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Item Description: This is a draft manuscript of a lengthy report compiled by the RAF Bomber Command Operational Research Section, probably some time in 1945. The report was authored by Dr. Basil Dickins, a rising star in the field of physics who served as Section head during the war. Using a thematic approach it explores in excellent detail the challenges inherent in strategic bombing, making it a valuable source for both historians of air power and those studying Europe in the Second World War.

Keywords: Bomber Command; Operational Research; Operations; Technique; Bombing; Navigation

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CHAPTER 7
WEAPON EFFECTIVENESS AND GENERAL EFFECTIVENESS

Introduction

The power of a bomb to damage or destroy a particular type of target can be studied in several different ways. The most straightforward way is to detonate the bomb in proximity to a sample target and to examine the results. Another method is to measure the effect of various blast pressures on the target and then measure the strength of the blast wave at various distances from the bomb. An entirely different method made possible by the use of reconnaissance photography is to measure the damage caused in an actual raid and to determine if possible the particular bomb or the density of bombs which caused it.

The experimental approach has been exploited for many years but it has serious shortcomings in that the types of target attacked are legion and even against the same target the result can vary considerably according to the relative disposition of target and bomb and a large number of experiments are required before a reliable answer is obtained. Further more, particularly in the case of fire bombs, the extrapolation from single targets to a conglomeration, from experimental to operational conditions, is fraught with danger.

As soon as sufficient damage was caused in Bomber Command raids to be visible on post raid reconnaissance photographs the other approach was made available. It soon became evident, however, that satisfactory results could not be obtained with anything short of a full-scale analysis of the photographs in which the damage was made. Even so the results was subject to statistical variation to such a degree that a very large body of data was required before the result could be regarded as reliable.

With the increase in the tempo and success of the bomber offensive the necessary amount of data began to accumulate but at the same time it became clear that it was beyond the scope of the O.R.S. to deal with it. The detailed analysis was in fact beyond the scope of 'K' Section, Central Interpretation Unit, whose prime purpose was the appreciation of the damage from the operational point of view, a task which was already straining their resources. At this time, however, the Research and Experiments Department of the Ministry of Home Security was interested in the detailed analysis of damage photographs as a means towards assessing the economic effects of a raid. It was therefore suggested to them that an extension of their work would also provide such answers as could be obtained on the weapon effectiveness question.

Their collaboration was enthusiastic and complete and from that time most of this type of research emanated from R.E.8. It was a particularly appropriate arrangement since the Research and Experiments Department already contained many men of experience in bomb performance in which subject they had initially been interested from the defence aspect. Close liaison with this department was maintained in

order to ensure that their researched should be made with a full appreciation of the operational conditions involved and they were put in touch with 'N' Section, Central Interpretation Unit, whose studies of bombfall in night photographs proved invaluable in such matters as the pinpointing of particular bombs or the study of incendiary bomb density. After this stage the role of the O.R.S. became to a large extent passive although from time to time it was able to offer active assistance as, for instance, in providing an alternative method of assessing bomb densities from a study of night photographs.(1)

Within the Command it was now the function of the O.R.S. to maintain close liaison not only with R.E.8 but with all the various bodies studying bomb performance in order to keep the Air Staff in touch with new developments and to advise them, in collaboration with the Armament Branch, on the types and combinations of bombs which were most efficient against the various types of target attacked. This involved an appreciation of the stowage characteristics of each type of aircraft with respect to each type of bomb which were far more capricious than most people outside the Command realised. Before 1944 the target to be studied was the heterogenous complex presented by the German town and the manner in which the growing knowledge of the effectiveness of bombs was translated into practical recommendation is well illustrated in Bomber Command O.R.S. Report No. 76.(2) Another use to which this knowledge was put was in devising a method by which a first phase estimate of the amount of damage likely to have been caused in an attack where night photographs were available but circumstances caused a long delay in obtaining satisfactory post raid cover.(3)

In the field of incendiary bomb effectiveness the work was enlivened by the appearance of a controversy which engaged the attention of the experts on all aspects and which had a bearing not only on the design of incendiary weapons but also of the operations in which they were used. It centred about the question as to the relative contributions of primary fires and fire-spread to the overall effect of an incendiary raid. Although finally submitted to a forum of the Royal Society the question remained controversial. The academic questions involved may or may not have been important but clearly since they led to no outstanding indication one way or another and since the practical matters involved were of operational urgency they could not wait for the end of this apparently interminable discussion. Having been closely connected with the research relating to this question from the

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~~(1) Bomber Command O.R.S. Rept. Nos. 71 and 72 (Air Min. Science 1 Library).~~
~~(3) Bomber Commander O.R.S. Rept. No. 81 (Air Min. Science 1 Library)~~
~~(2) Bomber Command O.R.S. Rept. No. 76 (Air Min. Science 1 Library).~~

(1) O.R.S. Report Nos. 71 and 72. (Air Ministry Science 1 Library and A.H.B./II/39/1).
(2) O.R.S. Report No. 76. (Air Ministry Science 1 Library and A.H.B./IIH/258/1/155).
(3) O.R.S. Report No. 81. (Air Ministry Science 1 Library and A.H.B./II/39/1).

very beginning the O.R.S. was able to make a separate appraisal so that the Command could take a firm stand on the choice and disposal of weapons. There has been no evidence produced since then to indicate that they were seriously misled.

The principle of assessment having been established no more was published on this subject but the frequent changes in stowage characteristics brought about constant revision of the result which was issued from time to time by the Air Staff as operations orders.

The standardisation of bombloads in this manner and the resolution of the Command views on the types of bombs preferred greatly assisted the work of bomb provisioning and as time went on the Command, actively assisted by the O.R.S., took a more and more definitive part in the policy underlying future production. This problem became increasingly complex as the bomber force became involved in the close support of ground forces since this presented a greater variety of potential targets.

Indeed the whole problem of bomb performance became more urgent and less straightforward with the advent of this phase since the amount of experience on the effectiveness of various types of bombs against the many different types of target involved, which included guns, minefields, wire, troops in the open, troops in hutted camps, troops in slit trenches, ammunition dumps, tanks and other vehicles, was strictly limited. However, the work of the experimental establishments, of the mathematicians, of the photo interpretation experts and such information which accrued from ground survey in re-occupied territory was closely followed up so that the latest opinions on all these matters were always available at the Command and when the time came to attack these targets firm recommendations could be made. These were first made on a day to day basis but as the tactical target programme became more clear it was possible to crystallise this matter by drawing up a list of bombloads with fusings for each type of aircraft and for various routes appropriate to all the types of targets likely to be attacked. This was issued as an operations order so that by reference to a brief code it was ensured that the most efficient loading was used throughout the Command.

One ~~extremely~~ important aspect of H.E. bomb performance upon which it was extremely difficult to obtain quantitative information was the question of what proportion failed to explode. Full scale experiments likely to produce statistically satisfactory results were prohibitive in effort and cost and such indications as accrued from other trials suggested that the proportion was very small indeed. On the other hand the impressions gained during ground survey of targets in the Mediterranean theatre when these were eventually occupied did not support that view. Unfortunately neither of these sources of data were sufficiently complete to crystalise the impressions gained into even approximate figures.

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When a fairly satisfactory method of estimating the number of bombs falling on a given area had been devised using night photographic evidence it seemed that a comparison of such numbers with the craters detected within the same area on post raid reconnaissance would be a fruitful line of research. This was followed up (1) but the result was not satisfactory for two reasons. The estimate of bombs falling in the area was itself only approximate and there was at that time a strong suspicion that even the most assiduous examination of post raid photographs often failed to reveal all the impact points of exploding bombs. All that could be said was that the average failure rate of medium capacity/general purpose bombs did not exceed 24 per cent and of high capacity bombs was less than 18 per cent.

Later when all H.E. bombloads were being frequently used it was possible to pick out strings of craters evidently forming isolated sticks and the average number in such sticks was compared with the average number of bombs carried per aircraft. (2) Again the result was subject to doubt owing to the slight variation in the numbers carried per aircraft in any given attack and also to the possibility of gross instability which could divorce the point of impact of a bomb from the others out of the same aircraft without necessarily preventing its detonation. It was, however, more definitive than the earlier result and suggested that about 10 per cent of medium capacity/general purpose bombs failed to explode. Although this figure was still regarded in some circles with scepticism it was the figure normally used in planning the weapon requirements of future operations.

Ground Survey in France

In September 1944 a unit known as the Bombing Analysis Unit (B.A.U.) commanded by Group Captain E.S. Drury and with Professor Zuckermann as Scientific Director, was formed with a directive to carry out ground surveys of areas which had been subjected to bombing in support of the army. This was to include the bombing of tactical targets such as bridges and railways as well as close support operations and although not strictly within the terms of reference the bombing of V-weapon targets was to be included. On the orders of the Commander-in-Chief two members of the O.R.S., later joined by a third, were attached indefinitely to this mission and the Officer-in-Charge O.R.S. spent intermittent periods with it.

The B.A.U. was based at St. Germain-en-Laye, near Paris, and the field personnel were divided into parties consisting of several research officers backed by an administrative officer and such personnel, transport and equipment as was required to render the party

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~~(1) A.H.B./IIH/241/22/3 (Bomber Cmd. O.R.S. Int.Mem. No. 118).~~
~~(2) Bomber Cmd. O.R.S. Rept. No. 101 (Air Min. Science Library).~~

(1) O.R.S. Memo. No. 118. (A.H.B./IIH/241/22/3).
(2) O.R.S. Report No. 101. (Air Ministry Science Library and A.H.B./II/39/1).

self-contained. They were dispatched to various regions in France with instructions to set up semi-permanent field headquarters at a convenient centre and to study selected targets within easy reach (up to 50 miles) of that headquarters. The first field headquarters were located at Le Havre and St. Malo with projected ones at Caen, Calais and Brussels.

The Bomber Command O.R.S. personnel were assigned to and put in charge of the Le Havre party since this region included many targets attacked by Bomber Command including bombing in support of the battle of Le Havre. This party formed up in England and proceeded direct to Le Havre via the battle areas of Villers Bocage, Caen and Cagny and set up headquarters in a large but battered villa in the northern suburbs of the town about ten days after the occupation from which teams were sent out to make the following field studies.(1)

(a) Detailed survey of E-boat pens (B.A.U. Report No. 5)

(b) General Survey of defence positions in front of Le Havre (B.A.U. Report No. 27)

(c) Detailed survey of two permanent field gun positions (B.A.U. Report Nos. 15 & 26).

(d) General survey of coastal batteries between Le Havre and Abbeville (B.A.U. Report No. 31).

(e) Detailed survey of two coastal battery positions near Le Havre (B.A.U. Report No. 16 and 25).

(f) Detailed survey of a permanent barracks area known as the Hotel Pour Passagers north of Le Havre (B.A.U. Report No. 13).

(g) Examination of a number of incidents of tail instantaneous fused bombs on warehouses in the harbour (B.A.U. Report No. 28).

(h) Detailed survey of a railway viaduct at Merville which had been attacked by bombs and rockets (B.A.U. Report No. 32).

For most of these studies the teams were based on Le Havre but for the more northerly coastal battery surveys it was necessary to find a subsidiary base at Dieppe. In the case of the detailed surveys full particulars of the construction of the targets and subtargets was obtained as well as of the bomb damage inflicted and an accurate plot of all bombs in the vicinity of the targets was made. Local inhabitants present at the time of the attacks were interrogated in order to discover such information on the effects of the bomb which were not apparent from a physical survey. As the field surveys were completed the data obtained was analysed with a view to assessing the effectiveness of the bombing as a whole and wherever possible the effectiveness of individual weapons. A draft report was then written incorporating all the data from physical survey and interrogation including detailed drawings, the results of the analysis and the conlcusions reached, and forwarded to the B.A.U. headquarters for editing and publication.

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(1) Copies of the B.A.U. Reports may be found in A.H.B./IIS/136/1-32.

In October 1944 one of the Bomber Command O.R.S. officers from the Le Havre Field Headquarters was detached to take charge of a new field headquarters based on Caen with instructions to study the results of Operations Goodwood, Totalise and Tractable which were carried out in close support of the Army's advance from Caen to Falaise. Owing to the insufficient data received from Twenty-first Army Group on the ground aspect a complete satisfactory study was impossible but the information and indications obtained are recorded in Bomber Command O.R.S. Memorandum No. M. (1).

In addition the following detailed studies of particular targets were made:-

(a) Detailed study of the effect of heavy bombing on a concentration of tanks (B.A.U. Report No. 22).

(b) The effect of bombing on a coke oven plant at Colombelles (B.A.U. Report No. 11).

(c) The distribution of weapons and their effect in a rocket attack on a mine-head buildings at Soumont St. Quentin (B.A.U. Report No. 23).

(d) The effect of Fighter-bomber attacks in a series of German military headquarters (B.A.U. Report No. 12).

In November a second Bomber Command O.R.S. officer from Le Havre was temporarily detached to take charge of a study of the effects of air attack on the large V-weapon site at Watten, working from the base at St. Omer. (B.A.U. Report No. 33).

During this period the B.A.U. was working closely with the United States Air Evaluation Board (U.S.A.E.B.) and most of the field parties included officers from that organisation. The problem of target selection was studied in collaboration with their Headquarters staff by a Committee composed of members of the B.A.U. and the U.S.A.E.B. of which the Officer-in-Charge Bomber Command O.R.S. acted as joint chairman.

By the end of January 1945 all the studies listed above were complete and the reports ready for editing and publication. The Commander-in-Chief, Bomber Command, decided that the time had come for his O.R.S. officers to transfer their attention from tactical targets to those of a more strategic nature since strategic bombing had been the first and still remained the most important role of the heavy bomber force. Such targets however were outside the terms of reference of the B.A.U. and it was therefore necessary at that stage for the O.R.S. officers to sever their connection with that body.

One research officer was withdrawn completely and the remaining two were attached to the British Bombing Research Mission. This Mission was planned on an ambitious scale with a view to surveying targets in Germany as soon as they became available for inspection. At the beginning of 1945 it had already set up an advanced headquarters near Paris with a skeleton administrative staff and pending the availability of targets in Germany it was providing liaison, transport and

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base facilities to various investigating teams who were working on French targets. The scheme here was different from that within the B.A.U. in that an investigating team was not self-supporting but depended for accommodation and supplies on such military formations as were found in the neighbourhood of the target. Although preliminary introductions were dispatched from the B.B.R.M. Headquarters it often occurred that these had not reached the relevant officials by the time the party arrived and it was then necessary for the investigating team to make its own arrangements. This gave rise to temporary difficulties but also to many interesting and amusing situations.

Under these auspices the remaining two O.R.S. officers studied three factories in France which had been subject to attacks by Bomber Command with a view to assessing the effects of the bombing both as to physical damage and production loss and to obtain such information on weapon effectiveness as was available. Detailed plots of damage and bombfall were made, production records were scrutinized when available and the management of the factory together with people living nearby at the time of the attack were interrogated. The results of these investigations were forwarded to Bomber Command O.R.S. and are recorded in the following papers:-

(a) Bomber Command O.R.S. Report No. S.228 - Ground Survey of the Effects of Air Attack on the Gnome and Rhone Works at Gennevilliers. (1)

(b) Bomber Command O.R.S. Report No. S.229 - The Effect of Air Attack on the B.H.W. and G.S.P. Works at Albert. (2)

(c) Bomber Command O.R.S. Memorandum No. M. The Effect of Air Attacks on the ? and Primagaz factories at St. Pierre de Corps near Tours. (3)

The second of these is particularly interesting since it includes observations on the performance of 12,000 pound heavy capacity bombs. The third was not published as an O.R.S. report because the absence of records or of executives who had held office during the occupation made a complete study impossible.

Ground Survey in Germany

By the beginning of March when these studies were completed it had become possible to consider targets in Germany and arrangements were put in hand for the O.R.S. team, reinforced by two further O.R.S. officers and an American officer from the Ministry of Home Security, to proceed to Aachen. The party left on 9 March and were away ten days.

This was the first attempt made on a general study of the effects of bombing on a town as a whole and the investigation was largely exploratory. The general situation was naturally chaotic since the main concern of the occupying force was to facilitate the movement of supplies to the front and efforts at reconstruction of the municipal

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(1) A.H.B./IIS/70
(2) A.H.B./IIS1/11.
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and industrial life of the town and the entertainment of non-operational personnel were subjugated to this overriding necessity. Add to this the fact that only one member of the team spoke German and it will be seen that conditions were in general against a highly scientific and quantitative assessment being made. However a good approximate picture was obtained and perhaps more important still a very good idea of the difficulties to be encountered, the general set-up and the sort of information which could be expected under these circumstances was obtained. A report on the investigation was rendered to Bomber Command[1] and to the B.B.R.M. who published it as B.B.R.M. Report No. F.16

During April the O.R.S. team, again reduced to two, were attached to a B.B.R.M. team operating in Krefeld to make a similar study of Krefeld and Uerdingen. Conditions were here somewhat better than in Aachen but with the enemy just across the river full freedom of action was somewhat impaired. Here, however, any attempt to make a physical survey of damage beyond taking representative photographs was frankly discarded and a more orderly selection of firms and programme of interviews was instituted and the use of written questionnaires was introduced. There was an United States Strategic Bombing Survey team also working in Krefeld at this time with whom close contact was kept and it is certain that both teams benefited mutually from each others experiences as well as from their own. The result of the study[2] is a little more quantitative than in the case of Aachen but the amount of reliable statistics found still remained small.

It was not until the end of April that any really important industrial cities were occupied, in fact, the liquidation of the Ruhr pocket took place towards the end of the visit to Krefeld. By the time the Krefeld report was written preparations for a properly equipped ground survey unit were coming to fruition and on 11 May 1945 the Bomber Command Bombing Research Unit came into being. The two O.R.S. officers already operating were joined by a third and were backed up by a completely self-contained staff of drivers, interpreters, aircrafthand and a cook equipped with transport and everything necessary to work as a separate unit. This was headed by a group captain and administered by an adjutant, the whole unit being attached for administrative purposes to the B.B.R.M. which later became amalgamated with the B.A.U. to form the British Bombing Survey Unit.

The first mission of this new unit, a survey of the effect of bombing on Essen, was marred by tragedy. The commanding officer, accompanied by a driver and interpreter, set off to make preliminary arrangements for the accommodation of the unit and on his way back to Paris where the unit had formed up was involved in a road accident and killed. The interpreter and driver were put out of action and further

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(1) A.H.B./IIM/a1/6a, June 1945.
(2) A.H.B./IIM/a1/6a, Oct.1945 (Bomber Cmd O.R.S. Rept. No. S.232).

to complicate matters the adjutant was posted at short notice. However the unit set out for Essen on 17 May and began operating on 19 May. Later the research team, working under difficulties owing to the loss of one of their interpreters were strengthened temporarily by the advent of the Officer-in-Charge O.R.S. and one other officer.

In Essen the written questionnaire technique was extended and this together with the experience gained in the earlier studies resulted in a more satisfactory investigation. Krupps which, of course, dominates the industrial fabric of Essen was dealt with separately and a fairly detailed inquiry involving the collaboration of most of the higher executives of the concern was made. By this time the general situation was improved by the cessation of hostilities and more statistics particularly with regard to the municipal life of the town were obtained. The result of the investigation appears in Bomber Command O.R.S. Reports No. S.233 - Essen General (1) and No. S.235 - Krupps.(2)

During the survey of Essen the three latest additions to the research staff were withdrawn and the one was replaced. The new adjutant and commanding officer also arrived about this time.

It was observed that the three other towns in the Ruhr which were to be surveyed were within an hour or less by car from Essen and it was decided that much time would be saved if instead of moving the unit to each town, the work was carried on from the quarters in Essen which were very satisfactory particularly from the point of view of office space. This also enabled more than one target to be worked at one time without splitting up the unit.

From that time on the following routine was instituted. First, an advance officer visited the town under review and made arrangements for an office in the military government and lunch for the period during which interviews would take place, at the same time arranging for the distribution and subsequent collection of written questionnaires. With each successive target these questionnaires were modified and enlarged so that they provided very good information on the damage sustained and the fluctuation in production of most of the larger firms in the town. They were eventually extended to take in the matters of interest concerning the municipal offices of the city so that interviewing could be concentrated on the very large firms and such amplification of the questionnaires as was considered necessary. After a week or ten days two research officers accompanied by interpreters collected the questionnaires, examined them, selected personalities for interview, and carried out their interviews in the office provided by the military government. The third research officer was meantime analysing the data collected on the previous target and writing up the report. This scheme was made possible only by the keenness and versatility of

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(1) A.H.B./IIM/a1/6a. Oct.1945.
(2) A.H.B./IIM/a1/6a. June 1945.

interpreters and clerks who soon learned to perform the duties of statistical clerks in between their normal duties. In this way everyone was fully employed all the time and the time taken for the whole task considerably shortened.

The other towns in the Ruhr which were investigated were Bochum,(1) Dortmund(2) and Dusseldorf.(3) Whilst operating in the Ruhr a number of synthetic oil works which had been attacked by the Command were covered and the data were dispatched to the O.R.S. where they were analysed from the operational and planning aspect(4) and then handed over to the B.B.S.U. who were concerned with the economic aspect. The Ruhr is, of course, concerned to a large extent with heavy industry and the importance of attack on underground services with medium cased H.E. in such an area was constantly being observed. It appeared important to bring this to immediate notice and an interim report on this subject was submitted (O.R.S. Memorandum No. M.115).(5)

During the examination of Krupps it was discovered that a large number of pistols from unexploded bombs had been retained and the bomb-disposal experts were still available. It was considered desirable therefore that an armaments expert should examine these pistols and discuss the question of unexploded bombs with the bomb disposal experts and also to see the A.R.P. personnel of surrounding districts particularly the oil targets with a view to discovering the causes of bomb failure, the incidence of which was found to be high. Accordingly an armament officer from Bomber Command was attached to the Bomber Command Bombing Research Unit and his findings are recorded in ? .

Towards the end of July the Unit moved to Hamburg and from that base the City of Hamburg itself(6) and the port of Bremen were studied. About a month later the last move from Hamburg to the B.B.S.U. Headquarters near Hannover was made and from there Kassel(8) and Hannover(9) were surveyed. In the case of Bremen and Kassel it was necessary to detach a small team from base during the interview period.

The original programme of targets to be dealt with included two further towns, Nuremberg and Friedrichshafen. By this time, however, the Japanese war had come to an end and the B.B.S.U. had embarked on a new approach to the economic study of bombing of towns using largely data collected by the United States Strategic Bombing Survey. It was therefore decided to curtail the original programme and call a halt when

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(1) A.H.B./IIM/a1/6a, Aug.1945 (Bomber Cmd. O.R.S. Rept. No. S.234.)
(2) A.H.B./iv/A/47.
(3) A.H.B./IIM/a1/6a, Oct. 1945 (Bomber Cmd. O.R.S. Rept. No. S.239)
(4) A.H.B./IIM/a1/6a, Nov.1945 (Bomber Cmd. O.R.S. Rept. No. S.245)
(5) A.H.B./IIH/241/22/3.
(6) A.H.B./IIM/a1/6a, Oct.1945 (Bomber Cmd.O.R.S. Rept.No.S.240)
(7) A.H.B./IIM/a1/6a, Oct.1945 (Bomber Cmd. O.R.S. Rept.No.S.241)
(8) A.H.B./IIM/a1/6a, Oct. 1945 (Bomber Cmd. O.R.S. Rept. No. S.242)
(9) A.H.B./IIM/a1/6a, Nov.1945. (Bomber Cmd.O.R.S. Rept. No.S.243).

Kassel was completed. Since the domestic staff of Bomber Command Bombing Research Unit was not required at Hannover these were sent back to England and when the draft reports on Hannover and Kassel were complete the unit was disbanded, handing over most of its transport and all its documents to the B.B.S.U. These documents included production data on submarines at Kiel which had been collected while the Unit was at Hamburg. Together with similar data relating to Hamburg and Bremen this covered all the submarine production of Germany with the exception of Danzig.

Before leaving Germany the ~~Commanding~~ Officer-in-Charge O.R.S. and one research officer visited Berlin and saw the executives of a number of important firms. No attempt at a survey was made but the visit produced some interesting observations which are recorded in Bomber Command O.R.S. Memorandum No. M.116.(1)

(1) A.H.B./IIH/241/22/3.