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UNDERGROUND FACTORIES IN GERMANY

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COMBINED INTELLIGENCE OBJECTIVES SUB-COMMITTEE

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UNDERGROUND FACTORIES IN GERMANY

Reported by

C.I.O.S. Party 536.

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(4)

Secret.

Underground Factories in Germany.

Report by C.I.O.S. Party 536.

PART I. PREAMBLE.

"The Party was formed by Sir Hugh Beaver, Controller General, Ministry of Works, following a request from the Chiefs of Staff, and emphasis was laid on the importance of inspecting certain underground factories in the area about to be occupied by the Russians."

(a) Compilation.

Key to
Information.

The particulars of Underground Factories in Germany recorded below were collected by a team whose interests include Mining, Civil Engineering, Mechanical Engineering (as applied both to Services and to Production and Layout) and the Technique of Bombing Effects. Most of the documents comprised in the dossier are the result of collaboration between these elements and comments on certain aspects of the whole subject necessarily occur in Sections dealing mainly with other aspects. It is desirable, therefore, to indicate, at the onset, where the various categories of information, factual or commentative, which it may be desired to extract from the Report can be found.

(b) The original quest.

Site
Observations
Categories.

The observations made in the course of the tour are comprised in Part III, DETAILED DESCRIPTIONS OF FACTORIES. This is divided into twelve sections, A to L, each devoted to a Factory, though not all these were visited. The heads under which the facts, where available, have been set out include:-

A general description.
Contacts and references.
Geology and Site Investigation
Layout.
Floor areas and levels.
Linings and supports.
Entrances.
Shafts.
Progress of Construction.
Cost.
Sewage Disposal
Water Supply

Excavation.
Drilling and Blasting.
Mucking.
Loading and Transport.
Falls of Ground.
Air Attack.
Engineering Services.
Heating.
Ventilation.
Electric Light and Power.
Compressed Air.
Production and Layout.

General
Commentary

A commentary of a more general nature is given in Part II, GENERAL SURVEY OF FACTORIES, and it is placed in the Report before the more detailed matter in Part III because it may be of wider interest. Part II deals with the subject, not Factory by Factory as does Part III, but under the heads of:-

- (1) General.
- (2) Geology and choice of Sites.
- (3) Construction Methods.
- (4) Engineering Services.
- (5) Production and layout.

Types of
Factory.

Section (1) General, includes some historical comments and divides the Factories inspected into two general types - "Single-Storey" and "Multi-Storey", all with horizontal approaches. There was also one Factory, reported upon but not inspected, to which the access was by means of a 440 metre vertical shaft; but this Factory was a converted salt mine and not constructed specifically for war purposes.

Construction
Methods.

Under (3). Construction Methods, the subjects considered are Excavation, Linings and Entrances. Further particulars in connection with the subject of Excavation will be found in Appendix 3, TUNNELING PLANT.

Services.

Section (4), Engineering Services, covers Electric Power Supply and Lighting, Compressed Air and Heating and Ventilation. Services such as Water Supply and Drainage are dealt with as individual cases in Part III, but are not generally commented on in Part II.

Production
and Layout;
Topics.

The concluding Section (5), Production and Layout, of Part II refers to the handicaps under which the Germans laboured in the equipment of these Factories, in which production had ceased before the inspection was made. It comments upon the type of layout generally adopted and it offers observations, from the Production Engineer's standpoint, upon the very

important question of the treatment of exposed surfaces in underground Corridors and Galleries. It calls attention to the lack of planning, which was observed in the layout of machine tools and other items of equipment, as well as to the paucity of lifting facilities, mechanical handling appliances, conveyor systems and means for the disposal of swarf. It records the free use which was made of accumulator-driven trucks. Observations are offered on the large range of production which, given proper planning, can be undertaken in Underground Factories and comment is made on the fact that part assembly only was in most cases aimed at.

Recommendations.
(Mechanical)

A summary of recommendations made in Section (4) and (5) is given at the end of Section (5).

Construction periods, labour and costs.

Before the members of the Party set out for Germany, they were asked to devote special attention to certain specific questions arising in connection with Underground Factories. Information regarding a number of these has duly been recorded in Part 3, DETAILED DESCRIPTIONS OF FACTORIES, but it was also thought that additional light could be shed on certain of them, relating to construction, if a comparison were made between a selected German Factory and a British Factory constructed during the war. A statement on this subject will be found in Appendix 2, COMPARISON BETWEEN A GERMAN AND A BRITISH UNDERGROUND FACTORY. The questions which were brought up at the briefing and which are referred to therein are:-

Appendix 2. Section IV. Periods of Construction.
do. Section V. Labour Forces.
do. Section VI. Costs.

(c) Further studies.

Linings and rock ratios.

Appendix 2 deals also with other points, not specifically referred to before the tour started, namely:-

Section VII. Exposed surfaces of Corridors and Galleries.
Section VIII. Residual Rock Areas.

Treatment of exposed rock surfaces.

Section VII of Appendix 2 discusses a leading question, which as already stated is alluded to in Part II, Section (5), Production and Layout. This is the question as to whether the walls and roofs of Corridors and Galleries should be lined or whether they should be left bare and treated in some way. The

(iv)

experience of the Chemical Engineer who gave advice in connection with the treatment of the exposed surfaces of the British Factories, used by way of comparison, has been drawn upon and his observations are made in Appendix 2(A) THE TREATMENT OF INTERNAL ROCK SURFACES OF CORRIDORS AND GALLERIES AT AN UNDERGROUND FACTORY CONSTRUCTED IN SANDSTONE IN GREAT BRITAIN DURING THE WAR. It is to be noted, in this connection, that production conditions may necessitate lining the rock surfaces of the galleries and corridors of a Factory, whether over the whole or in part, irrespective of the qualities of the rock.

Residual
Rock Areas

In Section VIII, Residual Rock Areas, of Appendix 2, the question is considered as to whether the Germans, in their haste, were ready to take risks which we in this country would not accept. The conclusion, in so far as the two Factories under comparison are concerned, is that the answer must be in the negative. The question of the respective merits of the layouts of the Corridors and Galleries in the two Factories is not made a subject of comparison.

(d) The Broad Issues.

Ineffect-
iveness of
German
effort.

The most comprehensive question put to the Party, when they were briefed, was that as to whether the efforts made by the Germans on their Underground Factories proved to be worth while. No direct and complete answer has been attempted in the succeeding Parts of this Report. It would be easy to reply "No, because in the majority of cases they started too late." That, however, would merely be begging the question. It was not realised, at the time of the briefing, how little in the way of war production the Party would be able to see in the course of their inspection. Otherwise, the question might have been framed thus:-

- (i) Did the measures undertaken by the Germans ensure to them, given time, the volume of production aimed at?
- and (ii) Were the efforts which they put forward out of proportion to the benefits which they stood to gain?

Degree of
protection
achieved

In considering (i), account has mainly to be taken of the degree of protection achieved from air attack. Appendix 1, Vulnerability to Air Attack, written by the Member of the Party whose special province this is, deals with this issue.

(v)

Recommendations as to future policy are also given. This subject is not one to which the rest of the Party have devoted exhaustive study. It is, however, thought appropriate to offer the remarks conveyed in the two following paragraphs.

Paucity of
raw materials

The number of Factories which it was possible to inspect in the short time available represented but a small fraction of those known to exist, or to be in course of construction, in Germany. Of these, too, only a certain proportion had come into production on any appreciable scale before the collapse of the German war effort. There was, however, an aspect of the situation which came under the observation of the party and which may have a bearing upon the whole question as to the advisability of resorting to underground construction for Factories as a precaution against future war risks. This was the striking paucity of supplies of raw materials, required for production in any of these installations. It was evident that the Factories which were in production were in the main depending on day-to-day supplies.

Possible
cause of
shortage

For the reasons underlying this, reference should be made to the observations of other investigators, for such circumstances were beyond the scope of the enquiries of this Mission. It may be that the damage inflicted upon the enemy's transport system precluded the carriage of such materials; or it may be that owing to the destruction caused at the sources of supply the materials were not available. In either event, the Factories appear to have been in no condition to function healthily and it is apparent that the Germans, prior to the collapse, had little expectation of reaping the reward of the vast efforts which they had put forth with a view to the exploitations of the overhead cover offered by their mountains and hills.

Labour
commensurate
with effort

With regard to (ii), the abundance of labour which the Germans had at their disposal points to a negative reply.

Development
in this
country

If the question, as originally put, were intended to lead up to the issue as to whether an effort, such as the Germans made, would prove worth while in this country in future, the Party can at this stage do no more than offer for consideration a suggestion as to a plan for a preliminary investigation of the whole

subject. The plan would in part constitute a process of elimination and would run on the following lines:-

<u>Order</u>	<u>Type of Authority to be consulted</u>	<u>Terms of Reference</u>
I	Military	To lay down conditions as regards cover in various types of rock.
II	Geological	To produce maps showing where the conditions could be met and the various rocks which would be encountered.
III	Chemical	To report on means for the induration of rock surfaces.
IV	Industrial & Economic	To eliminate from the geological plans areas which would be unsuitable on account of remoteness or of other considerations.
V	Civil Engineering	To eliminate from the Industrial & Economic plans areas unsuitable on account of local access or other considerations and to assess the extent of the accommodation available.
VI	Mechanical Engineering	To determine which classes of Industry are suitable for disposal underground (a) in lined galleries and (b) in unlined galleries suitably treated.

With the issue narrowed down in this fashion, an answer to the question could be hammered out. But so far as the observations go which were made on this tour, there would be little need, in this process, to draw upon German experience.

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6B.	"	Plant Details.
7A.	Denkmal Stollen, Barkhausen.	Plan and Sections.
7B.	" " "	Layout of Plant.
8A.	Dachs I. and Hammerwerke.	Plans and Geological Sections.

PART II. - GENERAL SURVEY OF FACTORIES

(1) General

There can be no doubt as to the importance which the German Government attached to underground factories as an answer to our air attack on their industries, and the members of this party were impressed both by the magnitude of their construction programme and by the wide variety of processes which were carried out or to be carried out below ground. Owing to their haste and to their disregard for the well being of their workers little trouble was taken over ventilation and matters of welfare and safety, but it is our opinion that a very wide range of processes can be carried out underground, and that conditions can be made as tolerable as those on the surface. Indeed there is no reason why underground factories should not be constructed which are almost completely self contained as regards power, water supply, and living accommodation and facilities for recreation for the workers, during periods of especial danger.

Evidently the possible need for underground protection had been foreseen before the war and parts of the "Mittelwerke" at Niedersachsenwerfen are said to have been built in 1936, but apparently it was not till the spring of 1944 that the Germans realised their full danger and made desperate efforts to get their factories below ground before it was too late. The amount of underground excavation which they completed in the year remaining to them is most impressive and though the high rate of progress was due to their ruthless and wholesale use of slave labour the rapidity with which underground plants such as Dachs I were designed and installed is equally remarkable.

In their haste to secure protection for key industries the Germans, as well as starting a very large programme of underground workings, made use of existing underground space such as caves and mine workings, although some of these were small and others most inconvenient. Thus near Halberstadt (MAKRELE II) caves previously used for mushroom culture with a floor area of only 9,000 square feet were used for the production of detail parts of Junkers aircraft and at Gros Schierstadt near Aschersleben Junkers aircraft components were manufactured in old workings of a producing salt mine which could be reached only through a vertical shaft 1,200 feet deep.

Manufacturers appeared to have received instructions from the Government department concerned to provide underground accommodation for their plant and to make their own arrangements for the execution of the work, which was generally supervised by an Engineer-Architect in private practice. At Dachs IV (q.v.)-an oil refinery constructed for the Shell-Rhenania-Ossag-the underground workings were designed by the Deutsche Bergwerke und Huttenbaugesellschaft m.b.H. and mining work was carried out by the Grossdeutsche Schachtbau und

Tiefbau-Gesellschaft m.b.H. In one case where the contractor made poor progress (LMBW) the work was taken over by the Tiefbaugenossenschaft m.b.H said to be a branch of the Todt organisation.

Amongst the new factories visited two types could be distinguished, the single storey factory with a rectangular plan of tunnels and the multi-storey factory such as "Hammerwerke" at Porta Westfalica, in which reinforced concrete floors are built into an excavation of great height. Only two multi-storey factories were seen, but as they have certain definite advantages it is interesting to compare the two types.

Single Storey

Advantages

- (1) Immediate rail access to all parts of the factory if required.
- (2) Fullest use made of existing topographical cover.
- (3) Minimum of structural work.
- (4) Construction rapid as tunnelling can be carried on at many points simultaneously, and part of the factory area may be put into production before the construction of the whole is completed.
- (5) Less vulnerable in the case of a direct hit as the workings are widely dispersed and the pillars form a protection against blast.
- (6) The installation of heavy machinery is much simpler than in a multi-storey type.

Disadvantages

- (1) The area of roof is much greater and hence there is more chance of falls.
- (2) Where lining is required the cost is greater.
- (3) The cost of installing services is high owing to the great extent in plan.

Multi-Storey

Advantages

- (1) The layout is compact and the fullest use is made of the space provided by excavation.
- (2) The roof area is comparatively small and the danger of falls is less and is limited to the top storey.
- (3) The cost of ventilation and other services is low.
- (4) Materials and parts can be distributed by gravity.

Disadvantages

- (1) This design can only be used where the topographical cover is great, and suitable strata of great thickness are found.
- (2) It is not suited to processes which require heavy plant.
- (3) If a direct hit should penetrate to the workings the damage may be widespread.

Generally speaking the multi-storey type is well suited to the manufacture of light detail parts and in fact the two known examples produced ball bearings and radio valves.

As regard the relative ease of construction this will depend on the type of rock and under suitable conditions multi-storey factories might be built rapidly and cheaply by "stoping" methods.

2. GEOLOGY AND THE CHOICE OF SITES

In spite of the urgency of their works much attention was paid to site exploration, and that this was justified appears from Herr Heese's statement that at Langenstein, where as an exception it was omitted, the plan of the workings had to be changed after tunnelling had started owing to falls of ground and a high accident rate.

All the factory sites in the Hartz area were reported on by a consulting geologist (Hr. Schriel of Gottingen) and data was obtained by core borings and at Niedersachswerfen by geophysical methods.

Following such exploration considerable ingenuity was shown in making the best use of site conditions, as for example in adapting the layout of the group of factories at Porta Westfalica (Dachs I, Hammerwerke and Denkmal Stollen) to the occurrence of the Porta Sandstone (see Fig. 8A) and in avoiding the gypsum capping at Dachs IV and Niedersachswerfen.

In general the sites chosen had the following characteristics.

- (1) They were beneath hills high enough to give adequate cover against air attack (see App. No. 1).
- (2) Steep hillsides or escarpments were chosen for the site of entrance tunnels, to avoid long and vulnerable approaches.
- (3) Areas were chosen where such topography coincided with the occurrence of rocks well suited to tunnelling operations. The ideal rock is one which is readily excavated by drilling and blasting, but is sufficiently strong to stand without support over an arched span of 30 feet. Igneous rocks such as granite are too difficult to excavate. Sedimentary rocks of sufficient strength are suitable if they occur in massive strata of considerable thickness and preferably with horizontal beddings. Thinly bedded rocks, and zones of fracturing and faulting should be avoided. Soft sandstones may stand well without support but are liable to shed sand grains from exposed surfaces as they are dried by

ventilating currents, and severe damage to machines may result. The prevention of this state of affairs is discussed in Appendix 2A.

The twelve factories inspected were all sited in either sandstones of moderate strength or in the massive beds of anhydrite (Ca SO_4) which occur in the Hartz area. The anhydrite was an almost ideal rock for the purpose and had the additional advantage that the spoil from excavation was a valuable mineral substance, but similar deposits do not occur in Great Britain.

An important factor in the design of single storey factories is the crushing strength of the rock and the size of pillars required to support the roof load, and this is dealt with in appendix 2.

Although these geological features are of the first importance ease of access to the site by rail and road and facilities for sewage disposal and water supply must also be taken into account. At Langenstein wells for the water supply were sunk within the factory and where possible this is most desirable.

Should at any time the construction of underground factories be necessary in England a preliminary reconnaissance by the Geological Survey should be followed by a detailed investigation of sites, including deep borings which should be carried out under the supervision of an engineering geologist.

The planning of such factories calls for close co-operation between geologists, and civil engineers experienced in tunnelling, otherwise dangerous and costly failures may result.

(3) CONSTRUCTION METHODS

(a) Excavation

The methods of tunnelling were of little interest. Except for the mechanical loaders they were old fashioned and generally the rate of advance per working face was small. In spite of this the overall rate of construction was high for with almost unlimited slave labour it was possible to work a large number of faces simultaneously and thus to reach the maximum possible rate of excavation, this being governed by the number of exits from the workings, and the length of haul to the spoil dumps.

Drilling in every case observed, was by means of light hand held jackhammers using 1 in. dia. round steel with various types of bit, in one case only were detachable bits used (Makrole I). At Niedersachswerfen, judging by the drill marks, rounds of up to 10 feet in depth were broken, but elsewhere the advance per round was very much less than this.

In most cases the tunnels were driven to full size, but in the complex workings at Dachs IV pilot tunnels and raises were driven first and then chambered out to the required dimensions. In the soft sandstones near Halberstadt the tunnels were driven to a small size and trimmed to the finished dimensions with pneumatic picks. This prevented overbreak, saved explosives and increased safety by removing rock loosened by blasting.

Air compressors of many types were used, and at Langenstein they were installed underground, a necessary precaution.

In blasting, a more powerful explosive was used in the cut than in the square-up holes. Electrically fired delay action fuses were used. Much use was made of mechanical loaders of all types, but by far the most popular was the Salzgitter-Lader which is fully described in App.3.

For haulage a great variety of locomotives were used including steam (at Dachs IV), Diesel (at Langenstein) and compressed air (at Niedersachswerfen) any existing plant being pressed into service.

The attempts to camouflage waste dumps were generally half-hearted and unsuccessful, but in one case, at Elben, great care was taken and the workings appear to have remained undetected.

(b) Linings

As the sites were chosen in firm rock temporary support was rarely necessary, but was used in the railway access tunnel at Dachs I which traversed thinly bedded limestones (see Photo).

In workings in Anhydrite no permanent support was required, but a variety of linings were used elsewhere in sandstones. Those observed were:-

Brick Arch (5 ring)	Alben
Steel Ribs with pre-cast RC. Polings	Langenstein
Steel ribs with brick jack-arches	"
In Situ concrete	"
Reinforced concrete arch	Wakrole I.

At Langenstein it was proposed to line the entire factory but elsewhere lining was only used at weak spots or where falls had actually occurred.

As regards the treatment of exposed surfaces of rock, which is discussed in detail in appendix 2A, the usual German practice was merely to whitewash them. This is no doubt preferable to a coating of cement grout which may conceal weaknesses in the rock without giving them support.

(c) Entrances

The entrance to an underground factory is obviously a vulnerable point and several methods of protection were seen.

At Langenstein it was proposed to use a heavy door of reinforced concrete, capable of rolling into a chamber cut in the side of the tunnel. We were informed by the designer Herr Heese that such a door 3 metres thick, and 7 metres high was installed in an old railway tunnel at Kochom, in the Moselle, the tunnel having been converted into a factory. This door was said to have resisted bombing. The disadvantage of this type of protection is that the door itself if damaged in the closed position may form a serious obstruction, and this may account for the fact that heavy doors were little use.

At Niedersachswerfen the tunnel portals, although lined with concrete were fitted with comparatively light steel doors.

Perhaps the most interesting type of entrance was that seen at Makrele I, here the main gallery of the factory did not emerge directly at the surface, but communicated with a short Tee gallery at right angles to the main gallery. Obviously in the case of a direct hit at either portal the blast in the factory will be much reduced.

In most cases the galleries were carried to the surface without reduction in size. This is inadvisable and access tunnels should be kept as small as possible for some yards from the portal, provided this does not create a bottleneck for the purpose for which the factory is required.

(4) ENGINEERING SERVICES (ELECTRIC POWER SUPPLY, COMPRESSED AIR, HEATING AND VENTILATION)

(a) General

Out of the ten underground factories visited three only had been in production for a reasonable period, namely, Nordhausen, Makrele II and Porta (Ball-bearing Factory) and one - Porta (Philips Valve Factory) where production was in the embryo stage. The remaining factories comprised two classes:-

- (1) Where construction was still proceeding, but where certain of the machine tools and/or process plant had been installed with production just starting.
- (2) Where construction work was still proceeding, but with no machine tools or process plant yet installed.

The salient impression gained from the general survey of the factories in the two classes mentioned above was that there was an urgent need to get into production as quickly as possible, therefore the summarised remarks below and the more detailed observations given in the appendices should not be accepted as representing the general standard of installation work in German underground factories, as undoubtedly there are others (underground and surface) not covered by this particular tour where the time factor had not exercised such a restrictive influence. This view is borne out by the higher standard of treatment evidenced in the factories mentioned above as having been in production.

(b) Electric Power supply and lighting

In all cases examined, reliance for power supply was placed on outside sources, all factories being fed from the grid system at high tension and subsequently reduced to the required working voltages by means of transformers situated within the underground factories. It should be made clear however that the reduction to working voltages at individual factories was effected by means of a number of transformers which were positioned to suit the incidence of loading. This arrangement would appear to have been adopted, in principle, for all installations. In no case was any standby or local generating plant provided and there was no reason to assume that there was any intention of providing same.

The standard of wiring installation work varied from normal to indifferent, the general character being influenced by the considerations already outlined. The general illumination provided was of a reasonable standard and invariably machine tools were fitted with individual lighting in addition. A particularly good standard had been reached in the Philips Works at Porta and also at Malachit (Langenstein) where, in addition to ordinary metal filament lamps, fluorescent lighting had also been provided. This was, however, the only instance of fluorescent lighting observed and it was gathered that its general adoption had been precluded by the lack of availability.

(c) Compressed Air

In all factories the compressed air stations for production purposes were placed underground, but only in two instances was any attempt made to provide a circulating system for cooling water. For the remainder, the cooling water apparently was allowed to run to waste. Generally, a series of small units was installed and positioned to suit the incidence of loading in preference to one large compressor station and the compressors were of approximately 200 cu. ft. per minute capacity. Compressors of the rotary type appear to have been most favoured, but it was clear that no particular choice was allowed regarding types that could be installed and this would appear to explain the mixture of types found in the various

factories. Evidence suggested that had rotary compressors been freely available, the installations would have been standardised on this type. The compressors were sited in separately excavated chambers offset in most cases from the main transit tunnels rather than from the production bays and this undoubtedly achieved a reduction of the noise and vibration effects.

(d) Heating and Ventilation

Nothing worthy of special remark has been observed in respect of novelty or advancement of technique, and in certain cases Makrolid I and II, Malachit (Langenstein) and Elben, the ventilation arrangements were of quite an elementary character showing no evidence of real concern for balanced distribution of air or of humidity control. A much better approach to the problem of balanced distribution of air was observed in the Nordhausen factory, Regenstein factory, Porta (Ball-bearing factory) and Porta (Philips Thermionic Valve factory) where both intake and extract duct work systems had been installed, but no air filtration or humidity control is essential for underground factories such as these, since during operative periods production heat energy within the factory will probably maintain tunnel surfaces and plant at a temperature above the dew point of incoming air for the greater part of the year. It is, however, considered most desirable that the ventilation of underground factories should receive much closer attention than appears to have been given in the factories inspected. With the cessation of production and the consequent fall of temperature towards 50°F, condensation is unavoidable as a result of the introduction of outside air and this was noticeable in all factories visited except Nordhausen which undoubtedly had accumulated a large heat storage as a result of a lengthy production period.

It should be particularly noted that the workings examined were usually free of water seepage and this undoubtedly simplified the ventilation problem for these factories. This consideration may have been an important factor in the initial selection of the sites. A very different approach to the problem involving the use of more elaborate equipment would have been necessary if this freedom from water had not existed.

In nearly all cases the heating was achieved by means of the ventilating air and relied therefore on the continuous operation of the ventilating plant. The type of boiler most favoured was the solid fuel fired cast iron sectional low pressure boiler with steam or hot water as the heating medium. There was a noticeable absence of gauges, thermometers, control valves and other usual means of control and adjustment.

(5) PRODUCTION AND LAYOUT

Initially it should be made clear that the summarised remarks and the conclusions as stated below are based on the results of visits
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to ten underground factories, of which only one, viz. Bernthausen, had been in major production for a long period. The remaining factories, even where they had been in production for a short period, or were completed to the stage of just starting up, had been subjected to the adverse circumstances appertaining over the last six months. Apart from irregularities in the delivery of raw materials due to general transport difficulties, it was obvious that they had been denied the choice and availability of those types of machine tools and plant best suited to a particular production, and for installation in underground workshops. In spite of these difficulties there was evidence of undue haste and endeavour to obtain production. This report therefore should be treated in the light that it is not conclusive nor necessarily representative of the best practice as applied to layout and production methods in their underground factories generally.

All the factories visited had ceased production, and were depleted of workpeople and staffs. The conclusions arrived at, and details submitted on the individuals reports for the respective factories are therefore based on observation, estimation, and in certain cases reinforced by interrogation. With regard to interrogation, this was not found to be too reliable owing to the apparent anxiety of the Germans questioned to give ready and quick answers, and probably without the appropriate consideration or knowledge of the production as a whole.

All the factories inspected were constructed in hill or mountain sides, and consisted in the cases of major factories of a complete tunnel system, and in minor factories of caverns, or an adaptation of existing caves or workings. The type generally favoured would appear to be the ladderlike formation, or as an alternative to this, a single main tunnel giving through access and having offworking galleries. In all cases the actual formations were governed by the geographical and geological conditions existing at site. Plans of respective factories are included with this report.

With regard to the general construction other than for Makrole II, floors were made up in concrete. Many of the tunnel systems and workshop galleries were unlined, and in these cases whitewashing was the only treatment given the virgin tunnel surface. However, at the Regenstein factory where automatic machines were installed, concrete protecting walls had been provided up to a height of 9' but this was obviously to meet special circumstances by reason of having to insert bar stock into the machines and to minimise the creation of grit and dust which would have been occasioned by contact of the bars with the virgin tunnel surfaces.

While there was no convincing evidence of the deleterious effect of grit and dust on installed machine tools, it does not follow that this would not be felt over a relatively long period. In this connection, machines in the main were not new and had been comparatively recently installed. Nevertheless, there was evidence that the combination of dust from tunnel surfaces and floors was in greater

quantity than one would find in a surface factory. Apart from the ultimate effect on machine tools and plant, where it is the intention to assemble and erect stores such as engines and the like in underground factories, it is obviously imperative that the dust content in the atmosphere be reduced to a minimum, and at least equal to the conditions prevailing in good surface factories. It is therefore suggested that for projects where 100% tunnel lining is not essential from a constructional aspect, the question of special treatment of tunnel surfaces is a subject worthy of investigation. Also, consideration should be given to the use of vacuum cleaning methods for shop floors so as to reduce to a minimum the amount of dust that could be taken up by the forced draught airstreams.

In the installations seen, there was evidence of restriction in the availability of machine tools. Those being installed in the underground factories were mainly obtained from existing surface factories, augmented by machine tools removed from other European countries. It was obvious that there was either a general shortage of new machines, or the transport position had become impossible. In this connection, the absence of one particular machine may have had a very adverse effect on production, and this was instanced in the case of the Porta Ball-bearing factory at Bachhausen where it was ascertained that one vital machine for this specific production was ready at the maker's works but could not be delivered. Further, there was an almost entire absence of lathes of the capstan type, resulting in the use of an abnormally large number of standard lathes, the latter not being so productive and demanding a higher standard of skill in their usage.

No outstanding new features regarding layout and production methods were seen during this tour, and it was evident that the general machining methods and layout of plant adopted in these particular factories were not up to the standard reached in Britain during the war. This condition may have been partly due to the shortage of suitable machines, but it did appear that the operational methods and sequences used on underground production, where floor space is very valuable, had not received the special consideration that one would have expected. In some cases costly floor space was being wasted by using large machines for relatively small operations, and horizontal broaching machines where vertical machines would have been more suitable.

Of the engineering factories only in the cases of Makrele II and the Regenstein factory was there real evidence that planning had received serious consideration.

The main effort, however, that was apparently being made to obtain maximum output per unit of floor area, was more in the direction of overcrowding machine tools than of careful planning. The congested condition of machine shops was found to vary between the various factories, the worst congestion being evident in those

factories where slave labour had been employed. In these cases the possibility of obtaining maximum output by overcrowding had been allowed to outweigh all considerations for the workers comfort and safety.

Overhead lifting facilities were provided only in cases where its provision was absolutely essential, and then the installation was solely local to the particular work concerned. There was a remarkable absence of conveyor systems in most of the production shops, even where (a) the congested conditions of working could to some extent have been relieved, and (b) where output would obviously have been directly increased by such provision. It appeared that the large number of slave workers generally available for lifting and transporting purposes, possibly coupled with the saving of conveyor and crane producing capacity in favour of direct armament production, may have been the principal reasons for the absence of such equipment. No special arrangements were made for handling arisings such as swarf, and even in shops containing automatic machinery, swarf had to be dealt with by hand methods.

Regarding internal factory transport, accumulator driven trucks were normally adopted for transportation between workbays and the storage areas.

There was no attempt made to provide noise damping devices such as curtains which would have reduced the transmission of plant noises in the tunnel systems, and no special methods were apparently used to insulate the foundations of plant such as reciprocating compressors. Vibration arising from reciprocating machinery could have been very troublesome in confined spaces such as tunnel workings.

From the various types of factories inspected, and in particular Nordhausen and Dachs I, it is apparent that given satisfactory geographical and geological conditions there are few types of installations which could not be sited underground, provided, of course, that the proper technical considerations were given in the planning stage. With this in mind, and with the knowledge that there was serious interference with production at the various factories owing to transport difficulties resulting from bombing, it is difficult to appreciate the German policy of having mainly planned the manufacture of components, and carrying out part assemblies only in their underground factories which generally applied except in the case of Nordhausen where V Weapons were constructed in their entirety. One would have thought the obvious course would have been to avoid the risk of destruction of components and part assemblies both during transit to, and at the surface factories where it was intended to effect the complete assembly. This would particularly apply in the case of those equipments which were being manufactured specifically for the defence of vital surface targets and communications. This is a point of policy which would appear to justify every consideration in future planning.

Although this tour did not bring to light any particularly outstanding features as to layout or production methods, it has indicated the practicability of carrying out a very wide range of production in underground factories, and has stressed the points summarised below:-

- (1) It does not appear wise to depend solely on grid connections for electric power supplies, and an alternative standby source of supply by local generating plant contained within the workings would be advisable as part of the permanent installation.
- (2) In order to obtain the best use of floor area, machine tool layouts should include only the most efficient types of machines, and provided the production to be undertaken is reasonably stable then special types - even to the extent of new designs - should form part of the equipment. Where time factor is concerned, such provision could only be made effective if the planning is undertaken sufficiently well ahead to allow for design and manufacture.
- (3) There should be no hesitation to adopt the use of conveyor systems and mechanical handling where these would be advantageous both from production and labour aspects, and particular attention should be given to dealing with such arisings as swarf.
- (4) Tunnel surfaces if unlined should be suitably treated to reduce dust effects to a minimum, and provision made for cleaning the machine shop floors by means of vacuum appliances.
- (5) In order to reduce noise effect and vibration, compressors and plant of a like nature should be of the rotary type.
- (6) Insulated foundations should be provided for plant which creates undue vibration, and for certain classes of precision machines such as grinders.
- (7) Noise damping screens should be used where advantageous.
- (8) The provision of ventilation and heating by means of a balanced plenum system appears to be the most satisfactory type of installation, but the practicability of some form of automatic humidity and temperature control should always be considered.
- (9) Production at each factory engaged on vital defence equipment should as far as practicable aim at the manufacture and assembly of the complete store.

PART III

DETAILED DESCRIPTIONS OF FACTORIES

(A). MITTELWERKE FACTORY, Niedersachswerfen, Near Nordhausen, Code Name. HYDRAS	021/1320 022/3460 031/2800
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This large factory, situated beneath the Kohnstein, a hill 2 Kilometres south west of the village of Niedersachswerfen and 6 Kilometres north of Nordhausen, was said to be one of a group of eight factories in the vicinity of Nordhausen. It was used for the production of aircraft engines, and V1 and V2 weapons, which were to be seen in every stage of manufacture.

All the underground workings were of new construction, although access was from old anhydrite quarries.

Tunnelling work is said to have started in August, 1936, and the transverse tunnels, Nos. 1 to 17 completed in 1937. This involved the excavation of 276,000 cubic metres of rock. Transverse tunnels were built in two stages Nos. 18 to 36 and 37 to 46 between 1937 and March 1944. We were informed that the galleries were originally intended for the storage of chemicals, but were converted for use as a factory starting in September, 1943. Production started in March, 1944, Tunnels 1 - 19 being used for Junkers engines and the remainder for V weapons.

Contacts and References

At the time of our visit the factory was guarded by the 5th Armoured Division, U.S. Forces, Commanding Officer Major Treadwell, whom we met together with Major Wilkins and Lieutenant Hobbing, (Intelligence Officer). Lieutenant Hobbing introduced Herr Karl Neu who was in charge of construction from 1936 - 1944, for the firm responsible for carrying out the work, WIFO. (Wissenschaftliche Forschungs Gesellschaft). Other technicians associated with the work whom we were unable to meet were:-

Professor Schriol (Geologist) of Gottingen
Herr Winkeltraeter (Ventilation) of Wuppertal.
Herr Naumann, Niedersachswerfen
Herr Schmidt, Woffleben
Herr Von Lingelsholm, Nordhausen.

As the area was due to be occupied by the Russians we were unable to make as thorough an examination as we could have wished and no information was obtained on costs or on progress. It was arranged that Herr Neu should prepare a detailed report for Lieutenant Hobbing, a copy of which would be forwarded to us within a week. As the Russians moved into the area within three days of our visit this was not

received, and we requested Colonel Reford-Brown, O.C. "T" Force, 30 Corps, Goslar to trace Lieutenant Hobbing and if possible Herr Neu, who had been taken into custody by the Americans. So far this report has not been received.

Previous to the visit our party was supplied with C.I.U. reports giving maps, air photographs, geological sections, etc. The factory had been reported on by C.I.O.S. party No. 163, and it is understood that methods of construction have been reported on by Lt. Colonel Clarke, Air Corps, U.S. Army and Mr. Jansen (U.S. Civilian). The geology of the site is described in Prussian Geological Survey Sheet 2525, (scale 1/25,000), 1930, and the accompanying Memoir (1935).

Geology and Site Investigations

Before the commencement of work core-borings were put down, and a geological and geophysical survey made under the supervision of a geologist, Professor Schriel. As shown on drawing No. 1 B a section of the Kohnstein shows anhydrite overlain by gypsum, with a capping of dolomite on the highest points of the ridge. Anhydrite (calcium sulphate) occurs as a massive deposit with a fine grained crystalline structure, bluish white in colour. It is well suited to tunnelling as it is readily excavated by drilling and blasting, but being comparatively free from joints and other planes of weakness will stand unsupported over widths of 30 and 40 feet. The face of the Kohnstein is exceedingly steep (see photograph No. 3) and gives ample cover.

At its upper surface the anhydrite has altered to gypsum to an average depth of about 30 feet, this mineral is soft and unsuitable for tunnelling, and ventilation shafts passing through it were lined with brickwork. The tunnels were confined to the anhydrite stratum.

No falls of rock were seen in the factory, but we were informed by Herr Neu that falls occurred if the temperature was allowed to rise above 68°F, and that several heavy falls occurred during 1944 and 1945, one of which killed 12 workers.

Layout of Factory

A Plan of the factory is shown in Fig. 1A It is based on sketches made on the site and is not strictly accurate. It will be seen that the factory consists of two main parallel tunnels each over one mile in length and about 170 metres apart. These are S shaped in plan apparently to take advantage of the maximum cover. They are connected by 46 transverse tunnels, so that the whole is ladder like in plan.

A minimum cover of 50 metres was aimed at, and is shown in Fig 1B.

The main galleries were about 30 feet wide and 25 feet high and the transverse galleries of approximately the same size, though some of these had an upper storey consisting of a timber floor

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resting on steel joists.

It is said that a total floor area of 600,000 sq. metres was planned and that the area in use was 120,000 sq. metres at floor level, and 45,000 on the upper storay.

Lining and Support

In spite of occasional falls of rock the galleries were unlined, though steel supports and cross beams had been placed at a few places where the roof was weak. Ventilating ducts, cables, etc., were carried on light steel frames as shown in Fig. 1A.

Entrances

The tunnel portals were lined with concrete, with wing walls (see Photographs Nos. 2 and 3). Steel doors were fitted to the entrances, but these would not have given much protection from a near miss.

Shafts

There were 8 shafts, seven of which were for ventilation, and one a flue to a furnace. These were all 2.5 M. x 1.5 m. in section. They were unlined in the anhydrite, but lined with brick in the gypsum and dolomite. A typical shaft section is shown in Fig. 1A. this section was adopted to prevent sabotage. The risk from bombing was considered negligible.

Sewage Disposal

All sewage was pumped to an overhead main (See Fig. 1A).

Water Supply

No information was collected on this point.

Labour

Very little information could be obtained, it is said that there were between 15,000 and 20,000 workers (6,000 per shift), but it is uncertain how many of these were engaged on construction.

Workers in the factory are said to have become acclimatised in from 4 to 5 weeks. The sickness rate is said to have been 4% to 5%.

Excavation

Methods of excavation were seen in new workings on the East side of the Kohnstein. These were said to be intended for an oil refinery.

Drilling

With hand held jack hammers. Drill steel 1" round up to 16'0" long. Chisel, 4 point and six point bits used. Advance per round, 10 ft. to 12 ft. Holes per round, 48. Three 8 hour shifts worked underground, one Drilling, one Blasting and one Mucking.

Mucking

One loading machine to 3 faces. The breadth of 9 M. permitted the use of a $\frac{3}{4}$ cu. M. shovel.

Transport

95 cm. gauge track. Compressed air locomotives used owing to shortage of fuel oil.

Miscellaneous

The production side of the factory was carried out by E.M.F. (Elektrisches Mechanisches Werke.) Lieut. Hobbing stated that document and 15 cases of films covering tests of V.2 projects were turned over to E.M.W. personnel on 27th March, 1945.

An R.A.F. Wing Commander stationed in Nordhausen previous to Americans taking over factories, was reported to have obtained and taken away the 15 cases of films.

V.2 Plans All copies except copy "A" reported to have been burnt by the S.S. Copy "A" taken by S.S. officer to the Schneekopel, a mountain in the Riesengebirge between Silesia and Czechoslovakia.

The first two transverse tunnels from the Northern end were two storeyed with concrete floors and equipped as a hospital and possible living accommodation for German supervisors and key personnel. The equipment was of a high standard including the hospital equipment. This was in marked contrast to the Southern end of the factory where slave labour was used to a much greater extent.

Air Attack

There was no evidence of air attack on this factory.

Engineering Services

(a) Heating

The heating medium used was high-pressure hot water and the boiler plant, which was of the coal fired water tube type, was installed underground in one of the cross

tunnels together with circulating pumps and ancillary equipment. It was not possible to examine the boiler house equipment in detail as the floor was under an unknown depth of water.

The boiler flue gases were taken through the top ground cover by means of a shaft, but it was not possible to ascertain the normal methods of fuel delivery or for ash removal. For a boiler installation in such a position it is reasonable to suppose that solid fuel would not have been used if liquid fuel had been available.

The greater proportion of the heat generated was supplied to the air heater batteries of the main ventilating system and then delivered to the workings through the medium of the air supply. Heat was also taken to individual unit air heaters of the suspended pattern at key points in the workings, notably at main tunnel entrances.

The main batteries, unit heaters, and the pipe work which was entirely jointed by welding, were of the conventional pattern and represented a normal standard of design and workmanship.

It was ascertained that it was considered necessary to ensure the temperature of the workings did not exceed 68°F since it was feared that temperature exceeding this would provoke falls of rock.

(b) Ventilation

Ventilation was provided by a simple mechanical air supply and extraction, the supply air being taken from outside and warmed, but not cleaned or otherwise treated. A central fan chamber located in the same cross tunnel as the boiler house supplied fresh air for dealing with one main tunnel, and this arrangement was probably duplicated on the other side for the second main tunnel. This chamber contained three centrifugal fans, operating in parallel, each drawing fresh air through a heater battery from the base of a vertical shaft running adjacent to the flue shaft, and rising to the surface above. Air was discharged from these fans into a common supply duct and the division of the load between the three fans was probably adopted to minimise head room in the fan chamber, and to obtain some standby against breakdowns and for repairs.

The distribution of warm fresh air was carried out by means of galvanised sheet steel duct work, running along the main tunnel, with branch ducts along the cross tunnels. All ducts ran at high level and to one side. Outlet gratings were provided at intervals on all ducts.

The inlet system was paralleled by a similar system of extraction duct work run in the main tunnel on the same side as the inlet ducts, and in the cross tunnels on the opposite side to the inlet ducts. Extraction branches were in general brought down to low level, and interrogation disclosed that this was done in the case of the main tunnels for the purpose of removing fumes from Diesel locomotives.

Paint spraying booths and the like were also directly connected to the extraction ducts and appeared to have been generally sited near to the main tunnel for this purpose. The extraction duct-work system was taken to exhaust fans which were sited in cross tunnels at each end of the main tunnels, and the vitiated air was discharged to atmosphere through the open ends of the tunnel.

It was stated that the total quantity of fresh air supplied was 950,000 cubic metres per hour, which represents approximately one air change per hour as an average throughout the system. At the commencement, however, tunnels 1 to 17, were provided with about 0.6 air change per hour, but this was found to be insufficient. When cross tunnels Nos. 20 to 46 were afterwards equipped, the air change for these tunnels was increased to approximately 1.4 changes per hour. The final standard of ventilation is stated to have been quite satisfactory for the production machinery installed and for a working shift of six to seven thousand employees.

The installation was of conventional design, it possessed no novel features and the workmanship was moderately good.

(c) Electric Lighting and Power

There appeared to be one main High Tension intake station, with a number of transformer sub-stations located along the main tunnels. The main distribution cables were run in a boarded duct at floor level on one side of the main tunnel, and emerged at convenient distribution points where the usual gear was provided. Local circuiting to motors and lighting points was carried out by means of cables suspended from straining wires running along the tunnel centre line. The distribution was arranged as a three-phase, four-wire system and in several instances circuits are tee'd off the mains without the insertion of any protective devices.

No information could be obtained regarding the use of earth leakage trips, and no standard system of group motor control was evidenced. The general lighting in the tunnels was provided by means of well distributed metal filament lamps. The wattage of the lamps however was not consistent, probably due to replacement since the occupation by Military Forces.

The general installation work was of a very ordinary standard.

(d) Compressed Air

Compressors of both the rotary and reciprocating types were installed, and these were distributed in reasonably small units to suit production requirements, the compressors being generally sited in small rooms off the main transit tunnels.

Cooling water was apparently run to waste.

The compressed air, at 6 atmospheres pressure, was mainly used for operating pneumatic jib cranes, and for blowing swarf from machines particularly where gang milling was carried out.

Production and Layout

The Mittelwerk and Nordwerk tunnel system had been in reasonably full production up to the cessation of hostilities, the main production being:-

- V1 and V2 components and assembly
- Taifun - flak rocket components
- Schildkroete - flak rocket components
- Junkers Engines - Junk 004 components and assembly
- Junk 213 components and assembly

While it was not possible to obtain any reliable information on site, it is considered that this factory had been in production for a period of at least 12 months. It is also estimated that the total labour force (two 12 hour shifts) employed on production was in the neighbourhood of 12,000 of which 75% would be foreign workers. Having regard to the two 12 hour shifts worked, the factory no doubt would have been in a position to have reached an output of 800 to 1,000 V. Weapons per month, and also about 200 Junkers Engines per month. Although it was not possible to investigate the whole workshop area owing to local flooding and presence of mines, we would assess the number of machine tools installed as about 5,000.

The general layout and production arrangements were based on two main tunnels, each about a mile long by 30 ft. wide extending from one side of the hill to the other, thus giving double entry on both sides. These two main tunnels were connected by 46 cross galleries each about 520 ft. long by 30 ft. wide. The two main tunnels were used for main and inter-bay transport, having double track railway throughout their length for the main incoming and outgoing traffic, and diesel and accumulator driven floor trucks for inter-bay transport. Prepared roads giving access to the four main entrances permitted the use of road transport both to and throughout the main tunnels.

Storage, including castings was accommodated in the two main tunnels leaving the cross galleries for machining work and assembly, and of these approximately a third was devoted solely to machining operations and smaller erections such as the Junkers Engines.

Lifting arrangements were strictly confined to requirements, and in the main tunnels comprised floor operated electric hoist blocks carried on beams mounted crosswise, and in some cases extending into the workshop bays where lifting was essential. This particularly applied to the handling for vertical assembly of V2 castings, and for handling dies on the large power presses which were installed. In this connection it should be noted that while the average height of tunnels and galleries was 25 to 30 ft a sub-floor giving more effective height and situated in certain cross galleries, adjacent to the main tunnel, overcame the question of headroom for those particular operations and assembly where more than the normal height was essential. Further, the electric hoists were of the Maag type giving maximum headroom and lift. Every consideration had obviously been given to the lifting aspect for handling work in the cross galleries, particularly the machine bays. Individual pneumatic cranes of the jib type were installed adjacent to these machines where it was not possible to man-handle the work.

In the shops devoted to cylinder block and like machining operations, 4-wheel flat topped trolleys were provided and arranged to run on a light tubular conveyor rail system. This provisioning was made on both sides of the machine bank for handling the heavier work and no doubt used also for removal of swarf to the main tunnels.

While for an underground factory the general arrangement was good, it could have been improved by the installation of more conveyor systems. It is pointed out, however, that the working conditions in the machine shops were bad, due to the congested state arising from the large number of machine tools installed in the area. This rendered a condition which would not be tolerated except where the labour was controlled to the extent of coercion and the management were not concerned with accident rates; generally there was sufficient room only for the operator to stand and load his machine. Sketch attached shows typical instances of the endeavour to site machine tools in a minimum area.

A certain amount of this congestion could have been avoided had machine tools of better productive capacity been available, and was instanced in the case of grinding the bores of connecting rods where grinders of the Planetary type were installed. Based on our experience in the manufacture of T.L.C. engine con rods the Bryant machine (American), had it been available, would have given equal output for half the floor space absorbed by the Planetary machines. This remark applies equally to other cases had not lack of availability precluded choice.

Few machines of a special nature were installed and the condition of machine tools with very few exceptions could only be described as fair.

Machines were levelled and grouted, and only in isolated and essential cases were they bolted down to the floor.

(B) LANGENSTEIN FACTORY
Near Halberstadt
Code Name - MALACHIT

021/1321

022/3461

031/2801

The Langenstein factory was the second largest factory visited by this party, and was intended to be entirely devoted to the manufacture of jet engines. It was of particular interest as both in plan and in the type of rock in which it was situated it resembled an underground factory constructed in England during the war. A detailed comparison of the two factories is given in Appendix 2.

The factory is situated beneath the Thakenberg, a hill on the edge of the Halberstadter Stadt Forest about 3 miles South of Halberstadt, and one mile North West of the village of Langenstein.

The workings were entirely new, although the northern entrance was from an old sandstone quarry.

The factory was built by the "Ersbergbau Salzgitter G.m.b.H." a branch of the Herman Goering Werke, and was intended for the manufacture of Jet aircraft engines by the "Junkers Flugzug Motorenbau", whose works at Dessau had been bombed in February 1944 and temporarily transferred to Sittau.

CONTACTS AND REFERENCES

Herr Heese - Civil Engineer and Architect in charge of construction.
Employed by the Herman Goering Werke; previously in private practise in Berlin.

Herr Lüder - Chief Assistant to Herr Heese.

Herr Hoffman - Chief Production Engineer to the Junker's
Flugzug Motorenbau.

Herr Faupel - Chief Assistant to Herr Hoffman.

Herr Direktor Schölfer of the Junkers Flugzug Motorenbau was not interrogated as he was ill.

- (1) Air Ministry Interpretation Report No. L.260 dated 18th October, 1944, together with aerial photographs.
- (2) Prussian Geological Survey. Sheet 230 (Halberstadt) 1/25,000 1927. Memoir 1928.

Mr. Heese stated that many drawings were removed by the S.S. and that a plan had been taken about June 1st by Captain Smallice of the U.S. Army. Some drawings remained in his own office at Halberstadt and he agreed to prepare a report giving full particulars of labour employed under various categories together with an analysis of costs. On our return to Goslar on 30th June, a request was made to "T" Force Headquarters that Herr Heese and his records should be removed from the Russian Zone at once. Unfortunately Halberstadt was occupied by the Russians that night and contact with him lost. For this reason our information on costs and progress is incomplete.

It is possible that Herr Heese may have moved out of his own accord and could be traced.

GEOLOGY AND SITE INVESTIGATIONS

We were informed by Herr Heese that owing to the extreme urgency of the work no borings were put down, but this was unusual, and that as a result changes had to be made in the layout after work had commenced. Other hills in the neighbourhood of Langenstein were investigated by boring as possible sites for a Krupp factory, but were found to be unsuitable.

The tunnels were driven in a fine grained sandstone of medium strength. This rock is exposed in the quarry at the north entrance. (See photographs). It is pale buff in colour, dips to the north at 2° to 3° and shows two systems of vertical joints striking 320° mag. and 230° mag. respectively. There are well marked partings or bedding planes at intervals of 4 or 5 feet and as the main joints are at about the same interval the rock is "blocky". Herr Heese stated that the overbreak was 10% of the total excavation. The top of the Thakenberg is capped by a stratum of harder sandstone as can be seen by the steeper slopes and the many pillar shaped outcrops which emerge from the forest as conspicuous landmarks.

These sandstones are said to be underlain by uncemented sands; this was not seen.

The workings were remarkably dry, and no water was seen, even in the neighbourhood of strong joints.

PLAN OF GALLERIES

A plan of the galleries is attached to this report.

VOLUME OF EXCAVATION

Total excavation planned	-	450,000 cu.M.
" " completed	-	400,000 cu.M.

FLOOR AREAS AND LEVELS

Total floor Area planned	-	72,000 sq.M.
" " " completed	-	67,000 sq.M.
Area in use for production	-	25,000 sq.M.

Floors graded to 1/33 to suit bedding of sandstone.

LABOUR DATA

The following rough figures were quoted by Herr Heese covering all classes of work on the job both surface and underground.

June 1944	500
July	900
August	2,000
September	3,000
October	4,000
November	4,500
December	4,500
January 1945	4,000
February	4,000
March	4,000

A sum of 4 marks per day per man was paid by contractors to the government for prisoners from concentration camps. Civil prisoners of war were paid the same hourly rate as Germans. The rate for skilled men was 80 pf. per hour with family allowances. The mean pay of skilled workers was 95 marks per week and for unskilled workers 50 marks per week.

PROGRESS DATA

According to Herr Faupel work started in June 1944 and construction was suspended in March 1945.

Production was started on 11th April, 1945.

COST DATA

According to Herr Heese:-

Expenditure to date on construction work only exclusive of all charges in connection with equipment - 25,000,000 marks.

Estimated total expenditure - 27,000,000 marks.

EXCAVATION

Drilling

All holes were drilled dry with light, hand held jackhammers, using an auger steel with a chisel bit. Electric drills were tried but were unsatisfactory. Much use was made of light pneumatic picks for trimming the roof and sides. Air pressure at the face was 90 lb./sq. in.

In the large galleries, 7 m. wide and 5 m. high 35 holes were drilled to a round. Normal progress was one round of 1.50 metres per 8 hour shift.

Immediately after blasting the drilling of top holes was started, the drillers working from the top of the muck pile. As mucking proceeded and the rest of the face was exposed the lower holes were drilled.

In the main north south gallery, 4.40 metres wide and 3.00 metres high, 20 holes were used per round. As progress in this gallery governed the progress of the whole project faster work was achieved, the average advance being 7.M./24 hours. It is said that an advance of 17.50 metres in 24 hours was reached, record for Europe.

Blasting

Explosives used were Tonarit 1 for the cut and Tonarit 2 for the square up. Charges were fired electrically with the usual delays.

Mucking

At Langenstein, as elsewhere, a compressed air loader of the face shovel type was much used. This machine the Salzgitter-Lader, manufactured by Herman Göring Werke A.G. für Bergbau und Hüttenbedarf, Salzgitter, is fully described in appendix (3). It has a bucket capacity of 0.3 cu.m. and a maximum output of 21 cu. M/Hr.

75 cm. gauge track was used with $1\frac{1}{2}$ cu.m. wagons and diesel locomotives for the transport of spoil. The exhaust fumes from the locos was troublesome and air conditions at the face were said to be extremely bad as a result.

All spoil was taken to the South end of the main tunnel, 900 metres long. Here the portal was at such a level that the track was carried out on a gantry on which two electrically operated tippers were installed. These delivered direct to 2 cu.m. side lifting wagons on the dump below.

On the dump steam locomotives were in use, and a spreader of unusual design was used for levelling (See Photograph No. 26).

Recently dumped material was spray painted with large portable sprayer fitted with a hand pump. Part of the dump had been soiled and seeded down to grass.

On the whole the camouflage was not effective.

FALLS OF GROUND

It was originally intended to use the South West entrance for rail access, and the galleries were started to the appropriate dimensions. After advancing a short distance work was stopped by a heavy fall which caused several fatal casualties and left a cavity extending 12 metres above the back of the tunnel. A brick arch $1\frac{1}{2}$ metres thick was constructed for a length of 12 metres at the point affected, and a borehole having been put down from the surface into the cavity, it was filled with grout.

The intention to use this gallery for rail access was abandoned and its dimensions were reduced for the remainder of its length.

Inspection shows that the cause of this fall was a stratum of very weak sandstone overlying the gallery.

Mr. Heese stated that minor falls of rock were common, and that the accident rate from this cause was high.

LINING AND SUPPORT OF GALLERIES

It was intended to line the workings throughout, and considerable progress had been made. Several types of lining were used but these were all based on steel ribs of Heavy H section 12 cm. x 10 cm. placed at 1 metre centres. The types observed were:-

- (a) Precast slabs spanning 1 metre and 9" deep placed between the mild steel ribs.
- (b) Two precast slabs each bearing on a steel rib at one end and on a central concrete voussoir at the other.
- (c) Brick lining between the steel ribs, built with a plane face up to the springing of the main arch and as a jack arch above it. The standard of workmanship of this brickwork was exceedingly poor and in places it appeared unsafe.
- (d) At the junctions of galleries where the rock was weak brick arches of heavy construction were used instead of steel rib construction.

In all cases the lining was backed with stones set in cement

mortar. In 1945 steel ribs became difficult to get and instead of building them in, they were used as supports for shutters to a mass concrete lining. These shutters were of 1" board 9" wide and 1 metre long wedged off the ribs. The concrete was 40 cm. thick to springing reducing to 10 cm. at the crown of the arch. Stone was hand packed behind it where necessary. As much as 7 metres per 24 hours of this type of lining could be placed per gang.

The concrete used was a 5: 1 mix., 215 Kg. of cement to 1 cu. ft. of aggregate. The coarse aggregate used was dolerite chippings - $\frac{3}{4}$ ", and the fine aggregate was formed by crushing the local sandstone.

The plant for fine aggregate consisted of a 40" chain conveyor feeding to a Chilean Mill with two rollers set eccentrically each 30" rad. 16" wide. The rock was crushed dry. Large blocks were put through a 16" x 10" Jaw Breaker before crushing.

Concrete was mixed underground in $\frac{1}{2}$ c.y. mixers, and transferred to a movable stage by means of an 18" portable conveyor. The concrete was shovelled from this stage to the shutters. The concrete as placed had about a 4" slump.

ENTRANCES

It was proposed to use an electrically operated reinforced concrete type of door, 3 metres thick, to roll into a chamber in the side of the gallery. These were not installed, but one chamber had been formed.

SHAFTS

Seven shafts were sunk for ventilation purposes at points shown on the plan. They had no features of interest.

WATER SUPPLY

5 wells were sunk outside, and one inside the workings to draw water from the underlying sands. Their depth varied from 40 to 46 M. Three were in use and yielded 40,000 li/day.

SEWAGE DISPOSAL

Salt glazed pipes laid in trenches beneath the main gallery carried sewage by gravity flow to a septic tank discharging to the river.

AIR ATTACK

We were informed that no attacks were made on this site. See appendix No. 1.

ENGINEERING SERVICES

(a) Heating

The permanent heating equipment had not been installed in this factory, but it was understood that steam boilers of the locomotive type were to be housed in a Boiler house outside the underground workings adjacent to the broad gauge railway tunnel entrance, coal being taken from the railway by means of a conveyor. The steam pipes were to be run through the tunnels to supply air heater batteries fixed at the bottom of vertical ventilating shafts. A previous intention to instal boilers underground appeared to have been dropped.

In order to enable the first completed section of tunnels to come into production, a temporary heating installation consisting of four cast-iron sectional boilers were installed in a building sited on the hill surface adjacent to one of the vertical ventilation shafts. A pumped low pressure hot water heating circuit passing down the vertical shaft served unit air heaters of Junkers make. The installation was of a very temporary character, and instruments usually considered necessary for the operation of a system such as this were not provided. It was stated in interrogation that the temporary heating arrangement had been far from satisfactory.

(b) Ventilation

The permanent ventilation intended for this factory had not been installed, and interrogation indicated that the exact nature and arrangements had not been finally decided.

The broad intention seems to have been to provide simple * mechanical fresh air supply, and extraction, the incoming air being warmed but not filtered or otherwise treated. The fresh air was to be drawn from the surface down vertical shafts, with fans and heater batteries at the base of the shafts and thence delivered to air ducts excavated below the floor of the main tunnels, from which branch ducts were to be taken. Several of the main tunnel floor ducts and branch ducts were taken up between the rock surface and the tunnel lining for the purpose of connecting to outlet boxes with adjustable grills projecting beyond the tunnel wall. These outlets were arranged so as to project warm air along the length of the cross tunnels with an upward bias.

It was stated that the ventilation rate intended was three air changes per hour, but from that portion of the installation already in position, it did not appear that the final arrangement would have been adequate for this capacity.

A temporary exhaust fan had been installed immediately outside one tunnel entrance and this fan extracted through black sheet

metal ducting from a point approximately 200 ft. inside the main tunnel. This extraction system had been operating in conjunction with two or three fresh air inlet shafts already referred to in the description of the temporary heating installation.

It was stated that the proposal was to provide a separate extraction system for welding work in the sheet metal shop, but no details were available.

The temporary arrangement bore every sign of hasty improvisation and was stated to have been unsatisfactory.

(c) Electric Power and Lighting

The incoming power supply was received at high tension from the grid system and transformed on site to working voltages of 380/220.

The main cables for power and lighting supply in the tunnels were run in a central floor duct or alternatively along the tunnel walls in special U shaped clips welded to the top of the compressed air main.

Distribution panels were mounted on wooden supports with wooden surrounds, pending the arrival of metal cabinets.

Circuit wiring was cleated to the walls of the tunnels and in several instances Tee connections were made direct off sub-mains. These sub-mains were generally confined to the high level of the tunnel and supported on straining wires.

It was not possible to discover any orderly system of earthing.

The lighting in general consisted of fluorescent tubes in fittings of conventional pattern, each fitting having two tubes approximately 3 ft. long, the fitting being spaced at approximately 20 ft. centres along the mid line of the tunnel. Metal filament lamps were interposed with this arrangement and the wattage of these latter lamps averaged 200.

(d) Compressed Air

The main air compressors for the tunnelling operations together with main water pumps were located in a special chamber in the side of the tunnel approach. This compressed air unit was provided with an atmospheric cooler placed outside the chamber.

A number of smaller compressors for production purposes were installed in chambers adjacent to main tunnels; in these instances all cooling water appeared to be run to waste. From the machines examined, there seemed to be a preference for compressors of the rotary type but sufficient rotaries were apparently not available for the entire installation required.

PRODUCTION AND LAYOUT

The Langenstein factory was being constructed to produce engine components for Junkers Jet Propelled Aircraft, and planning was apparently based on the manufacture of components for 1,000 complete engines per month. The final engine assembly was to be carried out at the Junkers surface factory at Zittau.

The total superficial area of the workshop was to be about 775,000 sq.ft. of which 500,000 sq.ft. would have been allocated to machining and production proper, the remaining area being for storage and transit purposes. At the time of inspection, tunnelling had extended to about 90% completion.

Production was only started in April, 1945, and it was intended to instal some 3,000 machine tools of which 230 had been transferred to the factory. Of these 125 had been sited and wired but only a few had been put to work, and these on the first stage operations for producing the rotary compressor section of the jet engine. We would assess that the total labour force required on the two 12 hour shifts would have been 6,500 and the proportion of German to foreign workers in the neighbourhood of 1 to 3.

From the amount of the constructional work already carried out, and the projected work necessary for completion, it is considered that the probable layout for transit, storage, workshops and general production flow would have been as shown on Sketch 2A attached. It will be noted that for incoming stores a single railway track had been provided at both entrances (a) and (b) and these lines extended about 350 ft. into the tunnels. In addition to this, separate road access had been provided at entrance (c);

With regard to outgoing traffic this was to be catered for by road access at (d) and rail at (e). At tunnel (e), the railway track was to be extended practically throughout the entire length of this tunnel thus giving a convenient arrangement for outgoing work from the workshop galleries.

Internal and inter-bay transport was to be by accumulator driven floor trucks.

No lifting gear was provided in this factory, and generally the weight of components did not render this necessary.

No conveyor systems had been installed, but it was clear that in certain of the workshop galleries, particularly where it was intended to instal machines of the standard lathe and turret type, in four lines in a width of about 22 ft., provision of a four line overhead conveyor system would have been essential for taking work to and from machines and for removal of swarf. The opinion was

formed that if the production were not to be adversely affected experience would have rendered suchlike installations imperative.

Other than for the galleries devoted to the machining of the compressor housing, which is bulky, there was evidence that machine tools were being sited in such close proximity and in continuous lines as to cause congestion and bad working conditions. Nevertheless, this position could to some extent have been relieved had there been better planning, and what is more important, had availability allowed a choice of machine tools compatible with the duty required and needing the minimum floor space. This was instanced in the case of the machining of a compressor rotor disc which operation was being carried out on a gap bed lathe having a distance of about 4 6" between centres, the work of course being quite local to the headstock. An appropriate machine for this work would have been a boring and surfacing lathe, and the same applies equally to the use of a number of horizontal Le Pointe broaching machines where the broaching operations could have been done on a vertical machine, such as the German Forst type; it was clear, however, that the latter were not available.

Generally, in this particular factory there appeared to have been undue haste to get in production with whatever machines could be obtained or transferred from other Junkers factories, and that the speed to get into production had over-ridden all other considerations.

The condition of machine tools, with very few exceptions, could only be described as fair; in fact some obviously needed overhaul and/or adjustment before they could have been put to work.

(C) CHAMPIGNON CAVES
Near Halberstadt.
Code Name: MAKRELE II

021/1322
022/3462
031/2802

This small factory situated 2 miles south of Halberstadt was used for the production of components for Junkers aero engines. It was situated in old quarries previously used for mushroom culture. These had not been enlarged, but had merely been cleaned out and white washed, before installing the plant. It is of interest as it shows that all suitable underground workings, however small, were used by the Germans for cover to their industries.

CONTRACTS

On visiting the factory we were accompanied by Herr Redaker and Herr Ziegler, both of the Junkers Flugzeugbau.

GEOLOGY

The quarries were situated in a massive fine grained sandstone of moderate strength. Dip, horizontal. This rock stands well without support, but it is friable and sheds grains of sand when the surface is dry. The workings were quite free of water.

LAYOUT OF FACTORY

A sketch plan of the factory is attached to this report. The floor area was about 9,000 square feet, most of the galleries were 7m x 4 m in section.

The entrances were without protection. There was one small, unlined, shaft for ventilation.

AIR ATTACK

There was no evidence of attack.

ENGINEERING SERVICES

(a) Heating

Caves Nos. 1 and 2 were heated by means of a simple gravity hot water system from a small cast-iron sectional boiler, located in a separate chamber at the rear end of one cave. The boiler was designed for use with solid fuel and the flue taken vertically through the rock to the surface above. Heat was distributed by lengths of gilled piping at low levels of each cave on one wall only.

Caves 3, 4, 5 and 6 which were of similar formation to 1 and 2 were heated by steam supplied from a portable loco type boiler sited in a brick building under the cover of trees and at approximately 150 ft. distance from the caves. Cave 7 had its own boiler and was heated similarly to caves Nos. 1 and 2.

(b) Ventilation

The equipment provided for ventilation purposes was small in extent, and very rudimentary in character.

The ventilation of the cave containing the boiler relied on fortuitous air leakage from the entrance, supplemented by the small positive flow of air required for maintaining boiler combustion.

At the far end of cave No. 2 a vertical down take shaft had been sunk from ground surface and a propeller fan and unit air heater fixed at the base in order to draw in fresh air from above and to heat it. A proportion of the air in this cave was passed on to the adjacent cave by means of a small propeller type fan in the

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dividing wall.

(c) Electric Power and Lighting

The initial power supply was obtained at 6,000 volts from external sources. A brick built transformer chamber and switch room was provided in the entrance to cave No. 1 and one 400 KVA.H.T. transformer was in position and connected. A second similar transformer was standing in the entrance to this cave. Working voltages in this factory were 380/220 volts.

All low tension wiring was either cleated or festooned from fuse boards with no defined layout apparent. Lighting points comprised metal filament lamps with enamelled iron reflectors for the general lighting, supplemented by local lights on or near machines.

The electrical installation generally resembled that which is experienced on works of a very temporary character.

(d) Compressed Air

No compressed air plant was installed at this factory.

PRODUCTION AND LAYOUT

This was a small factory of about 9,000 sq.ft. workshop area which had been adapted from a series of existing caves, previously used for mushroom cultivation. The production undertaken was detail parts for Junkers aircraft (not engine components). No production figures can be given but the factory was fully equipped with machine tools and no doubt had been working up to the cessation of hostilities. Total number of people employed was about 200 workers (two shifts), of which some 70% were foreign - said to be volunteers. It was clear from samples of work seen and information obtained that at the time the machine tools were installed, neither the quantity nor the types of work had been defined. This was instanced by the fact that there was a preponderance of standard screwcutting lathes ranging from 6" to 10" centres, and having distances between centres from 3' to 6'. The opinion was formed that for the production actually seen the output on turning operations could have been increased over the same floor area by some 300% had capstan lathes been installed instead of so many centre lathes.

The general layout and spacing of the machine tools was good. The principle adopted was to segregate the machine tools according to type into the individual caves, and in one cave 13 milling machines ranging from No. 1 to No. 3 sizes were installed in two lines with inclined formation, thus giving the best use of the area without undue congestion.

All external transport was effected by lorry, and internal transit carried out by hand. The latter did not cause any difficulty since the components manufactured were of a light nature.

Both the class and condition of machine tools was good. Each machine tool was grouted up and bolted down as the general floor area had not been made up. It was understood that machine tools were first moved into these caves from the Junkers factory at Halberstadt during March, 1944. The results obtained were stated to have been good and the obvious reason being that this particular factory had by reason of its earlier start a better class of labour than that being provided in the majority of other factories inspected on this tour. The cave walls and roof had been whitewashed and there was no evidence that dust or grit had affected any of the machine tools.

(D) CHAMPEIGNON CAVES
Nr. Halberstadt
Code Name: MAKRELE I.

031/2803
022/3463
021/1323

Like Makrele II this factory was situated in old underground quarries about 2 miles south of the town of Halberstadt. However unlike Makrele II the workings had been considerably enlarged as can be seen from the plan Fig. 3A., and the original quarries merely formed an entrance. Construction started in March, 1944, and production started in December, 1944. The factory ceased production in April, 1945.

During construction the peak labour force consisted of 280 men, divided into 2 shifts, all were French prisoners of War and were said to have been paid 50 to 55 marks per week. No detailed information was obtainable on costs or progress.

CONTACTS

The party visiting the factory were accompanied by Herr Redaker and Herr Ziegler of the Junkers Flugsug bau.

GEOLOGY AND SITE INVESTIGATIONS

All workings were in a fine grained, friable sandstone, lying horizontally with massive jointing. A number of core borings of 12" diameter had been put down on the site to a depth of 120 feet. No water was seen in the galleries.

LAYOUT OF FACTORY

A sketch plan is attached to this report (Fig. 3A). All

galleries were 7 m. wide and 4.5 to 5 m. high. The total floor area was 70,000 sq.ft. Details of cover are given in appendix 1.

LINING AND SUPPORT

Throughout most of the workings no lining was used, the sandstone of the walls and roof being merely whitewashed. Where roof falls had occurred as was the case at several intersections of galleries a reinforced concrete arch had been erected.

ENTRANCES

As can be seen on Drawing No. 34 the two main longitudinal galleries were driven from the old champignon cave. The two entrances to the cave were without protection (Photo. No.12) but obviously this form of entrance would give considerable protection against blast.

SHAFTS

There was one ventilating shaft, and this was provided with a simple form of concrete protection (Photo. No.13). The shaft was unlined.

WATER SUPPLY

There was a small reservoir on the top of the hill and this was connected with the town supply.

EXCAVATION

A pilot treading driven by drilling and blasting and then opened up to the finished size by trimming with pneumatic picks. This method prevented overbreak and by reducing the size of blasts made falls of roof less likely.

Pilot headings were driven with small hand-held jackhammers, using 1" diameter round steel with square shanks and chisel bits, all drilling was done dry. Spoil was removed in $\frac{1}{2}$ c.y. capacity, 2'0" gauge wagons.

AIR ATTACK

There was no direct air attack, but bombs aimed at the adjacent air field fell in the factory area. These are said to have done no damage. (See Appendix 1).

ENGINEERING SERVICES

(a) Heating

The heating medium used was steam at a pressure of approximately

7 lbs. per square inch gauge, generated by three coal fired boilers of the cast-iron sectional type installed underground.

Fuel was delivered to the factory by lorry, and dropped from surface level into an underground bunker adjacent to the Boiler House its floor being level with the boiler tops. Coal was then wheeled by hand barrows over the top of the boilers and fed through top firing doors.

Each boiler was fitted with an automatic damper control on the ash pit, and the normal pressure gauge. No relief valves were provided, but safety precautions were afforded by means of a syphon arrangement taken off the top of the main steam header whereby any excess of steam pressure depressed the water in the syphon and opened the header to atmosphere.

The boiler flue discharged into a vertical shaft rising approximately 70 feet to the surface.

The steam circuit was a closed one, with gravity condensate return.

(b) Ventilation

Ventilation was provided by means of one cased centrifugal fan which pulled fresh air down from the surface through a cement lined vertical intake shaft and discharged it through a heater battery into one of the main tunnels at a single point. There was no ducting of any sort provided for distribution in the workings. It did not appear from the arrangement seen that it had been intended to add any system of ducting for the distribution of air and the heat, and no mechanical extraction of air existed nor was apparently to be provided.

The air supplied to the workings was allowed to escape from the entrances and from a number of small vertical shafts approximately 12" diameter rising from the tunnels to the surface.

Temporary heating equipment comprising unit air heaters had apparently been used in several galleries before the installation of the main system and these heaters were still in position at the time of the inspection.

Interrogation disclosed that it was intended to instal a separate extraction system for dealing with the fumes from chemical treatment baths. This plant sited in a separate chamber was to be vented by means of an underground duct with fan extraction to the entrance of the main tunnel and thence to atmosphere by means of a vertical brick shaft.

At the time of the inspection, i.e. without the operation of

the ventilating plant, the following conditions were noted:-

Outside	dry	bulb	temperature	-	68° F
"	wet	"	"	-	58° F
Inside	dry	"	"	-	54° F
"	wet	"	"	-	53° F

The tunnel atmosphere was very humid and condensation was evident on the rock walls and on all machines.

(c) Electric Power and Lighting

Electric power was obtained at high tension from the grid system and transformed to working voltages of 380/220 by means of a 500 KVA transformer. The main cables from the switch room were conveyed in a floor trench along the main tunnels and rose to distribution boards on the walls. Circuit wiring was suspended by means of cleat insulators fixed to short lengths of flat iron grouted in to walls and roofs. All circuit wiring gave the impression of having been installed in a very temporary manner.

The lighting distribution was of a very ordinary standard, and it is presumed that the general illumination would have been supplemented by local machine lights.

(d) Compressed Air

Two chambers had been allocated for the air compressors required for production purposes. In these chambers no provision was noted for the re-circulation of compressor cooling water and it is presumed that it was the intention of all such water to run to waste.

A further compressor house had been operating at the main tunnel entrance having been mainly used for the provision of air for excavation work. In this instance an atmospheric water cooling tower had been sited outside the entrance to the tunnel.

General Conclusions

The ventilation was rudimentary in character and the equipment described could hardly be expected to have given satisfactory results, owing to the complete absence of any control over the distribution of air and heat throughout the tunnel network.

The service installations generally left an impression that work had been rushed through in order to get production started as soon as the various tunnel sections were completed.

PRODUCTION AND LAYOUT

Makrole I was being constructed to produce fuselages for Junkers 162, and wings for Junkers 88 aircraft, but no reliable figures of the planned output could be obtained on site. The projected area of this factory was about 70,000 sq.ft. thus giving an area of about 40,000 sq.ft. for workshop use with the remaining area for storage and transit purposes. Approximately 100 machines had been sited and put to work in this factory, but it is considered that a further 150 machines would have been added in due course. It is estimated that this factory, when completed, would have employed about 500 to 600 people per shift, at least half of whom would have been female. These figures do not take into account the further factory extension which was understood to be contemplated.

All access to Makrole I was by lorry, with internal bay to bay transport by means of battery driven trucks. Both the transit and production galleries were approximately 7 metres wide and 5 metres high.

The general allocation of areas, and the flow of work in this factory is indicated on the attached plan. The plant installed comprised essentially sheet metal working machines including Straightening Rolls, Spot Welders, Guillotines, Press Brakes and Forming Presses. The Press Brake section comprised 5 machines ranging from 1 metre to 5 metres capacity which were of first class manufacture (Pala), and in new condition. Spot Welders were also new and the general condition of all the plant was good. The general layout, having regard to convenience for handling sheet metal work, was also considered to be good.

Machine tools in the main had been transferred from the Junkers surface factory at Halberstadt, this being effected over a period from the end of August, 1944.

Adjacent to the main factory, 100 metres distant, a number of natural caves had been adapted for sheet metal work and welding, and in one, a sand blast cabinet had been installed and conveniently sited so as to exhaust the atmosphere. In this particular portion of the factory, mainly due to the use of a number of existing small caves, whose total area would be about 6,000 sq.ft. the arrangement of plant was congested, but in one of the caves used for cutting plate and small sections, a slat conveyor had been introduced to overcome handling difficulties due to the lack of space. Although no conveyor systems were installed in the main factory the arrangement of plant, and particularly in the case of the press brakes was such as to give the minimum amount of handling and with a flow towards the main assembly tunnel. No drainage was provided, nor was it considered necessary for the work handled.

(E) ELBEN UNDERGROUND FACTORY
Nr. Naumberg
Code Name: Unknown

021/132
022/3464
031/2804

Target lists stated that this factory was at Altenbauna, in a wood beside the Henschel Lohwerke factory, but on visiting the site no trace of underground workings could be found. Otto Alfred Eichler previously personnel manager, and Herr Strohm, previously chief electrician to the Lohwerke factory, and both now employed by the U.S. occupation forces were interrogated and stated that underground accommodation had been under construction at Elben, a small village 4 km. south of Naumberg and 15 km. west of Altenbauna.

With the aid of Herr Strohm the site was located and a rough survey made of the workings (Fig.44).

Tunnelling work is said to have started early in 1943 and to have been about 50% complete by March, 1945. The cover of sandstone varied between 35 m. and 107 m.

Contracts & References.

Herr Eichler
Herr Strohm, both of the Henschel, Lohwerke factory at Altenbauna.

The Tiefbau Berufsgenossenschaft, Berlin, Wilmerdorf, Babelsberger Strasse, 16, were concerned with some aspects of the work. We were informed that work was taken over by the Todt organisation after a contractor had failed to make sufficient progress.

Geology & Site Investigations

The factory was situated beneath an escarpment of sandstone, heavily wooded and rising abruptly from the flood plain of a small river. No signs of site investigation were seen, but little time was available to search the woods for boreholes.

The tunnels were all driven in a medium to coarse grained sandstone dipping to the west at 42°. Near the entrances the sandstone was massive, but as the tunnels were driven eastwards into it the dip of the beds exposed more thinly bedded sandstones with clay partings and in these rock falls were frequent. A notice at the entrance to the works "Helft alle mit Unfalle verbuten", "All should help to avoid rock falls" suggests that these were a serious danger.

Layout of Factory

As shown by the attached plan, the factory was of the common type with a rectilinear pattern of tunnels.

Lining and Support

The construction of lining had been in progress at several points, but it is impossible to say whether the intention was to line the galleries throughout. The type adopted was a fire ring brick arch, with random filling behind it where overbreak made this necessary. Timber centering of orthodox pattern was in use.

Entrances

Work had started from the portal to a small tunnel evidently of considerable age intended for farm storage but one new entrance was completed.

This was protected by masonry retaining walls but doors and blast walls had not been built, nor was there any provision for them.

Excavation

As elsewhere hand held air drills and pneumatic picks were used. Loading was done by means of light compressed air machines of the Saltzitter pattern.

Air Attack

There was no evidence of air attack on this site.

Miscellaneous

The most striking feature of this site was the extreme care taken over camouflage (Photograph No. 14). All buildings were hidden beneath the trees. Only the spoil dump was exposed and this was covered with soil dug ahead of the advancing tip and transported on to it by a portable belt conveyor. Soil spreading kept pace with rock tipping and the inclined face of the dump was covered with branches. These measures were apparently effective as the site was not mentioned on the target list.

Engineering Services

This factory was under construction and no work on the services had been commenced beyond temporary lighting and the provision of compressed air for the tunnel excavations.

Interrogation indicated that the heating of the tunnels was to be effected by means of a low pressure steam cast-iron sectional boiler, feeding a pipe heating system which was suggested as being the proposed method of heat distribution. The Boiler House was to be located inside one of the entrances with a flue taken through to the surface above.

Uptake shafts with 12" diameter sheet steel linings were to be used to give a natural gravity system of ventilation.

The full extent of these workings was to be comparatively small, and this system of heating and ventilation would probably have proved adequate, provided sufficient provision had been made at the tunnel entrance for heating the outside air drawn into the workings by the chimney effect of the gravity exhaust shafts.

Production and Layout

This factory was only partly constructed but it had been planned to produce details for the Henschel aero engine; the assembly and testing was to have been carried out at the Henschel surface factory, Altenbauna. At the time of inspection only 60,000 sq.ft. of production area had been tunnelled with the floors partly prepared. It was anticipated that the ultimate area would have been in the neighbourhood of 120,000 sq.ft. No machine tools had been delivered to site and it was understood that these would have been obtained from the various Henschel dispersal works. This dispersal was the result of bombing attacks on the Altenbauna works. It is estimated that some 500 machine tools would have been installed and a labour force of about 550/600 per shift required for this production.

The workshop bays had been constructed to a width of about 15' to 17' and although this was not as wide as most of the other major factories visited, we would assume that there would have been no undue congestion due to the fact that machines would no doubt have been sited in two rows per tunnel. Battery driven trucks would have been used for internal transport.

On the question of external transport the existing road access was poor; this, however, could have been made good, but it was doubtful whether it would have been used to any great extent for conveying parts to the Henschel Altenbauna works owing to the shortage of oil for diesel lorries. It was clear that a railway connection had been projected whereby they could link up this factory direct to the Altenbauna works, which incidentally was some 20 kilometres distance.

The work flow would have approximated to that indicated on sketch attached.

(F) OSTERODE
Code Name: DACHS IV.

C21/1325
C22/1221
C31/2805

These workings driven from anhydrite quarries on the east face of the Kalkberg, about 1 mile north west of Osterode were started in October 1944, and by April 1945 had reached the stage shown on the attached plan. (Fig.5A.). No machinery had been installed and plant delivered to the site was to be returned to Hamburg by order of the Military Government.

Dachs IV was intended to replace the Hamburg works of the Shel-Rhenania-Ossag which had been destroyed by air attack. The factory was designed by the technical staff of this company working with a consulting geologist, Professor Schriel, of Göttingen University and with engineers of the Deutsche Bergwerks-und Huttenbaugesellschaft m.b.H. Heiningeh-Osterode. The tunnels were constructed by the Grossdeutsche Schachtbau-und Tiefbohrgesellschaft m.b.H., of Stadtholendorf, Kreis Holmünden.

Contracts

The following were interrogated:-

Grossdeutsche Schachtbau-und Tiefbohrgesellschaft m.b.H.

Herr Bahr
Herr Budde
Herr Hanke

Deutsche Bergwerks-und Huttenbaugesellschaft m.b.H.

Herr Heinze

Shel-Rhenania-Ossag.

Herr Hagel
Herr Lubinski
Herr Koberger

It is probable that complete details of the plant and much data on construction could be obtained from the firms mentioned above, and from Professor Schriel.

Geology & Site Investigations

The geology of the site was investigated before the commencement of work by Dr. Schriel and the upper surface of the anhydrite determined.

As can be seen from the geological section attached to this

report (Fig.5B) the Kalkberg consists of a massive deposit of anhydrite overlain by dolomite. At its upper surface the anhydrite has altered to gypsum to a depth of not less than 20 metres. (Fig.5B)

The workings were entirely confined to the anhydrite, and for safety were never carried within 10 metres of the estimated underside of the gypsum.

The anhydrite appears to be an almost ideal rock for tunnelling as it is not so hard as to make excavation difficult, but being homogeneous and crystalline in structure it stands well without support. Only one fall of roof was seen and we were informed that no lining had been considered necessary.

It was intended to put in concrete floors and a 6" concrete pump was on the site for this purpose and for machinery foundations.

Some water entered the workings near the tunnel portals, but on the whole they were quite dry.

Layout of Factory

The factory was to consist of 15 parallel tunnels 20 metres apart and about 220 metres long, driven at right angles to the quarry face and connected at the far end by a railway tunnel, and at their mid-points by a transverse tunnel. The plan attached to this report shows the work as planned and as carried out to date (Fig.5A.)

A feature of the proposed working is their great size some of which were to be over 100 feet in height. These chambers were to be ventilated by inclined shafts emerging in the face of the quarry and there protected with concrete (Fig.5D.) Full details of them are given in Figures which give a clear picture of the size and intricacy of the workings necessary to house refinery plant. The elaborate system of ventilation shafts was required to prevent temperatures in excess of 68°F, above which point rock falls were found to occur.

Progress of Construction

A detailed programme of construction was obtained and copy of it is attached to this report (Fig.5E.); it is a document of great interest. In fact, the Allied air attack on transport made it impossible to adhere to this programme. Work was started in October, 1944 and by March, 1945, out of the total estimated excavation of 230,163 c.m. (solid) only 40,000 c.m. had been done, with a floor area of 8,000 m². Herr Hanke stated that in the pilot headings which were 4.6 m. wide and 4.0 m. high the usual advance was 3 metres in 24 hours.

Labour

Three 8-hour shifts were worked underground.

	End of Month	Average for Month	German 20% Foreign only
October 1944	140	20	
November 1944	320	280	
December 1944	360	360	
January 1945	500	500	
February 1945	860	650	
March 1945	1,000	850	

The statement about the number of foreigners employed, may be incorrect as there was a large concentration camp on the site. The Germans when interrogated on labour conditions gave evasive answers, saying that all labour was controlled by sub-contractors and that they were not familiar with the rates of pay.

Costs

COST DATA

The following details were given by Herr Bahr of the Grossdeutsche Schachtbau.

Contractors price for excavation	25 R.M. - cu. M.
Estimated Total cost of Mining Work, excluding Air Shafts	8,000,000 R.M.
Cost of Work completed to date	2,200,000 R.M.

Excavation

The method adopted was to drive a pilot heading 4.6 metres wide, and 4.0 metres high along the line of each tunnel, and from this, the chambers were broken out as required. The very high chambers such as those on Tunnel No. 7 were incomplete, but a start had been made and the method in use could be studied. In Tunnel No. 7 two raises were put up, one at each end of the chamber and to its full height. The raises were vertical with a cross-section of about 12'-0" x 6'-0" divided by a timber bulk head into a ladder way and a chute for rock. When completed these raises were connected at the top, by a heading along the line of the chamber and excavation to the finished dimensions proceeded from the top downwards. The spoil from excavation being tipped into the chutes and drawn off into wagons through gates built in the lower heading.

Drilling and Blasting

As in all the factories visited, compressed air rock drills of the hand held "jack hammer" type were used. In the pilot tunnels 60 holes were drilled per round. These were about 12 feet long, and a break of 3 metres per round was usual.

The number of men to a heading on each shift was 10, of these six were drilling and are said to have been German, with four foreign workers to operate the mechanical loaders.

The usual advance was one round of 3 metres in 24 hours. Owing to the hardness of the rock 60% of the time was spent in drilling.

In blasting the consumption of explosive is said to have been 2 kg. per hole, or 120 kg. per round, which is equivalent to 2.17 kg. per cu.m. of rock broken.

Loading & Transport

Loading appears to have been wholly mechanical and no less than 14 compressed air shovels (Saltgitter Lader) were found on the site, and we were informed that others had been removed by the Military Government for use in the coal mines of the Ruhr. In addition to these there were four bucket excavators of a smaller pattern, (Schrappner Lader) and two large drag bucket loaders of the type usually known as "slushers".

Steam locomotives of 1 m. gauge were used in the tunnels, and all spoil was dumped near the tunnel portals without attempt at camouflage. Presumably it was thought that the normal operations of quarrying anhydrite would mask the underground operations.

Shafts

All shafts were to be lined with brick where traversing dolomite and gypsum, but were to be unlined in the anhydrite.

Water Supply

No details of water supply could be obtained except that it was to be brought some distance by main, and would consequently be vulnerable.

Entrances

Apparently no form of protection had been planned for the entrances.

Air Attack

There was no evidence of air attack, though the railway at Osterode had been bombed.

Engineering Services

These workings were under construction and very little had been achieved in respect of plant and service installations other than to site the main transformers, and two air compressors.

The following information was obtained from interrogation:-

(a) Heating

In view of the nature of the operations to be carried out in this factory, i.e. oil refining, no provision was intended for factory heating, nor was it necessary.

(b) Ventilation

Due to the extent of the top cover over these workings it was anticipated that successful ventilation would be achieved by a series of uptake shafts rising towards the cliff face. High temperatures were anticipated in the plant located in the tall chambers and these would have induced a good chimney draught effect.

If this natural ventilation scheme had not proved satisfactory it was then proposed to instal extraction fans in the rising shafts.

(c) Electric Power and Lighting

The incoming electric power supply was at 16,000 volts and was transformed to 5,250 for large motors, and to 380/220 volts for small motors and lighting. No generation on site was intended.

(d) Compressed Air

Compressed air was to be supplied from one compressor station sited in a connecting tunnel as shown in drawing No. attached. Two machines had already been installed, one of the rotary type and one of the reciprocating type, and these machines provided compressed air at 6 atmospheres pressure. The compressed air was to be used initially for constructional purposes, but would ultimately have been required for handling oils in the production plant.

(e) Process Steam

Steam boilers were to be installed underground but doubt was expressed regarding the working pressure. It was assumed, however, that this pressure would have been of the order of 250 to 300 lbs. per square inch for oil refinery work.

Production and Layout

Osterode was one of the underground sites chosen for the general dispersal of the Shell Rhénania Oessag oil refinery from Harburg (Hamburg). At the time of visit constructional work on tunnelling was incomplete and although a few items of plant had been delivered to site no erection had been carried out. The plant was planned to deal with refining of oils for aero engines and also for the production of benzene. It was understood that crude oils were to be supplied from the Eastern Fields and from Hydrogenation plants. The ultimate capacity of the plant was given as 72,000 metric tons of crude oil per year, but this information was obtained by interrogation and not considered too reliable.

It was considered that a total labour force of about 1,200 employees would have been necessary to operate the plant on a three shift basis and the personnel would have been mainly German specialists in oil refinery work.

The areas that were to be allocated to the various refining operations are shown on the attached sketch.

The main tunnel (AB) was to be provided with a double track railway and used for both incoming and outgoing tank waggons. Apart from the small amount of buffer storage necessary for the various production stages, no provision had been made for either internal or external bulk storage. It would appear that refining would have been dependent upon the supplies held in the tanker waggons, and while this may have restricted the total quantity held at any one time it had the advantage that the working storage was in the most protected part of the factory.

Details of the plant and the equipment ultimately to be installed were not available, but it was understood that a complete underground plant and similar to the planning at Osterode was in production at Zement, Ebensee, b/attrang-Puchheim, Austria. It was also understood that all technical information on the Osterode project is with Herr Hagel of the Shell Rhénania, Oessag, Harburg.

(G) ODA-WERKE FACTORY

Situated beneath the Regenstein, near Blankenberg.

021/1326

022/3465

031/2806

This new factory had been occupied by the firm of Schaffer and Budenburg, manufacturers of valves, gauges etc. Work was stated on the tunnels in May, 1944 and abandoned in March, 1945. No details of progress or labour could be obtained but it was stated, by Herr Plattner, that the sum of 5,000,000 R.M. had been expended.

The labour is said to have been 50% German, and the remainder Poles, Belgians, French and Italians, mostly from concentration camps.

Contracts and References

Herr Platter, previously in charge of labour and Herr Holman, Kommandant of Labour were interrogated. Additional information might be obtained from Herr Dann, said to be as Essen, and Herr Morjan, said to have been imprisoned by the Military Government. Both were previously employees of Schaffer and Budenberg.

Geology

All galleries were driven in sandstone of medium strength, somewhat harder and firmer than that at Langenstein. This rock stood unsupported in elliptical arches of up to 8 m. span. The workings were quite dry except at the entrances. No falls of roof were observed but temporary supports were used in places.

Layout of Factory

A compass survey of the factory is attached to this report. All main longitudinal and cross galleries were 8 m. wide and 6 m. high with an elliptical arched roof. Transverse galleries did not form crossings with the main gallery, those on one side being staggered with those on the other. At intersections the rock was trimmed to a vaulted section. The smaller galleries were 3 m. x 3 m. in section with arched roof.

Lining and Support

Throughout most of the workings the surface was sprayed with cement grout. Four types of lining were used in places.

- (a) A lining of unreinforced concrete to a height of 3 m. above floor level only.
- (b) A complete lining of unreinforced concrete.
- (c) An arch of precast concrete blocks.

- (d) A polygonal frame of timber wedges into place.

Entrances

The entrances were without protection, or any other features of interest.

Water Supply

Water was obtained from a tube well and a reservoir on an adjacent hill.

Sewage

A gravity system was partly installed, but no information was obtained as to disposal.

Excavation

No details of the methods of excavation could be obtained. Spoil was loaded by a compressed air "Schrapplader" manufactured by Schmidt, Kranz u. Co. of Nordhausen.

Air Attack

There were no signs of air attack on the factory.

Engineering Services

(a) Heating

The heating medium was accelerated low pressure water generated in four cast-iron sectional boilers. These boilers were accommodated in an independent building outside the main tunnel entrance and were of the coal fired type.

The heating medium was to have been connected to a number of fresh air heaters in the workings, but only one of these heaters had been installed.

(b) Ventilation

Ventilation equipment was only installed in the one workshop tunnel which had been completed and put into production.

Fresh air was taken from the main tunnel by means of a centrifugal fan and delivered through a heater into the adjacent end of the cross tunnel. A second fan exhausted from the far end of the cross tunnel and rejected the air to the surface through a vertical shaft. The general arrangement is shown in drawing No. which accompanies this report.

The nett workshop length of this tunnel was 500 ft and the capacity about 160,000 cubic feet. It is considered that the ventilation plant installed was capable of handling up to approximately 35,000 cubic feet of air per minute, representing approximately 13 changes of air per hour. This was a high standard of air change but the very simplified manner in which the air was introduced and extracted would cause a degree of air movement which, in normal factory practice, would be regarded as objectionable.

There was no evidence to show whether the main tunnel was to be heated or ventilated but no plant has been installed for such purpose.

(c) Electric Power and Lighting

Electric power was obtained from external sources at 16,000 volts and transformed to working voltages of 380/220 by means of transformers sited within the workings.

Power distribution and lighting was generally up to modern standards, and the general lighting provided by means of metal filament lamps approximately 300 watts, in ordinary reflector fittings.

Production and Layout

This factory was only in part stage completion. It was intended to reinstate production hitherto carried out at Schaffer and Budenberg Works, Magdeburg. The production concerned was mainly valves for marine and general power work, including oil treatment plants. One workshop tunnel only had been completed to the extent of having machine tools installed and put to work, but this had only been started up over a very short period, probably not more than a fortnight. This tunnel was equipped with three 4-spindle Pittler Automatics and quite a number of single spindle Automatics, but it was clear from the number of general machine tools delivered but not yet sited in position, that other than for castings the factory would be manufacturing valves, and suchlike fittings in their entirety. The general layout so far completed was good, and the disposition of the automatics was as shown on attached sketch, leaving a gangway on one side of about 3' and on the other 5'. Further, the tunnel had a protecting wall on either side for a height of about 9' in which 4" diameter tubes had been inserted to facilitate feeding the single spindle autos. Without protecting walls it would not have been possible to have sited the single spindle autos crosswise to the tunnel since the handling of stock would have created dust and grit by contact with the virgin tunnel surface. The concrete protecting walls were also used for supporting the cable racks.

Although there was no special provision made for removal of swarf, two recesses 6' long x 3' deep, had been provided in the protecting wall adjacent to the 5' gangway for the purpose of by-passing, which to some extent would have helped to keep the gangway reasonable clear, and minimise interference with the feeding of autos and the removal of work.

At the date when work ceased the total number of production employees was in the neighbourhood of about 120 spread over two shifts with a ratio of German to foreign labour of about 1 to 3. It is considered that the ultimate total labour force would have been 1,200 spread over two shifts.

The storage and siting of ancillary services such as transformers was obviously going to be effected in a number of smaller tunnels excavated off the main access tunnel, and opposite to the workshop tunnels.

Although this factory was far from complete, the opinion was formed that the general arrangement and layout would have been reasonably good, and that there should have been no difficulty in obtaining and maintaining a good output. Inter-bay transport would have been effected by electric floor trucks. External transport would have had to be entirely by road, since there was no evidence of rail access being provided.

(H) Schidmanshell Kali-Werke A.G.
GROSSSCHIERSTADT, Near ASOHERSLEREN

021/1327

022/3466

031/2807

This factory operated by the Junkers Flugzeug U Motor Werken A.G. for the manufacture of aircraft components was situated in the old workings of a salt mine (potash) which is still producing.

The site was not visited and the following information was supplied by Hr. Schonborn, Technical Director for Junkers, and Target Evaluation Report Auth. O.G. E.T.O. dated June 13th, 1945.

The workings are entered through a vertical shaft 440 metres in depth and the area devoted to Junkers was about 8,000 sq. m. consisting of 8 galleries 10 m. wide, 100 m. long and 9 m. high, of these six were used for air frame components, one as an assembly plant for Panzer fausts, and one as a mess room etc.

All plant and equipment were taken underground in the cage except some large items which were lowered down the shaft, the cage having been temporarily removed. While in production the

18444

shaft was used by Junkers from 6 a.m. to 12 and by the mining company from 12 to 4 p.m.

The plant took six weeks to instal underground, this was done in June and July, 1944. About 180 machine tools were in use.

The total force of about 800 was divided between two 12 hour shifts and was made up as follows

Germans	250
Foreign Civilians	400 (men and women)
Prisoners of War	150

Foreign workers lived in a concentration camp at Aschersleben. Food was prepared on the surface and taken underground.

Exhaust fans in each section delivered to a gallery leading to the main upcast shaft of the mine. Temperature varied between 68°F and 77°F.

Power and water were brought in from the surface supply.

Sewage was removed by a series of pumps in the upcast shaft.

Although a small factory this site is of interest in that the Germans thought it worth while to instal plant under conditions which must have made work in-efficient and most inconvenient.

(I) GALGENBERG 021/1328
WERNIGERODE 022/3467
031/2808

This factory was intended for the Industrie Kontor G.M.T. who operated light metal (non-ferrous) works at Solingen (2,500 workers), Wernigerode (4,000 workers) and Oberthale (300 workers).

The Soligen factory was 80% destroyed by air attack.

Underground work was stated in October 1944. If completed the factory would have had 5,000 sq.m. floor space and would have employed 1,000 men, 50% skilled Germans, 50% foreign.

Tunnels were in soft sandstone which required a concrete lining.

The site was not visited and the above information was obtained from Herr R. Rautenbach and Herr H. Rautenbach, directors of the Industrie Kontor, and from Herr Sendler of Thale Ironworks.

(J) A/2B, Denkmal Stollen: Barkhausen 021/1329
Porta Westfalica, near Minden 022/3468
031/8

The Denkmal Stollen was a factory of the multi-storey type construction in an old freestone quarry on the west side of the Weser valley, near Minden. The quarry consisted of a single chamber about 90 metres long, 12 metres wide, and 17 metres high. The work of conversion was carried out departmentally by the Government. There was no additional excavation, but three reinforced concrete floors with access stairways were installed, and a concrete blast wall built at the entrance. Conversion work is said to have started in the autumn of 1943 and to have been completed in the middle of 1944. No details of labour, costs or progress could be obtained.

The second and third floors had been occupied by "Antrupa" from Aachen for the manufacture of "Panzerfaust" components, the first and ground floors were used for the manufacture of ball bearings by the firm of Dr. Ing. Boehme & Co., Metallwarenfabrik, Minden-Lubbecherstrasse.

CONTACTS & REFERENCES

The following Germans were interrogated:-

Herr Roettgen, Assistant Production Manager, and
Herr Bodenmuller, Production Engineer, for Dr. Ing.
Boehme & Co.

The Site is described in:-

Air Ministry Interpretation Report No. U.19 (Cross Bow)
31.1.45, Prussian Geological Survey, Sheet 2016, 1/25,000,
Minden 1930 and Memoir 1933.

GEOLOGY

The area is underlain by sedimentary rocks of Jurassic age striking east and west and dipping to the north at about 20°. The outcrop of comparatively resistant sandstones is marked by a range of hills about 900 feet high running east and west for about 20 miles, through which the river Weser flows in a water gap known as the Porta sandstone. It is a massive moderately coarse grained

calcareous sandstone 40 metres thick, in the outcrop of which underground freestone quarries have been worked on both sides of the gap.

The Porta Sandstone is overlain by clay shales, the so called, Ornamentone, and is underlain by the Cornbrash, which were seen in the railway access tunnel to Dachs I on the opposite side of the valley consists of thinly bedded limestone.

In the Denional Stollen there were no signs of rock falls, but it was observed that the roof of the gallery near the entrance was in an unsafe condition.

LAYOUT OF FACTORY

Plans of the factory are attached to this report. (Figs. 7A & 7B).

LINING & SUPPORT

On the ground floor a concrete wall 1 metre high and 9" thick was formed against the side of the gallery, the top of this was dished to form a channel for moisture running down from above. Elsewhere the natural rock was whitewashed.

A ceiling of wall-board and timber was built beneath the roof of the quarry.

ENTRANCE

A blast wall of concrete 1.3 m. thick was constructed at the entrance to the quarry. (Photograph No. 20). There was a main entrance on the ground floor with openings at each storey for handling materials.

WATER SUPPLY

Water from the municipal supply was pumped to two small storage tanks near the factory.

SEWAGE

Sewage was water-borne, and discharged crude into the River Weser.

AIR ATTACK

There were no signs of air attack on this factory.

ENGINEERING SERVICES

(a) Heating

The Boiler House was excavated in the cliff face near the main factory entrance, and contained three cast-iron sectional low pressure steam boilers.

The steam generated was taken to an air heater battery used for the main factory ventilation, a second heater battery for stores, and to several items of plant requiring process steam. The condensate was returned by gravity in a closed system.

Coke was initially delivered to the factory by lorry and subsequently delivered by narrow gauge railway into an outside fuel bunker. From this bunker it was barrowed on to the top of the boilers and dropped into top firing doors.

(b) Ventilation

The main factory ventilation comprised a heated fresh air supply and an extraction system, each having a main duct at the ceiling level of the 3rd floor. Air delivered to one of these ducts through a heater battery by means of an intake fan of the double entry type. This fan was located in a sealed chamber and drew air from outside at the cliff face through a simple spray washer and horizontal spray eliminator plates. The water sprayed in the washer was taken from the main water supply and rejected to waste.

It was noted that no valves or thermostatic controls had been provided, and the control of air temperature was effected by proportionate bye-passing of the air heater as necessary. The water spray was intended to give a degree of cooling in hot weather only, and it was not used during the winter months.

The following information regarding the optimum heating and ventilating conditions was obtained by interrogation:-

- (1) Relative humidity 58 to 69%.
- (2) Temperature 65 - 72°F.
- (3) 8 air changes per hour

The maintenance of the stated relative humidity was obviously not possible, nor necessary, in the cold weather.

From the main supply duct at third floor ceiling level and which was constructed in building board, air was distributed to the various floors by means of vertical drops in painted sheet metal, and was discharged through adjustable

outlets near floor level. On the opposing walls, vertical risers with inlets at high level of each floor were taken to the exhaust main trunking, also made in building board, at third floor ceiling level. The discharge drops were staggered in relation to extraction risers.

On the third floor near the entrance, an additional installation had been provided comprising supply and extract fans, with ducts and a heater battery forming a simple plenum heating and extraction system for the separate chambers offset from the main tunnels.

(c) Electric Power and Lighting

The main supply was taken from a 6,000 volt feeder and transformed to 380/220 volts, 3 phase. The main low tension switchroom was adjacent to the Boiler House and distribution cables were carried on boards supported from transverse concrete beams by hangers. Very little metal conduit work was used except for risers passing through floors and in these instances protection was afforded to a height of 4'6" above floor level.

In general, the lighting comprised metal filament lamps with enamelled iron industrial type reflectors and all circuit wiring was carried out in the form of surface cleat work.

No systematic earthing arrangements appeared to have been provided.

(d) Compressed Air

Compressed air at 6 atmospheres was supplied by two small vertical reciprocating compressors, one for standby, sited on the ground floor, as shown in drawing attached. Cooling water from these compressors was run to waste.

Compressed air was mainly used for pneumatic chucks for holding bearing rings for radius turning, and also for clearing swarf from machines.

PRODUCTION & LAYOUT

This factory comprised four storeys built in the side of a hill. The ground and first floors had been devoted entirely to the production of ball bearings, the second and third floors having been used for the manufacture of a detail for the Panzer Faust (Bazooka). Access was by door on the ground floor with stairways connecting each floor for employees use.

For goods service, an electric lift of 2,000 kilogram capacity was installed, serving all floors. Additional to this a clearway had been cut in the first, second and third floors, giving an opening of about 6' x 10' with an overhead beam with hand operated lifting block secured to the roof of the third floor. This had obviously been used for handling of plant of a heavy nature, particularly during the period of installation. Internal transport was effected by hand, augmented where essential with battery driven floor trucks. External transport to and from the factory was by means of lorry only, the approach road being had and having a very steep gradient.

It was understood that this factory started production in September, 1944, and it is estimated that the total labour force was about 400/500 spread over two 12 hour shifts. Two thirds of the labour would have been foreign workers.

The drawing attached indicates how factory floors were arranged, i.e. immediately above each other and also shows the formation of the tunnels. All tunnels were unlined, the walls being whitewashed.

Ball Bearing Section

The bearings manufactured were of the non-precision type, ranging from $5/8"$ to about 2" diameter. Although the complete assembly was undertaken at this factory, the balls were obtained from Schucoinfurt (or elsewhere) and the cages from the parent surface factory at Minden.

With regard to output, the Production Engineer stated that they were aiming at 350,000 completed bearings per month, but on further questioning he stated that the maximum output reached was 250,000 completed bearings per month. He also gave a total output of 3,000,000 bearings up to the time that the factory stopped producing, but this is considered to be an impossible figure having regard to the fact that the factory had only been producing for a period of six months. Making allowances for the embryo stages our assessment is more in the neighbourhood of $1\frac{1}{2}$ million.

No provision had been made within the factory for storage of bar stock, other than alongside the respective automatics, and deliveries of bars were no doubt made at irregular intervals owing to transport difficulties. It is not only possible but very likely that there were times when production of certain sizes of bearings had to be temporarily eased owing to lack of material.

All single and multi-spindle automatics were installed on the ground floor and in an inclined formation of about 27° to the longitudinal axis of the tunnel, thus giving a clearance on one side of about 3' and a gangway at the other side of about 5'.

The bearing races were produced from the bar (not forgings) and the multi-spindle autos comprised one 60 m.m. 4-spindle Hasse & Wrede, five Pittler 4-spindle machines - two of which were 52 m.m., two of 42 m.m., and one 22 m.m. capacity, one 6-spindle Pittler of 22 m.m. capacity. The single spindle autos of which there were three, were 20 Brown & Sharpes. The Hasse & Wrede 4-spindle auto was unduly heavy and unwieldy for the class of work required, and the opinion was formed that this machine, owing to its stroke, was originally designed for small shell production. The question of the absence of a machine of the rotary surface grinder type was taken up with the Production Engineer, who stated that they had had to resort to finishing after hardening by lapping operation only; on further questioning he stated that a Naxos Union rotary surface grinder was on order, but although completed at the maker's works, it could not be delivered owing to transport difficulties.

A swarf breaker and oil extractor had been installed and sited near the tunnel entrance on the ground floor, but as no special arrangements for the removal of swarf existed it was clear that this could only have been done at such times as were convenient. Swarf, after treatment in the oil extractor, was removed to a stock external to the factory where advantage had been taken of a short run of rail track left by the constructional engineers.

In view of the fact that the tunnels were unlined and the ventilating system was by bottom inlet and top outlet, the question of inclusion of dust or grit into the machine tools was discussed and we were assured that they had had no trouble from this source. This claim no doubt was true since apart from the fact that tunnels were whitewashed, the presence of oilmist from the autos and the absorption of oil in the floors would to a large extent overcome this difficulty as compared to conditions where the grit and dust is in free suspension in the atmosphere.

Opinion was expressed that having regard to the formation of the tunnels and the type of ventilating system installed, the oilmist arising from the use of a large number of multi-spindle automatics would create an unpleasant atmosphere. It was claimed, however, that this difficulty had been overcome by the introduction of a deodoriser into the cutting oil up to the extent of $\frac{1}{2}\%$. Details of the deodoriser were not available, but this was known as "Konsotal" and had been supplied by a Dr. Hammer of Deutsche Gasolin, Hamburg.

It was ultimately intended to transfer the production of cages from firm's surface factory to Minden to this underground factory but they would still have been dependent on supply of balls from other sources.

All hardening was by electric furnaces, and these, together with their dipping tanks, were installed in separate chambers offset to the first and second floor main tunnels.

Print attached shows the layout of automatic machines installed on the ground floor for ball bearing production.

Detail for Panze Faust (Bazooka)

This detail involved the cutting of a tube, insertion of a plug, welding the plug and then subsequent machining operations. Although at the time of visit all machine tools had been removed, the machining operations were obviously very simple and would have presented no difficulty, but here in this particular portion of the factory a welding room had been partitioned off at the blind end of the tunnel on the third floor, and having regard to its area - 36' x 22' - and the fact that it contained fourteen welding booths together with a storage rack sited in the centre of the room and which in itself occupied an area of about 18' x 2'6", opinion was formed that apart from the restriction in space, the atmosphere and working conditions in this room with all booths occupied would have been very undesirable, particularly having regard to the long hours worked per shift. Ventilating in this room was on the general principle of bottom inlet and top extraction, and would not have compensated for the conditions which would prevail when operators were working simultaneously in all welding booths.

(K) PORTA WESTFALICA
Oil Refinery in the Arminsberg, south of Minden
Code Name: DACHS I.

021/1330
022/1034
031/1201

This factory, a wartime enterprise, was intended as a refinery for the treatment of topped crude oil from the Hanoverian field. At the time of our visit it was about 90% complete. It is of particular interest owing to the size and complexity of the plant which was installed underground, as can be seen in photographs Nos. 23 and 25.

The factory is constructed from underground quarries in the Porta sandstone, but these were greatly enlarged to accommodate the plant. Railway access to the plant was intended (Photo. No. 1) but was not completed.

Excavation was started in March 1944. The planning of installation was started in August 1944, and installation of plant started in October 1944. It is said that the plant was within six weeks of completion at the end of the war; a remarkable achievement.

Contracts and References

The following were interrogated: Herr Schroder, (Dutch, English speaking) previously employed by the firm of Fr. Uhde A.G. of Dortmund, as engineer on plant installation, now employed by the Military Government.

Herr Pott, Mining engineer, Manager of the Gewerkschaft Porta, a firm working iron mines near Haverstadt. This firm carried out all tunnelling work in the Porta Westfalica area.

Further information will be found in:-

- (a) C.I.U. Report, ref: U.19 dated Jan. 1945, including air photographs, plan and geological sections.
- (b) C.I.O.S. Advance Field Assessment Report No. 8 dated 14/15/16 April, 1945.
- (c) Report prepared by C.T. Branch. I Corps District, dated 29th May, 1945.
- (d) Assessment Report by Commander F.G. Springer U.S. Navy, dated 15th April, 1945.
- (e) Report from 307 P.Mil.Gn.Dot. to 21 Army Group (D.F.) C.F.A. "Report on lubricating Oil Refinery, Dachs I". Ref.307/1724/F/7 5th July, 1945.

It is probable that more detailed information could be obtained from Herr Schroeder and Herr Pott, from the staff of the Misburgh Refinery, Hanover, and details of the Furfural Extraction Unit from the Still Co., Rocklinghausen who were responsible for its design and construction.

Geology and Site Investigations

The geology of the district has already been described in section J. At Dachs I all workings except the railway tunnels were confined to the Porta Sandstone. This stratum is 40 m. thick, and dips to the North at 20°. Owing to this dip the headroom within the sandstone increases to the south and advantage was taken of this to suit the layout of the plant.

We were informed that no detailed site investigation was necessary as the staff of the constructors, the Gewerkschaft Porta, had a thorough knowledge of the geology of the district.

No falls of roof were seen in the factory area, but a heavy fall was seen in the railway tunnel where this traverses the

"Cronbrash". This tunnel was supported by steel ribs and timber laggings.

Layout of Factory

Plans of the refinery and of the proposed system of railway tunnels are given in this report. Cross sections are also given, and the cover against air attack is described in Appendix 1.

Volume of Excavation

The completed work amounted to 62,000 cu.m.

Floor Area

The total floor area completed was 4,500 sq.m.

Labour Data

The total labour on the construction of Dachs I and the Adjacent Hammerwerke factory including the installation of plant was 4,000 to 4,500; of these 2,000 were German (mostly craftsmen) the remainder were civil prisoners 1,100 of whom came from concentration camps; they included Russians, French, Poles, Italians and Letts.

Total labour on civil engineering work at Dachs I was 450, labour on actual tunnelling consisted of 50 men per shift, 3 shifts a day, made up of miners and concentration camp labourers.

Progress data:

The progress made is difficult to arrive at as the work was carried out in conjunction with the nine storey Philips factory adjacent known as Hammerwerke.

Cost data:

The total cost of structural and installation work at Dachs I and Hammerwerke was 15 million marks, of this 2 million marks covered the cost of underground excavation which was made up as follows:

(1)	Preliminary works	50,300	
(2)	Excavation of 1st section of Tunnels A.B. & C. 34,000 cu.m.	644,102.	80
(3)	Excavation of 2nd. section of Tunnels. Extensions to A.B. & C and parallel tunnels 20,500 cu.m.	384,331.	45
(4)	Excavation for Boiler House 4,000 cu.m	224,128.	13
(5)	Dayworks, 3,500 cu.m.	292,158.	88

(6)	Welfare, travelling expenses, etc.	74,299.	36
(7)	Overhead charges	180,250	
(8)	Machinery charges and maintenance	70,200	
(9)	Recovery of plant and materials	8,000	
		<u>1,927,770</u>	<u>62</u>

The contract was based on 58,000 c.M. of excavation at 19 marks per c.M. Special excavation in the boiler house by hand labour, 4,000 c.M. at 55 marks per cubic meter and 3,500 paid at daywork rates plus 76%. Herr Pott stated that this returned a nett 20%.

Excavation

The methods used differed in no way from those already described mechanical loaders including the Saltgitter Lader, the Schrappner Lader and Belt Conveyors were used, Herr Pott stated that the Schrappner Lader was the most flexible and that maintenance charges were heavy on the Saltgitter Lader.

The steel sharpening shop was well equipped with mechanical sharpeners, oil fixed furnaces and automatic tempering device.

Spoil was transported by standard gauge locomotives and wagons.

Lining

The factory tunnels were unlined and sprayed with whitewash, though in places brick walls were built to carry structural loads. The partly constructed railway tunnel was lined with steel ribs and wooden laggings where it traversed thinly bedded limestones.

Special points at the entrance of galleries: None

Shafts: None

Water supply: Pumped from river Weser in addition to tapping local supplies.

Sewage disposal: Linked up with sewage disposal from Phillips factory gravitation system. After treatment discharged into river.

Miscellaneous

It was of great interest to see plant as large and as elaborate as that required for oil refining housed in underground workings, for this suggests that there are few industrial operations which cannot be carried on underground if necessary.

Other features to be noted are the great size of the workings, some as much as 90 feet high, and the immunity to air attack given

by the choice of site.

Finally the rapidity with which the design and construction of the work was carried out is most remarkable.

Engineering Services

(a) Heating

In view of the nature of the proposed production for this factory viz. oil refining, no arrangements had been made for heating the incoming air. The main problem obviously was to remove the heat resulting from the process operations.

(b) Process Steam

High pressure steam was required for process and for this purpose two boiler houses were under construction inside the workings with access at road level in the cliff face. The constructional work for these boiler houses was not sufficiently advanced to suit the anticipated commencing date for production consequently one boiler had already been delivered and erected temporarily in an old quarry close to the workings, together with steam mains and provision for picking up the permanent boiler houses when completed. It was intended to erect the second boiler in its permanent boiler house and when in a condition to accept the load, the first boiler was to be dismantled and re-erected in its own permanent boiler house.

The boilers were of water tube type, with single steam drum and water cooled furnace walls. It was stated that the furnace was designed for burning crude oil, gas from the Rhur grid system, or asphaltic, but it was admitted that no experience had yet been gained on the last named type of fuel, and it was anticipated that difficulties would have been met. The boiler pressure required was 330 lbs./sq.inch although these particular boilers were capable of developing a pressure of 500 lbs./sq.inch.

A lime soda feed water treatment plant had been erected beside the boiler in the quarry, but it was not clear whether this was to be duplicated within the tunnel workings or to be allowed to remain outside.

(c) Ventilation

For the proposed ventilation of the complete installation it was intended to instal one main axial flow fan (alleged duty 5,000 cubic metres per minute) at the rear of the tunnel network and with the fan chamber so arranged as to

draw air through one half of the workings and to discharge through the second half.

It was evident that great reliance was being placed on the heat given off by the process plant, motors, etc. to keep the humidity under control.

When the factory was inspected, a temporary fan was exhausting to atmosphere near the cliff base, but was quite inadequate for maintaining any perceptible air movement, except in the near vicinity of the fan.

Observations taken during the inspection were as follows:-

Dry bulb temperature 57°F
Wet bulb temperature 56°F

Deeper in the workings there was complete saturation with condensation everywhere.

(d) Electric Power and Lighting

The electric power supply was obtained from an outside source at 25,000V and two transformers each of 2,500 KVA transforming from 25,000V to 6,000V had been installed. Two additional transformers each of 1,000 K.V.A. capacity had also been provided for transforming from 6,000 to 400V; these transformers were located inside the workings and were enclosed in well built cubicles with fan ventilation (inlet at bottom and outlet at top).

It was understood that this transformer station also supplied electric power to the Philips factory in the adjacent workings at higher level.

(e) Services Generally

The installation of services was well advanced, and represented in total a tremendous achievement in planning, erection and the co-ordination of trades.

Economy of space for cables, pipes etc., had been rigidly observed and full use has been made of multi-purpose service gantries, cantilever supports and vertical box type assemblies for orderly distribution of services.

Massive cross bearers at high level and spanning the full width of the chambers were used for the heavier pipes.

Overhead runways had been provided for handling plant components and the larger vessels had been built up in either welded or riveted construction in situ.

The whole of the installation was deteriorating rapidly with the excessive humidity condition of the air as already observed under the section dealing with ventilation.

Production and Layout

This plant had been installed underground and was intended to deal with 300 tons of topped crude oil per day. The installation within the workings was about 90% complete, the remaining 10% of work yet to be done involved the completion of the internal production storage tanks and general inter-connection of pipe lines.

Since this factory has already been the subject of a comprehensive report in Subject:- (Oil Refinery NH/903/5, Reference 307/1724/1 dated 29th May, 1945) there is no need to add further detail. Nevertheless, we would express the opinion that the installing of this plant underground was an engineering feat of no mean order, particularly since it was essentially standard equipment and not subjected to any major modifications. For general reference we have added a plan of the workings and indicated thereon the areas allocated to the various refining operations.

(L) HAMMERWERKE FACTORY, near Hausberg
Porta Westfalica, Minden

021/1331
022/3469
031/2809

This factory, of the multi-storey type, was constructed in underground quarries on the East side of the Weser gap south of Minden. The quarries were situated in the Porta Sandstone above the Dachs I Refinery, and had been enlarged by the Gewerkschaft Porta to house the Phillips Radio Valve factory from Eindhoven, in Holland.

Constructional work is said to have started in March, 1944 and to have been completed in September, 1944. Production started in February, 1945.

Contracts

The following were interrogated:-

Herr Goosens, engineer, Dutch, speaks English.

Herr Pott, mining engineer, manager of the Gewerkschaft,

18444

64.

Porta.

Herr Haupt, formerly engineer on plant installation,
now custodian of the factory for the Military Government.

Geology

The geology of the area has already been described in the sections dealing with Dachs I and Denkmal Stollen. The Hammerwerke factory nine storeys high was constructed in the Porta sandstone (photograph No. 21) and being south of Dachs I was at a higher level as a result of the dip of this stratum as can be seen in the geological section attached to this report (Fig. 8A.) The two factories were to have been connected by an internal shaft.

There was no evidence of rock falls in the factory area.

Lining & Support

The workings were for the most part unsupported and the rock surface only whitewashed. At a few points steel joists and timber laggings had been used.

Excavation

The little excavation done on this site was carried out simultaneously with Dachs I and no separate data was available on labour, costs or progress.

Entrance

The main entrance, on the seventh floor, was protected by a blast wall of concrete 1.1 metres thick, and was connected with the main road at Hausberg by a funicular railway.

Water Supply

Process water was pumped from the River Weser. Water was available from the town supply.

Sewage Disposal

Sewage was disposed by gravity into the Weser after treatment.

Air Attack

There was no evidence of air attack on this site.

Engineering Services

(a) Heating

The Boiler House was located on the surface at road
65.

level adjacent to the entrance of the Porta (Daehs I) factory.

The boiler was of the horizontal type in three sections:-

1. Cornish boiler design with corrugated flue.
2. Section comprising smoke tubes
3. Smoke box section.

Steam was taken off the middle section, which was also provided with dead weight safety valve, and thence proceeds to the super heater section located round the crown of the smoke box.

Steam and condense mains were taken through the entrance of the Daehs I factory and thence by means of a sloping tunnel up to the ground floor of the Hammerwerke Factory and to the various steam heater batteries associated with the ventilation plants.

(b) Ventilation

Six separate plenum extract systems were installed, all of similar character and dealing with the floors in groups. Each system draws fresh air from, and discharges vitiated air to, the cliff face.

Each inlet system comprised a main inlet fitted with a wire grill leading into a concrete spray chamber thence to an eliminator and finally to the fan chamber. The water sprays were not connected, but it was clear that they were to be supplied with water from the main supply and that this water would be rejected to waste.

Two types of delivery fans were used -

1. Double inlet type in an enclosed fan chamber following spray and eliminator chamber.
2. Single inlet fan with duct connection to the spray and eliminator chamber.

Each inlet fan discharged into a main delivery duct constructed in building board, at the respective ceiling level, and vertical metal ducts were taken down to floors as required with adjustable discharge openings near each floor level.

Vertical extraction ducts with inlets at high level, as required, were connected to a main extraction duct, also constructed in building board, running adjacent to the corresponding main fresh air delivery duct. The main extraction duct was connected to the extraction fan chamber and thence to atmosphere. At the time of the inspection all fans were running but heater batteries and water sprays were out of commission. Condensation was evident on the lower floors but the general state of the factory suggests that production heat energy in conjunction with the use of steam heater batteries had resulted in a reasonable air condition.

(c) Electric Power and Lighting

The electric supply was taken from the sub-station at Porta (Dachs I) at 6,000 volts and the high tension cables were brought up through the service tunnel and taken to four transformer stations. The voltage was then transformed from 6,000 volts to 400 volts 3 phase 4 wire, each of these transformers was rated at 800 KVA.

Low tension feeder cables were taken as risers to metal closed cabinets containing main switches, fuses, circuit breakers and relays.

Circuit wiring was taken at high level and in general was supported by a series of galvanised multi-strand steel cables which also served as an earthing wire collectors. Each steel cable was thoroughly bonded to the rising watermain.

Drops to machines and table inspection lights were taken from special metal junction boxes with porcelain interiors.

All metal parts and components were earthed on to the galvanised straining cables by means of single strand cables, approximately No. 18 gauge.

An attempt was made by interrogation to gain information regarding the type of earth leakage system installed but the only information offered was that every power unit had a leakage trip and that transformers were earthed at the star point.

The general illumination and local bench lighting were of a high standard for example 4 kilowatts of lighting load has been installed in an inspection bay approximately 25' x 25'.

(d) Fire Protection

Fire hydrants complete with hose reels were provided in metal cabinets fixed to walls and connected to the rising waterman. Portable fire extinguishers were also provided.

(e) Gas Installation

Gas for process work was obtained from the town supply and the installation followed conventional standards for the class of work under consideration.

Production and Layout

This factory consisted of nine floors with layout as shown on the attached print and situated in the same hill as the Oil Refinery, Dachs I, which is the subject of a separate report. This factory was first put into operation in February, 1945 when it was intended to reinstate the production hitherto obtained from Philips Eindhoven factory, Holland. All plant and equipment, even down to the inspection benches and stools, were transferred from Eindhoven. This factory was very impressive in so far that there was ample spacing, and lighting was particularly good.

The ultimate production was to have been 12,000 radio valves per day, but it was ascertained that up to the date of ceasing production, some 7,000 serviceable valves only had been issued. This in no way represents the total number of valves actually manufactured since it was made clear by the Production Engineer (Dutch) that the number of defectives was considerable and this in the main was due to inclusion of dust at the final assembly stages. It should be appreciated that this dust trouble would not be discernible by casual observation. Nevertheless, the question of dust did not apparently interfere with the manufacture of component parts nor did it affect work carried out in the tool room and maintenance shop. Walls had been whitewashed but not otherwise treated or lined.

The total labour force spread over three shifts would have been 1,200/1,400, the vast majority being females, mainly young Jewish girls from concentration camps. Three shifts were arranged viz:- two of 6 hours, and one of 8 hours, the break coming between 3.0 a.m. and 7.0 a.m.

Production arrangements were as follows:-

1st floor - Toolroom and general maintenance shop. This plant was in first class condition, amply spaced and machines were of first class make, including several American tools such as Gorton and Milwaukee Milling machines. This floor also housed the gas

mixing plant required in production and was distributed to the required stations on the other floors by normal pipe distributing system.

- 2nd floor - This was essentially devoted to grid rolling and all the requisite plant for this operation had been installed and its condition was good.
- 3rd floor - Allocated to component assembly. This floor was also used as a main stores for component parts.
- 4th floor - Mainly for assembly and testing.
- 5th floor - This was laid out for the drawing of filament wires and testing, but it was obviously not yet in full production. A side gallery on this floor was occupied by a separate firm, Carsten of Hamburg, who were apparently responsible for stamping out the mica parts which were subsequently used by Philips in the assembly.
- 6th floor - Had no defined use at the time of visit, except for a few offices and it was understood to have been used as sleeping quarters.
- 7th floor - This was the main entrance and exit for the whole factory, and contained a certain amount of plant for preparation of cathodes and filaments.
- 8th floor - Preparation of cathodes and filaments.
- 9th floor - This was used for offices and ablution, and had a small exit probably used by staff only.

Access for employees to the respective floors was by stairway, and for goods, a lift 4 x 3 metres and having a capacity of 5,000 kilograms was installed to serve floors 1 to 7.

The only external access provided to this factory from the main road was by means of a funicular railway which terminated at the level of floor 7 and about 200 ft. from the tunnel entrance.

TABLE 1

ANALYSIS OF VULNERABILITY TO AIR ATTACK

(see also Appendix No. 1)

	Approx. overhead cover (ft.)				Vulnerability				Blast protection from bombs at or near entrances		Whether bombed and size of bombs	Remarks	
	Description of principal strata	Entrance tunnels		Factory area	Estimated percentage of factory area safe from medium sized penetrating bombs in high level attack				Access tunnels	Factory area			
		Min.	Max.		1000 lb.	Tallboy (M) 18000 lb.	Tallboy (C) 28000 lb.	Hypothetical 30000 lb.					
Niederachseverfen Mittelwerke (N. Nordhausen)	Anhydrite & gypsum	Rises steeply to 40 at 80 ft. from N. entrance (see sketches A & B.)	135	135	480	100	100	80	80	If U.S. doors at N. entrance give protection from small bombs	None except from cross galleries being at right angles to main tunnels.	No.	Practically all invulnerable to penetrating bombs in operational use at end of German War in 1945. Large light cased blast bombs dropped in or near entrances however would have caused severe blast effects in much of the system of tunnels, sufficient to cause casualties and dislocation of light partitions, etc.
Langenstein II	Sandstone	Rises from 10 to 20 ft. in first 80 ft. from N. entrance and then steeply to 80 ft. (see sketch B)	58	36	100	100	40	15	5	None installed. Preparations made to install concrete door 3 metres thick	Ditto	No	Tallboy (C) bombs dropped from high level over the tunnelled areas might have caused local tunnel blocks in rather less than half the area. Large blast bombs at entrance would have had good effect in the main through tunnels, but the diversified layout of the galleries would have prevented severe blast effects elsewhere.
Nakritz II (small champagne caves near Langenstein)	Sandstone	5	25	25	15	0	0	0	0	No effective doors	Changes in direction in access give fair protection	No	A small and unimportant place giving protection from direct hits by small bombs only.
Nakritz I (extensive champagne caves near Langenstein)	Sandstone	80 (vertical cliff)	65	50 ?	65	20	0	0	0	No effective doors	Fair protection because of ramified layout	Yes, probably U.S. 500 lb. G.P.	6 small craters observed in surface above tunnels; possibly intended for Halberstadt airfield which is near by. Roof falls in galleries probably were not caused by bombs, but were due to natural causes.
Ostfildes	Anhydrite & gypsum	135 (nearly vertical cliff)	150	150	260	100	180	75	60	None	Cross Galleries give fair protection	No	An oil refinery was to have been installed. High level attack by Tallboy might have had some effect, especially on riser shafts containing vertical retorts.
Kibitz	Sandstone	10 (steep wooded hill-side)	115	115	360	100	100	100	80	None	Ditto	No	Attack on entrances for blast effect, or on communications and power supply would have been the only justifiable means of air assault.
Olderitz, Regenstein, (Nr. Blankenberg)	Sandstone	180 (nearly vertical cliff, see sketch C)	150	115	185	100	100	100	80	None	Ditto	No	Ditto

* It was reported that a German general, when inspecting the Langenstein tunnels, remarked that experience in the V weapon tunnels in France indicated that the overhead cover at Langenstein was inadequate.

APPENDIX 1

UNDERGROUND FACTORIES - VULNERABILITY TO AIR ATTACK

INTRODUCTION

For successful air bombardment of underground factories three types of attack suggest themselves:

- (1) Bombs striking the surface over the tunnelled area must penetrate deep enough for the explosion to block or damage the tunnels, either by perforating and exploding within the tunnel (a remote contingency), or by shock through the intervening thickness of earth or rock.

For this purpose medium-cased bombs, such as the Tallboy 12,000 lb., appear to be suitable since they represent the best combination of high sectional density and strength for deep penetration in rock without breaking up, together with a large charge of explosive for earth-shock effect.

In the case of deep tunnels, such as the majority of those constructed or adapted by the Germans for use as factories, a high striking velocity (i.e. bombs released from a high level), and delay fusing to ensure that the bomb comes to rest at or near its maximum penetration depth before detonating, are evidently desirable.

- (2) Bombs dropped to detonate in or near entrances in order to cause blast damage within the galleries. For this purpose light-cased bombs with a high charge-weight ratio and instantaneous fusing should give the best results.

It should be noted that blast effects within tunnels are much more severe, and travel far greater distances, than in the open. Protection can be provided by very strong and specially designed doors or traverses, or by a layout embodying special blast traps or pockets in the access tunnels (see Min. of Home Security R1/E. Note 218).

Consequently straight through tunnels with a system of short cross galleries are more vulnerable to blast than a diversified system with many turns between the entrance and the majority of the galleries.

- (3) If the conditions are such that neither (1) nor (2) are likely to be successful there is always the alternative of attacking communications, external sources of power supply, labour camps in the vicinity, etc., and, in the case of factories in deep mines, the

Head Race and shafts.

It is probable that method (1) is a better proposition than (2) because of the much bigger target represented by the surface area over the tunnel system, provided that the overhead cover is not too great. But whatever the circumstances there is always the problem of whether it might not be more profitable to interrupt the flow of raw material and finished products by attacking the communications rather than the factory itself.

A very important factor in successful air attack on underground factories must surely be the adverse effect on the morale of the workers, for to the natural aversion to working underground which is experienced by many people there is added the fear of being trapped or killed in a place which had previously been considered safe from bombs. Since the morale effect is probably greater for underground than for surface factories the material damage should not be regarded as the sole yardstick of success.

The explosion of a bomb actually within a tunnel is likely to cause a local enlargement of the tunnel section, but not necessarily a block - though severe blast effects causing light material such as doors, partitions, furniture, etc., to be violently displaced would be felt over a wide area, (see S.B.R.M. Report No. F/14 from R. & E. Princess Risborough as "R.C.437" - see paragraph 8.1.)

On the other hand a bomb detonating in the ground above a tunnel within the ~~the~~ quarters of the Radius of Rupture (see Appendix 1) will almost certainly cause a blow through resulting in a complete block.

Hence, for maximum structural damage to the tunnel, leading to the most difficult and lengthy repair work, it may often be that it is better for the bomb to detonate above, or above and to a side of a tunnel than actually within the tunnel; and since the latter is far less likely to occur than the former this is a fortuitous circumstance.

The basis of the assessment of vulnerability is given in Appendix 1, and the results, including opinions on the results which would have attended attack methods (2) and (3), as applied to the underground factories covered by this report, are tabulated below. In addition to assessing the probable effects of large bombs in operational use at the end of the German War in 1945 an attempt has been made to forecast on the same basis the vulnerability of the factories to possible larger bombs of the same type.

ASSESSMENT OF THICKNESS OF OVERHEAD COVER

Since it was evident that only a few hours could be allocated for the inspection of each underground factory anything in the nature of a detailed survey was obviously impossible. Attempts to obtain

layout plans were seldom successful, and the plan was forthcoming from the site. On the other hand, plans were followed by visitors to offices, copies of certain drawings were obtained subsequent to the visit to the factories. In other instances plans may be attributed to the fact that previous teams visiting the area had naturally taken them away (e.g. Niederrhein - Trip 163).

Doubtless such plans obtained by previous visitors would have been made available in advance to members of O.I.O.S. Trip 536 if time had permitted. Hence it was necessary for a considerable portion of the brief time available at nearly every site to be spent in getting an idea of the layout of the tunnels by pacing and pocket compass, and of the overhead cover (as far as could be seen from outside entrances) by Abney level. In addition, local Germans were questioned about the thickness of overhead cover at various points within the tunnels or workings, though it became evident that information obtained thus was not always reliable.

In these circumstances, therefore, some of the figures given in the following table reflect the judgment of the investigator, and are approximations rather than surveyed measurements.

CONCLUSIONS

If the 10 underground factories visited can be taken as representative it is clear that the thickness of overhead cover was usually, though not always, sufficient to have made air attack with even the largest penetrating bombs in use at the end of the German war unprofitable.

An outstanding exception is Langenstein, much of which was judged to be vulnerable to the 12,000 lb. Tallboy (M) bomb. But if the statement attributed to a German general that there was not enough thickness overhead in this instance in view of the successful Tallboy (M) attacks on tunnels in the Pas de Calais area is authentic the Germans were not unaware of the vulnerability of Langenstein.

The Germans do not appear to have been fully alive to the possibility of serious blast effects being caused by bomb explosions in or near entrances, since designed blast protective measures in entrances and access tunnels were not generally observed. Some of the tunnelled factories are, however, reasonably well protected in this respect because of the complexity of layout whereby the majority of the galleries are reached only after many turns in the route from the main access tunnels.

No evidence was obtained that any of the underground factories visited were bombed from the air (except Makrole 1, which was

probably accidental and without effect in view of the small size of the few bombs which fell over the tunneled area). If air attacks had taken place it is doubtful whether attempts to block the tunnels by Tallboy bombs would have paid as well as the same weight of attack with smaller bombs on communications and sources of external power supply.

All the evidence obtained suggests that the Germans were in the process of transferring on a vast scale their main war production from normal unprotected surface factories to underground factories (generally in tunnels rapidly driven for the purpose) providing a very high degree of protection from air attack with any bomb in operational use. It is probably an understatement to say that on the whole underground factories in tunnels of the types inspected are at least 20 times as safe as normal unprotected surface factories of the same shop floor space, even when the tunnels have no more than 100 ft. thickness of chalk overhead cover and are therefore vulnerable by the 12,000 lb. Tallboy (M) bomb (see B.E.R.M. Report No. F/7).

There can be no doubt that to provide for a surface factory the same standard of physical safety as that obtainable by going underground would be a gigantic task impossible of general application, requiring reinforced concrete, roofs and walls from 20 to 25 ft. thick to resist the 12,000 lb. Tallboy (M) bomb.

The issue is, therefore, whether the safety from air attack of normal unprotected surface factories can on a conservative basis be increased at least 20 times by the expedients of dispersal and camouflage. It is the view of those submitting this report that this could not be approached.

The Germans had shown by the energetic manner in which they tackled the problem, and by the remarkable results they achieved in so short a time (e.g. a large lubricating oil refinery for Hanoverian oils was almost ready to work in well under a year), that their war production in surface factories could not survive the weight of modern air assault. On the other hand, if the Germans had been able to gain, say, another year in which to press on with the transference of main factories underground, the task of the Allies might have been made much more difficult.

ASSESSMENT OF UNDERGROUND FACTORIES FOR SAFETY FROM AIR ATTACK

In assessing the vulnerability to air attack of the underground factories covered by this Report the bombs (penetrating type) have been assumed to be dropped from a high level and to strike the ground at 1,000 ft./sec. Fusing is presumed to be long enough to ensure that the bombs reach their maximum depth of penetration in the ground (i.e. come to rest) before detonating.

Data on penetration reached by various types and sizes of bombs or rocks, and over a range of striking velocities. Although several theories for computing the problem have been advanced, since that first propounded by the Metz Commission over a hundred years ago the problem is still being investigated, and no finality had not yet been reached. Consequently it has been thought desirable for this Report to keep the matter on as simple a basis as possible, and so the figures given in Table 2 for depth of penetration by impact at a striking velocity of 1,000 ft./sec. (which represents about the maximum at present obtainable by normal bombs) are based on the observed depths of penetration of German bombs which fell on England (as recorded by the B.D.S.), on sectional density theory, and on U.S., N.D.R.C. Weapon Data Sheet 2A2. From these considerations the following simple relationship has been adopted for the purpose of this Report:-

Where y = depth of penetration (feet at S.V. 1000 ft/sec, &
 x = cross sectional density of the bomb (lb/sq.in.)
 then for CLAY (soft) $y = 6.0 x$
 CLAY (hard) or CHALK (soft) $y = 4.7 x$
 CHALK (hard), ANHYDRITE OR GYPSUM $y = 3.3 x$
 SAND $y = 2.6 x$
 SANDSTONE (Hard) $y = 2.0 x$

The Radius of Rupture in Table 2 means the maximum distance through the ground from the centre of charge in the bomb (detonating in the ground at its maximum depth of penetration) at which tunnels, whether concrete-lined or not, are likely to be spalled as a result of the explosion. The figures given in the Rad. Rup. columns have been derived from data obtained in a study of the effects of air bombardment on underground tunnelled workings in the Pas de Calais area which suggested that the Rad. Rup. for tunnels in hard chalk is about 80 feet for a bomb containing a charge equivalent to 7,000 lb. of T.N.T. exploding in the ground at its maximum depth of penetration (see B.B.R.M. report No. F/...). The Rad. Rup. for sandstone has been taken as 2/3 that for hard chalk. For bombs with other weights of charge it has been assumed that the Rad. Rup. (feet) varies as the cube root of the charge weight (lb. of T.N.T.).

Table 1 gives details of the medium-cased bombs considered in the assessment of minimum thickness of overhead cover for safety in tunnels. The largest medium-cased bomb in operational use at the end of the German war in 1945 was the 22,000 lb. (gross weight) "Tallboy" (L). Two hypothetical bombs of the same type, weighing 30,000 and 40,000 lb. have been included in Table 1 in order to give some idea of the minimum thickness of overhead cover which might be desirable for safety at some future date (excluding the possibility of changes in bomb design leading to radically improved performance).

To compute the expected depth of penetration in the ground by impact of these two hypothetical bombs it was necessary to

estimate their probable sectional densities. The figures of 14.3 and 15.7 lb./sq.in. have been obtained by prolonging a curve showing the relation between sectional density and gross weight for various sizes of existing medium-cased bombs. These figures should, therefore, be regarded as no more than very rough predictions. Incidentally, they conform to the theory that sectional density is proportional to the cube root of the gross weight.

Table 3 gives the minimum thickness of overhead cover assumed for the tunnels inspected to be reasonably safe from air attack. The data obtained from the Pas de Calais area mentioned above inferred that for no significant damage likely to cause personnel casualties the Radius of Rupture (as defined in this Report) should be increased by about 25 per cent. Hence Table 3 figures represent the sum of the maximum penetration depth and the Rad. Rup. + 25%.

TABLE 1

**DETAILS OF MEDIUM-CASED BOMBS CONSIDERED FOR HIGH LEVEL ATTACK
ON THE SURFACE ABOVE UNDERGROUND FACTORIES**

Ref.	Description	Gross Weight (lb.)	Sectional density (lb./sq.in.)	Charge weight equivalent TNT. (lb.)
A	500 lb. MC or GP	510	4.0	220
B	1000 lb. MC or GP	1,050	4.3	500
C	UB 2,000 lb. GP	2,050	4.8	1,015
D	Tallboy (H)	11,850	10.5	7,000
E	Tallboy (L)	21,500	13.0	13,000
F	Hypothetical ^M	30,000	14.3	18,000
G	Hypothetical ^M	40,000	15.7	24,000

^M Assumed charge/weight ratio = 60%

TABLE 2

**MAXIMUM PENETRATION BY IMPACT AT S.V. 1000 FT/Sec., and
RADIUS OF RUPTURE TO CAUSE SPALLING IN TUNNELS**

Bomb Ref.	Impact penetration at S.V. 1000 ft/Sec.					Rad. rup. to spall tunnel	
	Type of ground or rock					Type of ground or rock	
	Clay (soft)	Clay (hard) Chalk (soft)	Chalk (hard) Anhydrite Gypsum	Sand	Sandstone (hard)	Chalk (hard) Anhydrite Gypsum	Sandstone (hard)
A	20	15	10	8	6	25	17
B	24	18	13	11	8	34	23
C	29	22	16	13	10	42	28
D	64	50	35	28	21	80	53
E	80	60	43	35	26	100	67
F	86	67	48	37	29	110	75
G	94	74	52	41	31	120	80

TABLE 3

MINIMUM THICKNESS OF OVERHEAD COVER ASSUMED FOR
 NO SIGNIFICANT EFFECT IN TUNNELS BY MEDIUM-CASED
 BOMBS STRIKING THE SURFACE AT S.V. 1,000 FT/SEC.
 AND PENETRATING TO MAXIMUM DEPTH BEFORE DETONATION

Bomb Ref.	Type of ground or Rock	
	Chalk (Hard), Anhydrite or Gypsum	Sandstone
A	40	30
B	60	45
C	70	50
D	135	90
E	170	110
F	190	125
G	200	130

APPENDIX 2

Comparison between a German and a British Underground Factory

Headings

- I. Preliminary
- II. Floor Areas
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- IV. Periods of Construction
- V. Labour Forces
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- VIII. Residual Rock Areas.
- IX. Review

APPENDIX 2

Comparison between a German and a British Underground Factory

I. Preliminary

The inspection which was made, during the course of the tour in Germany, of the Underground Factory at Langenstein, suggested that a few points of interest might emerge if a comparison were made between that Factory and a certain Underground Factory constructed during the war in England. Each of the two Factories was formed in a sandstone hill and the lay-outs were in a general sense comparable. The natures of the sandstones differed in the two cases, the German rock being of a stronger texture; it was deposited under water, whilst the British rock owed its origin to atmospheric action.

With a view to this comparison of characteristics, it was intended to enquire more fully into the conditions at Langenstein than would have been possible in the time available, in connection with other German Factories comprised in the programme of inspection. This plan was frustrated, as is recorded in the Report, by the advance of the Russian forces. Nevertheless, sufficient information was collected to furnish a basis for a comparison which may on one or two points prove instructive.

The purposes for which the factories were made were different and the comparison is confined to the work of construction, including the formation of the Corridors and Galleries, and the general internal and external Civil Engineering work. For simplicity, comparisons will generally be expressed by ratios (German: British), hard statistics being quoted in one or two cases only, to assist in visualising the scale of the works. An idea has first to be formed of how the two factories stand to each other in the way of magnitude.

II. Floor Area

The German Factory was more extensive than the British. One yardstick for comparison is the respective floor surface areas provided. The British Factory was wholly completed. The categories of work, referred to above, in the German Factory were very nearly completed and the figures applying to the completed portion only will be used, in deducing ratios, not those of the complete project.

The ratio of areas of floor surface is:-

$$\frac{\text{German Factory}}{\text{British Factory}} = \frac{67,000 \text{ sq. metres}}{26,000 \text{ sq. metres}} = 2.58$$

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so that, in round terms, we are considering a German Factory of $2\frac{1}{2}$ times the extent of the British one. The capacities of the two Factories, in potential output, are not strictly comparable.

III. Volumes of Excavation

The ratio in this case is 3.1. The difference is due to the fact that the Corridors and Galleries, beside being broader, were higher in the German than in the British Factory. So if one is considering not merely accommodation provided for production but volume of work involved in tunnelling, one has to regard the German Factory as some three times as big as the British one.

IV. Periods of Construction

The British Factory was started in June, 1941, and the items of work involved in this comparison were completed in March, 1943 - a period of 21 months.

The German Factory was started in June, 1944, at about the time when the enemy appears, from the information collected during this tour of inspection, to have embarked upon a very extensive programme of underground construction. Work was stopped, just short of completion, in March, 1945 - a period of 9 months only.

The rapid execution of this and other German projects will be commented on below. The ratio of construction is $\frac{9}{21} = 0.43$, as against a ratio of 3.1 in connection with the volumes of work.

V. Labour Forces

The analyses of the respective labour strength necessary for an exact statement are not available. From reasonable inferences, however, it appears that the ratio of personnel during the construction periods could not have been less than 6 and was probably well above.

VI. Costs

The value of the rentenmark is understood to have been reckoned at 12 to the pound sterling. On this basis, the cost of the work done on the German Factory bears the ratio of 3.2 to the cost incurred on the British. The actual figures of expenditure, which may help in visualising the scope of the jobs, are 25 million rentenmarks, or just over £2 millions, and about £650,000 respectively.

It is considered rather remarkable that this ratio should be so close to that of the respective volumes of excavation, namely 3.1,

for the factors making up the cost appear to be so unconnected. The exchange ratio is believed to have been, during the war, a purely arbitrary figure and the actual values of the pound and the rentenmark respectively under war conditions, when translated into commodities, must be somewhat difficult to assess. The cost to the German Contractors of concentration camp labour was low as compared even with pre-war rates in this country and the disparity between skilled and unskilled rates was marked. The workpeople on the British Factory were drawing wages which were well above the peacetime standard. On the other hand, the rate of progress achieved under great stress on the German Factory was probably above the truly economic pace.

Whilst statistics were being collected in the course of the tour regarding the costs involved on German Factories, it was thought probable that the figures would, on account of these very divergent circumstances, prove on examination to have little meaning to us. In so far as this comparison goes, however, it can be inferred that there is in fact a relationship, and that what the Germans had in mind, when they spoke of a war-time job costing 12 million rentenmarks, corresponded in a general way to what we should have regarded as a £1 million job. There are nevertheless certain other points, referred to below, to be borne in mind when considering such figures; but this comparison may be of some use when reviewing the costs of other German Underground Factories referred to in the Report.

VII. Exposed Surfaces of Corridors and Galleries

Considering the natures of the sandstones, one might have concluded that the German Factory was one in which internal linings could have been dispensed with (except in one area of weak rock) whilst linings would have been advisable in the British Factory. In fact, however, the opposite course was taken in each case. But if the other German Factories which were inspected are taken into account, it is necessary also to state that, in at least one important instance, linings were almost wholly omitted, although they may fairly be judged to have been at least as necessary there as in the German Factory now under consideration. We were not able to explain this seeming inconsistency. It can be said that, in the case of the British Factory, the need for protection of the production equipment from the presence in the atmosphere of particles of solid matter was no less than it was in the German case. It was, indeed, recognised from the onset as of prime importance. In neither case was there any serious percolation of water, though the rock of the British Factory was damp when excavated.

This question of whether to line or not, wherever weaknesses are not exposed, is obviously one of major importance when any underground Factory project is in contemplation. The decision in the case of the British Factory hung largely upon the shortage of

labour and the desire for the earliest possible completion. There was no shortage of labour on the German Factory. Some means had to be found at short notice, for the adequate treatment of the sandstone surfaces of the British Factory, there being no time to carry out the extended trials for which the case really called. A statement by the Chemical Engineer on whose advice a method of treatment was adopted is comprised in Appendix 2(A). The linings of the German Factory were exceedingly rough and ready from our point of view, but they must have cost appreciably more than the wall-treatment in the British Factory and, if the respective costs of these items were known, a refinement of the comparison made above of costs of work generally would be possible.

The particulars given in Appendix 2(A) are submitted by way of illustration only. The measures necessary for indurating surfaces would vary with the type of rock, the purpose for which the Factory was intended being also a factor in the matter. It is presumed that the visit of inspection to Germany would not have been arranged unless there were at least the possibility of extensive post-war underground work being embarked upon in this country. If that is so, then the various classes of rock in which such work may have to be executed ought to be determined as soon as possible, with due regard to economic and other considerations. It would then be possible to initiate research into the treatment of such rock surfaces under atmospheric conditions corresponding to those which would apply in an underground Factory and to carry out tests over an appreciable period of time. In this way, the expenditure on linings could be reduced to the minimum consistent with the objects in view. During the war, we had to take quick decisions and there is some reason for concluding that those of the Germans were as hastily formed. The comparison between the two Factories serves, therefore, to emphasise the importance of an investigation of the question as to the circumstances in which linings are essential, or where treatment of the rock surface will serve the purpose.

VIII. Residual Rock Areas

In laying out an Underground Factory, the Corridors and Galleries have to be aligned with due regard to the conclusion of the Engineer as to the percentages of rock which must be allowed to remain in various areas after the corridors and galleries are formed. The depths and weights of overburden covering the crowns of the arches have naturally to be taken into account when arriving at such basic figures. When, as in the cases under reference, the various conditions are such that little reliance can be placed upon arch or dome action within the structure of the hill, it becomes, in effect, a question of the permissible compressive stress upon a horizontal surface. The smaller this figure, the greater the expenditure will be; for though the areas of the galleries, in which the plant has to be installed, may be unaffected, the

lengths of the corridors connecting them will be very much affected. Incidentally, though this is not a point here under consideration, the cost of the services, too, depends very much upon the figure.

Sufficient information was collected regarding the German Factory to arrive at the limit set by the Engineer when planning the work. The rocks in the two Factories are somewhat dissimilar but it was impossible to form (from inspection and without physical tests) an idea of the ratio of the unit loads which a Civil Engineer would be disposed to allow upon each respectively. The question as to whether the Germans, in their haste to provide Underground Factories, were disposed to take greater risks than we were is not devoid of interest. It can be decided, as regards this instance, by deducing a comparison.

In the case of the British Factory, the design was altered after work had been in progress for some time by reason of a change of view as to the residual areas of rock. At the onset, galleries 19 ft. broad were formed at 34 ft. centres, the pillars in between them being 15 ft. broad only, and it was the intention to continue on those lines throughout. Taking into account the spacing of the corridors, the ratio of residual rock was 0.4. That was considered satisfactory where the overburden was shallow; but as the higher parts of the hill were approached and no improvement in the rock was disclosed, it was concluded that this ratio must be increased. The rest of the Factory was then re-designed, to increase the ratio, which under the crest of the hill became 0.6. The area occupied by the Factory was considerably extended, almost in fact to the limit of what the hill afforded. The volume of work to be carried out and the cost involved were each seriously enhanced. This circumstance is quoted in order to illustrate the significance of this ratio of residual rock.

The corresponding residual ratio, in the case of the German Factory, is to all intents and purposes the same as that in the British Factory, namely 0.6.

The ratio of depths of overburden is

$$\frac{\text{German}}{\text{British}} = \frac{40 \text{ metres}}{37 \text{ metres}} = 1.1 \text{ (about)}$$

Assuming approximately equal unit weights of overburden the ratio of compressive stress in the German rock to that in the British similarly becomes 1.1

It is quite possible that differences of opinion would arise among Engineers if it were a matter of assessing, in figures, the respective compressive stresses which these two rocks could, in such a type of construction, safely be expected to stand; but it is not conceivable that there would be a difference of opinion regarding the statement that the ratio of those stresses is not 1.1, or anything of that order. The opinion formed whilst at the German

Factory, and after an inspection of the rock in situ and of the debris of the spoil heaps, was that there could be no hesitation in imposing on the German rock at least twice as much load as one would be disposed to allow on the British.

There can be little doubt that, in the matter of stability, the Germans could have worked on a ratio of residual rock of, say, 0.4 which, as stated above, was the figure initially adopted in the British Factory. As already explained, the effects in the latter case of an increase in this residual ratio were far reaching, and the change was made only after very serious consideration. Why did the Germans impose upon themselves this high residual ratio, involving heavy effort and expenditure, on a job on which they were, before all things, desperately up against time? One would not expect all German Civil Engineers to have exactly the same approach to such problems; but were those concerned with this Factory more conservative than the British Engineers, or was their design governed by special factors which involved them in a seeming extravagance?

Very full particulars of the requirements stipulated by the Production Engineers would be necessary in order to give a perfectly conclusive answer to these questions, but it is possible to draw deductions from the information which was collected. The design of the German Factory shows that the residual ratio of rock was a factor kept well in view and that it was varied locally in relation to the cover. There is every indication that the Factory could have been laid out in a smaller area of the hill, had the Civil Engineers been prepared to work on a lower ratio of residual rock, and that the volume of work could thereby have been considerably diminished.

It must therefore be concluded that, in the instances under consideration, the British Engineers were prepared to adopt a lower factor of safety for their work than were the Germans. The comparison lends no support to the idea, if it be anywhere entertained, that the Germans were in part enabled to make the rapid progress which they achieved on Underground Factories by taking risks which British Engineers would not accept.

IX. Review

A German Factory of $2\frac{1}{2}$ times the floor area and of 3 times the volume of the British Factory was built for 3 times the cost. The comparison brings out differences of ideas in respect of linings and residual areas of rock. But the most striking fact is that the German Factory was constructed in well below half the time occupied on the British.

How is it that the Germans were able to build so much more rapidly than we were? The construction of the British Factory was undertaken by a firm of Civil Engineering Contractors quite in the first flight. Each job was well mechanised, though the

types of plant employed were quite different. In neither case did the lay-out seriously restrict the numbers of faces at which work could be carried on simultaneously. There were on each job adequate edits for the disposal of spoil.

The information which the inspection team were unable by force of circumstances to obtain might have made possible a complete answer to the question stated above. As it is, the following observations only can be made:-

- (a) For a job 3 times the size, the Germans employed at least 6 times the labour force. They appear to have had all the labour they required;
- (b) The Germans worked three shifts against our two, or at times one, and they worked for seven days a week;
- (c) It is clear enough, from the results achieved here and elsewhere, that though a high percentage of the men employed on the German jobs were civilians from occupied countries or Germans out of concentration camps, the people in charge did manage to get from them a satisfactory daily out-turn of work. The record of this job does not lend support to the stories of passive resistance which one hears.
- (d) The Germans had however at their disposal means of coercion which naturally could never even be considered on a British enterprise. The S.S. were in supreme control and the rigour with which they acted can be gauged from the fact that even the Engineer in charge put in a spell in a concentration camp. Particulars are not available of how long men generally lasted on the job;
- (e) A large proportion of the labour on the British job was of necessity of a type not normally employed on this class of work and they were a source of considerable trouble. The Germans might have found it easy to discipline them, but it was not so here. Progress was retarded, also, by discontent over bonus earnings;
- (f) Although the British Contractors mechanised their work, they lost a good deal of time through poor maintenance of plant - a failing of which they by no means have a monopoly among firms in this country. Statistics are lacking, but it is not seen that the Germans can possibly have lost much time from this cause and their plant did, in fact, call for less maintenance care than the British;

- (g) It should not be concluded that satisfaction was felt throughout with the rate of progress achieved on the British job; and when, for the reason stated above under "Residual Rock Areas", the scope of the job was extended, a second firm was brought in, to take over the additional work to be incurred.
- (h) In planning future jobs of this sort in this country, it ought, generally speaking, to be possible to reckon on more rapid completion than was achieved on the British Factory, whether the work be on the scale of that or of the German factory. But to accelerate to the pace realised in the latter case would, under the conditions prevailing in this country, probably involve heavy additional expenditure on overtime and on plant,

In conclusion, the Report refers to various aspects of the German Factory not considered above. The comparison has been confined to fundamental topics such as labour, costs, rapidity of execution, treatment of exposed surfaces and security of design because it appeared that by viewing these in a British perspective the significance of the German facts and ideas might more readily be assessed.

APPENDIX 2 (A)

BY H.W. CREMER, M.Sc., F.R.I.C., M.I. Chem E.

THE TREATMENT OF INTERNAL ROCK SURFACES OF CORRIDORS AND GALLERIES AT AN UNDERGROUND FACTORY CONSTRUCTED IN SANDSTONE IN GREAT BRITAIN DURING THE WAR

It having been decided that the galleries should not be lined except in a few special cases, it was necessary to devise a method whereby the freshly cut rock surface could be treated in such a manner as to render the walls and ceilings suitable for the operations to be carried on within the galleries. The conditions to be met were:-

- (1) Hardening of the surface of the sandstone walls and ceilings to ensure freedom from dust and to provide a good key for the final surface finish.
- (2) A decorative finish suitable in colour and light reflecting properties.
- (3) Porosity in the hardened outer layer of rock and finishing coat or coats of decorative material.
- (4) Resistance of the finished surfaces to the temperature which it was desired to maintain in the galleries and to process fumes, etc., without impairing (1) to (3) above.

Of these desiderata, (3) is of especial importance, in order to permit of "breathing" of the walls, without which pressures would be set up behind the treated surfaces due to percolating waters in the rock, resulting in breaking away or flaking off of portions of the roof and walls. Moreover, if sodium silicate is used as the hardening agent for the natural rock in (1), then the porosity of the hardened surface layer must be such as to permit of free efflorescence of salts. For, using sodium silicate, the hardening effect is attributed to the precipitation of silica in the pores by reaction with carbon dioxide from the surrounding atmosphere or in the moisture present in the rock. The sodium silicate does not enter into combination with the sandstone. The precipitated silica, being insoluble in water, is not readily washed out by the natural moisture in the rock, but sodium carbonate (the by-product of the reaction) is soluble, and this by-product, in addition to water, must be permitted to find its way freely to the surface. Unless this free access to the surface is ensured, additional pressures will be set up in the rock due to salt formation within the surface layer, pressures which are avoided if the treated surface is permeable, thus allowing the salt (sodium carbonate) to pass through it and to appear in crystalline form

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externally as an efflorescence. It is clear, therefore, that no method of treatment will be satisfactory which leaves in an impermeable condition either the hardened "skin" of natural rock or the decorative finish which is finally applied to it. For this reason, oil-bound paints were ruled out; also, on account of their incompatibility with the alkaline characteristics of sodium silicate.

As a result of trials in situ, followed by tests carried out at the Government Laboratory on samples of the treated rock, it was ascertained that the desired results could be obtained by hardening the freshly cut surface with sodium silicate (after preliminary brushing and air-blasting of the ceilings and walls to remove loose sand particles) followed by application of Messrs. Stucco's Stet Porous Paint of the desired colour. The Silicate solution employed was the P.84 quality supplied by Imperial Chemical Industries, Ltd. This was used in the proportion of 8 volumes silicate solution to 2 volumes of water, and the mixture was applied by a jet (not a fine spray), so that the rock was well washed down after the preliminary brushing. The Stet Porous Paint was applied as a spray.

In order to ensure uniformity in the application of the sodium silicate during the hardening pre-treatment, Paris White (calcium carbonate) was added in the proportion of 3 pounds to 1 gallon of the silicate solution to colour the latter. This provided an effective visual method of following the course of the operation, the object being to ensure that no part of the surface received more than one coat of the silicate solution. It had been previously ascertained that the addition of Paris White as a tinting agent had no deleterious effect on the porosity or on the final finish with Stet.

Tests on samples of the treated rock showed that with one coat of silicate of the above strength plus one coat of Stet finish, the rock remained porous and allowed free passage of water vapour and efflorescence of salts. With one coat of silicate plus two coats of Stet, the porosity was considerably reduced and had reached a point when it could not be said that the surface was sufficiently permeable for this to take place. The conclusion reached was that it might be dangerous to use more than one coat of Stet following a single pre-treatment with silicate of soda.

In carrying out these tests marked differences were noticed in the porosity of the untreated samples, and equally marked differences in the hardness of the silicate-treated surfaces. Obviously, these varying conditions should govern (a) the concentration of the silicate applied, and (b) the thickness of the Stet coating which followed. In general, the harder the natural rock, the less porous will it be, and consequently the applied silicate should be somewhat weaker and the coating of Stet thinner. Although in practice endeavours were made to allow for these varying conditions, the speed at which tunnelling and constructional work had to be carried out made it

impossible to control operations as carefully as would otherwise have been the case.

Tests were also carried out on samples of the treated rock to ascertain the effect of changes of temperature in the galleries. The rock surfaces were exposed each day to heating conditions for about 8 hours, followed by cooling conditions for the rest of the 24 hours. The temperature of the rock surface during the periods of heating was approximately 120°F., and during the periods of cooling it varied between 60° and 70° F. After 10 days, during which the samples were exposed to the higher temperatures for a total time of 60 hours, portions of the samples exposed to the test treatment were then compared with unexposed portions of the same samples as regards porosity and general appearance. The conclusions reached were that exposure to higher temperatures tended to make the surfaces more brittle and more easily removed, and, if anything, to increase very slightly the porosity. No noticeable difference in general appearance was observed.

In practice, as tunnelling proceeded, the final shaping of the walls and ceilings was immediately followed by removal of adhering sand by air-blast, followed in turn by pre-treatment of walls and ceilings with the tinted silicate solution. In cases where particularly wet patches of rock were encountered, an initial treatment with more dilute silicate solution was given, which permitted of greater penetration of the sodium silicate into the rock. The normal silicate treatment was then applied. In the rare cases in which a continuous flow of water emerged from the rock, the water was piped away to the drains below the floors through chases in the walls.

One coat of the Stet Porous Paint was then given to the roof and walls down to a height of 8 feet or so above floor level, the remainder of the Stet finish down to floor level being applied after the main constructional work had been completed. The object of this was to avoid as far as possible extra coatings of Stet to cover disfiguration of the walls during installation of services, plant, etc. In cases where later disfiguration occurred, provided the area to be made good was not excessive, it was considered that the general conditions would not be appreciably affected if a second coat of Stet were applied to ensure a good overall decorative finish.

Provided that the above procedure was rigidly adhered to, results showed that when heating was applied to the tunnels by means of the ventilation ducts, adjustment of the moisture equilibrium within and outside the walls appeared to take place quite satisfactorily. Free efflorescence of sodium carbonate occurred, which could be easily removed by wiping off with a damp cloth. An inspection of the tunnels some six months after the final wall treatment revealed that no serious trouble had been experienced, and that where there had been a tendency for the Stet to flake off here and there, the custom was to scrape the surfaces, renew the silicate hardened skin, and apply the

Stet finish as before. Where the walls or ceilings had become discoloured through accumulation of dust, this could readily be removed, leaving a perfectly clean surface.

In order to meet local conditions where corrosive fumes or corrosive liquids might come into contact with the rock surfaces portions of the walls were treated with a Cement Fondu/Silicate preparation supplied by Imperial Chemical Industries, Ltd. There was insufficient time, however, in which to test the results of such treatment, and, in places where splashing by acids was likely to occur, the walls were brick lined.

In conclusion, so far as the writer is aware, the method of treatment described above proved generally satisfactory for the purpose required. In view of the need for the greatest possible speed in making the underground factory available for production, as already indicated, it was inevitable that the treatment of the tunnels should not be as uniform and carefully controlled as was desirable. In places where extra thickness of Stet had been applied, such as to destroy or greatly reduce the porosity of the surfaces, the conclusions at first reached were confirmed, viz., that pressures would be set up which would tend to cause spalling of sections of the rock under these conditions.

The final appearance of the corridors and galleries, particularly where fluorescent lighting was used, was bright and pleasant, and, even in offices and canteens, exposed portions of the rock walls and ceilings by no means created the impression of a cave dwelling.

APPENDIX NO. 3

TUNNELLING PLANT

All the factories visited by this party were situated either in massive anhydrite or in soft to medium sandstone and in every case excavation was mainly by drilling and blasting.

Rock Drills

Light hand-held compressed air drills were used, and no bar mounted machines were seen. The machines were supported on a wooden leg when at work. The fact that all workings were in soft rock made their use possible, and they had the advantage that work could be started immediately after blasting, without any "mucking back". In the softer sandstones much use was made of light hand held pneumatic picks; a pilot heading was driven and opened out by their means to the finished size. This saved explosives, prevented overbreak, and made falls of loose rock less probable. In all cases drilling was dry.

At Dachs I and IV where many "Raises" were driven an interesting device was found. This consisted of a compressed air cylinder with a stud at one end fitting into a hole in the handle of a "jack hammer" thus converting the machine into a "stopper" drill for drilling vertical holes upwards. Probably as a result of the type of drill used holes were short, and 5' to 6' rounds were the rule, however, at Osterode and Niedersachswerfen rounds of 10' to 12' were obtained.

Drill Steel

As a rule 1" round steel with square shanks were used Chisel, 4 points and six point bits were seen, but chisel bits were the commonest. At Longenstein detachable bits were said to have been employed. At Niedersachswerfen auger steel was seen on the site.

As the rock was soft on all the sites visited, the steel sharpening was usually by hand, but at Dachs I a well equipped shop with mechanical sharpeners, oil fired furnaces and an automatic tempering device was found.

Loaders

Great use was made of mechanical loaders in all the factories visited and this is the more surprising as so much slave labour was available.

At Dachs IV "slusher's" of orthodox design were seen, but here and elsewhere compressed air shovels of a type known as the

"Salzgitter-Lader" were the most common. This machine is fully described below. A smaller but similar machine the Schrapper Lader was also used.

Salzgitter-Lader (mucking machine for Tunnel Work), manufactured by Herman Goring Werke (A.G. fur Bergbau und Huttenbedarf, Salzgitter).

Abridged
Abstract of Published
Particulars

A machine for use on ore, coal, potash - above or below ground - on sand, gravel lime or slate; on deep excavations, railway work and Tunnels.

For loading into trucks, or on to conveyors or for dumping. It digs the material and deposits it into a truck coupled to the machine or on to a belt. For instance, the loader can be run up to the job on a single track in a breadth of 1.8 metre (5 ft. 10 in.) and a height of 2.3.m. (7 ft. 6 in.)

Technical Data

	<u>Metrical Units</u>	<u>British Units</u>
Total weight	rd. 5½ t	5½ tons
Capacity	0.3 m ³	10.6 cu.ft.
Overall length (bucket advanced)	2650 m.m.	8' - 8"
Minimum length (bucket raised)	1750 m.m.	5' - 9"
Breadth, over controls	1200 m.m.	3' - 11"
Ditto. excluding controls	1000 m.m.	3' - 3"
Minimum height (whilst bucket is being tilted)	1650 m.m.	5' - 5"
Maximum height (whilst bucket is discharging)	2150 m.m.	7' - 0"
Permissible height of truck	1400 m.m.	4' - 7"
Wheelbase	1000 m.m.	3' - 3"
Gauge of track (min.)	485 m.m.	1' - 7"

18444

	<u>Metrical Units</u>	<u>British Units</u>
Swinging range, on either side	30°	30°
Breadth of working face	2200 mm.	7' - 3"
Output, according to material and working conditions	50/60 t/h	50 to 60 tons per hour

The travelling and cutting motions are effected by two interchangeable four-cylinder reversing compressed-air motors.

The swinging (30° each side) is by two compressed-air cylinders.

The bucket has two cradle-shaped sides and its action, when cutting, is elastic (N.B. By virtue of helical springs).

Swinging is effected by means of two compressed-air cylinders.

The filled bucket is guided during the raising motion and in its passage to the emptying position in such a manner that lateral motion is prevented. The attendant has nothing to do, and the emptying into a truck, which is coupled to the loader, or on to a conveyor belt, is automatic. The raising is done by a link chain which causes the sides of the bucket to roll back, it being steadied by the guide mechanism attached to the body. The discharge takes place by gravity.

The truck to be loaded is coupled to the loader automatically by means of a compressed-air coupling device, whilst the uncoupling is done by the attendant by means of a lever. Simultaneously, the same lever operates a mechanism which pushes the loaded truck to the rear. This automatic coupling device obviates the need for coupling and uncoupling by hand and prevents accidents.

The controls are so arranged that, on the release of the lever, the mechanism returns to the mid-position and danger is averted.

A sketch showing the operation of the machine is attached.

Transport

In the smaller workings hand tramming was usual, but elsewhere a great variety of locomotives of various gauges were employed. These included steam, diesel, compressed air and battery locomotives. No one of these types showed features of especial interest.

Miscellaneous Plant

(1) Spoil Spreaders

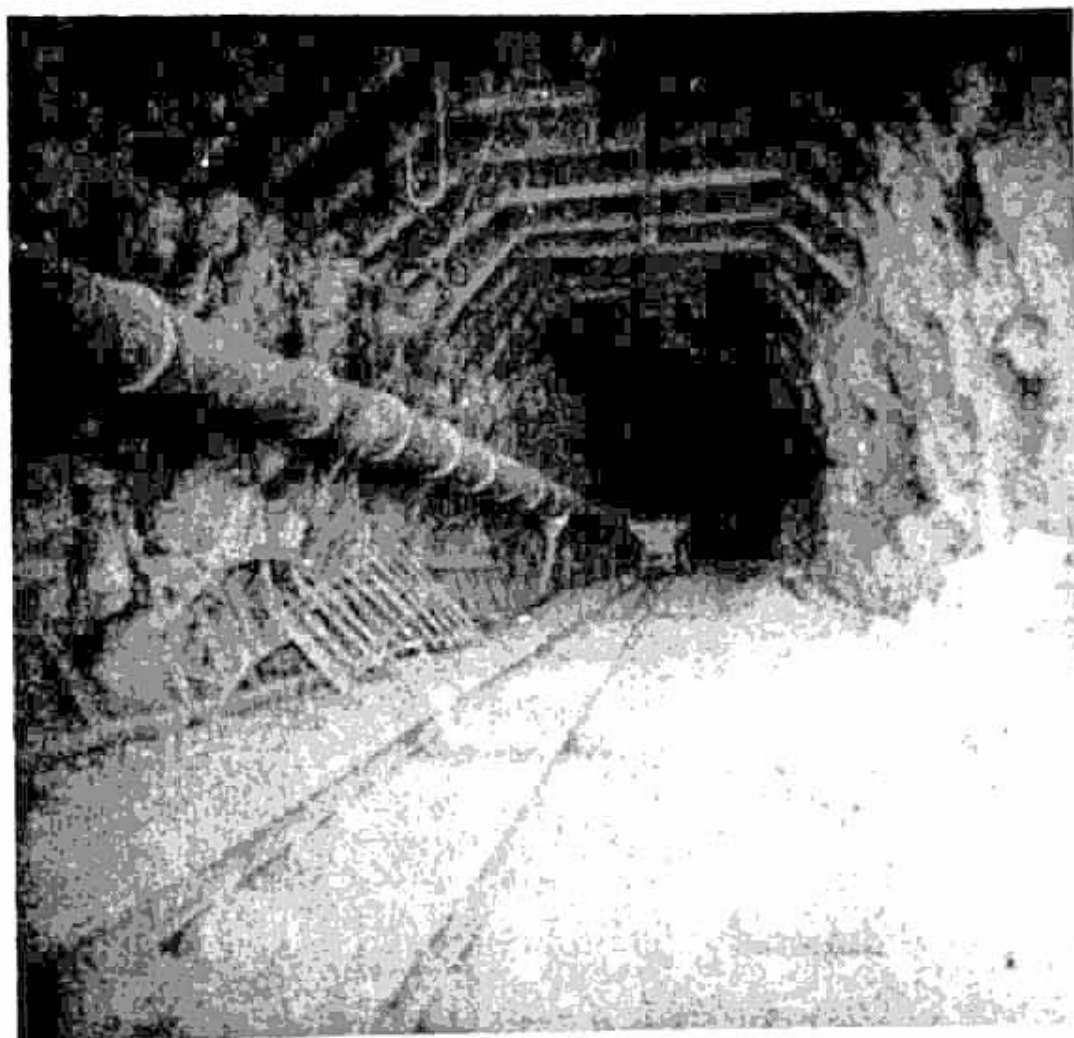
At Langenstein a type of spreader was seen which is obviously a useful labour saving device where spoil is to be disposed of by dumping and slewing. This machine, which is shown in photograph No. 28, consists of a bogey on which is mounted a crab winch and on either side of which are carried V shaped ploughs which can be raised or lowered by means of the winch; it thus operates on either side, or travelling in either direction. Attached to a train of wagons it spreads the spoil as it is dumped.

(2) Tunnelling Machine

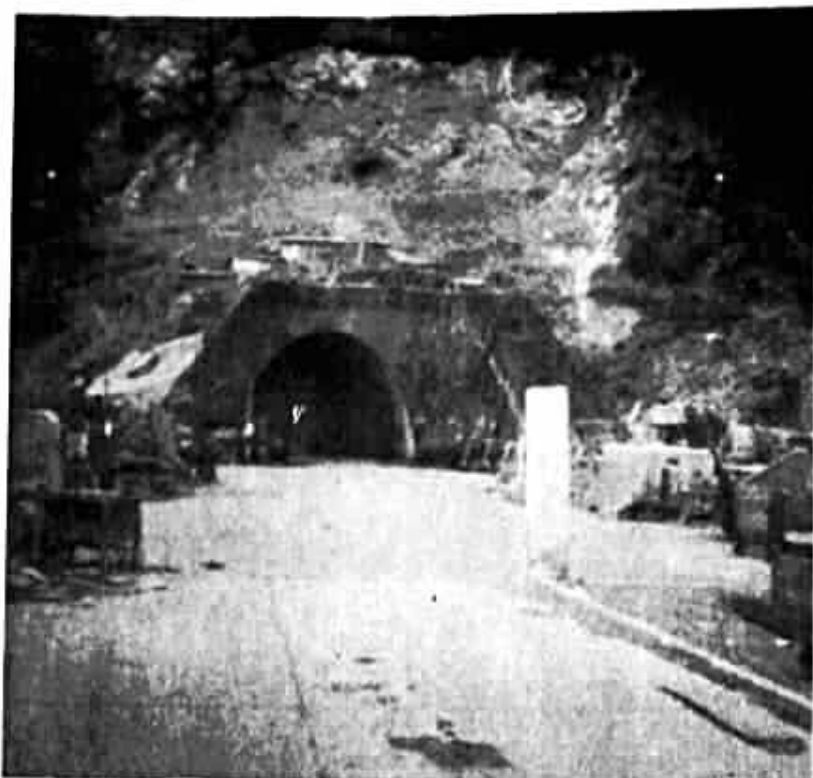
At the factory of the Aktiengesellschaft für Bergbau und Hottenbedorf near Salzgitter photographs were seen of a tunnelling machine intended to drive horizontal galleries of circular section of about 6' - 0" diameter in soft sand stone.

We were informed that one such machine had been built and put to work, but no information could be obtained on its performance. The machine consisted of spider carrying a number of rotating cutters about 6" diameter and tipped with a hard alloy, these cutters being spaced out radially and cutting a series of concentric circular grooves.

The design was mechanically ingenious, but it must be remembered that many tunnelling machines have been devised in the past, but with the exception of the Greathead Shield all have failed for they cannot be adapted to the many types of ground which are encountered even in comparatively homogeneous strata.



PHOTOGRAPH No.1. Temporary support for railway access tunnel to DACHS 1.



PHOTOGRAPH No.2.

Mittelwerke,
Neidersachswerfen.

Tunnel entrance "C"



PHOTOGRAPH No.3.

Mittelwerke,
Neidersachswerfen.

Tunnel entrance "D".



PHOTOGRAPH No.4.

Langenstein.
Cross Gallery.



PHOTOGRAPH No.5.

Melechit,
Langenstein.

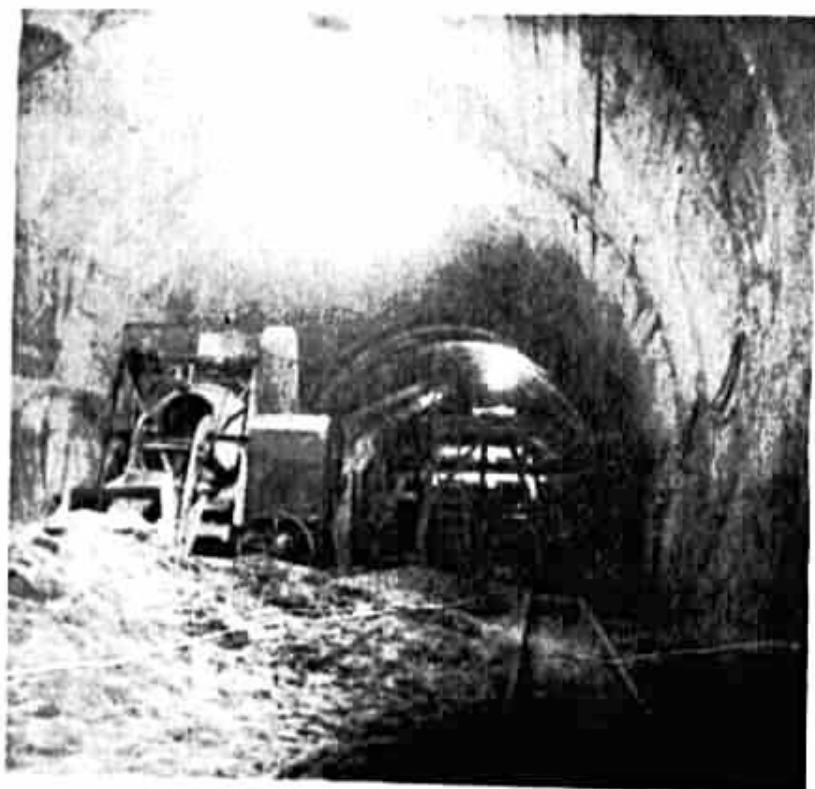
Entrance "N".



PHOTOGRAPH No.6.

Malachit,
Langenstein.

Entrance "D".



PHOTOGRAPH No.7.

Malachit,
Langenstein.

Concrete lining in
progress.



PHOTOGRAPH No.8.

Malachit,
Langenstein.

Concrete lining
in progress.



PHOTOGRAPH No.9.

Malachit,
Langenstein.

Brick lining at
intersection of
galleries.



PHOTOGRAPH No.10.

Malachit,
Langenstein.

Lining of steel
ribs with brick
jack arches.



PHOTOGRAPH No.11.

Mekrele II.
Halberstedt.

Entrance to
Champignon caves now
used as a factory.



PHOTOGRAPH No.12.

Makrele I.
Helberstadt.

Entrance to
Champignon caves.



PHOTOGRAPH No.13.

Makrele I.
Helberstadt.

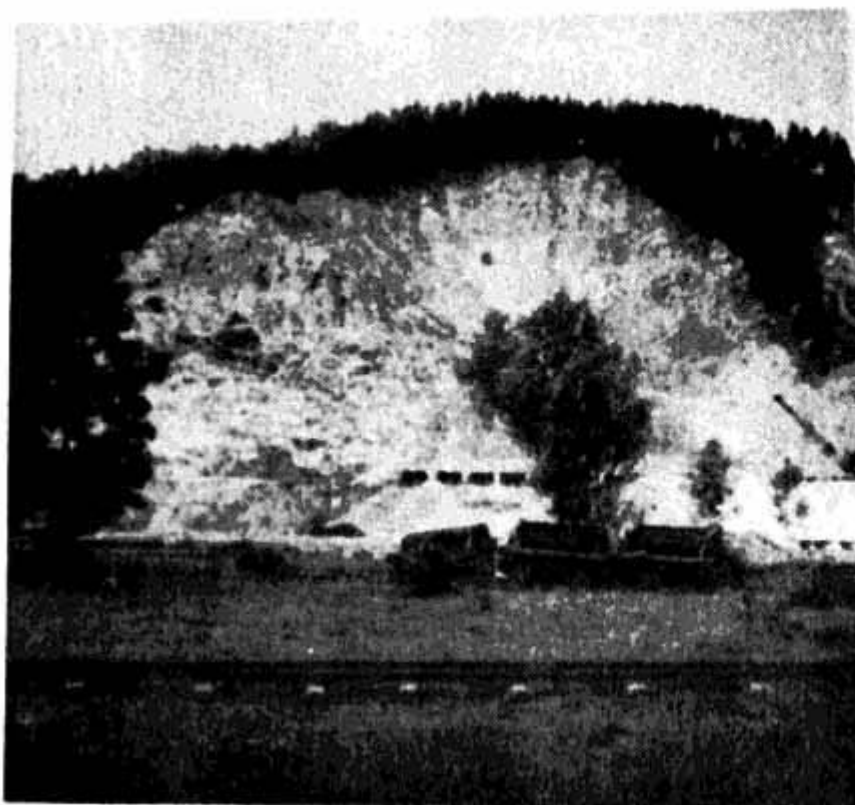
Protection to
ventilation shaft.



PHOTOGRAPH No. 14.

Elben.

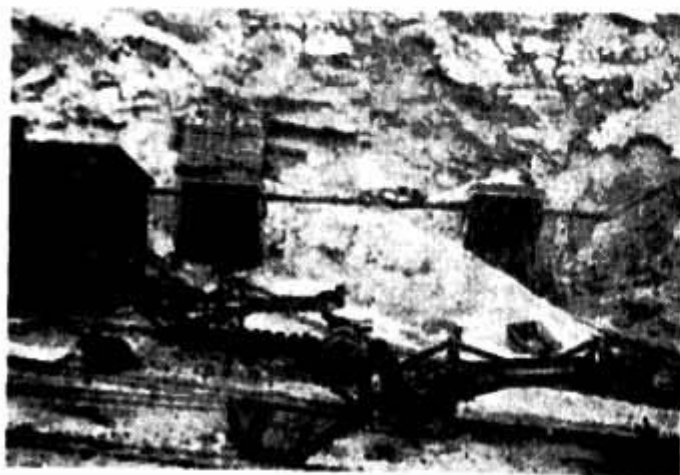
Camouflaged spoil
dump.



PHOTOGRAPH No.15.

Dechs IV,
Osterode.

Anhydrite quarry.



PHOTOGRAPH No.16.

Dechs IV,
Osterode.

Entrance to workings.



PHOTOGRAPH No.17.

Dachs IV,
Osterode.

Anhydrite quarry,
compressor plant
in foreground.



PHOTOGRAPH No.18.

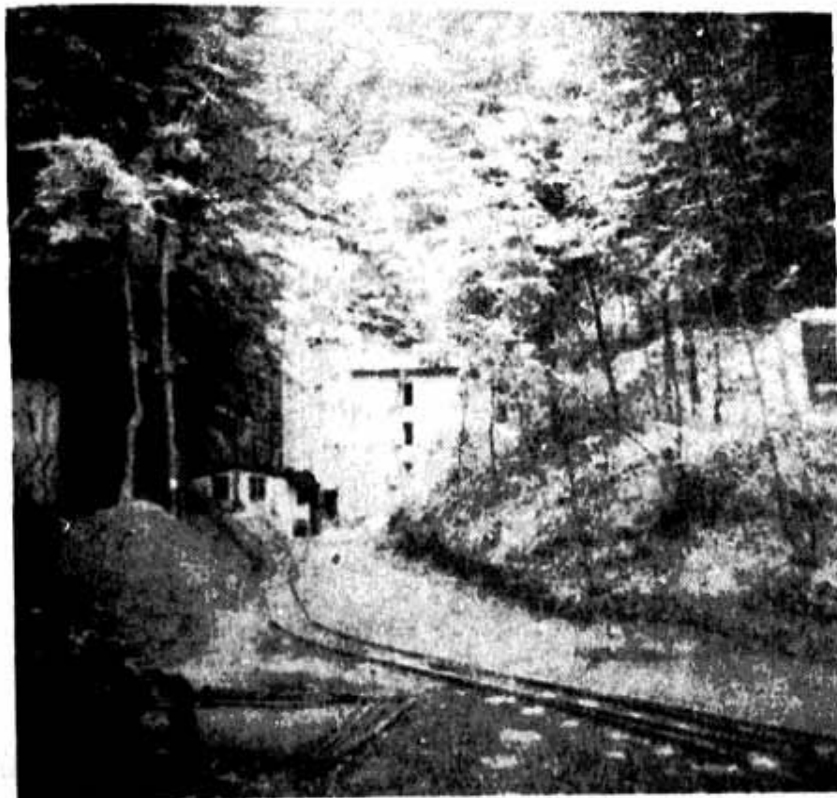
Odawerke,
Regenstein.



PHOTOGRAPH No.19.

Odawerke,
Regenstein.

Entrance to workings.



PHOTOGRAPH No.20.

Denkmal Stollen,
Berkhausen.

Entrance to
factory, showing
blast well.



PHOTOGRAPH No.21.

Denkmal Stollen,
Berkhausen.

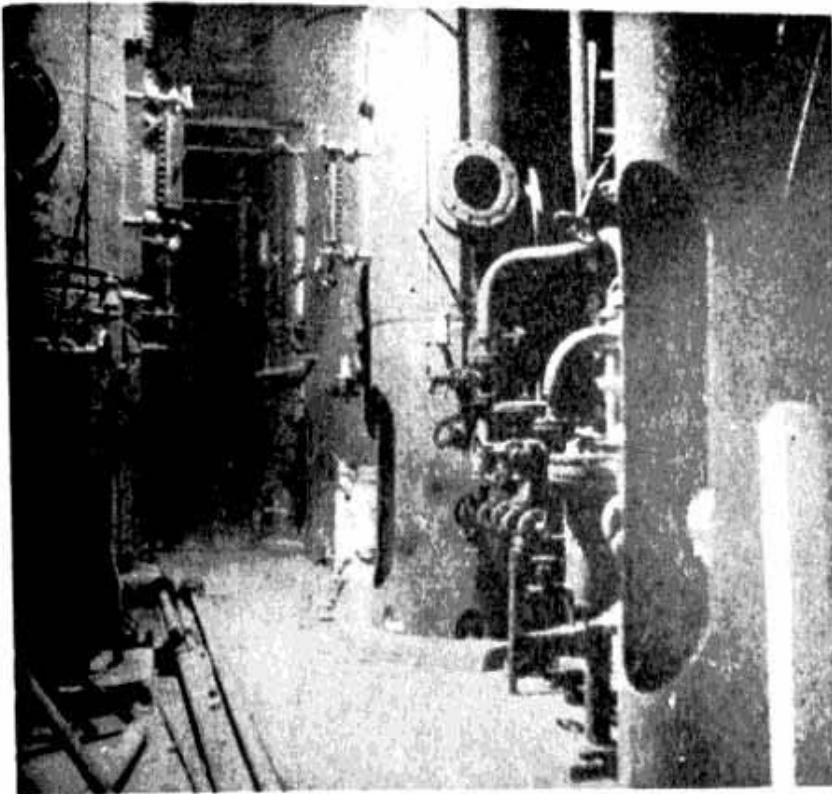
Outcrop of porte
sandstone showing
dip.



PHOTOGRAPH No.22.

Denkmal Stollen,
Barkhausen.

Groundfloor. Note
roof construction.



PHOTOGRAPH No.23.

Dachs I,
Porta Westfalica.

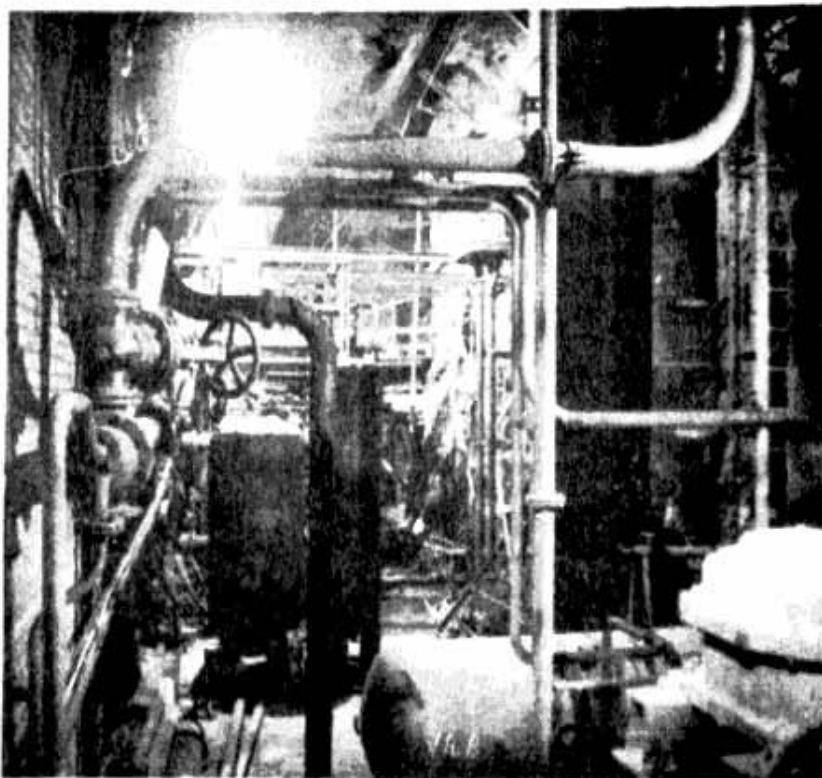
Oil Refinery.



PHOTOGRAPH No.24.

Dachs I,
Porta Westfalica.

Entrance to oil
refinery in Porta
sandstone,
Ornatentone above.



PHOTOGRAPH No.25.

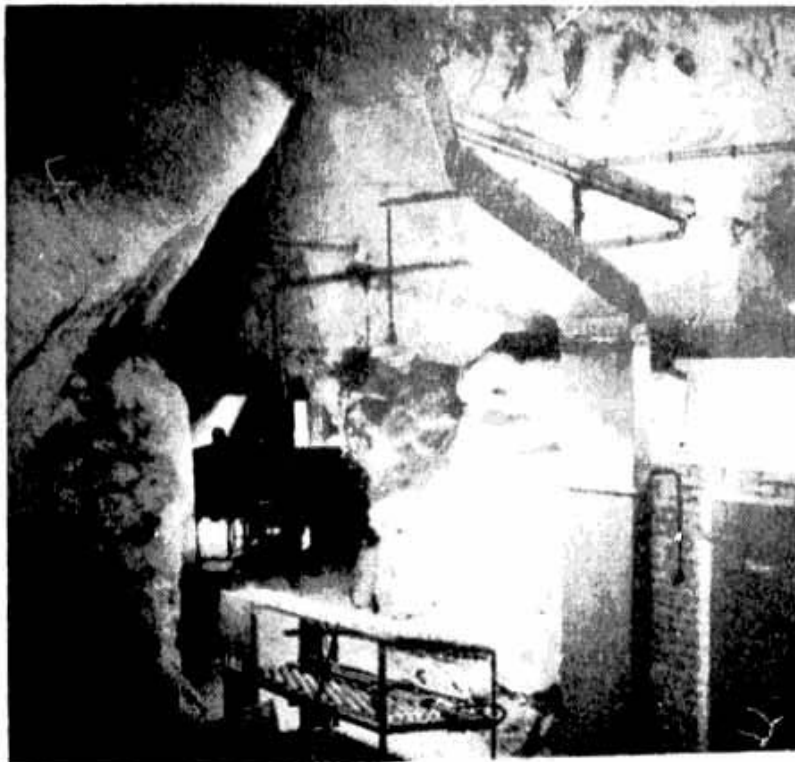
Dachs I,
Porta Westralica.

Oil Refinery



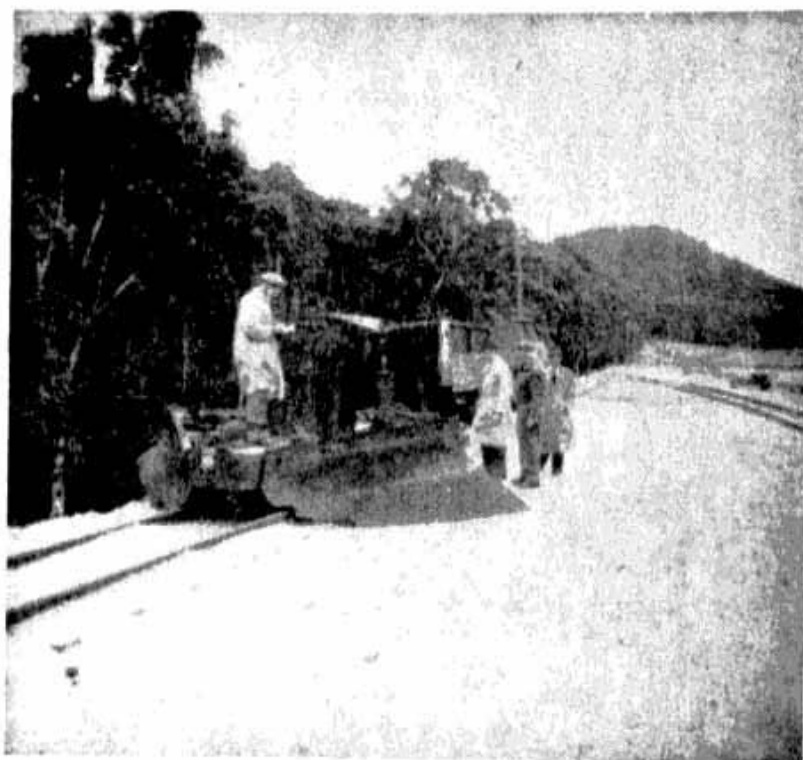
PHOTOGRAPH No. 26.

Hammerwerke,
Porta Westfalica.
Funicular railway from
the entrance to
Hammerwerke. Entrance
to Dachs I below,
River Weser in
distance.



PHOTOGRAPH No. 27.

Hammerwerke,
Porta Westfalica.



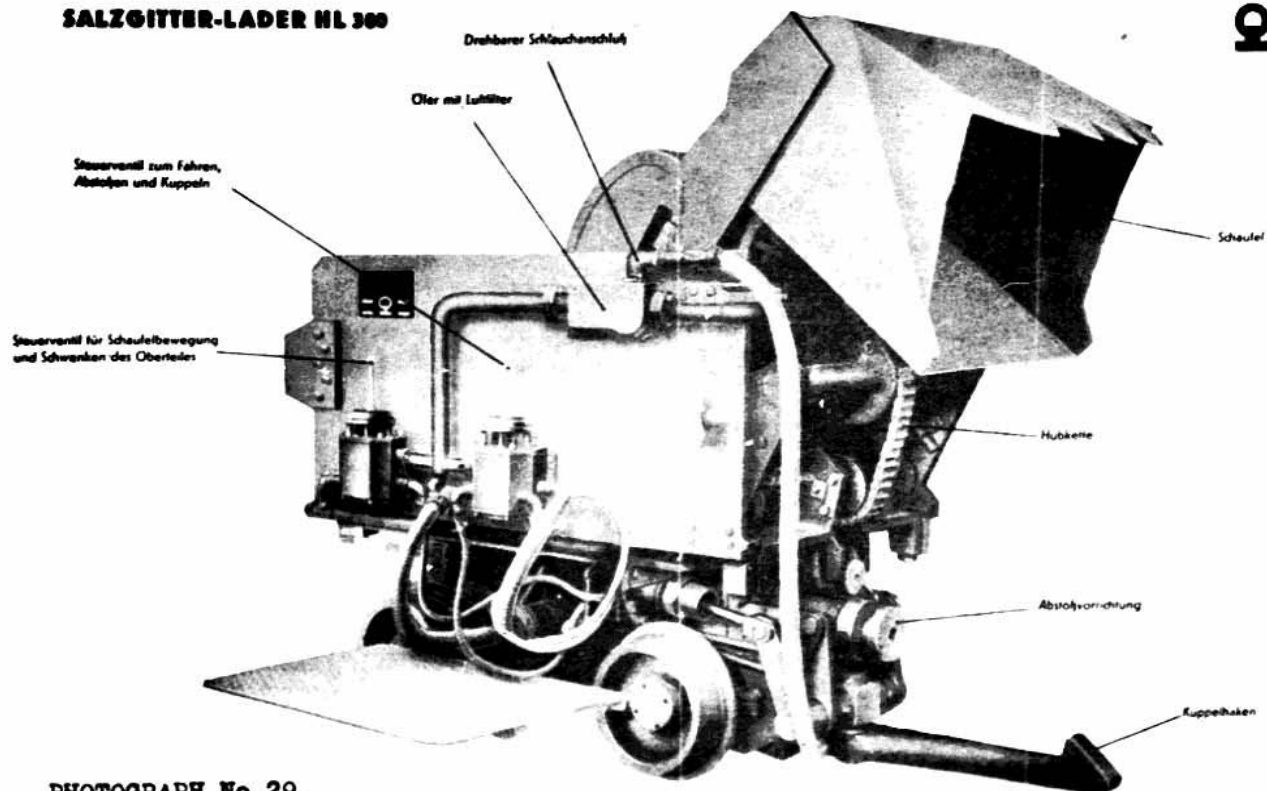
PHOTOGRAPH No.28

Langenstein

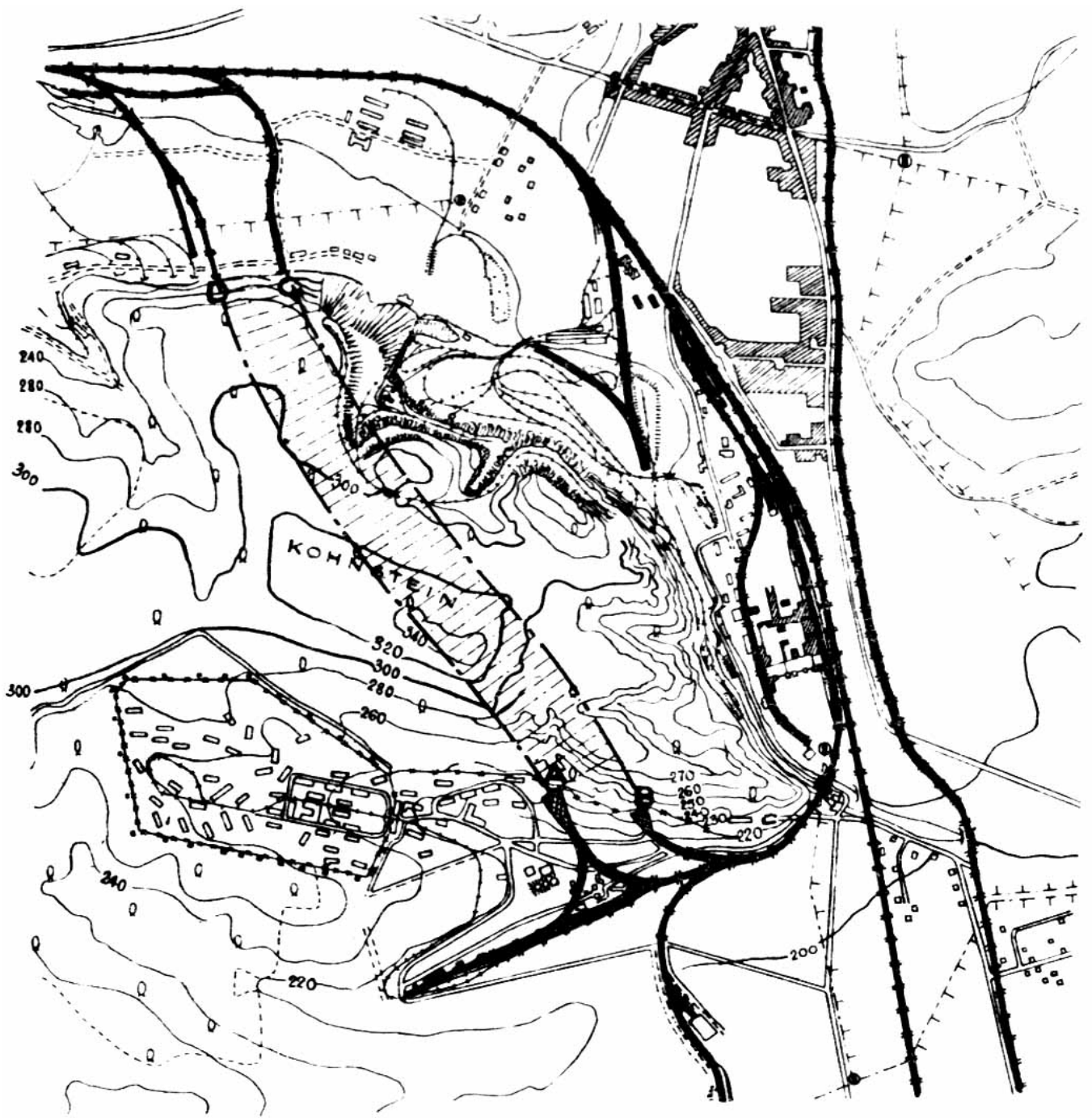
Spoil spreader
on dump.

SALZGITTER-LADER HL 300

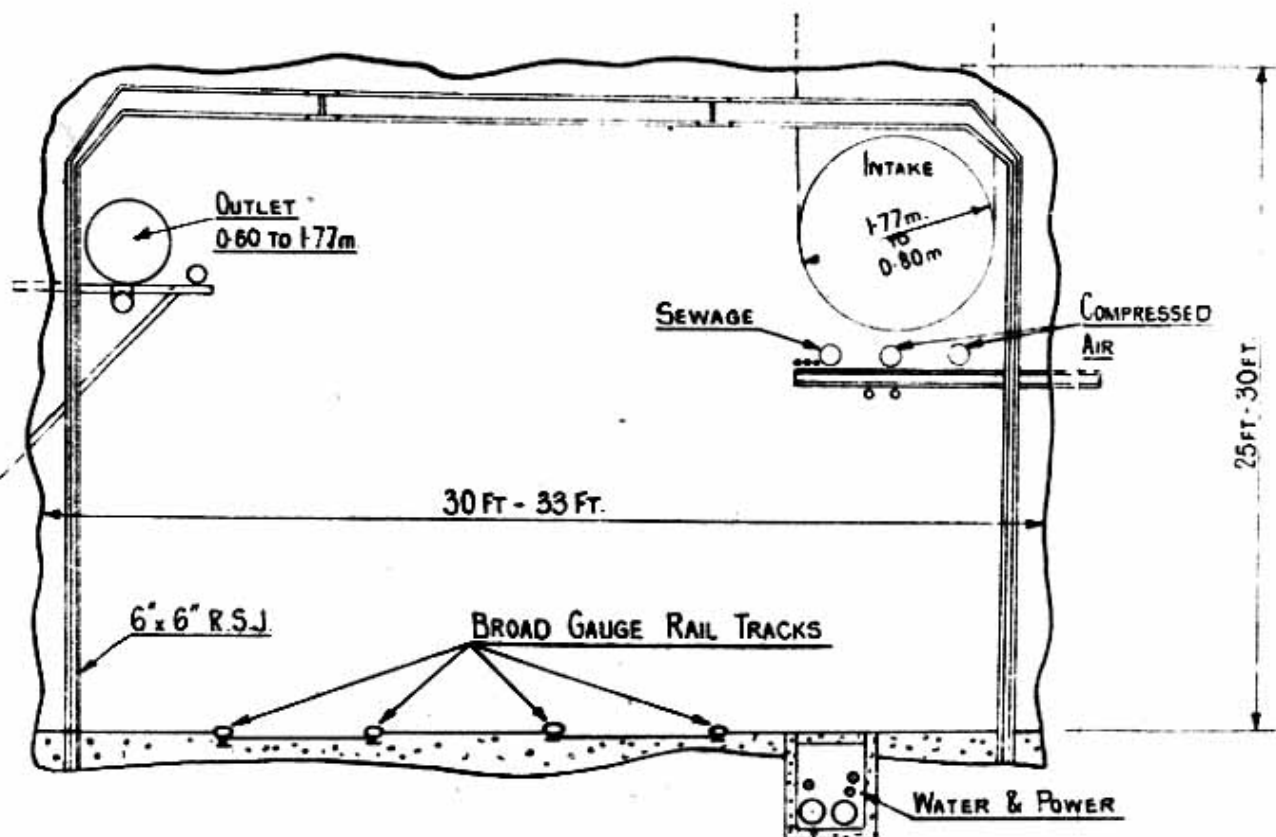
Ω



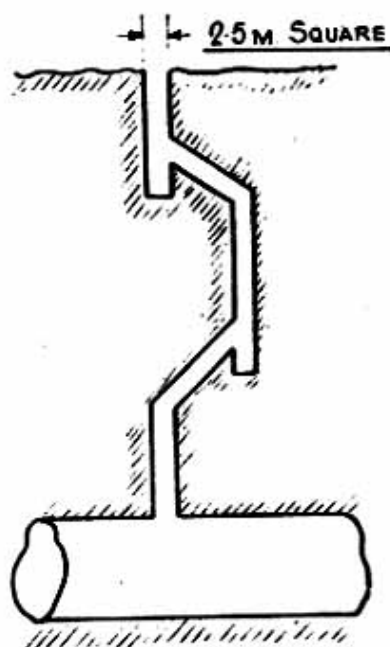
PHOTOGRAPH No.29.
Salzgitter-Lader



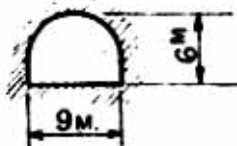
APPROXIMATE DISPOSITION OF TUNNELS SHOWN THUS -----



SKETCH SHOWING GENERAL DISPOSITION OF MAIN SERVICES IN TUNNEL BC



GENERAL ARRANGEMENT OF VERTICAL AIR SHAFTS
FOR PROTECTION AGAINST SABOTAGE AND BOMBS

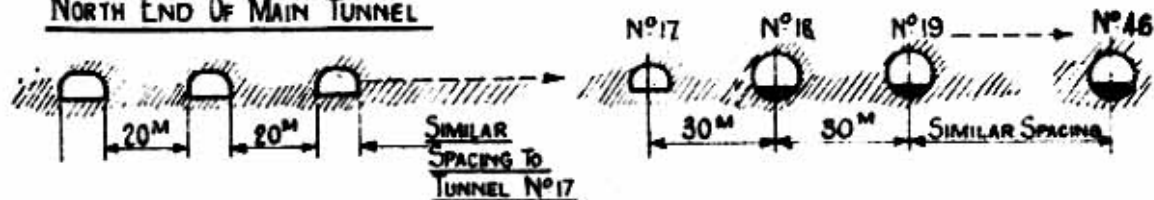


CROSS TUNNELS N^{os} 1 TO 17



CROSS TUNNELS N^{os} 18 TO 46

NORTH END OF MAIN TUNNEL



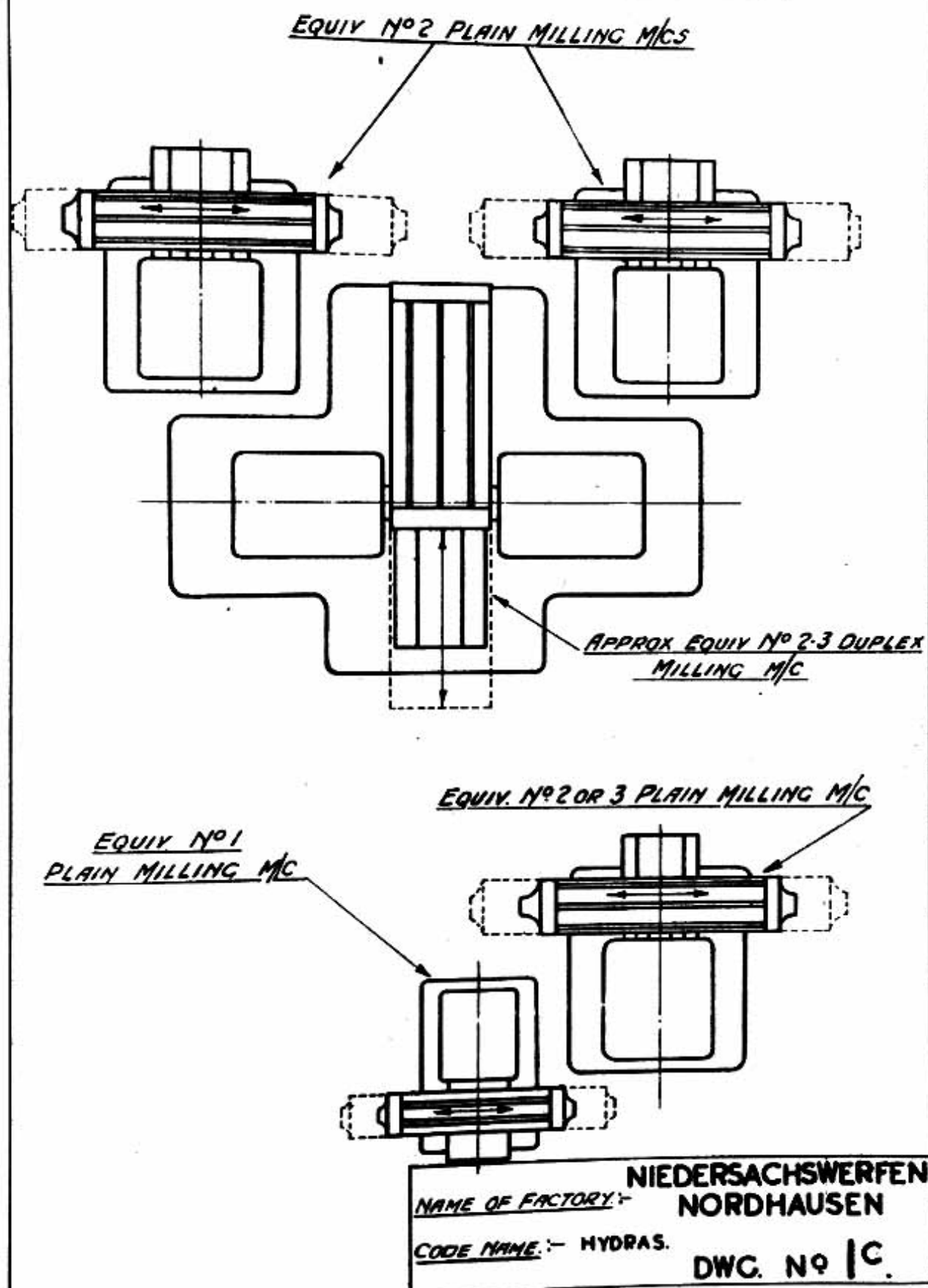
SKETCH SHOWING THE TWO TYPES OF CROSS TUNNELS
AND APPROXIMATE SPACING OF SAME

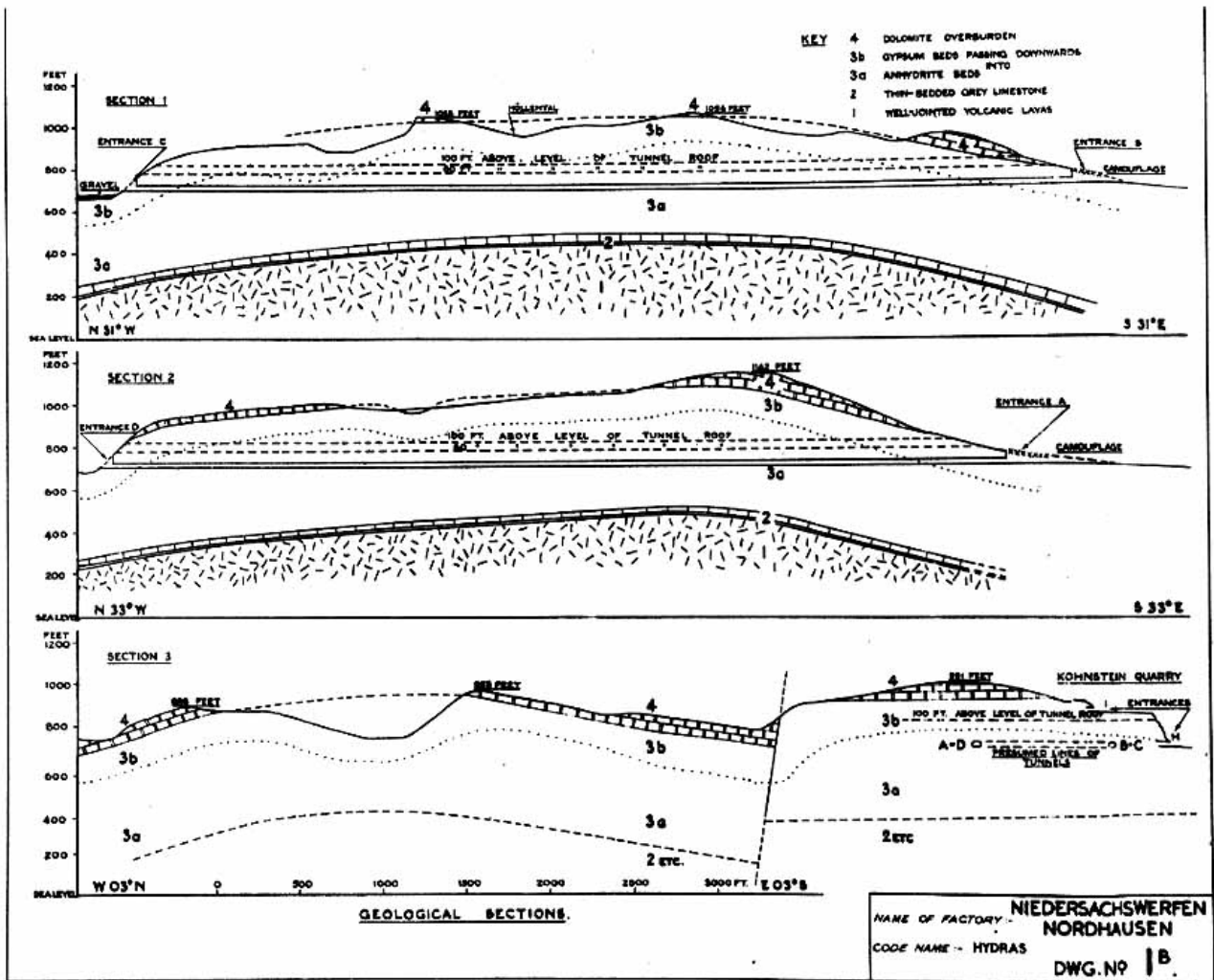
SEE ALSO DWG. N° —
DWG. N° —

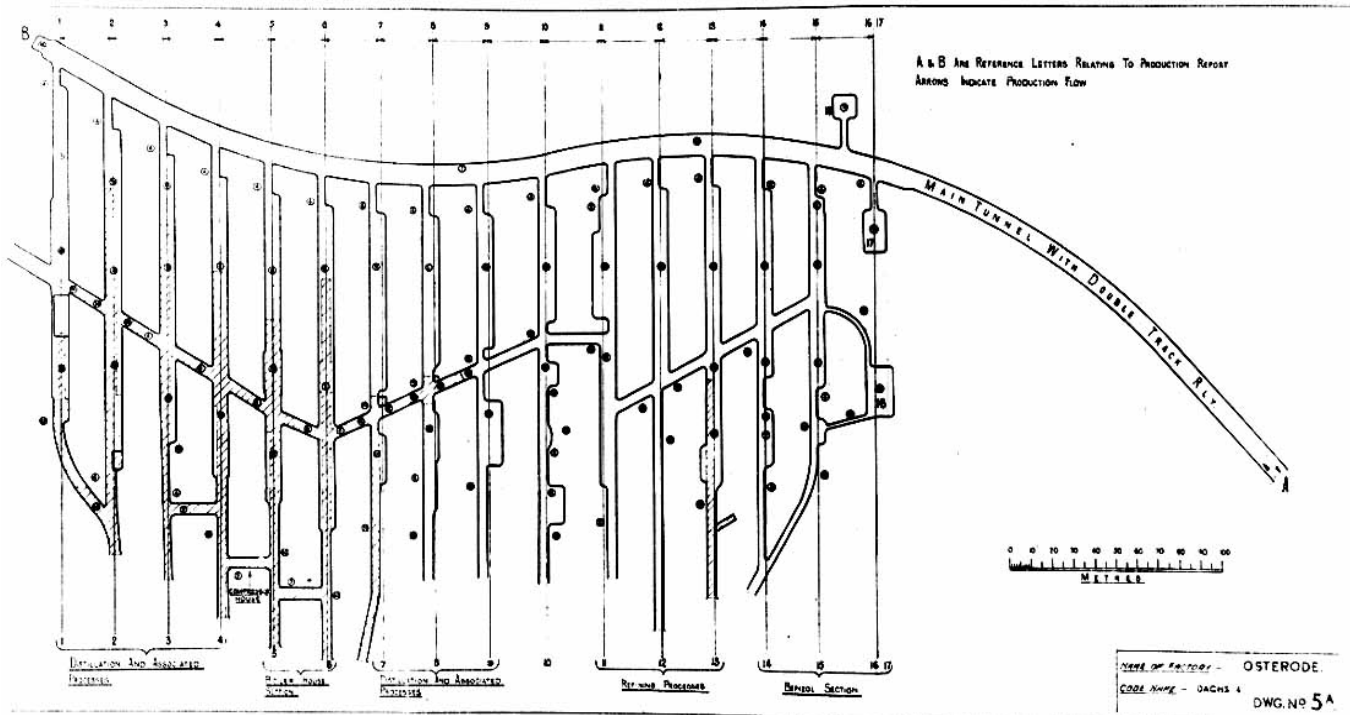
FOR GEOLOGICAL FORMATIONS
FOR SKETCHES RELATING TO
PRODUCTION.

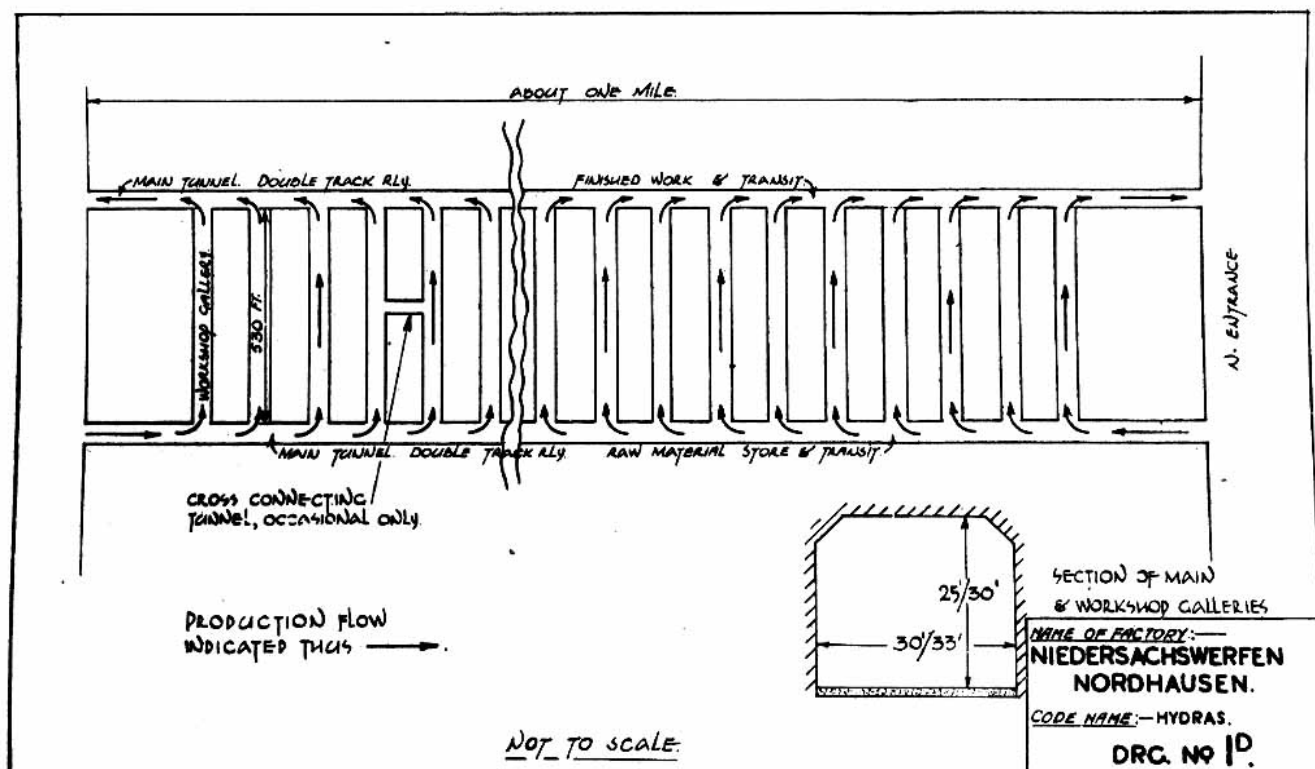
NAME OF FACTORY: — **NIEDERSACHSWERFEN**
NORDHAUSEN.
CODE NAME: — **HYDRAS.**
DWG. No 1A.

TYPICAL SPACE-ECONOMY GROUPING OF MACHINES.

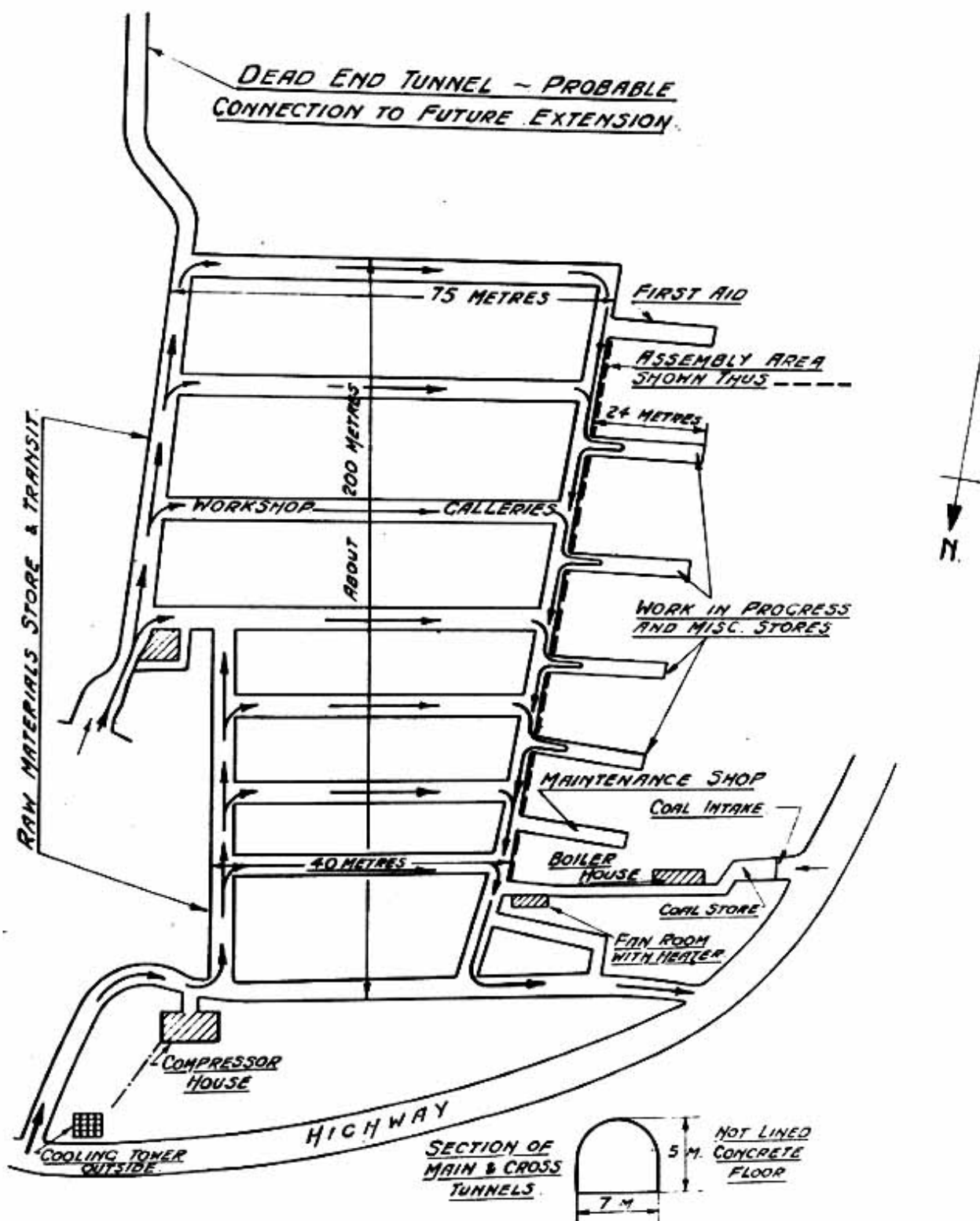






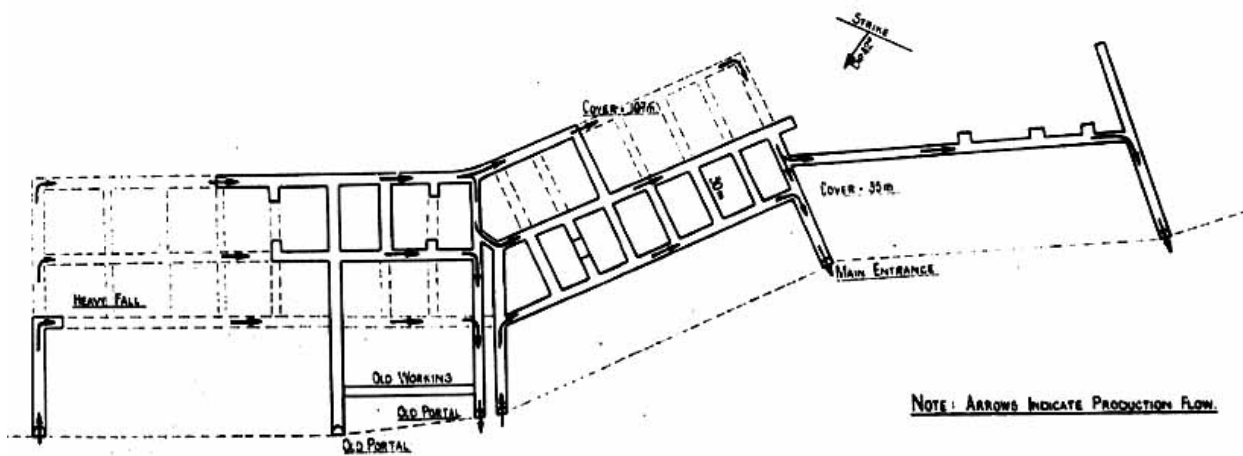
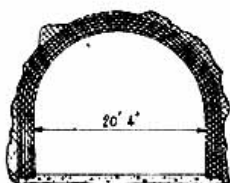
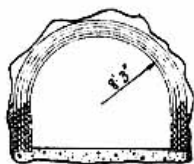




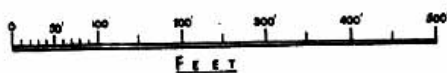


NOT TO SCALE

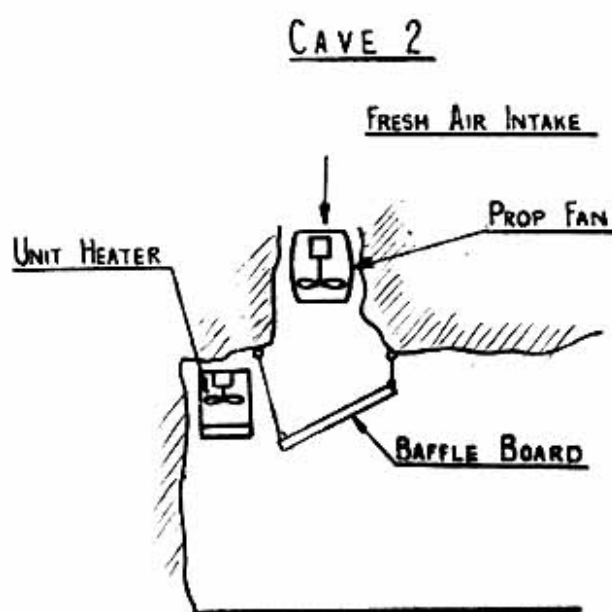
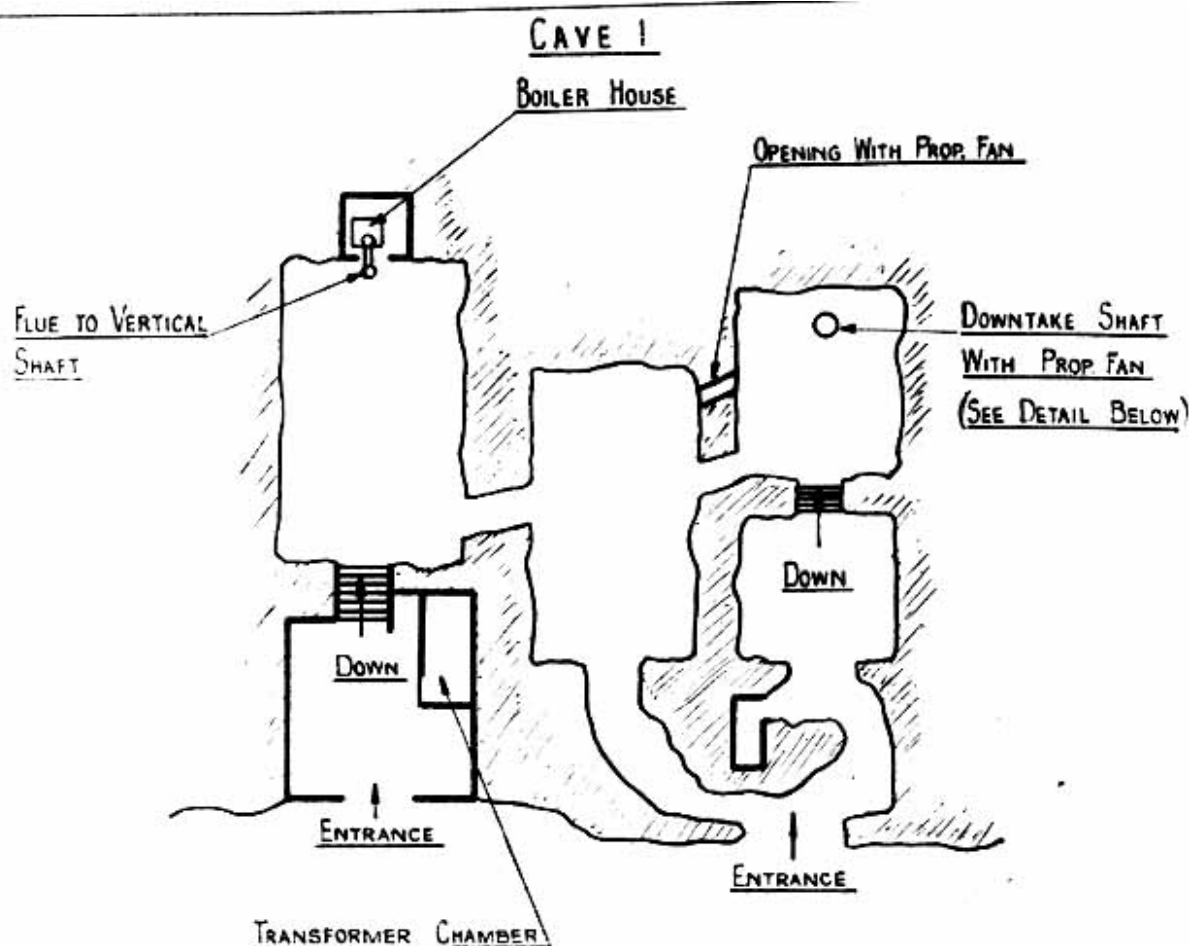
NAME OF FACTORY: **CHAMPIGNON CAVES.**
N^R HALBERSTADT.
 CODE NAME: **MAKRELE I.**
 DWG. No **3A.**



NOTE: ARROWS INDICATE PRODUCTION FLOW.



NAME OF FACTORY: — EL BEN.
 3 MILES SE. OF NAUMBERG.
 CODE NAME: — NOT KNOWN.
 DWG. NO 4A.



NOT TO SCALE

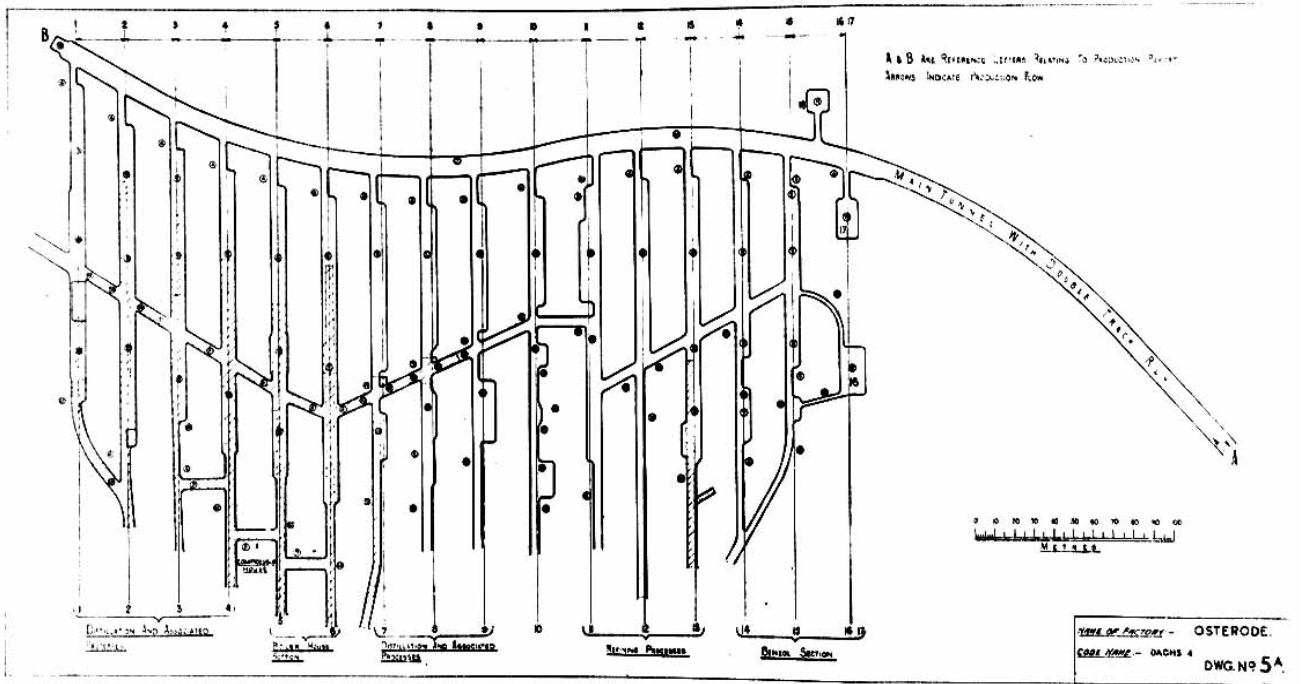
ELEVATION

NOTE: DRAWING RELATES TO CAVES 1 & 2 ONLY
CAVES 3,4,5,6,&7 WERE OF SIMILAR
FORMATION.

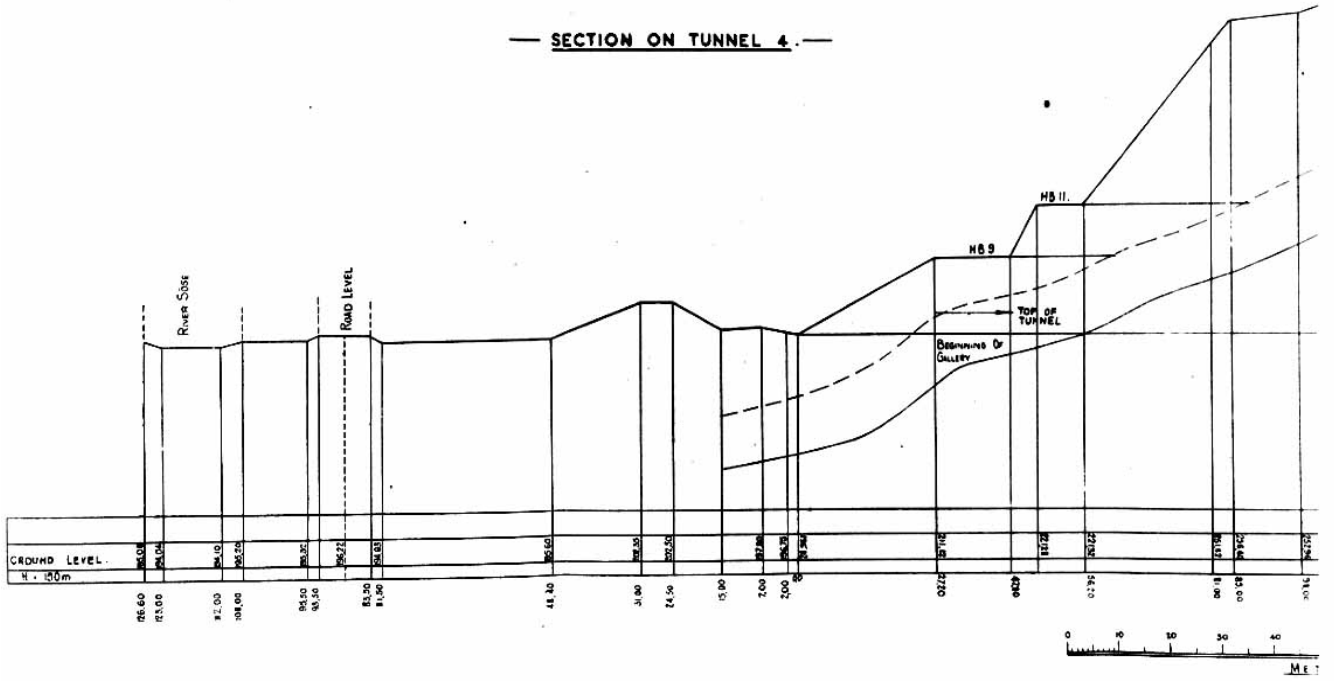
NAME OF FACTORY:-
CHAMPIGNON CAVES.
Nº HALBERSTADT.

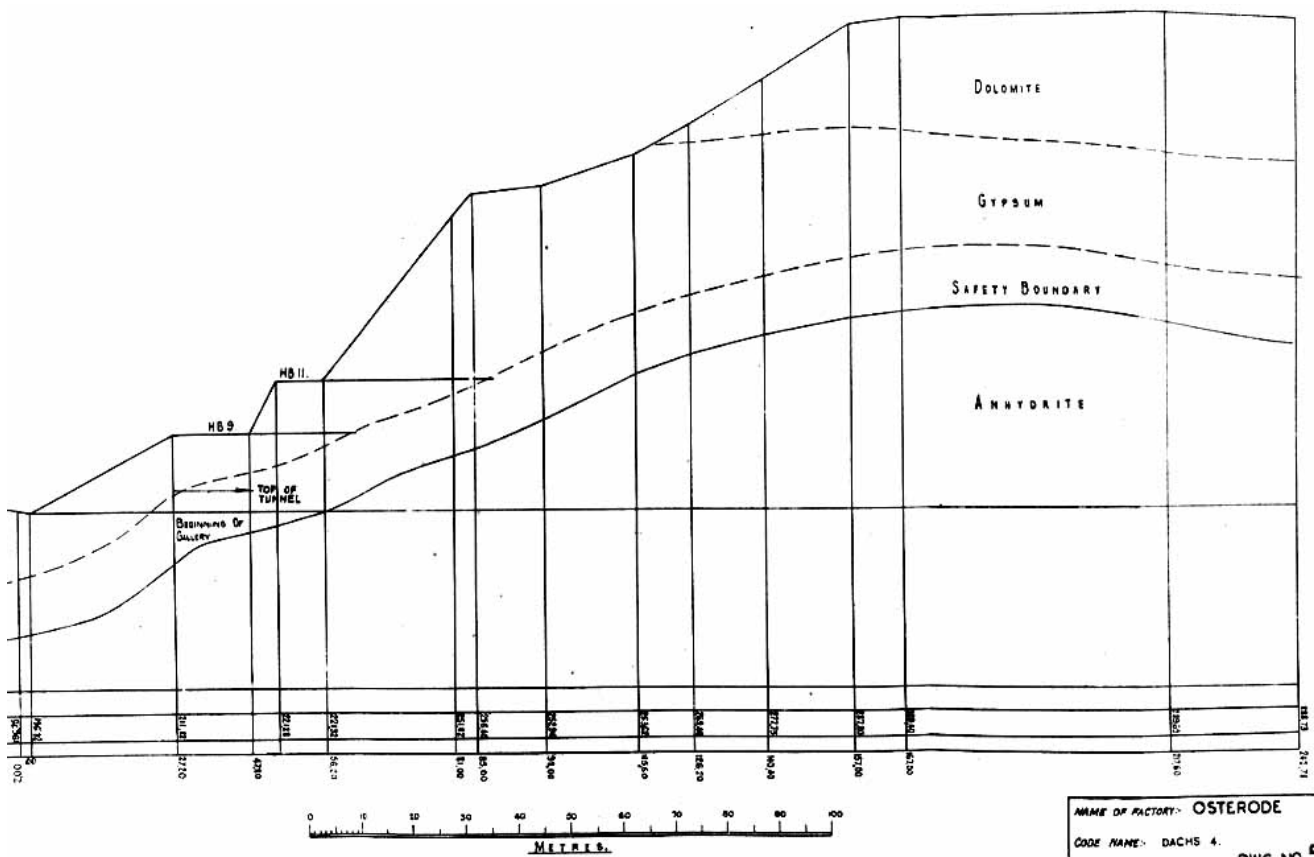
CODE NAME:-MAKRELE II.

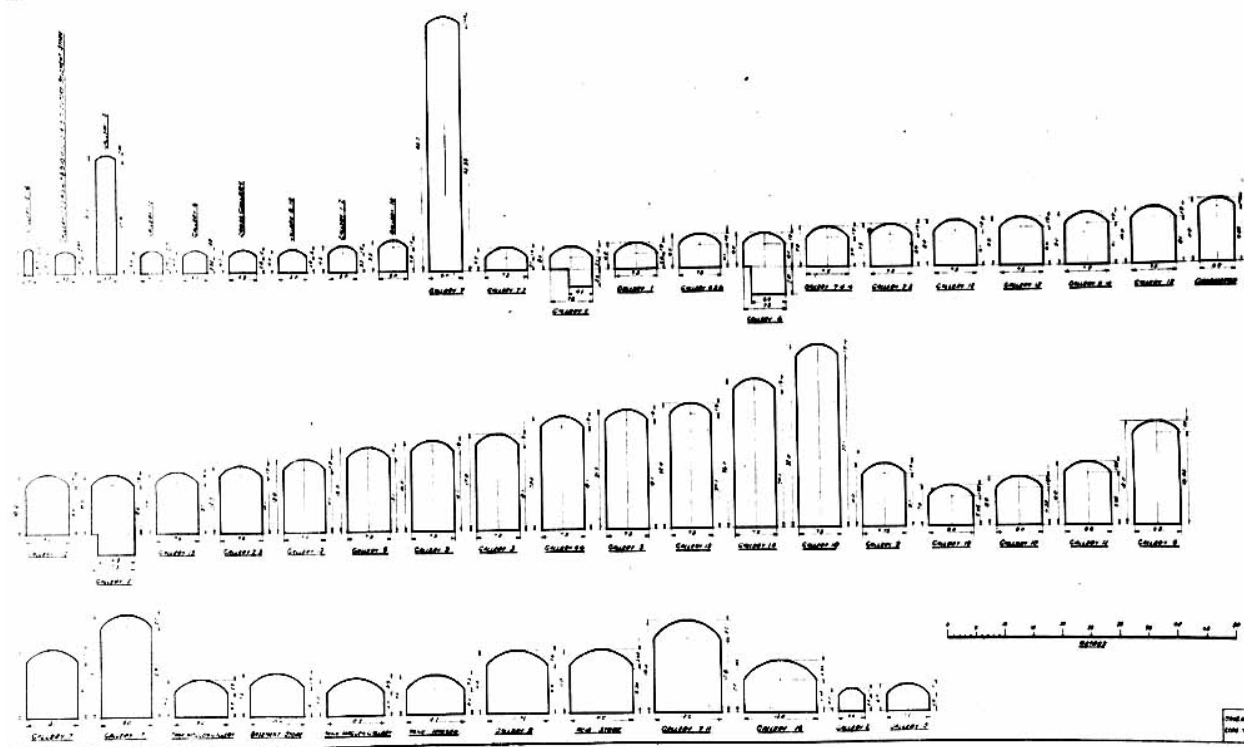
DWG. Nº 3^B.

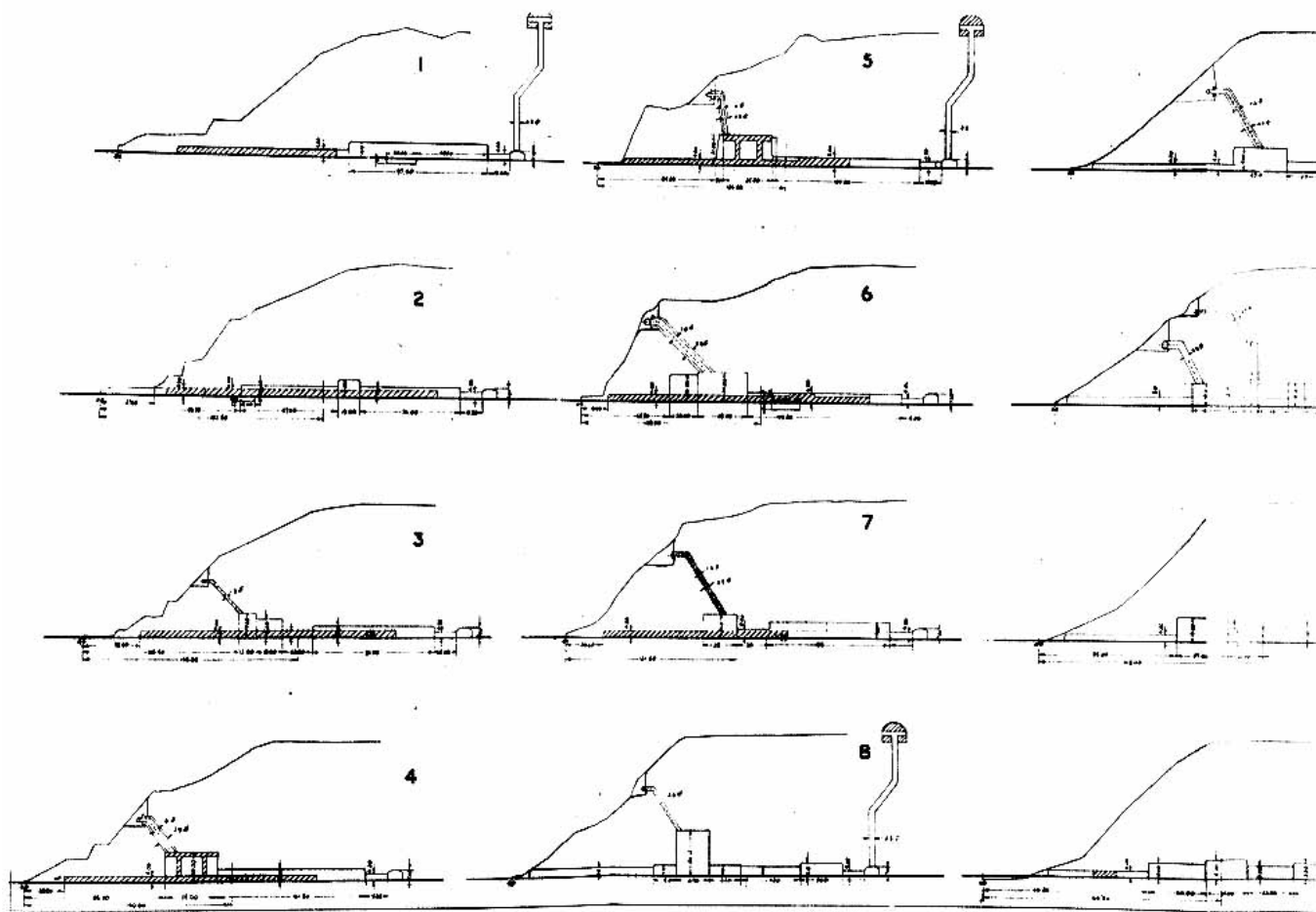


— SECTION ON TUNNEL 4. —



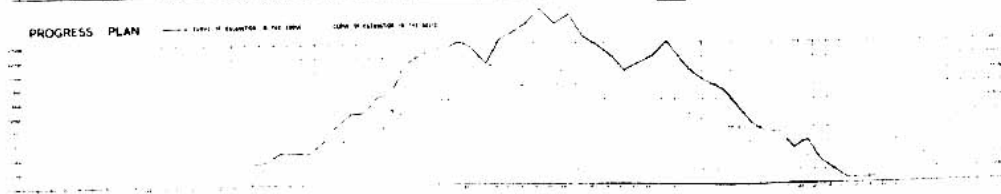
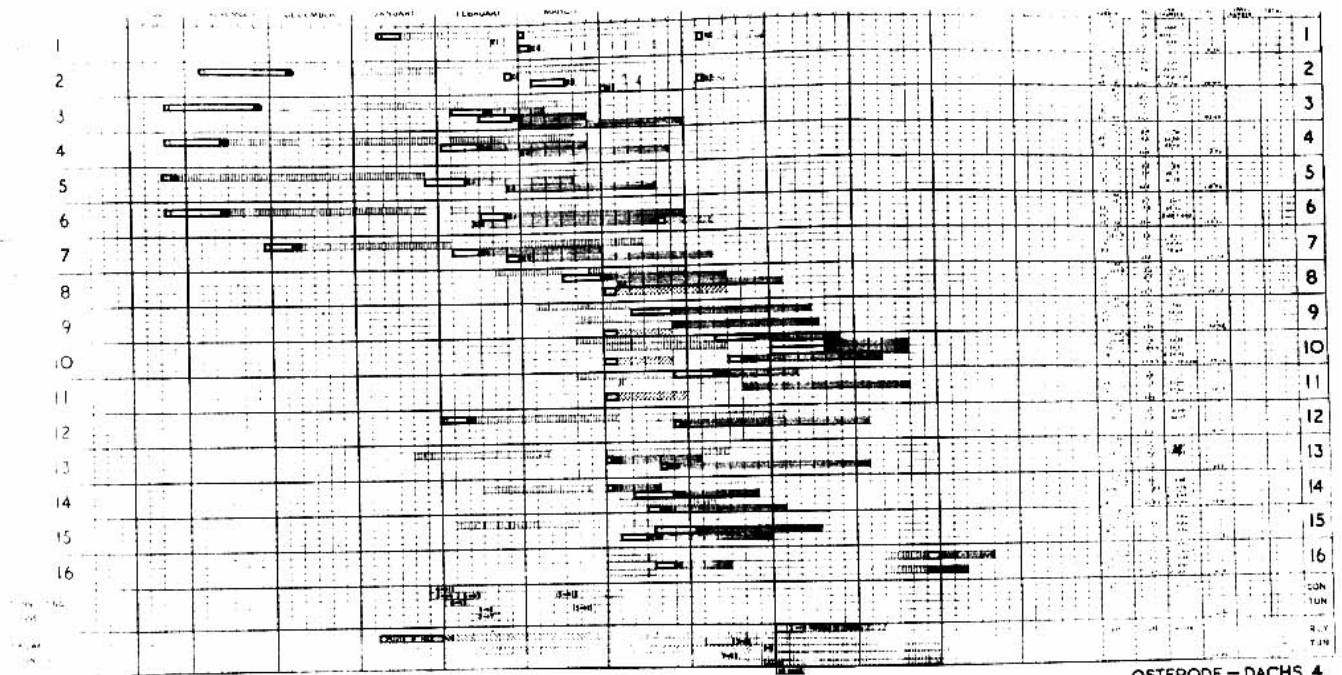








74845
75170 40 50



OSTERODE - DACHS 4.
DRAWING NO. 1 ACCOMPANYING REPORT
BY G-2 INVESTIGATION TEAM NO. 1
ON GERMAN UNDERGROUND FACTORIES

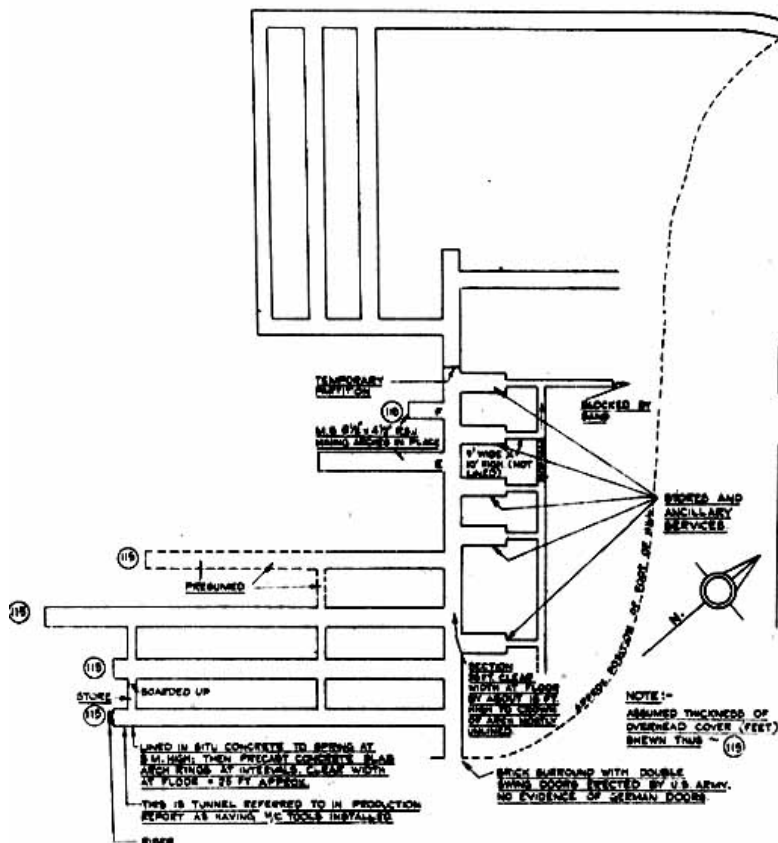
LEGEND

1. RESEARCH UNIT
2. RESEARCH UNIT
3. RESEARCH UNIT
4. RESEARCH UNIT
5. RESEARCH UNIT
6. RESEARCH UNIT
7. RESEARCH UNIT
8. RESEARCH UNIT
9. RESEARCH UNIT
10. RESEARCH UNIT
11. RESEARCH UNIT
12. RESEARCH UNIT
13. RESEARCH UNIT
14. RESEARCH UNIT
15. RESEARCH UNIT
16. RESEARCH UNIT

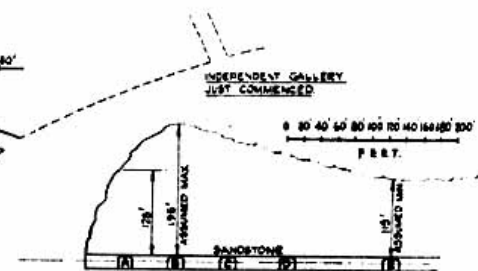
DWG 1P

200' 210' 220' 230' 240' 250' 260' 270' 280' 290' 300' 310' 320' 330' 340' 350' 360' 370' 380' 390' 400' 410' 420' 430' 440' 450' 460' 470' 480' 490' 500' 510' 520' 530' 540' 550' 560' 570' 580' 590' 600'

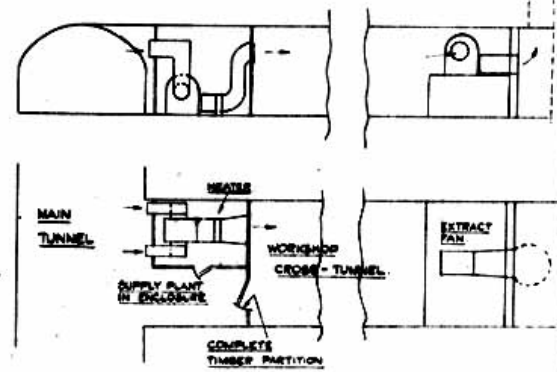
Feet



PLAN
APPROXIMATE LAYOUT OF TUNNELS FROM
DIMENSIONS TAKEN ON SITE



SECTION
SECTION THRO' MAIN TUNNEL LOOKING
SW. SHOWING COVER AS MEASURED BY
ASMEY LEVEL



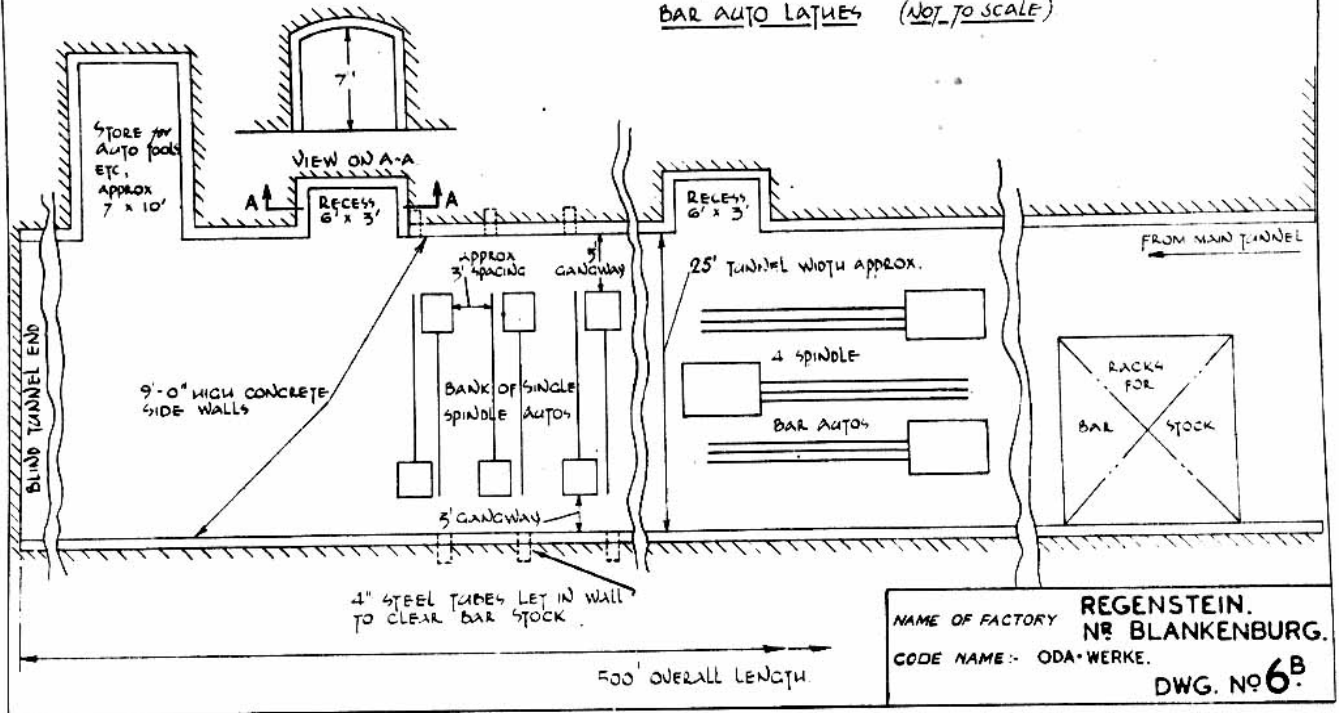
**PLAN & ELEVATION OF WORKSHOP
CROSS TUNNEL**
SHOWING ARRANGEMENT OF VENTILATION PLANT

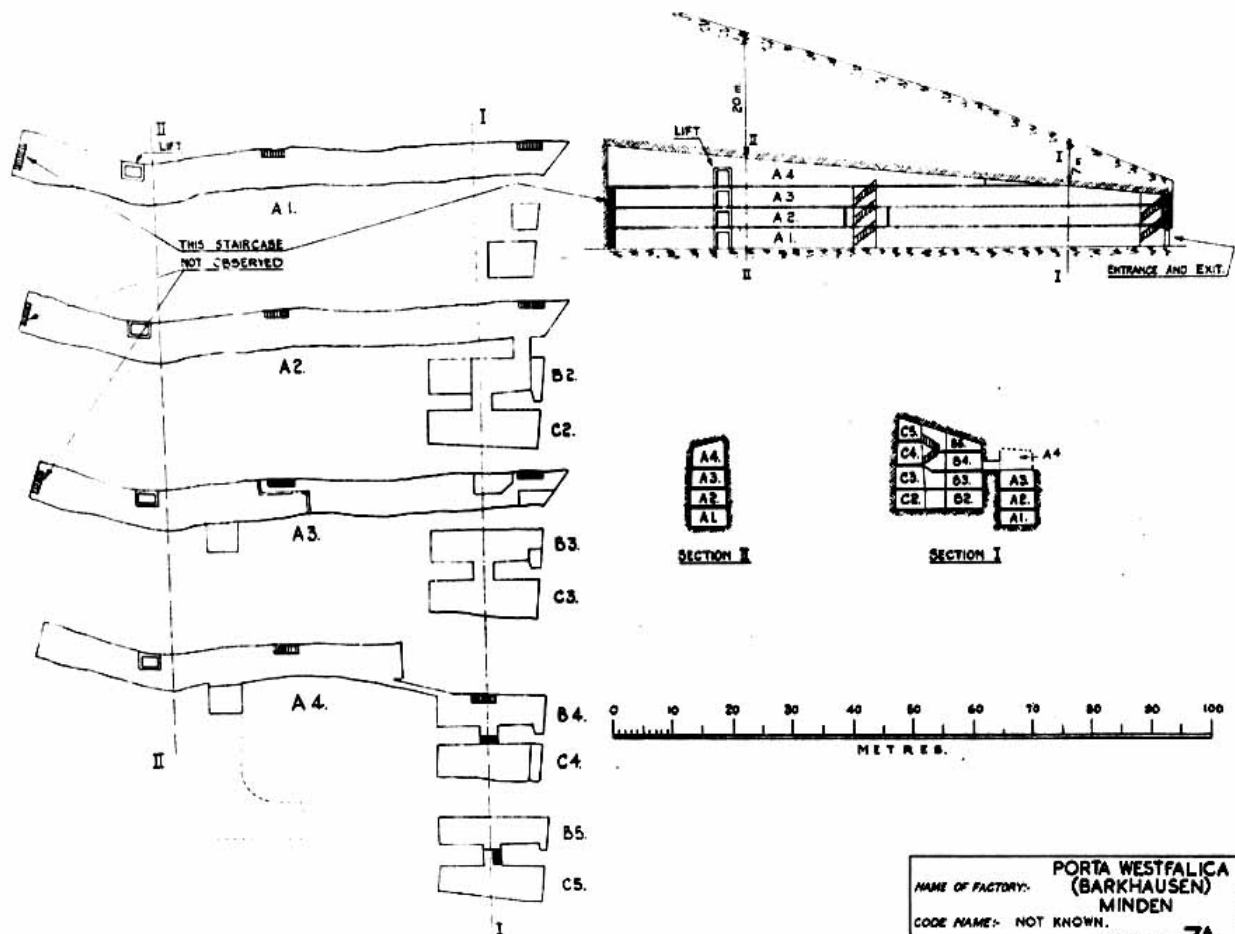
NOTE:-
ASSUMED THICKNESS OF
OVERHEAD COVER (FEET)
SHOWN THIS

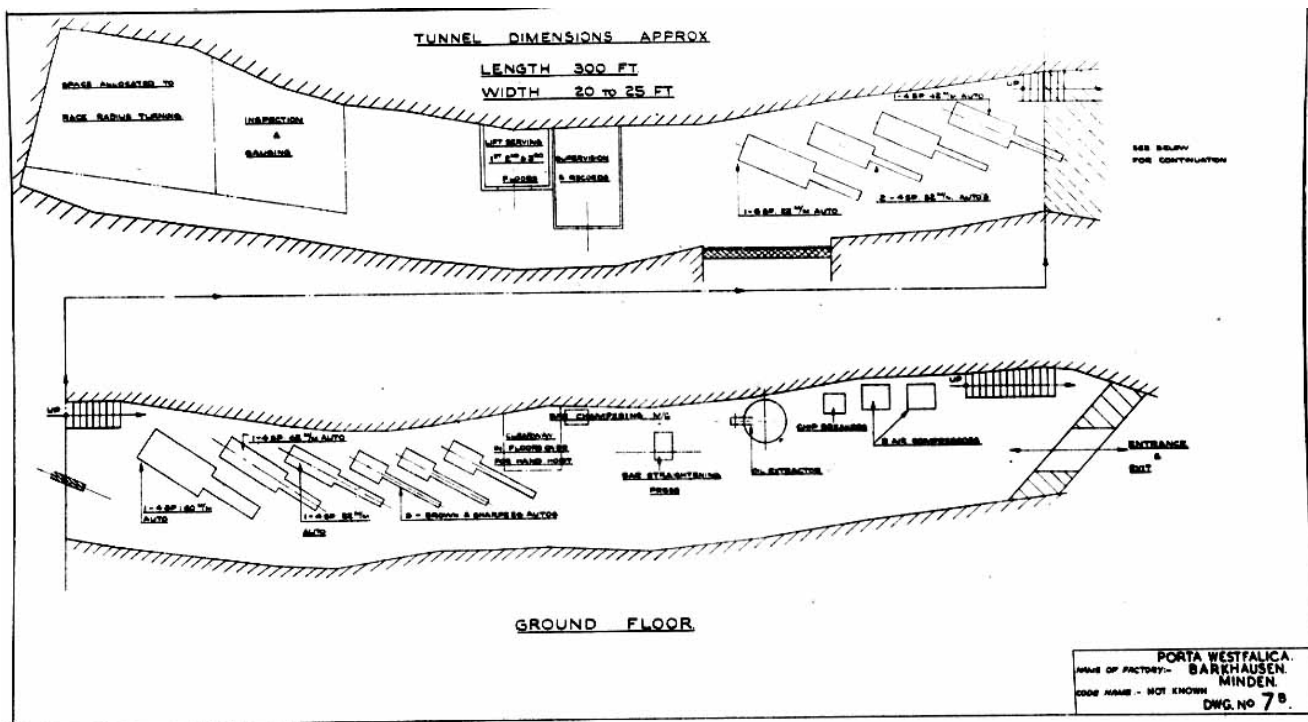
BRICK SURROUND WITH DOUBLE
SHING DOORS ERECTED BY U.S. ARMY.
NO EVIDENCE OF GERMAN DOORS

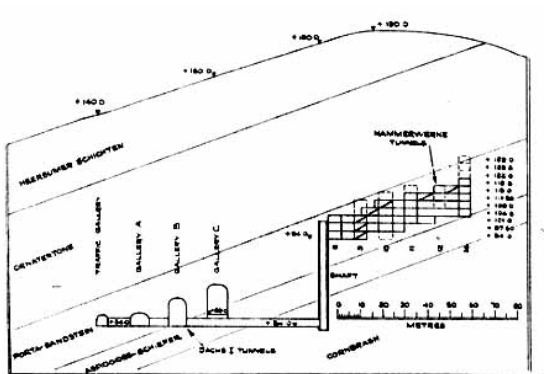
NAME OF FACTORY:- **REGENSTEIN**
NR BLANKENBURG
CODE NAME:- ODA-WERKE. **LA**

FEATURES OF TUNNEL HOUSING
BAR AUTO LATHES (NOT TO SCALE)

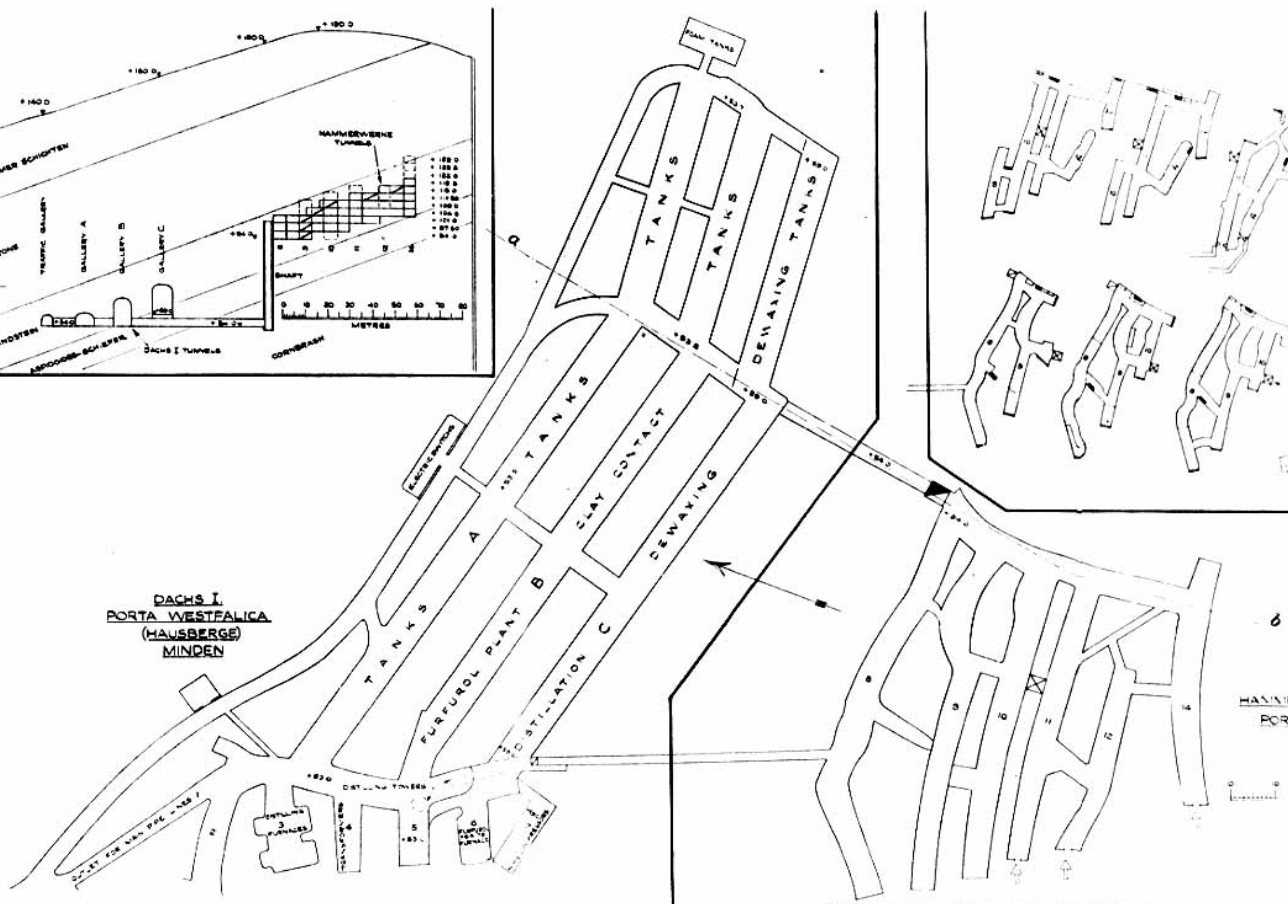




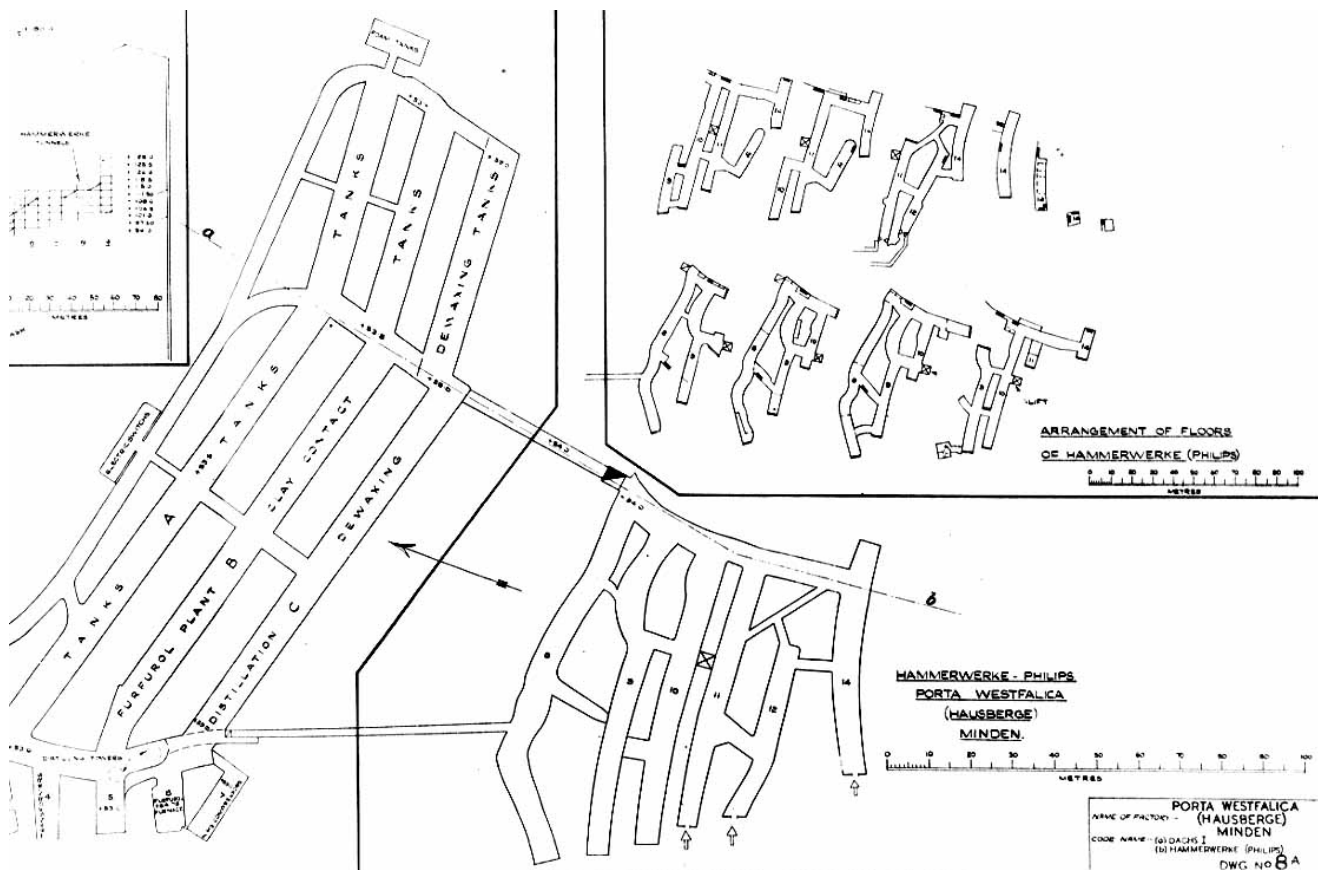




DACHS I
PORTA WESTFALICA
(HAUSBERGE)
MINDEN



HASSE
POR



End