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Report on
OPERATION "BACKFIRE"

VOLUME 1
Scope & Organisation of the Operation

Prepared for Printing by the Ministry of Supply

THE WAR OFFICE, LONDON, S.W.1

January 1946

JE

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Your reference

Our reference
300/39

Date
30 April 1976

BICENTENNIAL CELEBRATIONS: OPERATION "BACKFIRE"

1. Enclosed are Volumes 1-5 of the report on Operation BACKFIRE as requested.

2. MOD(OS8) state that these copies may be permanently retained.

M O F FAUSSET
Major GSO2(W)
for Colonel GS
Technical Intelligence(Army)

Headquarters, Special Projectile Operations Group,
B.A.O.R.

SPOG/500/12

7th November, 1945

TO : The Under-Secretary of State,
The War Office.

Commanding General, United States Forces,
European Theatre.

Sir,

1. I have the honour to submit my report on Operation " BACKFIRE."

2. On the 22nd June, 1945, I was instructed by the Supreme Commander, Allied Expeditionary Force, in " BACKFIRE " Instruction No. 1, that the object of this operation was as follows :—

> " The primary object of the operation is to ascertain the German technique of launching long range rockets and to prove it by actual launch. As complete, undamaged and fully-tested rockets are not available, it is necessary first to assemble rockets from the available components. In addition to the primary object, the operation will therefore provide opportunities to study certain subsidiary matters such as the preparation of the rocket and ancillary equipment, the handling of fuels, and control in flight."

3. On the 11th August, 1945, after the War Office had assumed responsibility for this operation on the dissolution of Supreme Headquarters, I was instructed by the Army Council in War Office letter 43/Training/3548(R.A.3) that the object of the operation was as follows :—

> " The object of this operation is to obtain while the German technical staff originally employed on long range rockets are still available and the details are still fresh in their minds :—
>
> (*a*) Information on the testing, assembly and filling of the German A-4 rocket.
>
> (*b*) Detailed knowledge and experience of the German technique for launching long range rockets."
>
> " The intention is that you will collect this information by carrying out the operation of assembly and filling in Germany, using German disarmed personnel supervised by British technical experts, and that the successful completion of the operation will be proved by the firing of a number of A-4 rockets. Observation of the trajectory and photographic records will be taken as far as possible and the drill employed for firing the rockets will be recorded in detail."

4. The main text of my report describes the means by which these tasks were accomplished ; my conclusions on the future of this weapon are stated in Section 8. Information which has been gathered on the preparation of the rocket and ancillary equipment and on testing and assembly is recorded in Volume 2. The technique of launching is described, and the drill is recorded in detail in Volume 3. It was proved by actual launches on the 2nd, 4th and 15th October, 1945. The results of observations of the trajectory and photographic records are set out in Volume 5. Section 5, and Volume 5 contains information on the handling of fuels and filling of the rocket. As no equipment for the remote control of the rocket in flight was uncovered, I have been unable to study this subject.

5. At a later date I was instructed by the War Office to make certain film records. These have been made and a brief description is given in Volume 5.

6. At Section 9 is a list of officers who have acquired special knowledge through participation in this operation.

I have the honour to be,
Sir,
Your obedient Servant,
(Sgd.) A. M. Cameron,
Major-General,
Commander, Special Projectile Operations Group.

Copy to : The Secretary, The Ministry of Supply.

HEADQUARTERS SPECIAL PROJECTILE OPERATION GROUP

Report on Operation "BACKFIRE"

MAY TO OCTOBER 1945

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Scope of the OPERATION . . . . SECTION 1

1. "BACKFIRE" was essentially an Allied military operation—carried out against time—and inspired, organised and conducted by the armies on the Continent. Because it had to take place in the British Zone, the organisation set up was predominantly British. The actual work of building and launching A-4 rockets was carried out by Germans. The United States and the United Kingdom were invited to provide an equal number of technical officers to participate in the operation. The United States were unable to do more than provide observers, but the British Ministry of Supply loaned some six technical officers. To the military and technical officers of the "BACKFIRE" organisation is due the entire credit for such success as was obtained.

2. During the last month of the campaign on the Continent, a large number of German A-4 personnel fell into the hands of the Allies, and there were indications that a considerable quantity of A-4 rockets and ancillary equipment would also be captured. Early in May, 1945, therefore, an investigation was carried out to see if it was desirable and feasible to use German personnel to fire captured A-4 rockets in Germany. A Staff Officer of the Air Defence Division, Supreme Headquarters, Allied Expeditionary Force, was despatched to the United Kingdom on the 7th May to discuss the project with interested authorities. At the War Office he saw the Scientific Adviser to the Army Council, the Deputy Chief of the Imperial General Staff and the Assistant Chief of the Imperial General Staff (Weapons); at the Ministry of Supply he saw the Director-General of Munitions Production, and the Controller of Projectile Development. They were unanimous that it was most desirable to carry out such an operation. They stated that it might save years of development work, and they agreed that the launching and control of rockets was a complicated operation which it was necessary for the German technicians to demonstrate in the near future, before they lost their skill. They also considered that unless some captured rockets were fired, it might be discovered at a later date that certain technical information essential to rocket operation was missing. The Supreme Commander therefore directed that the operation be put in hand as a joint United States and British military operation under the control of Supreme Headquarters, Allied Expeditionary Force, and obtained the approval of the Combined Chiefs of Staff. He also directed that it should be completed as soon as possible.

3. The original conception was that a number of complete rockets would be captured in a fit state to fire, together with the necessary ancillary equipment. In addition to studying the technique of launching, it was proposed to use and study the three methods of control in flight which the Germans had employed, and to aim at three successful launches by each method. A total of thirty rockets was considered necessary because some 50 per cent. of the attempted launches might be unsuccessful and the rocket damaged past repair, and because a number of rockets were likely to be received in such a battered condition that they could never be made fit to launch.

4. Actually no complete, undamaged and serviceable rockets were found. It was therefore necessary to collect component parts, and to set up an assembly shop in which these could be put together by German personnel.

5. The idea of studying the various German methods of control had to be abandoned because none of the ground equipment for remote control was uncovered. Instead a simple adaptation was made to the existing on-board equipment to ensure that the rocket would fall within a given area of sea. Efforts were then concentrated on producing only eight rockets fit to fire, out of which it was hoped that perhaps four would be launched successfully.

6. The failure to obtain complete rockets produced many complications. It now became necessary to carry out tests of the sub-assemblies and of the completed rocket before it could be accepted as fit to fire. The proper test apparatus was not forthcoming, and it was therefore necessary to design and build apparatus especially for this operation. The importance of the time factor was also enhanced. It became obvious that the operation would drag on and on if the ordinary routine delays were accepted. A high priority for the operation and permission to short-circuit the normal channels were therefore obtained.

7. By the middle of August, 1945, the operation had crystallised itself into two parts; one, the production of the completed rockets, and recording of all technical lessons which gradually came to light in doing so; and the other, the field operation of handling the completed rocket, setting it up on its firing site, launching it, and recording so far as possible its behaviour in flight.

8. The second half of September had been set as the target date for the first launch. The launch actually took place on 2nd October, two attempts the previous day having failed. There was a second successful launch on the 4th October, when the rocket used was the one which had failed twice on 1st October. It was then decided that no useful scientific purpose would be served by any further launch. Orders were, however, received to carry out a demonstration launch, and this was effected successfully on the 15th October.

9. In order to obtain such records as were possible of the rocket in flight, the initial part of the trajectory was photographed by kine-theodolites and plotted by radar stations, and one radar station was deployed in Denmark to plot the fall of shot.

10. It is perhaps worthy of note that when the Germans were first assembled, they clamoured for some guarantee of compensation in the event of injury or death resulting from an accident. Yet, from the first day until the last launch, not one single man, British or German, was even injured.

ORGANISATION . . . . . SECTION 2

COMMAND

11. The Supreme Commander delegated to the Chief, Air Defense Division, Supreme Headquarters, Allied Expeditionary Force (Major-General A. M. CAMERON), responsibility for the organisation and conduct of the operation. This officer and his staff being part of Supreme Headquarters, it was necessary to nominate a subordinate headquarters, which would open up the necessary establishment for the firing of rockets, and take command of all activities at the site. As it was necessary to fire over the sea, it was decided to carry out the operation in the British Zone. In order to simplify administraton, it was planned to have a primarily British organisation, with the attachment of such United States advisers, staff officers, and technicians as the United States desired.

12. On the 22nd May, Headquarters, 21 Army Group, were asked to place a brigade headquarters under the operational control of Supreme Headquarters, Allied Expeditionary Force, and on the 26th May, 1945, they nominated Headquarters, 307 Infantry Brigade (Brigadier L. K. LOCKHART). Brigadier Lockhart's functions were to reconnoitre and select a suitable site for the operation; to arrange for the allocation or construction of the necessary workshop and firing facilities; to command all troops assigned to the operation; to administer all Germans employed on the operation; and to receive the rocket components and equipment.

13. On the dissolution of Supreme Headquarters, Allied Expeditionary Force, on the 14th July, provision had to be made for the continuity of the higher direction of the operation previously exercised by the Supreme Commander through his Air Defense Division. The Combined Chiefs of Staff therefore placed the responsibility on the War Office, who in turn reconstituted the British component of the Air Defense Division as an independent formation headquarters. On the 15th July, this component moved from FRANKFURT to CUXHAVEN, the site selected for the operation, and reopened their office as Headquarters, Special Projectile Operations Group (S.P.O.G.).

BRITISH MILITARY UNITS

14. All the administrative units required for the conduct of the operation were provided by 21 Army Group. They were under command of H.Q.307 Inf. Bde., and comprised:—

- 1L.A.A./S.L. Battery, R.A.
- 177 L.A.A. Battery, R.A.
- Detachment 952 Railway Operating Company, R.E.
- 307 Infantry Brigade Signals Section, Royal Signals.
- 1685 Artillery Platoon, R.A.S.C.
- 1689 L.A.A./S.L. Section, R.A.S.C.
- Detachment 17 Canadian Field Ambulance Section, R.C.A.M.C.
- 101 A.A. Brigade Workshop, R.E.M.E.
- 1 L.A.A./S.L. Workshop, R.E.M.E.
- 76 F.C.F. Brigade, A.F.S.
- 6 Canadian Field Security Reserve Detachment.
- 736 German Labour Company.

15. Certain other units of 21 Army Group, though not placed under command, were employed on various work in connection with the operation, chiefly construction. They comprised :—

- 593 Army Troops Company, R.E.
- 670 Artizan Works Company, R.E.
- 1 Platoon, 113 Road Construction Company, R.E.
- 2 Platoons, 700 Artizan Works Company, R.E.
- 23 Mechanical Equipment Platoon, R.E.
- 145 Pioneer Company, Pnr. Corps.

16. Three operational units and an Army Film Unit were found by the War Office, viz.:—

- X Special A.A. Radar Battery, R.A.
- 20 Special Survey Detachment, R.A.
- 2AA (A.T.S.) Kine-Theodolite Detachment.
- 355 A.K.S. Detachment, R.A.O.C.

21 Army Group also provided a Westex Recording Unit, R.A., and No. 1 Independent Administrative Company, Royal Signals.

BRITISH TECHNICAL STAFF

17. Although the work of assembling and testing rockets was to be carried out by German scientists and technicians, it was early appreciated that British technical officers would be required. Their role was to supervise the German technical activities, to ensure so far as possible that there was no deception by the Germans, and above all to record technical information of value. It was obvious that they should, if possible, be expert in long range rocket matters, but the officers who were eventually nominated did not in fact have this experience.

18. On the 22nd May, the Ministry of Supply were approached, and on the 24th May, a signal was sent asking for a senior officer as technical adviser to General Cameron,

and an officer with knowledge of rocket construction to supervise the collection of components, to ensure correctness of assembly, and to inspect the completed rockets. On the 3rd June, a liaison officer from the Ministry of Supply was appointed; but the officer to supervise construction (Colonel C. W. RABY) did not arrive till the 9th July, and he had then also to assume the functions of chief technical adviser. Colonel Raby brought with him an Assistant Superintendent and an expert on fuels. Three more technical officers from the Ministry of Supply had reported for duty by the 2nd August. On the 10th September, just three weeks before the first launch, Brigadier W. H. WHEELER was added to the staff of S.P.O.G., but the technical direction remained in the hands of Colonel Raby.

UNITED STATES REPRESENTATION

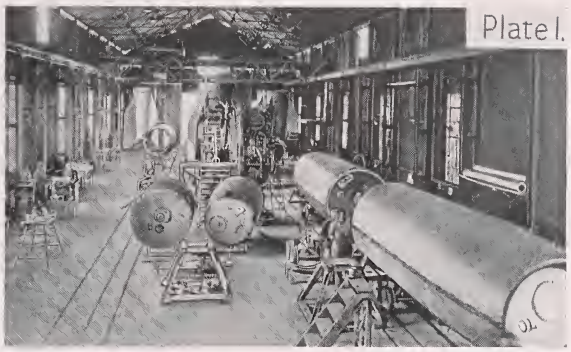
19. On the 28th May, Headquarters European Theatre of Operations, United States Army, were asked for a senior United States officer to advise and assist in the setting up of the appropriate organisation, but replied that no officer was available. A similar request was therefore made to the War Department, WASHINGTON, on the 2nd June. They replied suggesting one of two officers who were already in the theatre. Eventually, on the 4th July, Colonel W. I. WILSON, United States Army Ordnance Department, reported for duty as senior United States officer, with the role of watching the United States interests, and of assisting S.P.O.G. by procuring from United States sources such personnel and material as might be required. Colonel Wilson was accompanied by two other officers and was succeeded on the 14th August, by Colonel J. H. WEBER, United States Army Ordnance Department.

INSTALLATIONS

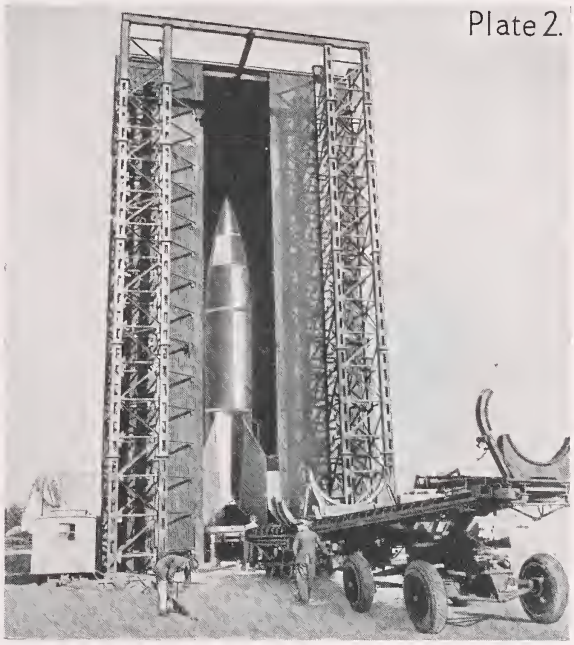
20. It was known that after the bombing of PEENEMUNDE in September, 1943, the Germans had transferred their experimental V-1 and V-2 establishments elsewhere and that the former had fetched up in the vicinity of CUXHAVEN; it was therefore thought that this might prove a suitable place to carry out operation "BACKFIRE." Reconnaissance confirmed this view, and the KRUPPS gun proving grounds were taken over for the operation. Not only did this site provide some useful facilities in the way of workshops, offices, roads, railway sidings, etc., but it was so located that the whole trajectory of the rocket could be over the sea, and yet close enough to the shores of SCHLESWIG and DENMARK for both the upward and downward portions to be plotted by radar.

21. The month of June was devoted to clearing the site and constructing the additional facilities required. The chief of these were:—

(*a*) An Assembly Shop for the simultaneous assembly of four rockets, consisting of a Marston shelter 200 ft. long, 45 ft. wide and 17 ft. 9 in. from the floor to the hook of the overhead 10-ton gantry. (Plate 1.)



(*b*) A Vertical Testing Chamber, 56 ft. high, with an overhead crane lift of 5 tons, capable of accommodating a rocket in the vertical position. (Plate 2.)



(*c*) A concrete firing site, together with approach roads, reinforced concrete command post (Plate 3) and two reinforced concrete observation shelters.

The German Personnel Employed . . SECTION 3

22. After the German A-4 Division surrendered at the end of April, 1945, 107 of its officers and men had been selected by M.I. for interrogation. They were chosen from amongst those with the longest practical experience and the most knowledge of improvements and simplifications in launching methods. They included officers who held important operational, administrative and technical appointments in the Division. At the end of May, the party was taken over for operation " BACKFIRE." They were segregated in a camp near BRUSSELS, and interrogated intensively, not only with a view to finding out what further personnel would be required, but also with a view to locating rocket equipment abandoned by the Division. By the beginning of July, the party had been increased to 137 in all, and was removed to ALTENWALDE near CUXHAVEN. A prisoner of war Labour Company for routine tasks was also moved to CUXHAVEN.

23. As soon as it became apparent that the building of rockets was going to be a complicated and tricky business, it was decided to supplement this party of soldiers by civilian scientists and other technicians. Permission was therefore obtained to select 79 technicians from amongst those whom the United States had concentrated at GARMISCH PARTENKIRCHEN, and they arrived at CUXHAVEN at the end of July.

24. It was realised from the beginning that the handling of the Germans would be a delicate matter. The problem was very different from normal interrogation. If the difficulties of building rockets were to be overcome, and the launching procedure learnt, active co-operation rather than passive obedience was essential. At the same time there was uncertainty as to how far their apparent willingness to co-operate could be trusted. In the end it was decided to organise them into two parties; all soldiers and civilians required to work in the shops and launching unit were organised into a military unit under command of the senior German officer, Lieutenant-Colonel WEBER, who had commanded an A-4 Regiment, and had previously been in command of the A-4 experimental battery. This unit was called AVKO (ALTENWALDE Versucha-Kommando). The second party, comprising civilian experts, was kept in a separate camp in the village of BROCKESWALDE, for interrogation purposes only. It was hoped by this means to ensure that information provided by one party could be checked against information provided by the other party. Lieutenant-General Dornberger had also been brought to CUXHAVEN and he was kept separate from both parties as it was feared that his considerable influence might be embarrassing. After some weeks no further use for him was found and he was sent to England.

25. In order to keep the Germans in a co-operative frame of mind it was thought desirable to ameliorate their lot to some extent. Permission was therefore obtained to increase their pay and their rations, and towards the end of the operation to pay a bonus, *pro rata* according to responsibility and technical efficiency.

26. In August a request was received from the United States for 26 of the civilians drawn from GARMISCH-PARTENKIRCHEN to be handed over to the United States authorities, as they were urgently required for development work on weapons required for use in the Japanese war. These 26 were all key personnel, and it was pointed out that their withdrawal would seriously prejudice the success of operation " BACKFIRE." Eventually, the Japanese war having ended, fourteen were handed over, and it was agreed to hand over the remaining twelve on conclusion of the operation. After the withdrawal of these fourteen, some replacements were necessary, and 25 technicians were obtained from WITZENHAUSEN-ESCHWEGE and incorporated into AVKO.

27. The status of the Germans employed varied at the start. Some were Prisoners of War, some were disarmed enemy personnel and some were civilians. In order to put the matter on a proper footing and to comply with international law, all the soldiers were converted into disarmed enemy personnel, and all civilians " beamted " i.e., made into officials of the German army.

28. In all, some 600 Germans were employed of whom not more than 70 were A-4 technicians from experimental establishments and about 128 were troops of the A-4 Division. The remainder were troops and civilians who had had no previous connection with A-4.

The organisation of AVKO on the 2nd. October, 1945, the first launching date, is given at Table " A."

Table A

German Organisation for Operation "Backfire"

HQ AVKO
Leiter AVKO
Oberstleutnant Weber
Assistant: Lt. Lucke
Total: 2

Tech Advisor
TECHNISCHE BERATUNG
Prof. Wierer
Total: 1

Tech Director
TECHNISCHE LEITUNG
Dir. Lindenberg
Total: 2

Production Dept
FERTIGUNGS-ABTEILUNG
Dir. Rudolph
Deputy; Dipl. Ing. Heimburg
Total: 5

Technical Office	Ground and Rocket Circuits	Range Control (B.S)	Steering	Assembly (Control Compartment and Testing)	Assembly (Centre Section & Tail Unit)	Stores and Works Transport	Museum	Special Det at VOELKENRODE
Technisches Büro	Bord-und Bodennetz	Brennschlussgabe	Steuerung	Montage(18) Geräteraum Armaturenprüfung	Montage (19)	Lager-und Werktransp.	Museum	Aussenst. LFA Braunschweig
Ing. Priesner Ing. [Ofhr] Bringer	Dipl. Ing. Hintze Dipl. Ing. Pinsker	Dr. Kirschstien Dr. Mühlner	Dipl. Ing. Hoelzer Dr. Ing Müller II	Ing. Bader (Oblt) Ing. Rauchenwald (Uffz)	Ing. Huttenberger (Ofw) Ing. Endler (Gefr)	Maj. Schlesiger Ofw. Kuhle	Hptm. Muller.	Ing. Schuran
					Propulsion unit: Antriebsblock: Koenig			Mechonical Section: Mech. Sektor: Beyrich
					Tail Unit: Heck: Gardian			Electrical Section: Elektr. Sektor: Dipl. Ing Kouba
					Centre Section: Mittelteil: Viergutz			
Totals: 21	23	2	10	18	51	37	3	14

Total for Production Dept: 186

Operations Dept
OPERATIONS-ABTEILUNG
Dipl. Ing. v. Chlingensperg (Hptm d.R)
Deputy. Dr. Ing. Friedrich
Total: 4

Testing (Vertical)	Ballistics and Survey	Special Vehicals Sec:	Fuelling	Trans-loading Sec:	Launching Group
Prüfung	Ballistik u. Vermessung	Spezial-fahrzeuge	Betankung	Umschlag	Start
Ing. Ralle (Oblt) Dipl. Ing. Maras (Gefr)	Maj. Thomschke Dr. Ing Strobel	Baurat v. Gottberg Ing. Viebach (Uffz)	Lt. Kapp Wm. Dexheimer	Lt. Bergemann	Ing. Zimmermann Ing. [Lt. Rüdiger [Uffz
					Propulsion Control: Triebwerk: Viebach, Voigt (Uffz)
					Steering Control: Steuerung Stephan (Uffz
					Rocket & Ground circuits: Bord-u. Boden netz: Kloos (Ogfr) Berle (Wm)
Totals: 12	7	14	6	9	13

Total for Operations Dept: 92

Works-Adm.
BETRIEBS-VERWALTUNG
Maj. Mathels
Deputy. Dr. Merz (Stabsfeld.R)
Total: 3

Supplies
BESCHAFFUNG
Hptm. Bauch

Personnel Appointments
STELLENBESETZUNG
Reg. Rat Thies (Lt)

Translations, Insurance
UBERSETZG. UNFALLSCHUTZ
Dr. Merz

Registry
REGISTRATUR
Ofw. Hussong

Professional Advice Bureau
BERUFSBERATG *)
Dr. Merz, Dr. Lohmann (Lft)

Testimonials
BEGLAUBIGUNG *)
Hussong

Total 29

Camp & Station Adm.
LAGER-U-PLATZ-KOMMANDANTUR
Maj. Schultze
Deputy. Hptm. Schmaller
Total: 2

Rations
VERPFLEGUNG
Ozm. Bienias

Billets and Clothing
UNTERKUNFT; BEKLEIDUNG
Ltn. Hoelzer

Medical
ARZT
Ass. Arzt Dr. Kriegk

Welfare
FURSORGE
Oberstltn. Wetzling

M.T. Section
FAHRBEREITSCHAFT
Ob. Schirrm Koehler

Works Engineer
BETRIEBSINGENIEUR
Ing. Spangenberg (Ofhr)

Signals
NACHRICHTENVERBDG
Klein

OC 736 Lab Coy
FUHRER 736 COY
Hptm Braun
Labour Parties
Arbeitskdo

Total 274

Electrical Workshop
Elektro-Werkstatt
Rosinski
Total 10

Workshop
Werkstatt
Lt. Fuchs
Wm. Giese
Total 26

Number of Germans engaged in Operation BACKFIRE

HQ AVKO	2	Camp and Station Adm.	
Technical Director	2	(Camp only)	66
Technical Advisor	1	Guard Det	8
Production Dept.		Labour Parties	150
and Voelkenrode	186	Total	224
Operations Dept.	92		
Works Adm.	32	Total for Works	367
Camp & Station Adm (Works only)	52		224
Total for Works (ALTENWALDE & VOELKENRODE)	367	Grand Total	591

Anmerkungen:
Note:

*) Beim Schieben von Gruppe Spezialfahrzeuge nach Gruppe Start Kommandiert
Transferred for Launching from Special-Vehicle Section to Launching Group

**) Nach Umgliederung vom 18.9.45 neu gebildete Gruppe
New Sections formed after re-organisation on 18 Sept 45

ROCKET EQUIPMENT

29. It was early appreciated by Supreme Headquarters, Allied Expeditionary Force, that if such A-4 equipment as was available was allowed to be evacuated and shipped overseas haphazard, the chance of obtaining sufficient material to carry through the operation would be indeed slender. Accordingly, on the 4th May, orders were issued to all Allied formations, freezing the stocks of A-4 equipment in the European theatre until the question of allocation (with particular reference to operation "BACKFIRE") had been settled. This order was later confirmed by the Combined Chiefs of Staff.

30. Among the first enemy units to be withdrawn when threatened by the advancing Allied armies were the rocket-firing troops based in the ZWOLLE-ENSCHEDE area in North-east Holland and in the HACHENBURG-MONTABAUR area North-east of KOBLENZ. These units made their way Eastwards, evacuating their field equipment and most of their stores. As they retreated they scattered, and, as petrol supplies gave out and the chain of command broke down, their equipment was abandoned more or less where it stood at scattered points along the Western front. Destruction of the equipment by the rocket-firing troops had been carried out in a half-hearted and haphazard manner, but weather and looting combined to make up for the lack of thoroughness on the part of the troops. It soon became apparent that few complete and undamaged rockets were available, and so arrangements were put in hand to recover sufficient sub-assemblies and component parts for all purposes.

31. Many technical reports—principally those published by the Royal Aircraft Establishment, FARNBOROUGH—had appeared prior to May, 1945, and the Air Defense Division was, so far as the actual rocket was concerned, in possession of accurate details regarding the electrical and mechanical components required, including the "on-board" control equipment. It was proposed to use all types of control for range and line which the Germans had employed. On the 20th May, a request was submitted to G-2 Division (Technical Intelligence), Supreme Headquarters, Allied Expeditionary Force, for the allocation of component parts for thirty complete rockets, these rockets to be representative of all types of control. The matter did not rest with a formal demand having been submitted. Work was pushed ahead on the task of collating all available information as to the location of A-4 equipment and producing centres. Information for this purpose was obtained principally from reports by Allied armies, from intelligence reports and by interrogation of Prisoners of War.

32. From the information thus available, it soon became clear that there were four main sources of supply. These were :—

(*a*) The vast underground factory and assembly centre known as MITTELWERK at NIEDERSACHSWERFEN near NORDHAUSEN.

(*b*) 12th U.S. Army Group Area
(*c*) 21 Army Group Area
} Dumps of A-4 and associated ground equipment

(*d*) The various factories throughout Germany which had been engaged on A-4 production in one way or another.

33. It was decided, about the middle of May, to exploit the first three sources as rapidly as possible, because NORDHAUSEN was destined to come under Russian control in the near future, and the equipment abandoned in the Army Group areas was deteriorating daily and was constantly liable to be removed by other interested parties. The vast underground assembly plant at NORDHAUSEN had been exploited initially by United States Ordnance Officers, who reported at the end of May that they had recovered sufficient A-4 component parts and sub-assemblies to construct the 100 rockets required for the United States, and that sufficient equipment remained for the 30 rockets required for operation "BACKFIRE," and the 120 rockets required by the Air Ministry. Air Defense Division therefore undertook the recovery of this equipment. The evacuation from NORDHAUSEN began on the 3rd June, and was completed on the 20th June, despite very considerable difficulties. The underground tunnels and bays at NORDHAUSEN cover approximately 18 miles, and the whole of this vast assembly plant was combed for the equipment required. Fortunately, electric power was still laid on to the factory and the overhead cranes were working. Use was made of the detailed knowledge possessed by the German personnel who had worked in the factory and were still living in the district. It was discovered that there were few complete sub-assemblies available and it was necessary, therefore, to recover those component parts required for building the control compartment, the centre section, the steam unit, the thrust unit, and the tail unit of the rocket. In addition, certain jigs, tools, and other machinery required for assembling the various sections of the rocket were recovered, and some 640 tons of equipment were removed from the factory at NORDHAUSEN and put on rail cars for delivery at CUXHAVEN. In all five train loads of equipment left NORDHAUSEN, two were despatched from KASSEL and two from GOTTINGEN. There was an average of

fifty-five trucks in each train making three miles of trucks in all.

34. The absence of complete sub-assemblies at NORDHAUSEN meant that considerably more time would be required for the construction of rockets than had been planned. This was particularly true of the tail units, the assembly of which required special jigs and tools which it was impossible to recover from NORDHAUSEN. Accordingly six of the tail unit sub-assemblies, previously recovered by the United States Army Ordnance Department were requested for operation " BACKFIRE." Before authority could be obtained for their release they were loaded for shipment to the United States. Fortunately the authority arrived before the ship sailed and unloading began at once. The units eventually arrived at CUXHAVEN and were used.

35. On the 25th May, it was arranged that a search party, consisting of British and United States Officers, should begin the search in the 12th U.S. Army Group area. On arrival at Headquarters, 12th U.S. Army Group, the party was told that the area had already been thoroughly combed. The matter was referred to Ordnance, Headquarters U.S. Forces European Theatre, who agreed with the view expressed by 12th Army Group and stated that the equipment recovered in that area to date was not merely for U.S. projects but would also be made available to other bidders. In the face of this it was decided to withdraw the party from this Army Group and to push forward the search elsewhere.

36. As soon as the search party returned from 12th U.S. Army Group, a second was at once organised and left for 21 Army Group area on 31st May. The party covered a large part of Northern Germany and returned to base on the 10th June, having uncovered a considerable quantity of rocket equipment abandoned by German operational units, including eighteen incomplete rockets which were located on rail at JERXHEIM (D.1792) and various bits and pieces such as valves, pipes, batteries, fuses and electrical components.

37. By the beginning of August, all the rocket equipment involved had been received at CUXHAVEN. On the 21st August a further consignment of twelve rockets arrived from LEESE and DUREN ; these had also been found by the above-mentioned search party, and included the best specimen ever recovered. Their unloading was delayed by the fact that they were found to have the original demolition charges in position.

38. Rocket components in sufficient quantity were fairly readily available for the operation, with one important exception, control equipment. As far back as the 27th May, all interested parties reported that there was an acute shortage of all types of control equipment. Not only were the control compartments of recovered rockets almost always completely gutted, but few parts of the ground installations necessary for radio control were ever found. NORDHAUSEN itself, home of the A-4 rocket, yielded little or nothing in this direction. A considerable amount of information had been obtained from Prisoners of War as to sources of supply of this equipment, but the Germans themselves stated that certain items of control gear had been in very short supply even when rocket operations were at their height. The information available was immediately converted into briefs for search parties, and all the search parties sent out since the operation began had the location and recovery of control equipment as the whole or part of their task. Reports from these parties were disappointing. Many of the sources reported by the Germans, apparently in good faith, were unproductive for a variety of reasons. Factories had suffered by bombing, shortage of materials prior to the final collapse, and so on ; control equipment on the rocket itself had been the first target for destruction by the rocket troops.

39. By the beginning of July, it was realised that it would not be possible to use all the different methods of control which the Germans used, and that efforts would have to be concentrated on obtaining sufficient equipment to ensure that the rocket was put on to its trajectory, and fuel cut-off obtained, by means of the ZEITSCHALTWERK or time-switch, ordinarily used as an overriding control should the normal method (FUNK-BRENNSCHLUSS or I-GERÄT) fail. There were three main difficulties even in this. Some 160 rocket gyros had been recovered from KIEL by the search party operating there from the 1st to 7th July, but these were all VERTIKANT ; only two or three HORIZONT had been discovered. The batteries required were of unusual construction, and the specimens left in abandoned rockets or buried in the ground had been ruined by exposure. Only twenty Control Amplifiers (MISCHGERÄT) in various states of repair had been recovered in the course of the search for control equipment; all were in need of thorough tests and a large number of the necessary radio valves were missing. This situation gave rise to a considerable amount of anxiety, and it was realised that herein lay a serious limiting factor. Eventually it was decided to assemble only eight rockets, sufficient elementary control equipment being available to make this number fit for firing.

GROUND EQUIPMENT

40. Before the task of recovering the necessary ground equipment could begin, detailed information was necessary as to exactly what was required. This information was obtained largely by interrogation of Prisoners of War. It will be appreciated that prior to the surrender, intelligence on this matter fell far short of what was known about the construction of the rocket itself. By the 19th May, interrogation had been completed, and a list was drawn up of those items of ground equipment required. The amount of equipment to be recovered was formidable, including, as it did, control cars, oxygen, alcohol, and hydrogen-peroxide tankers, firing platforms, transport and erection vehicles, testing vehicles, generators, cranes, ladders, air compressors and other ancillary equipment such as cables, connecting plugs, hoses and igniters.

41. The search party which operated in the 21 Army Group area from the 31st May to the 10th June uncovered considerable quantities of ground equipment. Their targets were based on information provided by Prisoners of War. Often hundreds of miles were covered, only to find that the equipment had been effectively destroyed; on more than one occasion targets proved to be just within the Russian area and the party had to return empty-handed from such expeditions. Despite innumerable set-backs, most of the items were, in fact, uncovered, but seldom in serviceable condition. The area most productive of equipment was that around CELLE and FALLING-BOSTEL; it was to this locality that the majority of the equipment used by the units operating from THE HAGUE and ENSCHEDE had been evacuated. As each item of equipment was located, it was tagged and complete lists were sent in to T-Force, 21 Army Group, who undertook the task of recovery and transportation to CUXHAVEN.

42. The area around NORDHAUSEN also produced many items of ground equipment. This region had been used by the Germans as a concentration area for A-4 equipment and, incidentally, for personnel withdrawn from PEENEMUNDE and operational firing sites. The area was therefore thoroughly combed by search parties and, despite the fact that large quantities of the equipment had been thoroughly destroyed, a number of serviceable items was obtained before the area was handed over to the Russians.

43. It is, perhaps, worthy of note that, although many of the firing sites used by the Germans were visited by search parties, not one item of ground equipment had been recovered from these sites.

44. In July many items of ground equipment were still outstanding. Accordingly, a further interrogation of Prisoners of War was carried out with the object of establishing further sources of supply. Prisoners of War who had buried equipment, or otherwise hidden it, accompanied search parties, whose operations at this stage ranged from LEIDEN, in HOLLAND, to UELZEN in Germany, and from HEIDE, in SCHLESWIG-HOLSTEIN, to HANNAU, near FRANKFURT-ON-MAIN. Often excavation was carried out and, in one instance, dredging proved to be necessary.

45. By the middle of September, all the ground equipment necessary for the operation had been assembled at CUXHAVEN. Much of the equipment arrived in an unserviceable condition, but all essential items were repaired by the German staff or R.E.M.E., who were forced to cannibalise extensively.

ENGINEER TOOLS AND STORES

46. The rockets and the component parts recovered varied enormously in their state of repair; the work of stripping, examination and reconditioning was an unexplored field and one of the main drawbacks encountered was that it was never possible to say exactly what was required in the way of tools, plant and materials—every day produced some new difficulty and new requirements for the materials to overcome it. The German personnel also complicated the problem. The demand for every kind of tool and engineering store was enormous, and it was only as a result of painstaking checking and investigation that a marked weakness of the German personnel was discovered. They were unwilling in the extreme to indulge in any form of improvisation, and were very often unaware of the destruction which had overtaken the German producing centres as a result of the war. Consequently each day produced new and lengthy demands and glib references to sources of supply which no longer existed. Nevertheless, a very great need did in fact exist for machine and hand-tools and practically every form of workshop requisite as a result of the unexpected amount of repair and construction work which had to be undertaken. The problem was to meet these requirements in the shortest possible time so that vital work would not be held up.

47. Many of the tools and stores were standard and a normal British Ordnance supply, but the majority were, naturally, in metric sizes. Some of the tools were very special manufacture, and only one or two firms in Germany were known to have made them. Even for those requirements which could probably be met from British Army sources another factor—time—entered into the calculations, and the normal time-lag involved in the provision of stores through Ordnance channels could not be accepted.

48. The answer was not far to seek, but considerably harder to put into practice. Search parties could be organised to scour all the big German industrial and manufacturing towns, dumps of captured material, air-fields, and the like, with the task of locating and recovering the tools so urgently wanted. Thus a time-lag of several weeks inherent in the normal Ordnance channels could be reduced to days. First of all the difficulty of requisitioning had to be overcome. The normal drill required approval of Corps Headquarters on each occasion—regardless of the time involved in that process. So far as operation "BACKFIRE" was concerned, that procedure involved too much delay, and therefore, on the 30th July, permission was obtained to carry out requisitioning throughout 21 Army Group area, of technical equipment needed for operation "BACKFIRE" without prior reference to Corps Headquarters.

49. Once freedom of action had been obtained no time was lost, and during August twelve search parties, with German guides, interpreters and transport were sent out to DANNENBERG, CELLE/HANOVER, BRUNSWICK, ALFELD/WENNIGSEN, BLANKENBURG/GOSLAR, GOTTINGEN, HAMBURG, KIEL/LUBECK, MUNSTER/RUHR. By the end of the second week in August a very fair measure of success had been obtained and about 70 per cent. of the requirements were met in a matter of twelve days. It was found that electrical measuring instruments were the stores most difficult to obtain and comparatively few of these were ever found. However, sufficient material was recovered to enable the work of repair and minor manufacture to continue unhindered.

50. Up to this time the demand had been almost entirely for standard tools, electrical components, welding and soldering materials, glassware, insulation materials, cable, hot air blowers, technical books, mathematical tables and optical instruments, all of a standard nature, and therefore collection could be allocated to search parties as described above. Towards the end of the month, however, demands were received for more basic materials such as steel, brass and copper in sheet, bar and strip form and for a wide variety of lubricating media. This introduced a further complication, as the materials were known to be in short supply in Germany, and Military Government were controlling their issue to certain essential services. Headquarters, 21 Army Group and the Ministry of Aircraft Production came to the rescue. The former gave a "blanket" authority to visit the main Service Depots concerned and to obtain whatever was required. The latter gave permission to take stores from the Hermann Goering Aeronautical Research Institute at VOLKENRODE, near BRUNSWICK. This Institute provided a vast amount of the raw materials required.

51. Organising and running the search parties was itself almost a major operation and was in the hands of Colonel W. S. J. CARTER. Every type of machine and hand-tool from a power-driven lathe to an electrician's screw-driver was supplied in the course of six weeks or so. Officers had to be instructed in the technical and administrative details necessary for running a search party; most of the personnel involved in the task of procuring the tools and materials required were untrained, in the engineering sense, and the task for them was therefore much harder than might be supposed. Transport had to be supplied, often at short notice, and all the necessary arrangements made for German personnel to accompany the parties, without, if possible, removing key men from the work in hand. Since the beginning of June, up to the end of the operation, Special Projectile Operations Group search parties have employed over 200 men working for nearly 200,000 man hours, using 100 vehicles and over 400 rail waggons. These parties have covered nearly half a million miles operating throughout the length and breadth of Germany and many other European countries.

Fuels . . . . . SECTION 5

(*See also Vol.* 5, *Section* 3)

52. The A-4 rocket is propelled by a bi-fuel propulsion unit using liquid oxygen (A-Stoff) and ethyl-alcohol (B-Stoff). The main fuel pumps are powered by a turbine driven by steam generated in an auxiliary power unit employing hydrogen-peroxide (T-Stoff) and sodium permanganate (Z-Stoff). The supply, transportation, and handling of these fuels presented many problems.

LIQUID OXYGEN

53. Liquid oxygen suffers heavy evaporation losses when stored and the available facilities for transportation were limited. It was therefore necessary to find a source of production not too distant from CUXHAVEN. No suitable plants were in operation and eventually it was decided to open up the plant at FASSBURG, 130 miles from CUXHAVEN.

54. Allowing for evaporation losses, it was necessary to produce at least 6 tons of liquid oxygen for every rocket launched. The FASSBURG plant had an estimated maximum production of 2 tons per day and a storage tank which would hold 56 tons; the plant had been idle since the spring but was put to work again on 7th August, solely for operation "BACKFIRE." Unfortunately, owing to failures in the electricity supply, production was far below the estimated maximum. In order to meet requirements it became necessary, not only to install a special generating plant, but also to draw 13 tons from another liquid oxygen plant at BRUNSWICK.

55. The Germans transported liquid oxygen over long distances in 30-ton rail tank cars and used the $6\frac{1}{2}$-ton A-4 road tankers for distribution from railhead over short distances of not more than 15 miles. It was not practicable to use rail tank cars in operation "BACKFIRE," and therefore the A-4 road tankers drew direct from FASSBURG. The jolting over bad roads on the long journey resulted in failure of the brass bellows-piece leading to the bottom outlet valve, and two fuel loads (13 tons) were lost through leakage. Subsequent interrogation revealed that these bottom connections had been a constant source of trouble to the Germans, and the fact

that this valve is at all times covered with ice would seem to indicate that it was added to the design without full realisation of the handicap involved. Two 5-ton commercial tankers, without bottom outlet valves, were then used for the journey from FASSBURG to KRUPPS, where the oxygen was transferred to A-4 road tankers for transport to the firing site. Losses from evaporation were about one-third of a ton per tanker during the journey from FASSBURG and about the same amount each day whilst standing in road tankers. The time required for filling or emptying two 5-ton tankers was slightly under one hour. On more than one occasion the round trip to FASSBURG and back, including filling, was completed in fourteen hours.

56. Complete sets of asbestos clothing were provided for the Germans fuelling the rocket, but they only wore the gloves. Two liquid oxygen pumps were used and gave no trouble except during a preliminary fuelling trial when one of them froze up. The pump had been left exposed to rain during the previous night and moisture in the pump froze, thereby locking the impeller against the rotation. It was later discovered that the pump body includes a drain plug for freeing such water accumulations.

ALCOHOL

57. Five 20-ton rail tank cars containing 70 tons of ethyl alcohol were found in the NORDHAUSEN Area and despatched to CUXHAVEN, where the fuel was transferred to A-4 road tankers.

58. Analysis revealed that the alcohol was initially at 93 per cent. concentration. It was therefore diluted by the addition of about 10 per cent. distilled water, the pump being used to stir the liquid by circulating it back to the top of the tank. There was then nearly 80 tons of A-4 ethyl alcohol, of specific gravity 0·86. One launching requires 4 tons of alcohol.

59. Except against fire, no precautions were necessary when handling alcohol, but measures had to be taken to prevent pilfering the fuel for purposes other than rocket propulsion.

60. At the firing site on 1st October, a considerable leak occurred on the delivery side of the alcohol pump, although the pump had previously given good service. The Germans found no objection to continuing to use the petrol engine of the pump with the surrounding concrete flooded with alcohol, nor later did they show any hesitation in starting up the second petrol engine of the liquid oxygen pump. They did, however, delay handling the hydrogen peroxide, where spillage might have fallen on the alcohol. When alcohol pumping had been completed the concrete was washed over by the fire party before the handling of the hydrogen-peroxide begun. At all times during fuelling, the Army Fire Service was in attendance.

HYDROGEN-PEROXIDE

61. Hydrogen-peroxide was obtained from the Walterwerke at KIEL which had been taken over by the Royal Navy. It was transported to CUXHAVEN in an A-4 hydrogen-peroxide road tanker also made available by the Royal Navy. The factory grade material was diluted with distilled water. Stirring was effected by using the pump to circulate the liquid back to the top of the tank.

62. The men employed on hydrogen-peroxide fuelling wore chemical rubber-wear clothing, consisting of wellingtons, aprons and gloves. A hand pump is preferred to a motor pump when fuelling as there is then no splashing of the liquid. Liberal supplies of water were always kept available, and were used for flushing the hoses and measuring tank on the Meilerwagen and for dilution of any liquid spilt.

SODIUM PERMANGANATE

63. Sodium permanganate is only used in very small quantities and a sufficient quantity was recovered by search parties from the NORDHAUSEN area. No special precautions were necessary for handling this fuel. Before pouring into the rocket, the permanganate is heated slightly, and failure to have it ready at the correct temperature caused a delay in firing on one occasion.

Assembly and Testing of Rockets . . SECTION 6

(*See also Volume* 2)

64. The site chosen for the assembling and testing of the rockets was the Krupps Naval Gun Testing Ground at ALTENWALDE, near CUXHAVEN. Certain facilities already existed on the site, including good buildings for stores, a reasonable carpenters' shop and a very inadequate and out-of-date machine shop. The first problem was the provision of the extra shops required.

65. A Marston shed was erected to serve as a main Assembly Shop. It was fitted with a 10-ton overhead travelling crane to handle completed rockets and heavy assemblies. Two sets of 60-cm. rails were installed to carry the assembly bogies, together with a 7-in. plate pillar drill, lathe, bench drill and two tool post grinders. Benches, Assembly Platforms and Steps, etc., were made in the woodworking shop. A small platform was erected on the end of the assembly line for the electrical test gear. To cater for the cleaning of pipes, etc., a water tank and a small acid tank were provided. For repairs to tanks and other assemblies three sets of gas welding equipment were installed. Men engaged in the handling of glass-wool were provided with gauntlet gloves, protective suits and respirators. For test purposes a 27-volt supply was installed, together with a four-stage 230 atmosphere air compressor.

66. A Vertical Testing Chamber was erected to carry out the necessary tests with the rocket in the vertical position. It was provided with a 5-ton overhead travelling crane to lift the rocket off the Meilerwagen and carry it vertically into the Chamber. The design caused some trouble owing to the large area exposed to wind, whilst resting on a relatively small base.

67. An existing building was allocated as a Sub-assembly Shop for control gear. It was fitted out with benches equipped with vices, bench drill, pillar drill, and a small fitters' lathe. Two main test benches were installed with reducing valves, three-way cocks, batteries and air reservoirs. Airlines were run from the compressor house and a small outside test shed approximately 6-ft. square was built for steam unit tests, vision being obtained through an armoured glass slit in the Sub-Assembly Shop. Reducing valves, air reservoir and the necessary copper piping were installed, together with an electric control panel by which steam units under test could be remotely controlled.

68. A shop was set up for the repair of towing vehicles, special vehicles used for the transport of rockets, firing platforms, pumps and trailers. The shop was equipped with a portable forge, power saw, one 12-in. and one 7-in. screw cutting lathe, pillar drill, 25-in. shaper, two gas welding plants and two electric welding plants (350 kw.) three benches and bench drill. One portable gantry type crane was also available.

69. Concurrently with the preparation of shops, supplies of rocket parts and tools were arriving continually by road and rail. Much work was required sorting, cleaning, listing, and storing these.

70. A programme of work was drawn up which aimed at having the first rocket assembled and tested ready for firing by the middle of September. One of the damaged rockets was overhauled, missing or defective parts being replaced from stock. This was used as a museum specimen, and in order to obtain a view of the interior of the rocket, appropriate sections of the outer shell were cut away. The Museum was also equipped with sub-assemblies, individual parts, and drawings, to serve both as exhibits for visitors and to familiarise the British technical staff with the functioning and details of various rocket components. This work was carried out during the time that the installations in the Assembly Sheds were being completed.

71. The next rocket was assembled from new but untested parts from store for the purpose of satisfying British and German technicians that all the necessary parts were available on the site and to practise the German personnel in the assembly technique.

MECHANICAL ASSEMBLY

72. Examination of the damaged rockets showed that few of them would provide anything in the way of matched components fit for use. Some had come from railway trains which had been set on fire; some had been deliberately sabotaged by automatic weapons or explosive charges; others had been stripped of essential parts. All had suffered from corrosion and exposure to the weather. Nevertheless the least damaged were picked out for rebuilding and useful parts were removed from some of the others.

73. It was evident that the Germans had made little or no attempt to cater for long storage. Where grease had been

introduced for this purpose, it was of poor quality and useless. Even valves stamped by inspection authorities as serviceable, and still in their cardboard cartons, showed signs of deterioration and rust. All components had therefore to be subjected to tests, and test rigs had to be designed. It was impracticable to build and equip a suitable precision workshop at Krupps for the manufacture of this testing gear. Arrangements were therefore made for an AVKO party to be attached to the Ministry of Aircraft Production establishment at VÖLKENRODE where excellent workshop facilities and adequate electrical laboratory accommodation were made available.

74. A further difficulty in using miscellaneous assemblies and components now become apparent. It was obvious that the Germans had used a system of selective assembly, which allowed the matching of calibrated results, thereby reducing the number of rejects. This procedure, in the main, rendered impossible the substitution of one part for another, unless the characteristic performance of that part had been adjusted to suit its new working conditions. No technical data had been found and no information was available regarding the tolerances of this selective assembly. It was therefore decided to arrive at mean values by interrogation and, so far as possible, to select combustion chambers and pumps to conform to these mean values.

75. The German technicians went out of their way to stress the dangers due to rust in the venturi. This component combines the nozzles, combustion space and venturi tube, and is a complete all-welded steel fabricated structure having two, and in some places three, skins. It was impossible to extract the small nozzles for cleaning and the elimination of rust from inside the various components appeared an almost impossible task. In the nozzles were over 3,000 minute apertures, liable to become blocked by rust. According to the Germans this might result in incorrect fuel mixture and so cause the rocket to topple over when fired. To deal with this problem, various rust eliminators were obtained from the United Kingdom, and the Army Fire Service pumped water under high pressure through every venturi.

76. The Germans were also pessimistic about the state of the aluminium fuel tanks and pipes. Their manufacturers had apparently made no efforts to protect their welds as the life of the parts was assumed to be short, and the Germans had had experience of failures due to weld-decay. Many of the welds in the available tanks showed distinct signs of weakening and all parts had had a much longer life than any previously used. The only solution was to select those aluminium parts which appeared to be all right, subject them to air pressure tests, and hope for the best. This solution worked.

77. These were some of the major problems. By the second week in August, the prospects appeared to be extremely gloomy. Then on the 21st August a consignment of twelve rockets arrived at CUXHAVEN. Amongst them was an almost perfect specimen and several others in reasonable condition. From that date assembly never looked back. Using the mean values arrived at for tolerances, it was possible to find a sufficiency of matched components. Every part was examined and those defective were replaced; every sub-assembly was tested, and a month later the first rocket passed out of the Assembly Shop.

ELECTRICAL ASSEMBLY

78. The electrical system of the rockets built for operation "BACKFIRE" was designed to be as simple as possible. No radio control was fitted as no radio ground equipment was available. The main function of the electrical system is the control of the rocket in flight, and the subsidiary functions include the control of fuel valves and initiation of fuel cut-off. With the sole exception of a circuit diagram of the control amplifier, no circuit diagrams or wiring diagrams were available. These had to be reconstructed either from memory or examination of parts which were considered to be complete. Eventually a complete set of circuit diagrams and, where necessary, wiring diagrams were made, traced, checked and issued.

79. A working model of the complete control system was made and installed at Krupps for initial investigations and for demonstration purposes. This model comprised a control compartment arranged on a special mounting permitting three degrees of freedom; a skeleton tail unit was equipped with servos, trim motors, vanes, etc., to demonstrate their operation; and a control desk to enable items of control apparatus to be operated and tested. The model could also be free of the control desk, but under control of the gyroscopes so that any desired movement of the control compartment could be transmitted by electrical signals via the control amplifier to the vanes on the tail unit.

80. A good supply of miscellaneous rocket cables and cable forms was obtained and sorted as far as possible into complete sets. Where sets were incomplete, the missing cable forms were made, using wire obtained by stripping surplus cable forms, or wire specially obtained from the United Kingdom. Great importance was attached to the construction of these cable forms, for they are used to connect the electrical apparatus in the tail of the rocket with the control apparatus mounted in the control compartment. Any failure or low insulation in these cable forms would have resulted in a failure of the rocket in flight, consequently they were carefully tested for sound mechanical construction, continuity and insulation resistance.

81. There are two types of distribution panels in each rocket, the larger carrying all the wires from the control compartment in the nose of the rocket, including the leads which come to ground test equipment via special throw-off plugs and sockets, and a number of relays which are arranged to connect the control apparatus inside the rocket to the ground test equipment. The smaller one is an intermediate distribution panel located approximately at the centre of the rocket for convenience of manufacture, and carries the connections to the steering mechanisms in

the tail. A number of these panels were received in fair condition and carefully examined for broken plugs and sockets, broken relays and bad connections. Where necessary, the faulty parts were replaced and all relays readjusted. In some cases the distribution panels had to be completely rewired.

82. Two gyroscopes were fitted to each rocket, one (vertical) to control the roll and yaw, and the other (horizontal) to control the pitch of the rocket when in flight. A large number of vertical gyroscopes were obtained, but few horizontals. The vertical gyroscopes were examined mechanically and tested electrically and the best were selected for use. The horizontal gyroscopes were made by dismantling the vertical types and re-building. The control potentiometers were modified and small programme motors were fitted to initiate the turning of the rocket in flight from the vertical on to a 47 degrees trajectory. The programme motors available had been exposed to very severe weather and were badly corroded. They were completely dismantled, cleaned and re-assembled, and mounted on the gyro-plates. The horizontal gyroscopes thus produced were then thoroughly tested, since the successful flight of the rocket depends on the correct functioning of this component.

83. A small number of control amplifiers (MISCHGERAT) were obtained but were practically all damaged. This amplifier, which comprises an assembly of five independent panels mounted on a common base plate, accepts the signals given by the gyroscopes and translates them into signals which can be recognised by the servo mechanisms controlling the steering vanes. It is a complicated piece of apparatus consisting of many small parts built into a very compact assembly. A survey was made of all the amplifiers and a programme laid down to re-build as many complete amplifiers as possible by using components from the damaged ones. By this means it was possible to make nine complete amplifiers. In the absence of detailed testing information it became necessary to investigate the performance of the best amplifiers, and adjust the remade amplifiers to the mean values thus obtained. The supply of thermionic valves for these amplifiers was difficult, particularly as they had to be matched in pairs, there being two pairs to each amplifier. The work of reconstructing these units was of a highly skilled nature and required special test instruments. Later a further supply of damaged control amplifiers was obtained from PARIS.

84. Time (or sequence) switches were obtained in an apparently good condition. They consist of a camshaft operating a number of electrical contacts driven through gears from a small electric motor. There is in addition a small vibrator unit mounted inside the case, which is nothing to do with the time switch, but is used to generate an interrupted current which drives the programme motor in the horizontal gyro. The cam-operated contacts are used to time the sequence of operations during flight. The cams must therefore be accurately set, and the timing of the contacts carefully checked. The bakelite moulding on which the vibrator was mounted had warped and upset the small contact clearance on the vibrating reed. These were, therefore, dismantled and readjusted.

85. Servo mechanisms are used to translate the steering signals from the control amplifier into movements of the control vanes in the tail of the rocket. A large number were received, apparently in good condition, but they were nevertheless inspected and tested. The test consisted of connecting the servo-mechanisms to a testing jig and verifying that with a predetermined current, a given weight could be lifted the required distance, in the correct time. This test revealed that a number were below standard and only servos whose minimum performance could be guaranteed were selected. Associated with the servo motors are separate trimming motors which control the external tabs on two of the rocket fins. These were inspected and tested for correctness of operation and for current consumption.

86. There are two batteries in each rocket. The main battery is a lead acid accumulator of 32 volts, and supplies the current for operating all the electrical apparatus in the rocket. The second, a nickel-cadmium battery of 50 volts, small capacity, supplies the control current to the potentiometers on the gyroscopes. Efforts were made to obtain these batteries from German sources, and contact was also made with battery makers in the United Kingdom to provide the nearest equivalent batteries should the German supply fail. At a late date a suitable German source was located and the German batteries were used in all the rockets launched. The British batteries were also available by then for use if required. The initial charging of the lead-acid battery was carried out on the site.

87. It had been a practice of the Germans to build a desk type of test equipment which incorporated the switches, relays, lamps, etc., needed to test the rocket during the course of manufacture and prior to launching. A number of these were found at NORDHAUSEN, but panels, instruments, and wiring were badly damaged and were completely stripped and remade. The circuit drawings for these desks had to be reconstructed and aligned with the circuits in the rocket. Every piece of apparatus was examined for mechanical and electrical damage, repaired where necessary, and then each desk rewired in accordance with diagrams previously prepared. Three types of desk were necessary. The first was used to test the rocket when it was still in the main Assembly Shop in a horizontal position and the second when the rocket reached the Vertical Testing Chamber and was in a vertical position. These two desks differed, because in the horizontal position it is not possible to install the gyroscopes in the rocket, hence they are not fitted until the rocket is in a vertical position. The third desk, which was normally built into the Feuerleitpanzer, is used for the final checking of the electrical control apparatus when the rocket is on the launching platform, and to ensure that damage has not been caused in transit. This desk also includes a panel which controls the sequence of operations inside the rocket when it is about to be launched. The large multiple pin sockets and cables required to connect the test-desks to the rocket were carefully inspected for mechanical accuracy, electrical continuity and insulation.

GROUND EQUIPMENT

88. Three serviceable Meilerwagens were built up by cannibalisation of damaged road and railway Meilerwagens. In two cases, the petrol-driven pump units were replaced by electric motors. Work had started on the reconstruction of a number of Vidalwagens, but it was not continued as three factory-fresh vehicles were found. Three firing platforms, complete with transporting trailers, were made up from a large number of damaged components. An armoured fire control vehicle was reconditioned so that it could move under its own power. The control panels inside were not rebuilt because fire control was carried out from a concrete Command Post, in which special firing panels were built. A mobile telescopic Strabo-crane was reconditioned. Two static and one transportable compressors were produced from a total of five received damaged. An additional compressor-booster was repaired and held as a standby. Hot air blowers delivering air at 100°C. were reconditoned. Small air blowers of the hair-dryer type were obtained for drying the smaller mechanical assemblies and components. To dry electrical components, ovens were installed and vacuum cleaners were provided to remove dust, etc.

89. For liquid oxygen (A-Stoff) four tankers, each of seven tons capacity, were overhauled, parts of pipework and fittings repaired or renewed, and tanks were pressure-tested, cleaned and washed out. Two pumps, approximately 1,200 lb. (540 kilograms)/minute capacity were rebuilt and petrol engines overhauled. For alcohol (B-Stoff) one tanker, approximately three tons capacity, and one tanker trailer approximately three tons capacity, were overhauled, cleaned and tested. Two pumping units approximately 55 gallons/minute capacity were rebuilt, one with internal combustion engines drive and the other with electric motor drive. For hydrogen-peroxide (T-Stoff) one tanker truck, three tons capacity, fitted with water tank, was received in good condition. A semi-rotary hand pump had to be adapted for use with this vehicle. One preheater, 4 cwts. capacity, was entirely rebuilt from composite parts and had to be modified to carry a pump. This entailed the manufacture of new parts and fittings to complete the assembly, including a rebuilt chassis. For towing and general transport, six Hanomag towing vehicles and three Tatra lorries were used. Three of the towing vehicles and three lorries had to be completely overhauled.

The Field Operation . . . . . SECTION 7

(*See also Volume* 3)

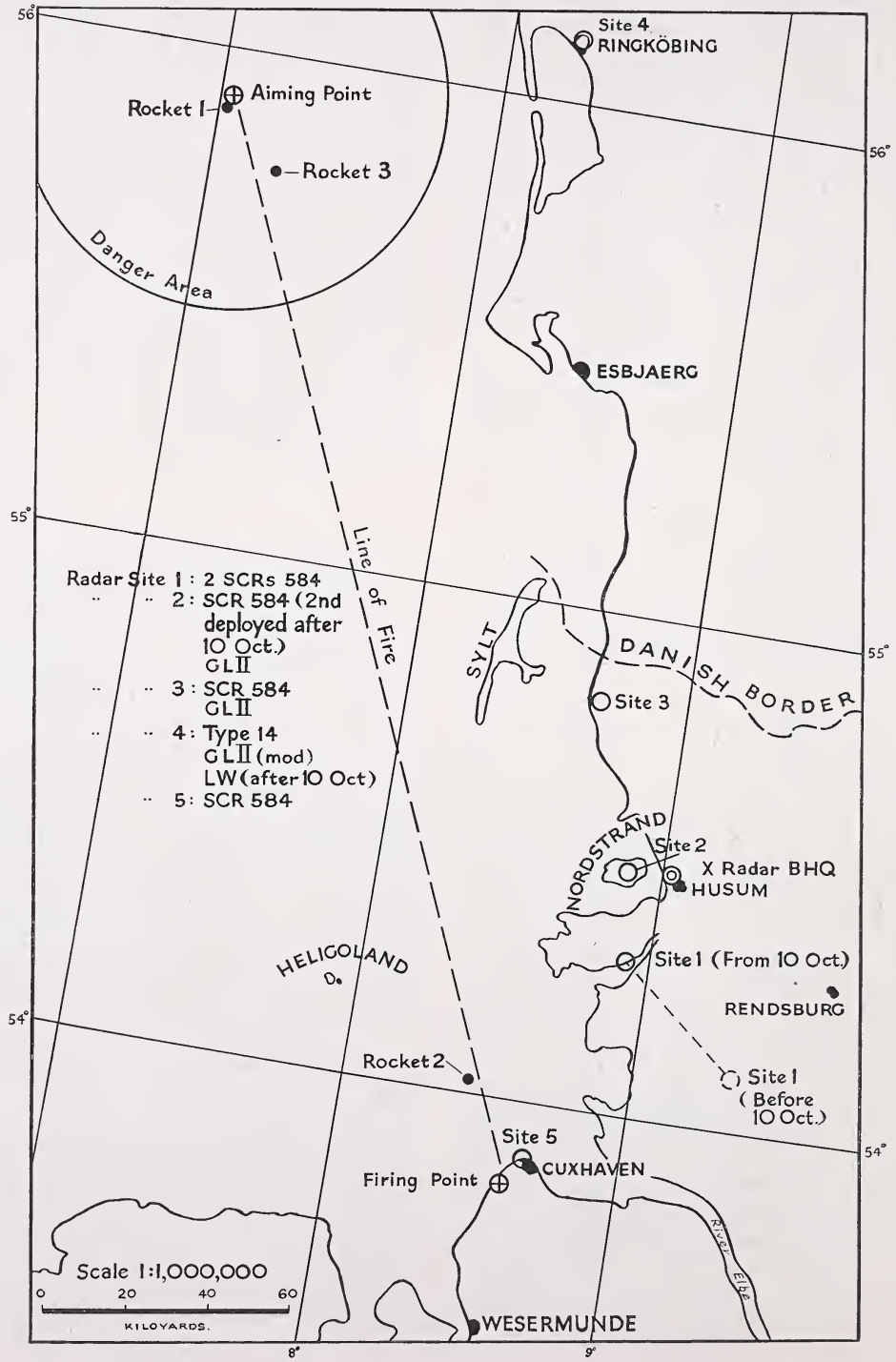
90. The British organisation set up to study the German field procedure operated independently of the technical staff responsible for the rebuilding and repair of rockets and auxiliary equipment. The technical staff's responsibility as regards the rocket ceased when its final tests in the Vertical Testing Chamber had been completed, and as regards the ground equipment, when it had been repaired. The British Field Staff then took over. This staff consisted of a number of Instructors in Gunnery and Assistant Instructors in Gunnery, working under the direct control of Col. W. S. J. Carter.

91. The original 107 German operational personnel were organised into a firing troop under British supervision, and while the complete establishment of a firing troop could not be filled, sufficient personnel were available to make each section capable of carrying out its functions in a satisfactory manner in the conditions of operation " BACKFIRE." The full German establishment was, of course, designed for continuous operations in the field.

92. No attempt was made to use a technical troop, whose function in the field was to receive the rocket at the railhead, transport it to the field store, fit the warhead and certain control equipment, test the rocket in the horizontal position and carry out any repairs or replacements necessary, then finally to hand the rocket to the launching troop. A technical troop was not necessary for operation " BACKFIRE " because the distance between the factory and the firing point was only a few miles and the rocket was fully tested and fitted when it was handed over to those responsible for the field operation. A careful study was, however, made of the operation of the technical troop by means of interrogation and demonstration by the Germans of certain aspects of their work.

93. Many of the German operational personnel were involved in the rebuilding of rockets and ground equipment; it was therefore not possible to carry out elaborate rehearsals of the field operations whilst assembly was still going on. Detailed studies were, however, made of the operation and use of all ground equipment as it became available, and a " drill " rocket was also built for handling. This provided a basic knowledge of the general handling procedure, including fuelling.

DETAILS OF AIMING POINT, LINE OF FIRE & RADAR DEPLOYMENT.



94. It was planned to launch the first rocket on the 1st October, and the last week of September was spent in carrying out complete field rehearsals including the testing procedure on the firing site. The information obtained from these rehearsals supplemented the knowledge which had already been obtained and which was completed during the actual launchings.

FIRING ARRANGEMENTS

95. The selected firing point was at RR.564841 (Norde de Guerre Zone Grid) (see Plate 4). So that firing could be carried out in the best possible conditions, a site was constructed, with a 60 yards by 30 yards concrete strip and good approach roads. In addition, strips of coconut matting, held down by heavy mesh wire, were laid over the rough ground between the firing point, command post and armoured camera shelters, so that visual observation would not be prevented by dirt and dust thrown up by the jet. Slit trenches were provided for the German launching troop personnel within 100 yards of the firing platform. It is interesting to note that no undue discomfort is felt at the time of launch by personnel in the open within 60 yards of the firing platform. In contrast to this, an operational site consisted simply of a clearing 23 ft. by 23 ft. in a wood usually of coniferous trees, with 14-ft. approach roads, and only slit trench protection was provided for personnel not in the Feuerleitpanzer. (For firing site layout see Plate 5.) The bearing of the line of fire was 336° 51′ true, including a correction of − 34′ for the rotation of the earth. This line was selected so that the expected 98 per cent. zone would still be clear of the Danish coast. The other 2 per cent. of rounds were so completely unpredictable that they were not taken into consideration. The point of aim was at VQ.960432 (North European Zone Grid) and arrangements were made to clear shipping to outside a circle 30 miles radius from this point. Aircraft were also warned off the course. This line of fire enabled radar stations to be deployed up the SCHLESWIG Peninsula into Denmark, thus permitting radar observation of practically the complete trajectory as well as the target area. Nine radar stations and four kine theodolite stations were deployed to record the flight of the projectile (see Plate 6.) A full description of the deployment and recording organisation is given at Volume 5, Section 3.

96. It was decided not to use the maximum range of the A-4 because this would have put the fall of shot at such a distance from the Danish coast that observation would have been improbable. Therefore the range was reduced from 200 miles to 156 miles.

97. Fire control was exercised from the concrete command post and not from a Feuerleitpanzer (Fire Control tank), so as to allow a number of officers to study the actual firing procedure.

98. The average working time from the moment a rocket was set up to the moment it was fired was just under four hours. No attempt was made, however, to hurry. The various operations were tackled singly rather than collectively so that the British Gunnery Staff could study them. It should also be borne in mind that all the rockets used were "fresh," being fired within a few days of leaving the Vertical Testing Chamber and after very short road journeys. In other circumstances, the main tests on the firing site might have brought to light difficulties which would have taken some time to remedy.

LAUNCHING

99. Details of the behaviour of each rocket in flight are given at Volume 5, Section 3, and a description of the sequence of events during launching is to be found in Volume 3, Part VI. A general description of each launch from an observer's point of view is given below. The fall of shot is shown on Plate 4.

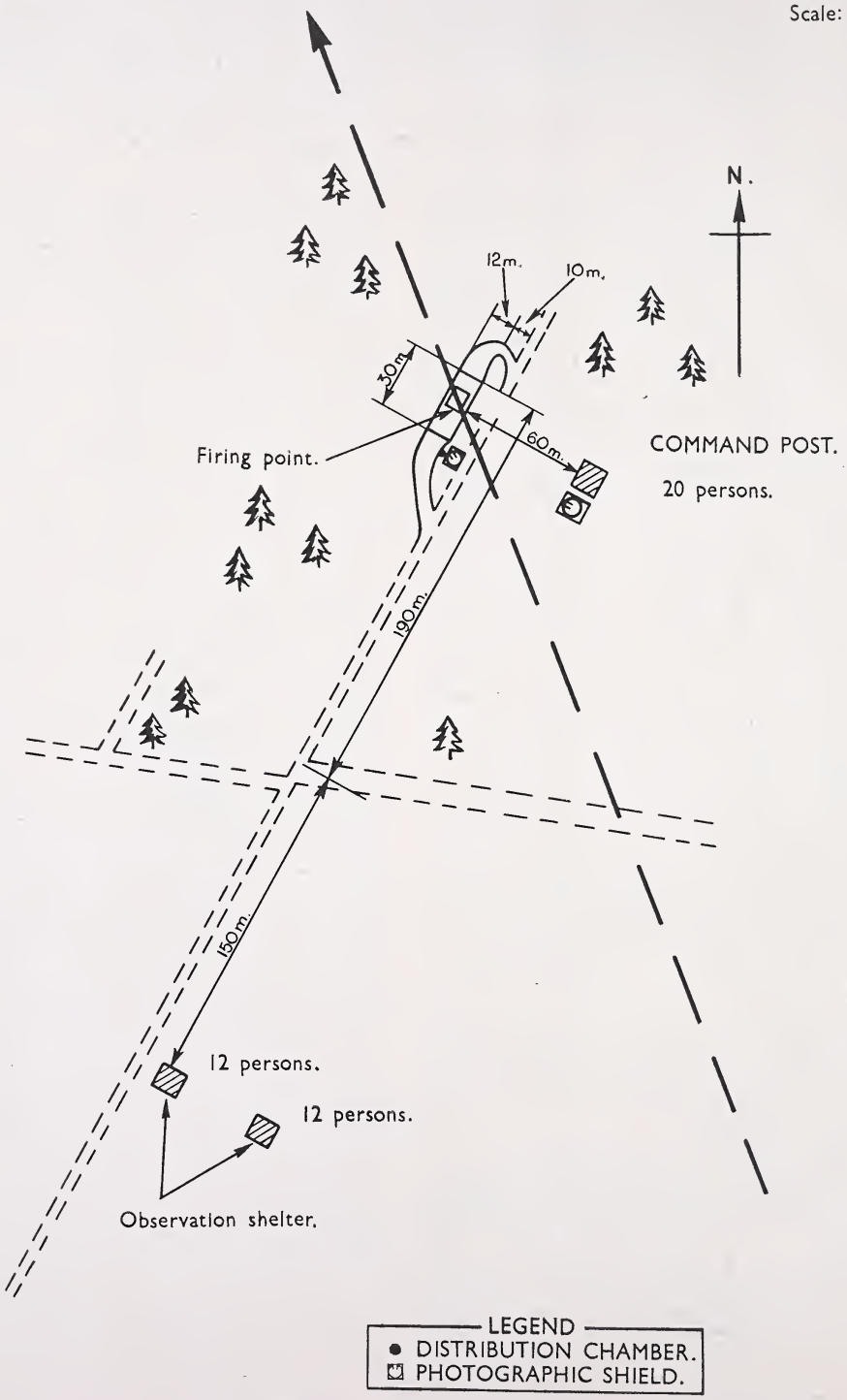
100. The first attempt to launch was on the 1st October, when a rocket was set up. During the main test, difficulty was experienced in getting the steam unit valves to open. This was eventually found to be due to a fault in the ground control equipment which had had to be wired from memory; the fault had not been discovered during the preliminary tests through two errors cancelling one another out. After the necessary repairs were carried out an attempt was made to launch at 1550 hours. The igniter functioned satisfactorily and the flame pattern was good. The Main Stage did not come on as the Stotz plugs (ground-connector plugs) did not throw off. The flame in the venturi was immediately put out by means of foam extinguishers and after preliminary examination it was decided to make a second attempt to launch. German personnel stated that the failure of the plugs to throw off occurred in one in every ten rockets. No fault could be found and they were of the opinion that it was worth making another attempt.

101. Before making this attempt, however, it was necessary to carry out certain work. The low melting point solder used to seal the 36 special alcohol cooling jets in the venturi had, in a number of cases, melted. Therefore the alcohol was leaking away in the venturi. Sometimes in field operations it was possible to get over this by plugging the holes with match-sticks. This, however, was not effective and it was necessary to remove 16 of the jets and replace them. This was done by a man climbing up inside the venturi wearing a mackintosh coat to protect him from the alcohol which was pouring down. Reports in the press that this man became "drunk with alcohol fumes" are not founded on fact. It is, however, understood that the man carrying out this operation usually wears a small face mask with breathing apparatus, as otherwise it is not possible to stay in the venturi for long without being overcome by the fumes. Also the venturi is uncomfortably hot. A fresh set of paper protecting cups for the oxygen jets were then inserted and a special sealing compound was smeared over the alcohol jets. A fresh igniter was inserted and a second attempt made to launch. As the batteries had run for only 20 seconds it was not considered necessary to change them. In order to prevent freezing-up, the hot air blower was kept in operation most of the time before the second attempt to fire.

DETAILS OF LAYOUT LAUNCHING SITE.

Plate 5.

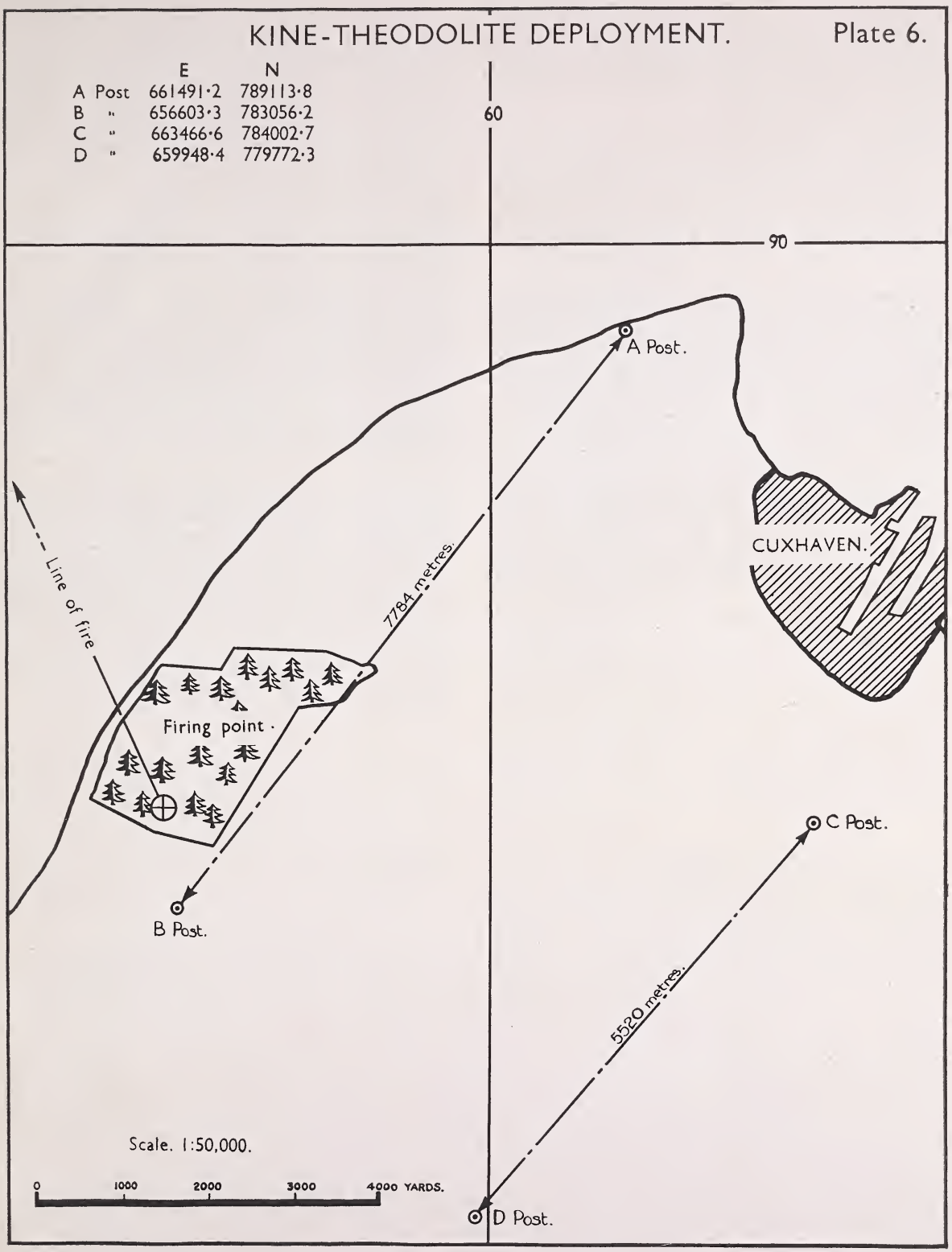
Scale: 1:2500



KINE-THEODOLITE DEPLOYMENT.

Plate 6.

	E	N
A Post	661491·2	789113·8
B "	656603·3	783056·2
C "	663466·6	784002·7
D "	659948·4	779772·3



102. In the second attempt the igniter lit properly but was thrown out before it had time to ignite the fuel. This happened because the sealing of the alcohol jets was not quite effective, and the free alcohol caused a slight explosion which expelled the igniter.

103. A further attempt to fire was not made owing to the lateness of the hour. The site was illuminated by means of searchlights which had been held in readiness for such an eventuality and the rocket was untanked. This procedure took approximately two and a half hours, the alcohol taking one and a half hours. The rocket was returned to the Vertical Testing Chamber for overhaul.

104. The next rocket was set up for firing on the 2nd October, 1945, and successfully launched at the first attempt at 1443 hours Zone A time. This was the first A-4 launching to be observed by Allied personnel at close quarters. Weather conditions were ideal; there was little wind and a clear sky. Only one fault was discovered during the main tests and this entailed the changing of an alternator. The behaviour of the rocket from the moment of take-off to the point of fall was perfect, the take-off was steady and the turn-over from the vertical occurred at the right moment. Brennschluss occurred after 65 seconds. The error in line was 1·2 kilometres left, and the error in range 1·9 kilometres short. The time of flight was four minutes 50 seconds. The method of control for range of this rocket and of all rockets used was by a time switch controlling cut-off of fuel. No form of radio control was employed.

105. The second launch took place on the 4th October. Weather conditions were again ideal; there was no wind and visibility was almost perfect. The rocket, which had failed to fire on the 1st October was set up, having been checked over in the intervening period, and was launched at 1415 hours. Brennschluss seemed to occur after approximately 35 seconds burning, and the projectile fell 24·95 kilometres from the point of launch, 0·99 kilometres to the left of the line of fire (2·28° deviation allowing for rotation). The time of flight was two minutes 16 seconds. It was originally thought that this failure was due to over-running of the turbine. If the turbine runs too fast there is a danger of explosion and air break-up. A centrifugal switch is therefore provided to give fuel cut-off if the rate of revolution of the turbine is excessive. In order that cut-off will not be given so soon as to land the rocket in friendly territory this switch is not energised until 40 seconds after launch. Cut-off can then be given in the hope that the rocket will reach enemy territory in one piece, even if it falls short. However, examination of the Kine Theodolite films (two stations followed the projectile through its complete course) indicated that thrust ceased after only 35 seconds. No satisfactory explanation has been produced. While the behaviour of the rocket was not satisfactory, its launching showed that it is possible to fuel and un-fuel a rocket, and later launch it, without carrying out any major overhaul.

106. The third and final rocket was launched on the 15th October, as a demonstration to representatives from the United States, Russia, France, the Dominions, Whitehall, and the Press. Weather conditions were poor, there being low cloud and a 30 miles an hour surface wind; but as the main object of the launch was to demonstrate to the visitors, it was carried through despite these poor conditions. The launch was made exactly on time, and no hitch occurred anywhere in the preliminary proceedings. The rocket behaved normally, but fell 18·6 kilometres short and 5·3 kilometres right of the point of aim. The time of flight was four minutes 37 seconds.

Conclusion . . . . . SECTION 8

107. The primary object of "BACKFIRE" was to learn and record detailed information on certain aspects of the A-4 rocket. This has been done in accordance with the instructions issued. If there is any point not now known to Britain and the United States the fault lies between those who drafted the instructions and those at S.P.O.G. who interpreted them. It is believed that all is known and that it now remains for others to make use of that knowledge.

108. The method of attaining this object was to collect component parts and damaged rockets from fields, from ditches, from railway yards, from canals, from factories; and then to employ Germans to clean them, repair them, test them, and assemble them into complete rockets. Eight rockets were built and tested as fit to fire. In proof of the correctness of the work, three of these were set up for firing, and all three were successfully launched.

109. The A-4 is the only long-range rocket the world has ever produced—the only weapon that has ever carried a payload of nearly one ton to a range of 180 miles in a time of flight of five minutes—and that in any weather by night or day. Without air superiority there is as yet no counter to it; once launched, nothing can be done. Its firing site requires no preparation; all that it needs is a hard-standing, 23 ft. square, with road access. It rises vertically and can be launched from the middle of a wood. Within two hours of first arrival on site, the rocket can be fired, and the site cleared leaving no visible trace. It can change its railhead every day. It possesses mobility and security to an unusual degree, and can only be countered by destruction of its factories or rail communications.

110. The disadvantage has been the large production effort required to achieve a relatively small and inaccurate result. But however much it may be decried, its achievements have been by no means negligible. Of the 1,800 rockets launched against ANTWERP, 44 per cent. landed within a circle of 10 kilometres radius. The effort, both military and civil, put into defensive measures was considerable. The physical destruction and morale effect both in LONDON and ANTWERP had to be taken into account. These were the results of the first operational model of an entirely new type of weapon. The aircraft of 1914-15 hardly achieved as much.

111. From such a start, the possibilities of development must be enormous—simplification of production, increased range, increased payload, improved accuracy, will magnify its effect. If the high explosive content of the warhead can be replaced by an atomic bomb, its destructive ability will be colossal. The Germans looked still further ahead; they were planning an A-9 to carry a pilot in a pressure cabin, with retractable wings to put out at the height of its trajectory so that when it came back into the atmosphere it could glide to earth in safety. A mail service which could bridge the ATLANTIC in 40 minutes might be of more value than a weapon of war.

112. Whatever the future may hold, the A-4 is undoubtedly already a feasible weapon of war. Even if Britain and the United States do not wish to use it, they must at all costs be prepared to counter it. Efficient and up-to-date counter-measures cannot be produced without developing the weapon itself.

113. The lesson of operation "BACKFIRE" is that what Britain and the United States can do, other nations can do. No nation can afford to allow the development of long-range rockets to jog along as a matter of routine. There is need of all the imagination, drive, and brains that can be mustered. For the sake of their very existence, Britain and the United States must be masters of this weapon of the future.

Officers who have acquired special knowledge through participation in Operation "BACKFIRE" . SECTION 9

114. HEADQUARTERS	NAME	REMARKS
H.Q. SPOG	*Maj.-Gen. A. M. CAMERON	COMMANDER
	*J/Comd. J. C. C. BERNARD, A.T.S.	P.A. to Commander
	*Col. W. S. J. CARTER	Colonel G.S., and responsible for complete field operation and flight recording
	Lt.-Col. F. SEEBOHM, R.A.	G.S.O. 1
	*Maj. C. W. LLOYD, R.A.	G.S.O. 2 (Technical), responsible for collection of equipment and provision of fuel; also for technical reports on auxiliary equipment
	Maj. B. H. F. FEHR, R.A.	S.I.G.; responsible for supervision of field work and recording of complete field procedure
	Maj. R. T. H. REDPATH, Int. Corps	G.S.O. 2 (Intelligence); responsible for all intelligence work in connection with the operation
	S/Ldr. H. M. STOKES, R.A.F.	Technical Interrogator; responsible for technical interrogation and translation
	*Capt. M. W. S. MEYER, Int. Corps	Interrogation Officer
	*Capt. J. L. ROBERTSON, R.A.	G.S.O 3; responsible for collection of equipment under G.S.O. 2
	*Capt. J. F. MILLS, Gen. List	A.O.R.G.; responsible for all technical recording and rocket ballistics
	*Capt. W. N. ISMAY, Gen. List	Ministry of Supply Liaison Officer, attached to H.Q. SPOG.
	Capt. D. BALDIE, R.A.	I.G.; assistant to SIG.
307 Bde.	*Brig. L. K. LOCKHART	Commander, 307 Bde.; responsible for all installations, British troops and German personnel employed on the operation
	*Maj. E. H. B. GREENFIELD, R.A.	B.M.
	Capt. D. K. WOOD, R.A.	I.O.
	*Maj. G. H. SMITH-PARR, R.E.M.E.	Bde. E.M.E.
	*Capt. J. R. BROUGH, R.E.M.E.	Tele-communications Officer
	Capt. D. S. CLARKE, R.A.	Interpreters Pool
	Capt. P. MARKSTEIN, Pioneer Corps	Interpreters Pool
	Capt. W. J. GAME, R.A.O.C.	Ordnance Section

HEADQUARTERS	NAME	REMARKS
" X " Radar Bty. R.A.	Maj. A. M. H. JONES, R.A.	O.C. and technical adviser on Radar
20 Special Svy. Det. R.A.	Capt. N. CHASKINS, R.A.	O.C. and responsible for all survey
Westex Recording Unit, R.A.	Lt. G. P. JAMES, R.A. Lt. R. HENRY, R.A. Lt. P. HUMPHREY, R.A. Lt. P. W. T. VINT, R.A. Lt. G. R. HATCHER, R.A. Lt. P. M. GOFFEY, R.A. Lt. H. W. THOMAS, R.A.	Recording and evaluation of Radar data
2 A.A. (A.T.S.) KT. Det.	Sub. R. NICHOLSON, A.T.S.	O.C. and responsible for all Kine operations and evaluation
United States Forces	†Col. W. I. WILSON Col. J. H. WEBER Lt.-Col. L. BALLARD †Maj. L. D. ROCKWELL 1st Lt. H. S. HOCHMUTH, of U.S.A. Ordnance Dept.	Present as observers and generally to represent the interests of Commanding General, United States Forces, European Theatre †Present only at the beginning of the operation
Ministry of Supply	Col. G. W. RABY	Chief Technical Superintendent
	W/Cdr. L. W. T. NEWMAN	Deputy Chief Technical Superintendent
	Lt.-Col. H. W. GOODGER, R.A.	Inspection Staff
	Lt.-Col. J. S. BROWN	Chief Fuel Adviser
	Maj. L. R. TARGETT	Technical Equipment Officer
	Maj. C. BLACK, R.E.M.E.	Superintendent on mechanical construction
	Maj. P. A. CHITTENDEN	Superintendent of Electrical and Electronic Assembly
	Brig. W. H. WHEELER	Represented D.G.P. in closing stages
Military Gov.	Mr. J. WORTLEY	Assistant Fuel Adviser

* *Employed through whole period of operation.*