick removal of the products of combustion, which otherwise tend to envelope the particles of combustible fuel and prevent the oxidant getting to it. Thus, a rocket motor designed for a "monergol" system is not rapidly convertible to a "hypergol" system or vice versa.

Monofuel Systems

9. Monofuels tested by the Germans include:-

(1) Monergol H (mixture of ammonia and ammonium nitrate).
Rejected because of crystallization trouble, although found not liable to detonation and otherwise promising.

(2) Monergol A (mixture of ammonia and nitrous oxide).
Rejected because, although otherwise suitable, was found too liable to detonation.

(3) Myrol (65 - 88 % solution of methyl nitrate in methanol).
Development being pressed forward with promising results. Great interest in Myrol for economic reasons described later in this report.

10. There is no evidence that any G.A.F. projects using "monergol" liquid rocket motors are yet in operation.

Bifuel Systems

11. The main oxidants used in German bifuel rockets are:-

(1) 80 % hydrogen peroxide.
Formerly known as T Stoff, now re-named D1R.

(2) 98 - 100 % nitric acid.
Known as Salbei, and sometimes as Hoko. If diluted with 10% sulphuric acid (for economy), is known as Mischsäure or MS 10.

(3) Liquid oxygen.
Sometimes termed A Stoff.

12. In addition to the above three oxidants, intensive development of Myrol as an alternative to hydrogen peroxide or nitric acid was being pressed on in the latter part of 1944 for economic reasons. In addition to 80% hydrogen peroxide, another oxidant - known as D2R - which is 60% hydrogen peroxide, is used for some unidentified purpose in the G.A.F. The 80% material is undoubtedly used for the majority of applications. The 60% solution might perhaps be employed for launching flying bombs, although there is no concrete evidence to support this suggestion.

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13. The main combustible fuels used with the above oxidants are the following:-

(a) With 80% hydrogen peroxide:-

(i) 30% hydrazine hydrate solution in methanol.
Known as C Stoff. (Hydrasine hydrate itself is known as B Stoff). Originally, the use of a 50% solution was envisaged but the concentration was reduced to 30% for economic reasons without apparent disadvantage.

(ii) Pyrocatechol.
Known as Ergol. No further details of concentration or of solvent known. Intended as alternative to C Stoff for economic reasons.

(iii) Crude Oil.
Intended to be used in an emergency if neither C Stoff nor Ergol were available.

(b) With 98 - 100% nitric acid:-

(i) Methanol.
Good experimental results obtained, igniter required to start combustion.

(ii) Petrol or J.2. (Light diesel oil)
Satisfactory tests carried out. Igniter required to start combustion.

(iii) 80% Furfuralcohol, 20% aniline mixture.
Good results obtained on test. Various other amines, e.g. aniline, monomethylaniline, dimethylaniline, triethylaniline, gave satisfactory experimental results. (An unidentified material "Tonker 505b and 505c" may be one of these amines and also gave satisfactory results on test).

In some cases ferric chloride has been added to the nitric acid as a catalyst to start ignition.

(c) With Liquid oxygen:-

(i) Methyl alcohol.

(ii) Ethyl alcohol.

14. Owing to the different physical and chemical properties of the above materials, and in particular of the oxidants, it is unlikely that all these alternatives are directly interchangeable in any particular rocket motor, although in some cases only minor alterations might be required.

15. T Stoff/Z Stoff system

A special variant of the bifuel system which may be considered separately, is the well-known T Stoff/Z Stoff combination, first used operationally in assisted take-off units and in the Hs 293. Strictly speaking, this is not a typical "hypergol" system, since the process involved is simply a very rapid decomposition of the hydrogen peroxide by the permanganate solution, and not the burning of fuel in oxidant. The products are essentially superheated steam and oxygen. contaminated by a brown sludge of manganese dioxide. This system is comparatively inefficient, because the oxygen produced is wasted and not used as an oxidant for further burning with combustible fuel. On the other hand, the arrangement is a convenient one for some purposes for which sufficient thrust is produced and where advantage can be taken of the

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fact that the combustion chamber and exhaust gases do not reach a very high temperature. T and Z Stoff units are sometimes refered to by the Germans as "cold units" to distinguish them from "hot units", which are typical "hypergol" systems involving actual combustion of the fuel and oxidant.

16. A variant of the T Stoff/Z Stoff system which brings it more into the "monergol" class is the replacement of liquid Z Stoff by a solid grid made up of small blocks composed essentially of manganese dioxide, which is fitted within the combustion chamber. This grid decomposes the hydrogen peroxide catalytically into superheated steam and oxygen, and contamination of the exhaust gases with manganese dioxide sludge is avoided. Such an arrangement is particularly convenient where the unit, instead of being designed as a rocket to produce thrust, is made in the form of a gas generator from which exhaust gases are led through a pipe system to drive a turbine.

Specific Employment of Monofuel and Bifuel Rockets

17. Monofuel rockets

It has already been noted above that no G.A.F. rocket motor employing a liquid monofuel system has been identified in operational use. As already mentioned, hydrogen peroxide, used with a solid manganese dioxide grid as catalyst, is employed in a gas generator unit used in the Me 163 B to drive a turbine which operates the two main fuel pumps.

18. Bifuel rockets

The most recently developed bifuel system employed in G.A.F. rocket motors is a combination of T and C Stoff as main fuels in the Me 163 B. For easy reference, a summary of the composition and uses of rocket fuels is attached as an appendix to this report. T and Z Stoff are used together for assisted take-off units for bombers, for the Hs 293 glider bomb, for ground launching of flying bombs, as main fuels for the Me 163 A, and in a gas generator unit employed in the A.4 long-range rocket to drive a turbine operating the two main fuel pumps. For this last application the manganese dioxide sludge present in the exhaust gases does not have time to clog the turbine blades owing to the very short time of operation. A liquid oxygen/alcohol combination is used as the main propellant for the A.4 rocket and also in some assisted take-off units designed at the same place as was the A.4 rocket, i.e. at HAP 11, Peenemünde. A variant of the liquid oxygen/alcohol system is provided by a rocket motor designed by Schmidding of Bodenbach, making use of compressed gaseous oxygen and methanol as the two fuels. This unit, designed as an alternative rocket motor for the Hs 293, proved superior in some respects to the T Stoff/Z Stoff combination of Walter, Kiel, especially in suitability for use at the low temperatures frequently met at high altitudes and in the possibility of being fuelled at the manufacturers works, thus avoiding the ground and storage organisation for T and Z Stoff otherwise needed on airfields.

19. It appears generally that, as oxidants, HAP 11 preferred working with liquid oxygen, Walter of Kiel were concerned chiefly with hydrogen peroxide and BMW of München-Allach were the chief exponents of nitric acid.

Supply and Manufacture of Liquid Rocket Fuels

20. Supply

The German choice of oxidants for liquid rocket fuels was inevitably influenced by supply considerations. It appears that a few years ago, when the German Air Ministry was first taking an interest in liquid rocket propellants, it was arranged with the Armament Supply Office (RLA) that development work was to be concentrated on hydrogen peroxide and nitric acid, which it was declared would be made available in sufficient quantities. By

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the summer of 1944, however, the position had altered substantially and a good deal of ill-feeling arose between the Air Ministry and RLA, partly over the inability of the latter to expand production of liquid rocket fuels at a sufficiently rapid rate, but mainly because in the meantime the German Navy had developed a project which, if successful, and if the Fuehrer's agreement were obtained, would take all available hydrogen peroxide by the middle of 1945. At a meeting in the RLA in June, 1944, production figures given showed that T Stoff was being manufactured at the rate of 1,200 tons per month and that 10,500 tons were then in stock. It was said that by the middle of 1945, this production would have been increased and that it would just meet the projected requirements of the Navy. Accordingly, circumstances might arise in which T Stoff would no longer be available for the Air Force from about the middle of 1945. It was also said to be impossible to increase substantially the production of concentrated nitric acid. These reasons were largely behind the great interest of the RLA in Myrol, which was to be developed with the greatest possible speed both as an oxidant to replace T Stoff where possible, and as a "monergol" to provide an alternative rocket fuel.

21. Objections raised by the German Air Ministry included the observation that if Myrol were used instead of T Stoff in the Me 163, the already limited range would be cut down by some 30%, and that there might be other technical difficulties on account of its low boiling point.

22. Intensive development of Myrol showed it to be a promising liquid rocket fuel, although various technical difficulties had still to be overcome. The progress of the war has made it unlikely that Myrol will now be used by the Germans as a rocket propellant, partly because the main manufacturing plant is now in Russian hands.

23. Manufacture

80% hydrogen peroxide - is manufactured in Germany by an electrolytic process developed by Dr. Pietsch and Dr. Adolfs of the Elektrochemische Werke München AG, Höllriegelskreuth. Manufacture of hydrogen peroxide may or may not be carried out at this place but full information on its preparation should be available there. It has been found that very concentrated hydrogen peroxide is less liable to decompose on storage than weaker peroxide. D1R (80% hydrogen peroxide) has to pass an acceptance test at which the strength must be 82% ± 0.2% and the SG 1.352 at 20° C. The limits permitted for its operational use in the G.A.F. lay down that the concentration must lie between 78.5% and 82.5% (SG 1.333 - 1.354). The material is stabilized by the addition of a maximum of 0.025 grams/litre of phosphoric acid. D2R (60% hydrogen peroxide) must have a concentration between 58.5% and 60.0% (SG 1.235 to 1.243) to be acceptable for operational use.

24. German schemes for bulk storage of 80% hydrogen peroxide have already been covered in a comprehensive C.I.O.S. Report based on examination of a storage site at Vaas.

25. 98 - 100% nitric acid

There is no indication that the Germans employ novel methods for the manufacture of 98 - 100% nitric acid, although from an experimental point of view they have noted that it can be made conveniently from 68% nitric acid and Myrol.

26. Liquid oxygen

For the manufacture of liquid oxygen the Germans embarked upon a large programme in conjunction with the employment of the A.4 long-range rocket. C.I.O.S. reports have already covered manufacturing, storage and transport procedure.

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27. Myrol - was manufactured by a recently developed process involving the continuous vapour-phase nitration of methanol. A pilot plant was built at Oberbirkigt, near Bodenbach, and the main plant at Christianstadt on the Bober.

28. Hydrazine hydrate - is manufactured by a process developed by the Elektrochemische Werke München AG, of Höllriegelskreuth. Small manufacturing plants were erected at IG Ludwigshafen and IG Leverkusen; the main plant is at the Chemische Fabrik Gersthofen, near Augsburg. At a meeting in May, 1944, the current production of B Stoff and C Stoff was stated to be 400 - 600 tons and 700 - 800 tons per month respectively. These do not appear to be reliable figures and are thought to be much exaggerated.

29. Pyrocatechol

No information is available from the Schmidding documents on the manufacture of pyrocatechol. The current production in May, 1944 was stated to be 300 - 500 tons per month - a figure which, like that given for C Stoff, may also by over-optimistic.

A.I.2(g)
D.of I.(R)
18th April, 1945.

(G.M. HEATH)
Squadron Leader,
for Wing Commander.

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APPENDIX TO A.I.2(g) REPORT 1768

Composition and employment of liquid rocket fuels used for G.A.F. and related purposes. (Uses by the German Navy are not included).

CODE NAME	COMPOSITION	EMPLOYMENT	
		In Conjunction With	For
D 1 R (formerly T-Stoff)	80% hydrogen peroxide	Z-Stoff	(Assisted take-off units (A.4 rocket (as gas generator to drive turbine for fuel pumps) (Hs 293 glider bomb (Me 163 A (as main fuels) (FZG 76 flying bomb (as propellant for land-launching)
		C-Stoff or Ergol	Me 163 B (as main fuels)
		Solid catalyst	Me 163 B (as gas generator to drive turbine for fuel pumps)
D 2 R	60% hydrogen peroxide	Unidentified G.A.F. application	
A-Stoff	Liquid oxygen	Methyl or ethyl alcohol	A.4 rocket (main fuels) Some A.T.O. units. (Note: gaseous oxygen and methanol used in some A.T.O. units and alternative rocket motor for Hs 293.)
B-Stoff	Hydrazine hydrate		In manufacture of C-Stoff
B-Stoff or Br-Stoff (Abbreviation for Brennstoff)	Ethyl alcohol	A-Stoff	A.4 as main fuels. (Note: this should not be confused with the B-Stoff used for manufacture of C-Stoff).
C-Stoff	30% solution of hydrazine hydrate in methyl alcohol	T-Stoff	Me 163 B (main fuels)
Z-Stoff	Saturated aqueous solution of sodium or calcium permanganate	T-Stoff	Uses shown under D 1 R above
	Solid catalyst based on manganese dioxide	T-Stoff	Me 163 B (as gas generator unit)
Salbei or Hoko MS 10	98-100% nitric acid above with addition of 10% concentrated sulphuric acid.	Petrol, J2 diesel oil, "Tonker" or various amine and furfuralcohol mixtures.	In some BMW designs. Possibly in X4. Possible alternative to T-Stoff in Me 163 B in an emergency.
Tonker 505b and 505c	Unidentified	Salbei or Hoko	In some BMW designs
Ergol	Pyrocatechol (probably in solution)	T-Stoff	Me 163 B (in place of C-Stoff)

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This refers to our letter to you dated October 7, 1999, regarding your appeal to the Information Security Oversight Office for 14 documents previously requested under Mandatory Declassification Review procedures. One document (AD346727) was provided to you by our letter dated November 19, 1999.

The review of 11 British documents you requested is complete and there are no objections to release. Titles of these documents are contained on the enclosed sheet and a copy of each is enclosed. We will advise you as soon as the reviews of the remaining two documents are completed.

Per DoD letter, Please mark these 11 documents "available to the public."

Sincerely,

SIGNED

H. J. McIntyre
Director

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I verified the docs could be marked available for public release via telecon with Pat Skinner, DoD Security Review, 695-9556/6428 on 21 Jan 2000,

Kelly Akers
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